Stop Signal Overrun Investigation
Washington Metropolitan Area Transit Authority (WMATA)

FINAL REPORT

Federal Transit Administration
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

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Acronyms

ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
CAP	Corrective Action Plan
FTA	Federal Transit Administration
FWSO	FTA WMATA Safety Oversight
MMIS	Maintenance Management Information System
MSRPH	Metrorail Safety Rules and Procedures Handbook
ROCC	Rail Operations Control Center
SMS	Safety Measurement System
SMI	Safety Management Investigation
SOP	Standard Operating Procedure
SSOA	State Safety Oversight Agency
TOC	Tri-State Oversight Committee
WMATA	Washington Metropolitan Area Transit Authority

1.0 Executive Summary

This report documents findings and required actions resulting from an investigation conducted by the Federal Transit Administration (FTA) into stop signal overruns on the Washington Metropolitan Area Transit Authority (WMATA) Metrorail system. A stop signal overrun occurs when a train fails to stop as required in advance of a stop signal, flag, or other indicator, as specified in a rail transit agency's operating rules and procedures. The FTA considers stop signal overruns significant safety events, with the potential to result in the derailment or collision of passenger trains and the striking of workers or equipment on the rail transit right-of-way.

The FTA WMATA Safety Oversight (FWSO) Office initiated this investigation at WMATA because, in calendar year 2015, the Metrorail system experienced more stop signal overruns than in either of the previous two years. In addition, FWSO's review of individual stop signal overrun incidents, occurring after FTA assumed direct oversight responsibility in October 2015, identified potential issues related to communications, training, signal identification, and the enforcement of train speeds that required systemwide analysis and evaluation. Finally, a near-miss collision with a passenger train at Smithsonian on February 3, 2016 highlighted the severe potential consequences associated with stop signal overruns, as well as the need to prioritize addressing them for the safety of the riding public.

FWSO's investigation focused on four main activities:

- Determining the frequency of stop signal overruns on the Metrorail system,
- Identifying the potential consequences of these events,
- Clarifying contributing factors to these events, and
- Assessing the adequacy of WMATA's actions and programs currently underway to prevent these incidents.

FWSO initiated its investigation on March 16, 2016 and concluded it on July 31, 2016.

During the course of this investigation, concerns raised regarding these events at WMATA led the FTA to issue an industry-wide safety advisory on April 8, 2016. [1] The FTA also requested additional information from state safety oversight agencies and rail transit agencies regarding how they define, track and investigate stop signal overruns. The FTA is currently reviewing this information to determine if additional action is needed to improve the investigation of stop signal overruns, industry-wide, and to standardize mitigations put in place to prevent these events.

Through the course of FWSO's investigation, working cooperatively with WMATA, FWSO identified 68 stop signal overruns that occurred during the 55-month period between January 1, 2012 and July 31, 2016. Investigations into these events, conducted by WMATA, focused largely on the behavior of the train operator, and more recently, on the rail traffic controller, and whether the stop signal overrun constituted a violation of WMATA's safety rules and procedures. While the quality of information collected in response to each of these specific stop signal overrun events varied, and limited data was available to support trend analysis back to 2012, the review of these reports nevertheless provided valuable information regarding the

[1] *See* Safety Advisory 16-1, "Stop Signal Overruns in 2015" (April 6, 2016).

actions of train operators and rail traffic controllers, the physical characteristics of WMATA's stop signal system, the functioning of WMATA's critical safety rules, and the potential consequences involved with these events.

Based on its evaluation of these reports, and additional observations and inspections conducted regarding WMATA's Metrorail operations through July 31, 2015, FWSO identified several contributing factors associated with stop signal overruns in the WMATA system:

- Lack of train operator familiarity with mainline and yard territory,
- Train operator inattention or confusion when departing from a station or terminal or moving under zero speed commands, and
- Poor or incomplete communication between the train operator and the Rail Operations Control Center (ROCC) regarding unusual train movements.

