National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

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In reply to refer to: R-10-8 through -22

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The National Transportation Safety Board (NTSB) is an independent federal agency charged by Congress with investigating transportation accidents, determining their probable cause, and making recommendations to prevent similar accidents from occurring. We are providing the following information to urge your organization to take action on the safety recommendations in this letter. The NTSB is vitally interested in these recommendations because they are designed to prevent accidents and save lives.

The recommendations in this letter are derived from the NTSB's investigation of the June 22, 2009, collision of two Washington Metropolitan Area Transit Authority (WMATA) Metrorail trains near the Fort Totten station and are consistent with the evidence we found and the analysis we performed. As a result of this investigation, the NTSB has issued 23 safety recommendations, 15 of which are addressed to WMATA. Information supporting these recommendations is discussed below. The NTSB would appreciate a response from you within 90 days addressing the actions you have taken or intend to take to implement our recommendations.

On Monday, June 22, 2009, about 4:58 p.m., eastern daylight time, inbound WMATA Metrorail train 112 struck the rear of stopped inbound Metrorail train 214. The accident occurred on aboveground track on the Metrorail Red Line near the Fort Totten station in Washington, D.C. The lead car of train 112 struck the rear car of train 214, causing the rear car of train 214 to telescope[1] into the lead car of train 112, resulting in a loss of occupant survival space in the lead car of about 63 feet (about 84 percent of its total length). Nine people aboard train 112, including

[1] *Telescoping* occurs when a railcar body breaches the end structure of another carbody and passes into the structure of that carbody.

the train operator, were killed. Emergency response agencies reported transporting 52 people to local hospitals. Damage to train equipment was estimated to be $12 million.[2]

The NTSB determined that the probable cause of the June 22, 2009, collision of WMATA Metrorail train 112 with the rear of standing train 214 near the Fort Totten station was (1) a failure of the track circuit modules, built by GRS/Alstom Signaling Inc., that caused the automatic train control system to lose detection of train 214 (the struck train) and thus transmit speed commands to train 112 (the striking train) up to the point of impact, and (2) WMATA's failure to ensure that the enhanced track circuit verification test (developed following the 2005 Rosslyn near-collisions) was institutionalized and used systemwide, which would have identified the faulty track circuit before the accident.

Contributing to the accident were (1) WMATA's lack of a safety culture, (2) WMATA's failure to effectively maintain and monitor the performance of its automatic train control system, (3) GRS/Alstom Signaling Inc.'s failure to provide a maintenance plan to detect spurious signals that could cause its track circuit modules to malfunction, (4) ineffective safety oversight by the WMATA Board of Directors, (5) the Tri-State Oversight Committee's ineffective oversight and lack of safety oversight authority, and (6) the Federal Transit Administration's lack of statutory authority to provide federal safety oversight.

Contributing to the severity of passenger injuries and the number of fatalities was WMATA's failure to replace or retrofit the 1000-series railcars after these cars were shown in a previous accident to exhibit poor crashworthiness.

Parasitic Oscillation in WMATA Track Circuit Modules

Train detection in the Metrorail system is accomplished through use of a coded audio signal. A track circuit transmitter module in the train control room generates a code-rate modulated audio frequency signal and supplies it to the transmitter impedance bond at one end of a track circuit. The transmitter impedance bond injects this signal into the rails. Assuming that no train occupies the block, the signal will travel through the rails and be picked up by the receiver impedance bond at the other end of the track circuit. When a train moves onto a track circuit, its wheelsets shunt the coded audio frequency signal away from the receiver impedance bond. Absent this signal, the track circuit receiver module deenergizes the track circuit relay, allowing the relay to drop, indicating an occupied track circuit.

When train 214 (the struck train) entered track circuit B2-304 on the day of the accident, it should have shunted the signal away from the receiver module, and the track relay should have dropped, indicating occupied. Once the track was detected as occupied, the automatic train control (ATC) system should have transmitted speed commands (1) to train 214 that were appropriate to maintain a safe separation from train 110 ahead and (2) to train 112 (the striking train) that were appropriate to maintain separation from train 214. Instead, because the track circuit failed to detect the presence of train 214, the ATC system stopped transmitting speed

[2] See *Collision of Two Washington Metropolitan Area Transit Authority Metrorail Trains Near Fort Totten Station, Washington, D.C., June 22, 2009,* Railroad Accident Report NTSB/RAR-10/02 (Washington, DC: National Transportation Safety Board, 2010) on the NTSB website at <http://ntsb.gov/publictn/2010/RAR1002.pdf>.

commands to train 214. As a result, without either speed commands or enough momentum to carry it into the next track circuit, the train came to a stop, thus setting the stage for the accident.

After the collision, trains 214 and 112 came to rest occupying track circuit B2-304. But when investigators examined the ATC components in the train control room at the Fort Totten station, they found that the relay for the track circuit was energized, indicating that the track circuit was reporting as vacant. A review of Advanced Information Management (AIM) system historical data revealed that track circuit B2-304 had failed to detect the presence of almost every train that had passed over it on the day of the accident and for the previous 5 days, since June 17.

The investigation determined that a failure mode was present when a series of conditions existed between the transmitter and receiver track circuit modules that generated a spurious signal of sufficient strength to be interpreted as a valid track circuit signal. First, the power output transistors of the track circuit module transmitter were producing parasitic oscillation. This oscillation was able to exploit an unintended path from the transmitter module to the respective receiver module by migrating through the equipment racks on which they were mounted. The oscillation was then coupled to the receiver module for that track circuit, producing a decaying pulse that was synchronized with the track circuit audio frequency. When the decaying pulses were of sufficient amplitude to drive the receiver module, the track circuit relay was energized, incorrectly indicating to the ATC system that the occupied track circuit was vacant. The NTSB therefore concludes that, on the day of the accident, parasitic oscillation in the track circuit modules for track circuit B2-304 was creating a spurious signal that mimicked a valid track circuit signal, thus causing the track circuit to fail to detect the presence of train 214.

On September 22, 2009, the NTSB made the following safety recommendations to WMATA:

> Examine track circuits within your system that may be susceptible to parasitic oscillation and spurious signals capable of exploiting unintended signal paths, and eliminate those adverse conditions that could affect the safe performance of your train control system. This work should be conducted in coordination with your signal and train control equipment manufacturer(s). (R-09-15 Urgent)
>
> Develop a program to periodically determine that electronic components in your train control system are performing within design tolerances. (R-09-16)

In response to the NTSB’s urgent Safety Recommendation R-09-15, WMATA issued test procedure T163 and trained its ATC technicians in its use to identify parasitic oscillation. Using the T163 test procedure, engineers and technicians identified a total of 208 track circuits as having parasitic oscillation that was generated in the transmitter module. They identified 82 track circuits that exhibited parasitic oscillation in both the transmitter and the receiver modules. Eight of the 82 track circuits required corrective action to reduce the amplitude of the parasitic oscillation signal below the threshold that WMATA had established in the test procedure.

In response to Safety Recommendation R-09-16, WMATA indicated that it had added six additional circuit tests to its periodic testing procedures. Additionally, at the public hearing for this accident, the former WMATA ATC assistant chief engineer said that a warning is also being added to the track circuit verification test procedures indicating that a bobbing track circuit cannot be verified until the source of the bobbing has been identified and corrected. Based on these responses, on April 27, 2010, the NTSB classified Safety Recommendations R-09-15 and -16 “Open—Acceptable Response.”

In a June 11, 2010, letter to the NTSB, WMATA provided an update of its activities in response to Safety Recommendations R-09-15 and -16. In response to Safety Recommendation R-09-16, WMATA offered that its T163 procedure met the intent of this recommendation. However, the T163 procedure only tests for parasitic oscillation and it does not specify periodic testing to detect changes in the operating characteristics of electronic components within the track circuit modules. Pending further information from WMATA with regard to its plans for developing a periodic preventive inspection and maintenance program to monitor the operating tolerances of the electronic components in the train control system, Safety Recommendation R-09-16 remains classified “Open—Acceptable Response.”

With regard to Safety Recommendation R-09-15, WMATA informed the NTSB that the WMATA Office of Engineering and Support Services had completed testing all track circuits using “components of the type identified as problematic in the Fort Totten investigation.” The letter stated that, while the examination had not identified any additional (beyond those previously identified) track circuits exhibiting parasitic oscillation, WMATA had identified and replaced an additional four sets of bonds and modules that, while they did not exhibit parasitic oscillation, did produce test results that WMATA considered to be unsatisfactory.

Although WMATA has taken action to identify track circuits with parasitic oscillation, it has not eliminated parasitic oscillation in all track circuit modules currently in service. The NTSB concludes that some of the GRS track circuit modules in use on the WMATA Metrorail system continue to exhibit parasitic oscillation, and the presence of this oscillation presents an unacceptable risk to Metrorail users.

The NTSB notes that WMATA’s T163 procedure contains a comprehensive explanation of a parasitic oscillation failure mode and a testing protocol; however, the test procedure is not required to be carried out on a periodic basis. Instead, the procedure is to be carried out “as directed.” The text of the procedure itself states that the procedure “or a portion or a variation” of it will be incorporated into “the future periodic maintenance program.” The NTSB concludes that WMATA Metrorail ATC test procedure T163, developed since this accident, will permit technicians to detect the presence of parasitic oscillation like that found in the failed track circuit modules at Fort Totten; however, unless these procedures are carried out on a periodic basis, an unsafe condition may persist for some time before being discovered and corrected. Therefore, because of the susceptibility to pulse-type parasitic oscillation that can cause a loss of train detection by the Generation 2 GRS audio frequency track circuit modules, the NTSB recommends that WMATA establish a program to permanently remove from service all of these modules within the Metrorail system. The NTSB further recommends that WMATA establish periodic inspection and maintenance procedures to examine all audio frequency track circuit modules within the Metrorail system to identify and remove from service any modules that exhibit pulse-type parasitic oscillation.

Implementation of ATC Test and Inspection Procedures

Four years before the Fort Totten accident, WMATA's investigation of the two Metrorail near-collisions occurring between the Rosslyn and Foggy Bottom stations determined that a track circuit had failed to detect trains occupying it. The investigation also revealed that a malfunctioning track circuit could pass a shunt verification test and detect the shunt when it was placed at either end of the circuit, but fail to detect the shunt when it was placed in the middle of the circuit.

Based on this finding, WMATA, on June 19, 2005, issued engineering bulletin and ATC safety notice *Update on Diminished Shunt Sensitivity in Audio Frequency Track Circuits* that stated that verification of audio frequency track circuits must involve placement of a shunt in the middle of the track circuit as well as near the transmitter end. This represented a change from the existing procedures (PMI [preventive maintenance instruction] 11000), which allowed use of a single shunt placed inside the transmitter end of the track circuit for verification.

None of the ATC personnel (five technicians and one supervisor) interviewed during this accident investigation were familiar with the June 19, 2005, bulletin or the requirement to verify a track circuit by placing a shunt in the middle of the circuit, even though all of them were working as Metrorail ATC technicians when the Rosslyn incidents occurred. This included technicians who were responsible for verifying track circuits after work had been performed, as well as those who were responsible for performing scheduled preventive maintenance inspections.

According to WMATA, the October 6, 2006, engineering bulletin and safety notice regarding track circuit verification, *US&S [Union Switch & Signal] Impedance Bonds in GRS ATP Track Circuits,* was intended to address concerns raised by some ATC technicians regarding the use of US&S impedance bonds with GRS modules. That safety notice stated that if a track circuit does not pass a three-shunt verification process (involving shunt placements at each end and in the middle of track circuits), the original impedance bond should be reinstalled. None of the technicians interviewed appeared familiar with the October 2006 bulletin regarding three-point shunt verification after installation of US&S impedance bonds. The supervisor of the installation crew was familiar with the bulletin, but he mistakenly believed that it referred only to high-current impedance bonds.

At the public hearing on this accident, the WMATA communications superintendent acknowledged that, during the 2005–2006 time frame, the process by which engineering and technical bulletins was distributed was "uneven." Given that no technician interviewed during this investigation was familiar with the June 2005 procedures for verifying track circuits and only one was even vaguely aware of the October 2006 bulletin, the bulletin distribution process was clearly ineffective.

For 5 years before this accident, WMATA engineers had known that attempting to verify a track circuit without placing a shunt in the middle of the circuit could result in a failure to identify malfunctioning circuits. But WMATA did not ensure that this information was provided to and understood by all ATC technicians and that the technicians subsequently acted upon it.

Although the leader of the crew that installed the US&S bond for track circuit B2-304 shortly before the accident said her crew had verified the track circuit using three shunts, one of which would presumably have been in the middle of the circuit, she could not provide a reason for using three shunts other than personal preference. In addition, NTSB testing found that track circuit B2-304 consistently failed to detect a shunt placed in the middle of the circuit, suggesting that if the impedance bond installation crew did use three shunt placements to verify the track circuit, these shunt placements did not include placing a shunt in the middle of the circuit. The NTSB therefore concludes that if proper shunt placements had been used, as required by WMATA's procedures, to verify track circuit B2-304 either immediately after the new impedance bond was installed on June 17, 2009, or when the track circuit was tested the following day, the work crews would have been able to determine that the track circuit was failing to detect trains, and actions could have been taken to resolve the problem and prevent the accident.

Based on NTSB testing, even a two-shunt verification test that involved placement of a shunt at the middle of the track circuit (in accordance with the guidance developed after the 2005 Rosslyn incidents) would have shown that track circuit B2-304 would fail to detect trains. The NTSB concludes that WMATA failed to institutionalize and employ systemwide the enhanced track circuit verification test developed following the 2005 Rosslyn near-collisions, and this test procedure, had it been formally implemented, would have been sufficient to identify track circuits that could fail in the manner of those at Rosslyn and Fort Totten.

During its investigation of a 1996 collision between a Metrorail train and an empty standing train at the Shady Grove station,[3] the NTSB identified deficiencies in Metrorail's procedures for disseminating information to operating personnel. Based on those findings, the NTSB made the following safety recommendation to WMATA:

> Develop and implement procedures to ensure that Metrorail operations personnel receive all bulletins, special orders, memoranda, or notices related to their responsibilities. These procedures should include a mechanism by which these personnel must sign or initial a document to signify that they have received, read, and understood any guidance intended for them. (R-96-34)

WMATA responded that it had adopted General Rule 1.7a, which requires acknowledgment, by signature, that an employee has received, reviewed, and understood new or modified rules, operating procedures, and safety-related postings or bulletins. Based on this response, the NTSB classified Safety Recommendation R-96-34 "Closed—Acceptable Action" on August 18, 1997.

As revealed during this investigation, however, WMATA has not effectively addressed the issues raised in the 1996 investigation of the Shady Grove accident. Although, according to public hearing testimony, WMATA does require employees to sign for updated bulletins and notices, the agency does not have mechanisms in place to ensure that the employees understand or act on the information. Assuming the ATC technicians interviewed in this investigation did receive and sign for the 2005 and 2006 bulletins having to do with shunt placement (these

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[3] *Collision of Washington Metropolitan Area Transit Authority Train T-111 With Standing Train at Shady Grove Passenger Station, Gaithersburg, Maryland, January 6, 1996,* Railroad Accident Report NTSB/RAR-96/04 (Washington, DC: National Transportation Safety Board, 1996).

records are retained for only 2 years and could not be produced for this investigation), their procedures did not change as a result. The technicians would have had no reason to ignore the new or updated procedures, which makes it likely that they failed to receive or understand the significance of the information. If that was the case, some followup action on the part of WMATA management to determine if the revised procedures were being followed would have revealed it. But no such action was taken. The NTSB therefore concludes that WMATA did not effectively distribute technical bulletins and safety information to its ATC technicians nor did it ensure that the information was received, understood, and properly acted upon by those technicians. The NTSB therefore recommends that WMATA review the process by which Metrorail technical bulletins and other safety information are provided to employees and revise that process as necessary to ensure that (1) employees have received the information intended for them, (2) employees understand the actions to be taken in response to the information, and (3) employees take the appropriate actions.

Maintenance Communication System

Each of the racks in a train control room and at wayside ATC installations has a telephone jack that connects to a maintenance communication system that allows workers in train control rooms to communicate with personnel at other train control rooms or equipment locations. The system is a deenergized two-wire network configured for handheld telephones. Maintenance personnel or others who must access the right-of-way can plug a handheld telephone into a wayside telephone jack and communicate with someone using another telephone plugged into a jack in the train control room.

The telephone lines are routed from the train control room to the field and linked in series to telephone jacks in every track junction box. The track junction boxes are also used to terminate the train control room bond cables and the cable connection from the track circuit impedance bonds.

Postaccident inspection of the maintenance communication system between the Takoma and Fort Totten stations revealed evidence that certain components of the system had been poorly maintained. For example, several inoperative telephone jacks were found in track junction boxes. The missing or unsecured telephone jacks left exposed mounting holes that could allow debris, rodents, or moisture into the box. In several instances, disconnected telephone jacks were found with bare wire terminals lying loose inside track junction boxes, and some of these were in proximity to track circuit impedance bond terminal connections. Because of this proximity and the poor condition of the terminals and boxes, the maintenance communication lines could potentially provide an alternative path for coded signals to travel from a transmitter impedance bond to a receiver bond without going through the rails (and thus bypassing any rail shunt). This alternative path could be completed through direct contact between loose wires and through the corrosion that can ground the terminals. Further, the poor condition of the nonvital communication system indicates that it is no longer of value to WMATA.

Near the site of the accident, maintenance communication lines were found to be shorted to ground through corrosion inside the junction boxes, and a spectrum analyzer detected the coded signal for track circuit B2-304 on the lines. Although these signals were of insufficient strength to be recognized by the track circuit receiver module as valid signals and thus played no role in this accident, the communication lines could provide a path for signals to bypass the rails. The NTSB therefore concludes that the Metrorail maintenance communication line system—a system that was in disrepair and was apparently no longer needed by WMATA—could allow unanticipated signal paths that could degrade the integrity, and thus the safety, of the Metrorail ATC system. The NTSB therefore recommends that WMATA completely remove the unnecessary Metrorail wayside maintenance communication system to eliminate its potential for interfering with the proper functioning of the train control system.

ATC System Design

The WMATA signal and train control system was designed using the closed-loop[4] and fail-safe principles that have been used in the rail industry for decades. Under closed-loop and fail-safe design principles, a single-point failure of a logical operation or the absence of a required input or output should not result in an unsafe condition.

The WMATA automatic train operation and automatic train protection (ATP) subsystems are referred to as "vital" or "safety-critical." Satisfying the design criteria for a vital train control system requires that if a track circuit fails to indicate correspondence with conditions at the wayside, the circuit should default to the safest condition, which is to indicate the presence of a train even when the block is actually unoccupied. This investigation determined that the fail-safe design principle can be compromised in the WMATA train control system as a result of two different conditions—the presence of corrugated rail and the presence of pulse-type parasitic oscillation in the track circuit transmitters.

Electrical arcing in the presence of corrugated rail can create harmonics that effectively mimic a valid track circuit signal that can be accepted by the receiver via the normal signal path. Parasitic oscillation in track circuit transmitters can create a spurious signal that effectively mimics the track circuit signal by entering the receiver via an unintended signal path. In each case, the receiver module detects a signal that it interprets as valid. WMATA ATC engineers consider harmonics resulting from corrugated rail to be a benign condition because of their transient nature. However, the NTSB believes that any condition that can result in a loss of train detection needs to be evaluated in a comprehensive safety analysis.

Examination of wayside junction boxes also revealed that WMATA maintenance communication system cables were co-located with track circuit cables. This design could potentially lead to the creation of an unintended signal path that could affect the operation of the track circuit system. For example, the maintenance communication system cables had become grounded due to corrosion, providing a potential alternative track circuit signal path. Also, loose cables in the junction boxes could possibly come into contact with a cable used by the track circuit and thereby establish an unintended track circuit signal path.

A key requirement of the fail-safe design approach is that the designer foresee all catastrophic failure modes in the system and develop a plan for mitigating the negative effects that such failure modes can have on system function. A comprehensive safety analysis of the

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[4] The *closed-loop* principle requires that all conditions necessary for the existence of any permissive state or action be verified to be present before the permissive state or action can be initiated or maintained.

system design, which considers all known failure modes, their effects on system function, and the timely detection and alerting of failures is critical to developing an effective mitigation plan. A June 1980 fault tree analysis performed for WMATA identified events that could lead to train collisions, but it did not explore failure modes involving the track circuitry, nor did it identify the possibility of parasitic oscillation in the track circuit modules. As a result, there was no plan to mitigate the effects of such failures on the WMATA ATC system.

The NTSB concludes that a comprehensive safety analysis of an ATC system must consider all foreseeable system failures that may result in a loss of train separation, including failures in train detection caused by track circuit failures. The NTSB therefore recommends that WMATA conduct a comprehensive safety analysis of the Metrorail ATC system to evaluate all foreseeable failures of this system that could result in a loss of train separation, and work with its train control equipment manufacturers to address in that analysis all potential failure modes that could cause a loss of train detection, including parasitic oscillation, cable faults and placement, and corrugated rail. The NTSB further recommends that based on the findings of the safety analysis recommended in the previous recommendation, WMATA should incorporate the design, operational, and maintenance controls necessary to address potential failures in the ATC system.

Insulation Resistance Testing

Metrorail ATC technical procedure T031, *Cable Insulation Resistance Testing*, dated November 25, 2008, was in draft form and under review at the time of this accident. This was a new manual with requirements for cable insulation resistance testing that previously had not been in place. WMATA representatives told the NTSB that no insulation resistance testing of cables had been conducted on the Metrorail system.

This draft technical procedure would require that all cables installed in conduits, in ducts, and along tunnel walls, or buried along the right-of-way, and wires and cables entering and leaving train control rooms, equipment cases, and junction boxes be measured for insulation resistance. The tests are intended to verify that the insulation resistance of a conductor used with a power source of less than 600 volts exceeds 1 megaohm and that the resistance of a conductor used with a power source greater than 600 volts exceeds 10 megaohms. This draft procedure requires that the applicable wires and cables be tested every 10 years or after new installations.

When investigators tested the insulation resistance of the cables serving the two impedance bonds of track circuit B2-304, they found resistance measurements that did not meet the standards spelled out in manual T031. For the tested cables, insulation resistance was 500 kiloohms, or only half of the resistance required by manual T031 for a power source of less than 600 volts. The NTSB therefore concludes that, as revealed by postaccident testing, the cables serving the impedance bonds for track circuit B2-304 did not meet proposed WMATA Metrorail standards for insulation resistance, and although this did not cause or contribute to the accident, such deficiencies, if undetected and uncorrected, could undermine the safety of the Metrorail train control system. The NTSB recommends that WMATA implement cable insulation resistance testing as part of Metrorail's periodic maintenance program.

State Safety Oversight of WMATA

During the Federal Transit Administration's (FTA) 2007 audit of the Tri-State Oversight Committee (TOC), the audit team developed 12 findings, 8 of which were for noncompliance. Two of the noncompliance findings were that (1) WMATA had not conducted internal safety audits according to the schedule specified in its system safety program plan and (2) WMATA corrective action plans (CAP) were not being reviewed and approved according to the time frame required by TOC program procedures. These were findings that had been identified during the FTA's 2005 audit of TOC and that were carried forward in the 2007 audit report.

The FTA's audit of TOC in 2009 again found shortcomings with the way TOC and WMATA handled issues related to safety. The 2009 FTA findings and recommendations for TOC and WMATA focused on a number of general safety issues noted with both agencies.

For TOC, the FTA's findings addressed, among other issues, (1) providing the resources, financial and personnel, necessary for TOC to carry out its responsibilities and ensuring that TOC members possess the technical and professional skill necessary for the job; (2) improving coordination and communication between WMATA and TOC; (3) resolving previously identified safety issues as well as open CAPs; (4) improving the safety audit process; and (5) ensuring that WMATA has an effective system safety program plan and hazard management program. The NTSB concludes that the results of this investigation, as well as the FTA's audit of TOC and WMATA, determined that TOC has been ineffective in providing proper safety oversight of and lacks the necessary authority to properly oversee the WMATA Metrorail system.

For WMATA, the FTA's recommendations addressed, among other issues, (1) providing the resources and expertise necessary for the WMATA safety department, (2) ensuring that the safety department is actively involved in all operations and maintenance decisions and activities, (3) providing the chief safety officer with direct access to the WMATA general manager, (4) performing a systemwide hazard analysis that involves all WMATA departments, and (5) implementing and providing employee training in new rules to increase worker safety along the WMATA right-of-way.

The NTSB concludes that the results of this investigation and the findings and recommendations contained in the FTA's March 4, 2010, Final Audit Report of its 2009 safety audit of TOC and WMATA, if implemented, will enhance WMATA Metrorail passenger and employee safety. Therefore the NTSB recommends that WMATA work with the TOC to satisfactorily address the recommendations contained in the FTA's March 4, 2010, final report of its audit of the TOC and WMATA.

Safety Culture Within WMATA

This accident investigation identified shortcomings in WMATA's internal communications, in its recognition of hazards, its assessment of risk from those hazards, and its implementation of corrective actions, all of which are evidence of an ineffective safety culture within the organization. A commonly cited model of an effective safety culture is that offered by Dr. James Reason, who describes a safety culture as (1) an *informed culture* in which those who operate and manage the system have knowledge about the human, technical, organizational, and environmental factors affecting the safety of the system; (2) a *reporting culture* in which people are able and encouraged to report safety concerns, errors, and near-misses; and (3) a *just culture* in which people are encouraged and rewarded for providing safety-related information without fear of blame.[5]

Informed Culture. An informed culture is characterized as

> one in which those who manage and operate the system have current knowledge about the human, technical, organizational, and environmental factors that determine the safety of the system as a whole. In most important respects, an informed culture *is* a safety culture.[6] [Emphasis in the original.]

The Metrorail ATC system was designed to prevent collisions by constantly monitoring train locations and slowing or stopping trains as necessary to maintain adequate train separation. Even when trains are operated in manual mode, WMATA expects the ATC system to override operator input if necessary to prevent collisions.

Keeping the risk of Metrorail injuries and accidents at or near zero requires that WMATA constantly monitor its operations and equipment, disseminate safety-critical information to all affected areas of the organization, and take immediate action to address potential defects. Actively monitoring all safety-critical aspects of an organization for problems is part of maintaining an informed safety culture. However, information gathered during this accident investigation indicates that before the Fort Totten accident, WMATA did not act aggressively to identify and remedy recurring defects in its ATC system. WMATA also did not take operational measures to mitigate the risk of collision until the defects could be corrected.

In this accident, failures to use the loss-of-shunt tool or the enhanced track circuit verification test procedures developed as a result of the investigation into the near-collision incidents near Rosslyn station in 2005 demonstrate failures to communicate safety-critical information within affected departments of WMATA. The circumstances of this accident exemplify the concerns repeatedly expressed by the NTSB, the FTA, and TOC about the need for coordinated communication of safety-critical functions within WMATA.

Three of the FTA’s 10 recommendations issued to WMATA in its March 2010 audit report address safety department deficiencies, including the following: (1) ensure that safety department staff has access to all operations and maintenance information so that potential safety risks can be identified, (2) require that safety-related information be made available to all departments, and (3) develop and implement a process to ensure that the chief safety officer can communicate safety priorities to the general manager in a consistent and timely manner.

The best way to assess the health of safety-critical systems is through active monitoring and evaluation of operations and equipment in search of “leading indicators” of system problems. Examples of leading safety indicators include recorded operational data, the results of

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[5] J. Reason, *Managing the Risks of Organizational Accidents* (Aldershot: Ashgate, 1997), pp. 293–306.

[6] *Managing the Risks of Organizational Accidents*, p. 195.

inspections, safety audits, and employee reports of safety concerns and near-miss events. The failure of WMATA to measure and address leading indicators of defects in its automatic train detection system suggests that the agency did not fully appreciate the risks represented by aberrations in the ATC system.

Reporting Culture. An informed culture starts with encouraging individuals throughout the organization to report safety-related information and concerns. Safety information is often gathered from accidents and incidents that result in measurable negative outcomes, but safety information can also be gathered from reports of errors, near-misses, and safety concerns that might otherwise go unnoticed. No organization can anticipate all safety problems, but the advantage of actively investigating nonaccident safety lapses is that it may allow an organization to identify and address a system's weaknesses before an accident points them out.[7] The NTSB found examples of a deficient reporting culture within WMATA.

A WMATA ATC engineer who was investigating the June 7, 2005, misrouting of trains at the Rosslyn station, overheard someone stating that the train operators had to apply emergency brakes to avoid colliding in the tunnel between Rosslyn and Foggy Bottom. This piece of information led the engineer to seek more information on the misrouting and the near-collisions and to contact other engineers to further investigate the incident. However, this information had not been reported, and the engineer learned of it only by chance.

WMATA was required by TOC, under Title 49 *Code of Federal Regulations* (CFR) 659.31, to have a process for identifying and resolving hazards. WMATA's operations have several possible sources of information with which to identify potential hazards, including the results of audits and inspections as well as the data recorded in newer railcars and the AIM system used by the operations control center. For example, the loss-of-shunt tool uses recorded AIM data to identify potential track circuit malfunctions.

Other modes of transportation have established safety programs for collecting and analyzing recorded operations data and collecting reports of safety concerns and near-misses from frontline personnel, such as vehicle operators and maintenance technicians. In commercial aviation, for example, many airline operators use data from recorders on board their aircraft to monitor trends in operations and identify possible safety concerns. The recorded operational data provide objective safety information that is not otherwise obtainable. The value of operational data analysis programs is the possible early identification of some types of adverse safety trends that, if uncorrected, could lead to accidents.[8]

Similarly, non-punitive self-reporting programs—such as the Federal Aviation Administration's Aviation Safety Action Program[9] and Air Traffic Safety Action Program,[10] and

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[7] R. Flin, "Safety Condition Monitoring: Lessons from "Man-Made Disasters," *Journal of Contingencies and Crisis Management*, vol. 6 (1998), pp. 88–92.

[8] See Federal Aviation Administration Advisory Circular (AC) 120-82, *Flight Operations Quality Assurance*: <http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/40C02FC39C1577B686256E8A005AFB0A>.

[9] See Federal Aviation Administration AC 120-66B, *Aviation Safety Action Program (ASAP)*: <http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/61C319D7A04907A886256C7900648358>.

the National Aeronautics and Space Administration's Aviation Safety Reporting System[11]—allow individuals to report safety issues without fear that the reports will be used to take disciplinary or enforcement action against them.

The Federal Railroad Administration (FRA) is currently conducting pilot tests of the Confidential Close Call Reporting System (C^{3}RS).[12] The C^{3}RS is a voluntary, confidential program of the FRA, the Bureau of Transportation Statistics (BTS), the U.S. Department of Transportation (DOT) Volpe Center, railroad carriers, carrier employees, and labor organizations. Operators implement the reporting system, employees make reports, labor organizations represent employees, the FRA sponsors and oversees the program, the BTS and the Volpe Center act as independent third-party managers, and a peer review team of various stakeholder representatives oversees corrective actions. The C^{3}RS includes several qualities that have been considered critical to the success of other safety reporting systems, including the following:

- The system is designed to capture close calls, safety concerns, and suggestions from all employees.
- The reporting process is voluntary and designed to maintain reporter confidentiality.
- The system provides the reporter protection from discipline and enforcement action, except in the case of intentional misconduct.
- The system is managed by an independent third-party—in this case, the BTS and the DOT Volpe Center.
- The system includes a mechanism to distribute reports (with identification removed) on safety trends and corrective actions to all participating organizations.
- The system tracks carrier reports on corrective actions to measure system impact on safety.
- The system evaluates and identifies ways to improve reporting system effectiveness.

Regular reviews of recorded data and non-punitive safety reports from these programs have identified safety issues and trends that would not have been readily identified through traditional oversight programs. The NTSB concludes that the safety of rail transit operations would be improved by periodic transit agency review of recorded operational data and non-punitive safety reports, which have been demonstrated to be effective tools for identifying safety problems in other modes of transportation. The NTSB recommends that WMATA require that its safety department; representatives of the operations, maintenance, and engineering departments; and representatives of labor organizations regularly review recorded operational data from Metrorail train onboard recorders and the AIM system to identify safety issues and trends and share the results across all divisions of its organization. The NTSB also recommends that

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[10] See Federal Aviation Administration Air Traffic Organization Policy Notice, N JO 7210.741, *Air Traffic Safety Action Program (ATSAP)*: <http://www.faa.gov/documentLibrary/media/Notice/N7210.741.pdf.>

[11] A detailed description is available on the Aviation Safety Reporting System website at <http://asrs.arc.nasa.gov/>.

[12] Three C^{3}RS demonstration sites are currently in operation, with a fourth scheduled to begin in fall 2010.

WMATA develop and implement a non-punitive safety reporting program to collect reports from employees in all divisions within its organization, and ensure that the safety department; representatives of the operations, maintenance, and engineering departments; and representatives of labor organizations regularly review these reports and share the results of those reviews across all divisions of its organization.

Just Culture. Individual behaviors and attitudes toward safety reporting are also influenced by the anticipated response from coworkers and leadership. The comments of the operator of train 214 regarding his decision to operate his train in manual mode are indicative of distrust between WMATA management and its employees. The operator told investigators that he switched from automatic to manual mode when entering the stations because he did not want to rely on the automated system to position the train properly along the platform. WMATA apparently treated improper train positioning in stations as a personnel problem rather than a system problem. Although the train operating mode was routinely displayed in the operations control center and recorded by the AIM system, operators choosing to operate in manual mode were never identified as an indication of a system safety concern held by frontline employees.[13] Ideally, safety concerns should be brought to the attention of the safety department and reviewed by a team with expertise from the various agency departments, such as rail operations, track and systems maintenance, and engineering services, for resolution.

Disciplinary practices perceived as unfair can motivate individuals to hide safety-related information or adopt behaviors to avoid blame. In this case, the train 214 operator not only chose to deviate from the policy initially, but he also continued to operate his train in manual mode after being counseled, suggesting that his perceived safety concerns and the threat of discipline for stopping at the wrong position outweighed the threat of discipline for violating the policy regarding operating mode. WMATA's inconsistent enforcement of organizational policies and safety directives is symptomatic of a lack of *just culture* within the agency with regard to safety oversight.

Learning Culture and Shared Concern for Hazards. In order to realize safety improvements, an organization must be capable of drawing the right conclusions from its safety information and must be willing to enact change when needed.

The near-collisions at the Rosslyn station in 2005 provided evidence that the assumed fail-safe design of the ATC system could be compromised and that a catastrophic accident could result. The Rosslyn incidents were investigated at the time, and as a result of that investigation, WMATA developed an enhanced track circuit verification test that was intended to identify track circuits with the potential to lose train detection. Also, following a detailed engineering analysis, WMATA developed the loss-of-shunt tool to better monitor track circuit performance. However, the enhanced track circuit verification test was never institutionalized within Metrorail and the loss-of-shunt tool eventually fell into disuse, indicating that WMATA either did not recognize the severity of the risk posed by the hazard identified at Rosslyn or did not communicate that hazard

[13] The NTSB notes that WMATA has been operating exclusively in manual mode since the accident.

to all departments of the agency. A hazard identification and resolution process[14] was in place at WMATA, as prescribed in its system safety program plan. The results of that hazard assessment should have been distributed to all affected departments of the agency, and the procedures for addressing the identified risk should have been integrated into the training and guidance materials for all affected personnel.

The NTSB concludes that WMATA failed to recognize that the near-collisions at Rosslyn in 2005 represented an unacceptable hazard that had not been considered in the fail-safe design of the ATC system, and WMATA failed to communicate that hazard to the affected divisions in the organization for resolution.

In addition to the problem of communicating safety-critical track circuit information identified by NTSB investigators, the FTA found in its March 2010 audit report of WMATA that WMATA did not have a process that ensures the timely identification and analysis of hazards and that WMATA managers were reactive rather than proactive in assessing and addressing the agency's most serious safety hazards.

The FTA audit report also cited a lack of effective interdepartmental coordination within WMATA with regard to identifying and managing maintenance-related safety hazards. Further, the audit report noted that WMATA lacked a formal process for identifying and managing the likely safety impacts of budgetary decisions that affected equipment maintenance.

The NTSB concludes that, based on the results of this investigation and the FTA's recent safety audit, WMATA was not adequately assessing the severity of hazardous risk associated with identified anomalies in its ATC system. Therefore, the NTSB recommends that WMATA review the Hazard Identification and Resolution Matrix process in its system safety program plan to ensure that safety-critical systems such as the ATC system and its subsystem components are assigned appropriate levels of risk in light of the issues identified in this accident.

The 2005 FTA audit of TOC focused on the ability of TOC to develop and implement plans and procedures required for the implementation of 49 CFR Part 659. As a result of this audit, the FTA issued nine deficiency findings and one recommendation regarding TOC's implementation of 49 CFR Part 659 requirements. Over the next 2 years, TOC and WMATA were unable to close several of these audit findings, prompting the FTA to conduct a series of meetings with TOC and WMATA executive leadership. The FTA was concerned about WMATA's ability to identify, elevate, and address safety deficiencies within its own agency as well as WMATA's lack of responsiveness to TOC.

As of February 3, 2010, a total of 48 CAPs from previous TOC triennial audits of WMATA were still classified as open, that is, unresolved. This included 9 CAPs from events in 2004, 6 from 2005, 6 from 2006, 11 from 2007, and 13 from 2008. Of the 48 open CAPs, 2 were related to the Rosslyn incidents in 2005, and 15 were related to NTSB recommendations issued

[14] The Hazard Identification and Resolution Matrix process, outlined in Section 6 of the WMATA system safety program plan, is a process for assessing hazard probability and severity of identified safety concerns intended to address TOC's program standards and procedures, which are in turn based on requirements of 49 CFR 659.31. The Hazard Identification and Resolution Matrix is based on the U.S. Department of Defense hazardous risk identification and assessment process specifications of MIL-STD-882 *Standard Practice for System Safety* <http://safetycenter.navy.mil/instructions/osh/milstd882d.pdf>.

in connection with WMATA accidents occurring at the Woodley Park station in 2004,[15] at the Eisenhower Avenue[16] and Dupont Circle[17] stations in 2006, and at the Mt. Vernon Square station in 2007.[18] The NTSB recommends that WMATA develop a formal process by which the general manager and managers responsible for WMATA operations, maintenance, and engineering will periodically review, in collaboration with the chief safety officer, all safety audits and open CAPs, and modify policy, identify and commit resources, and initiate any other action necessary to ensure that the plans are adequately addressed and closed within the required time frame.

Crashworthiness of Metrorail 1000-Series Railcars

Investigators inspected both trains after the collision. The front portion of the first car of train 112 (the striking train, made up of all 1000-series cars) had overridden and was breached by the last car of train 214. This breaching, or telescoping action, resulted in a "wall" of collision debris that consisted of a tightly compressed mass of dislodged, displaced, and crushed seats, floor and ceiling panels, stanchion posts, and other interior elements. The collision debris extended a linear distance of about 13 feet, and along with the 50 feet of telescoping penetration, resulted in a loss of occupant survival space in the striking car of about 63 feet (about 84 percent of its total length).

The NTSB investigated three previous WMATA Metrorail accidents that raised issues related to the crashworthiness of Metrorail passenger cars.[19] The accident that most closely paralleled the Fort Totten accident in terms of physical damage occurred at Metrorail's Woodley Park station in November 2004.[20] In that accident, a train consisting of 1000-series cars rolled backward down a grade and struck a standing train made up of 4000-series cars. The investigation of the Woodley Park accident determined that the rear car of the rolling train struck the front car of the standing train at an estimated speed of 36 mph. As a result of the collision, the 1000-series rear car of the striking train sustained catastrophic telescoping damage that resulted in a loss of about 34 feet of occupant survival space.[21] The 4000-series lead car of the struck train sustained negligible front-end intrusion damage (less than 2 feet) and suffered essentially no loss of occupant survival space.

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[15] *Collision Between Two Washington Metropolitan Area Transit Authority Trains at the Woodley Park-Zoo/Adams Morgan Station in Washington, D.C., November 3, 2004*, Railroad Accident Report NTSB/RAR-06/01 (Washington, DC: National Transportation Safety Board, 2006).

[16] *Washington Metropolitan Area Transit Authority Train Strikes Wayside Workers Near Eisenhower Avenue Station, Alexandria, Virginia, November 30, 2006*, Railroad Accident Brief NTSB/RAB-08/02 (Washington, DC: National Transportation Safety Board, 2008).

[17] *Washington Metropolitan Area Transit Authority Train Strikes Wayside Worker Near Dupont Circle Station, Washington, D.C., May 14, 2006*, Railroad Accident Brief NTSB/RAB-08/01 (Washington, DC: National Transportation Safety Board, 2008).

[18] *Derailment of Washington Metropolitan Area Transit Authority Train Near the Mt. Vernon Square Station, Washington, D.C., January 7, 2007*, Railroad Accident Report NTSB/RAR-07/03 (Washington, DC: National Transportation Safety Board, 2007).

[19] See (a) *Derailment of Washington Metropolitan Area Transit Authority Train No. 410 at Smithsonian Interlocking. January 13, 1982*, Railroad Accident Report NTSB/RAR-82/06 (Washington, DC: National Transportation Safety Board, 1982), (b) NTSB/RAR-96/04, and (c) NTSB/RAR-06/01.

[20] NTSB/RAR-06/01.

[21] At the time of the Woodley Park accident, the striking train was unoccupied except for the train operator.

Investigation of the Fort Totten accident determined that the front car of train 112 struck the rear car of train 214 at an estimated speed of at least 44 mph. This accident also involved a collision between 1000-series cars and newer cars that were built to later and more robust crashworthiness standards. Occupant survivability in the 1000-series lead car of train 112 (where all of the fatalities occurred) was almost exclusively determined by where the occupants were located at the time of the collision. For those occupying the section of the railcar that was subject to the telescoping action, including the train operator's compartment, the accident was essentially non-survivable.

As a result of its investigation of the Woodley Park accident, the NTSB issued the following safety recommendation to WMATA:

> Either accelerate retirement of Rohr-built[22] railcars, or if those railcars are not retired but instead rehabilitated, then the Rohr-built passenger railcars should incorporate a retrofit of crashworthiness collision protection that is comparable to the 6000-series railcars. (R-06-2)

WMATA responded in a January 10, 2007, letter that all cars are fitted with anti-climber features to help prevent carbody override (and thus telescoping in a collision). But as this accident showed, the 1000-series cars were not designed to effectively prevent telescoping. Further, WMATA stated that it was constrained by tax advantage leases, which require that WMATA keep the 1000-series cars in service at least until the end of 2014. WMATA also stated that it was not feasible to retrofit the 1000-series cars and that they would remain in service until replacement with the 7000-series cars in 2014. Based on this response, the NTSB classified Safety Recommendation R-06-2 "Closed—Unacceptable Action" on October 5, 2007.

On August 14, 2009, WMATA sent a letter formally requesting that the NTSB reconsider the status of Safety Recommendation R-06-2 because of WMATA's decision (stated in its January 10, 2007, letter) that it did not intend to perform a heavy overhaul of the 1000-series railcars. The NTSB has, on occasion, reclassified a closed safety recommendation when the recipient has acted in a timely manner after closure to complete the recommended action or has indicated a change in its position and intention to complete the action in a timely manner. WMATA's request, however, came almost 2 years after the recommendation was closed. The 1000-series railcars remain in service, and WMATA did not accelerate the retirement of these cars in response to the NTSB's recommendation. Accordingly, Safety Recommendation R-06-2 remains classified "Closed—Unacceptable Action."

WMATA subsequently informed the NTSB that the 7000-series cars, which are slated to replace the 1000-series cars beginning in 2013, will provide a higher degree of carbody end-structure collision protection than previous Metrorail cars. Although the new series of Metrorail passenger cars will bring a higher level of crashworthiness to the Metrorail fleet, initial delivery of the cars, at best, is about 3 years away. In the meantime, 294 1000-series cars will still be in use, and as shown by this accident and other recent accidents, they represent a serious risk to Metrorail users in the event of a collision. The NTSB concludes that the structural design of the 1000-series railcars offers little occupant protection against a catastrophic loss of occupant

[22] Rohr built the 1000-series railcars.

survival space in a collision, and the continued use of these cars in revenue service constitutes an unacceptable risk to WMATA Metrorail users. The NTSB therefore recommends that WMATA remove all 1000-series railcars as soon as possible and replace them with cars that have crashworthiness collision protection at least comparable to the 6000-series railcars.

After the Fort Totten accident, WMATA began placing 1000-series cars in the middle (belly) of trains with cars of a later design on either side. This “bellying” of the cars was intended to reduce the vulnerability of the cars to catastrophic damage during a collision. The engineering analysis conducted by WMATA after the NTSB’s public hearing on this accident showed a limited benefit to the bellying of 1000-series cars in a low speed collision (that is, below about 15 mph). The NTSB has reviewed WMATA’s analysis and notes that bellying the 1000-series cars would not be expected to provide appreciable benefit in higher-speed collisions like those occurring at Fort Totten and Woodley Park.

Significant damage was also sustained by bellied 1000-series cars involved in a recent accident that occurred on November 29, 2009, in the West Falls Church yard (which is currently under investigation by the NTSB). In that accident, the striking train was in nonrevenue service, and the operator was positioning the train behind another train in the yard for servicing. The onboard event data recorder indicated that the speed of the striking train at the time of the collision was about 17 mph. Both trains consisted of six cars, with 5000-series cars in the lead, 1000-series cars in the center (in the “belly”), and 3000-series cars in the trailing position. Three of the four 1000-series cars experienced significantly greater damage than the newer series cars as a result of the collision. Two of these cars were on the struck train, and one of these cars was on the striking train. The end structure of these three 1000-series cars were significantly compromised, and one of the 1000-series cars experienced substantial sidewall outward bowing, all of which is consistent with a loss of structural integrity similar to that found in carbody telescoping. The NTSB concludes that WMATA’s practice of bellying the 1000-series cars does not provide appreciable crashworthiness benefits and is not an acceptable substitute for removing the cars from service.

Onboard Event Recorders on Metrorail Trains

In this accident, striking train 112 consisted of 1000-series Metrorail cars that were not equipped with onboard event recorders. It also did not have any other source of recorded data. Because of the lack of recording devices on the striking train, NTSB investigators had to compile other sources of information from the investigation to arrive at a best estimate of the striking train’s speed, braking performance, and position time history. The NTSB concludes that the lack of onboard event recording capability on the striking train prevented a definitive determination of train performance, the status of the onboard systems, and the operator’s actions before the collision.

Although the NTSB recognizes the technical challenges to installing onboard recorders in 1000-series cars, the NTSB is concerned about the continued lack of recorded data for any event involving the 1000- and 4000-series cars. The NTSB notes that an operational event recorder in the lead car of a train will capture critical ATC information as well as train operational data. The NTSB therefore recommends that WMATA ensure that the lead married-pair car set of each train is equipped with an operating onboard event recorder.

Although Metrorail car sets other than 1000- and 4000-series are equipped with onboard recorders, these devices have frequently not been operating when needed. Since December 2006, the NTSB has investigated five WMATA accidents involving trains with onboard recorders. In these accident investigations, only 6 of 11 installed onboard recorders (54.5 percent) were found to contain accident data. As with the Fort Totten accident, the NTSB's investigations were hampered by a lack of recorded data. Investigators have had to gather data from other sources before they could reconstruct accident sequences and evaluate the electronic, mechanical, and human performance factors that led to the accidents.

This investigation determined that WMATA does not have a formal process to ensure the reliability of its onboard recorders. As a result, the recorders cannot do the job for which they were designed. Information received from WMATA indicates that from April 2006 to March 2010, WMATA personnel reported 737 vehicle monitoring system failures that would affect the capturing or recording of train data on the onboard recorder. Because WMATA does not have a program to monitor onboard recorder performance so that such defects are immediately found and remedied, the actual number of failures was likely much higher. The NTSB concludes that because WMATA does not have a program to monitor the performance of onboard event recorders or to ensure that they are functioning properly, these devices cannot be relied upon by WMATA to provide data that can be used for accident investigations or for equipment or operations monitoring and maintenance. The NTSB therefore recommends that WMATA develop and implement a program to monitor the performance of onboard event recorders and ensure they are functioning properly.

Therefore, the National Transportation Safety Board makes the following safety recommendations to the Washington Metropolitan Area Transit Authority:

> Because of the susceptibility to pulse-type parasitic oscillation that can cause a loss of train detection by the Generation 2 General Railway Signal Company audio frequency track circuit modules, establish a program to permanently remove from service all of these modules within the Metrorail system. (R-10-8)
>
> Establish periodic inspection and maintenance procedures to examine all audio frequency track circuit modules within the Metrorail system to identify and remove from service any modules that exhibit pulse-type parasitic oscillation. (R-10-9)
>
> Review the process by which Metrorail technical bulletins and other safety information are provided to employees and revise that process as necessary to ensure that (1) employees have received the information intended for them, (2) employees understand the actions to be taken in response to the information, and (3) employees take the appropriate actions. (R-10-10)
>
> Completely remove the unnecessary Metrorail wayside maintenance communication system to eliminate its potential for interfering with the proper functioning of the train control system. (R-10-11)

Conduct a comprehensive safety analysis of the Metrorail automatic train control system to evaluate all foreseeable failures of this system that could result in a loss of train separation, and work with your train control equipment manufacturers to address in that analysis all potential failure modes that could cause a loss of train detection, including parasitic oscillation, cable faults and placement, and corrugated rail. (R-10-12)

Based on the findings of the safety analysis recommended in R-10-12 incorporate the design, operational, and maintenance controls necessary to address potential failures in the automatic train control system. (R-10-13)

Implement cable insulation resistance testing as part of Metrorail's periodic maintenance program. (R-10-14)

Work with the Tri-State Oversight Committee to satisfactorily address the recommendations contained in the Federal Transit Administration's March 4, 2010, final report of its audit of the Tri-State Oversight Committee and the Washington Metropolitan Area Transit Authority. (R-10-15)

Require that your safety department; representatives of the operations, maintenance, and engineering departments; and representatives of labor organizations regularly review recorded operational data from Metrorail train onboard recorders and the Advanced Information Management system to identify safety issues and trends and share the results across all divisions of your organization. (R-10-16)

Develop and implement a non-punitive safety reporting program to collect reports from employees in all divisions within your organization, and ensure that the safety department; representatives of the operations, maintenance, and engineering departments; and representatives of labor organizations regularly review these reports and share the results of those reviews across all divisions of your organization. (R-10-17)

Review the Hazard Identification and Resolution Matrix process in your system safety program plan to ensure that safety-critical systems such as the automatic train control system and its subsystem components are assigned appropriate levels of risk in light of the issues identified in this accident. (R-10-18)

Develop a formal process by which the general manager and managers responsible for Washington Metropolitan Area Transit Authority operations, maintenance, and engineering will periodically review, in collaboration with the chief safety officer, all safety audits and open corrective action plans, and modify policy, identify and commit resources, and initiate any other action necessary to ensure that the plans are adequately addressed and closed within the required time frame. (R-10-19)

> Remove all 1000-series railcars as soon as possible and replace them with cars that have crashworthiness collision protection at least comparable to the 6000-series railcars. (R-10-20)

> Ensure that the lead married-pair car set of each train is equipped with an operating onboard event recorder. (R-10-21)

> Develop and implement a program to monitor the performance of onboard event recorders and ensure they are functioning properly. (R-10-22)

The National Transportation Safety Board has also reclassified the following safety recommendation previously issued to the Washington Metropolitan Area Transit Authority:

> Examine track circuits within your system that may be susceptible to parasitic oscillation and spurious signals capable of exploiting unintended signal paths, and eliminate those adverse conditions that could affect the safe performance of your train control system. This work should be conducted in coordination with your signal and train control equipment manufacturer(s). (R-09-15 Urgent)

Urgent Safety Recommendation R-09-15, previously classified "Open—Acceptable Response," is reclassified "Closed—Superseded" by Safety Recommendation R-10-8.

The NTSB also issued safety recommendations to the U.S. Department of Transportation, the Federal Transit Administration, the Tri-State Oversight Committee, the Washington Metropolitan Area Transit Authority Board of Directors, Alstom Signaling Inc., the Massachusetts Bay Transportation Authority, the Southeastern Pennsylvania Transportation Authority, the Greater Cleveland Regional Transit Authority, the Metropolitan Atlanta Regional Transportation Authority, the Los Angeles County Metropolitan Transportation Authority, and the Chicago Transit Authority.

In response to the recommendations in this letter, please refer to Safety Recommendations R-10-8 through -22. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our secure mailbox procedures. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, WEENER, and ROSEKIND concurred in these recommendations.

[Original Signed]

By: Deborah A.P. Hersman
Chairman