FWSO also found the need for more effective event reporting and analysis regarding stop signal overruns. Encouraging more open and complete reporting of stop signal overrun incidents and performing additional field and even simulator-based research will allow WMATA to better understand why stop signal overruns occur and identify more effective and targeted corrective actions to address them.

Since the FTA's Safety Management Inspection (SMI) in June 2015, and even more recently under the FTA's direct safety oversight, WMATA has taken a number of critical steps to improve the safety of its train operations. WMATA has made considerable progress in addressing findings previously issued by the FTA and recommendations resulting from WMATA's own internal assessments and evaluations. Many of these actions also address factors commonly considered to contribute to stop signal overruns, such as speeding, lack of familiarization with the location of stop signals, lack of operational testing, and ineffective communications between supervisors and train operators regarding safety rules and performance. For example, WMATA has revised operating rules, expanded training and supervision for train operators and rail traffic controllers, improved adherence to radio protocol, installed new signage in rail yards, and investigated options for modifying the signal system to automatically stop trains at red signals, even when they are operating in manual modes.

However, there is more that must be done. To build on WMATA activities already underway, this report identifies six (6) additional findings and eleven (11) required actions that WMATA must take to further reduce the risk of stop signal overruns in the Metrorail system. These requirements will be formally issued to WMATA separately through FTA Safety Directive 16-5.

As directed by Safety Directive 16-5, WMATA must develop additional corrective action plans to address the findings of this report and related required actions. FWSO will review and approve WMATA's work plans, and will monitor the agency's progress to implement the safety improvements.

2.0 Introduction

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2.1 Purpose

The FTA WMATA Safety Oversight (FWSO) Office initiated this investigation because, in calendar year 2015, the Metrorail system experienced more stop signal overruns than in either of the previous two years. In addition, FWSO's review of individual stop signal overrun incidents, occurring after FTA assumed direct oversight responsibility in October 2015, identified potential issues related to communications, training, signal identification, and the enforcement of train speeds that required systemwide analysis and evaluation. Finally, a near-miss collision with a passenger train at Smithsonian on February 3, 2016 highlighted the severe potential consequences associated with stop signal overruns, as well as the need to prioritize addressing them for the safety of the riding public.

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2.2 Major Activities

Working closely with WMATA, FWSO identified the stop signal overruns that occurred during the 55-month period between January 1, 2012 and July 31, 2016. In conducting this investigation, FWSO reviewed information assembled by WMATA personnel responding to each of these stop signal overruns, and by FTA's own investigators, including all investigation

[2] *See* Safety Advisory 16-1, "Stop Signal Overruns in 2015" (April 6, 2016).

reports and supporting documents. FWSO also met with WMATA multiple times to discuss stop signal overrun issues, including causes and contributing factors in specific stop signal overruns, and WMATA provided factual review of this report in mid-July and early August.

In carrying out its internal safety program, WMATA investigates each stop signal overrun to determine the cause, to assess potential contributing factors, and to issue recommended action. WMATA's investigation reports currently provide varying levels of detail, and are not structured in such a manner to facilitate trend analysis. But, in general, between January 1, 2012 and July 31, 2016, WMATA classified the primary cause of most stop signal overruns as train operator failure to follow proper operating procedures and a violation of safety rules. In response to these events, WMATA generally interviewed and reinstructed the train operator, and also may have taken disciplinary administrative action against the train operator.

More recently, in response to a finding issued in FTA's Safety Directive 15-1, WMATA has begun conducting a more thorough review of each stop signal overrun to determine if ROCC controllers, interlocking operators, and/or terminal supervisors may have contributed to the incident. In instances with conflicting reports between train operators and controllers, WMATA will review the configuration of the signal system at the overrun location, and pull radio recordings from the ROCC, to clarify the chronology of events and to determine how the overrun occurred. In two instances, involving eight-car trains in center pocket tracks, WMATA conducted engineering reviews of the design and performance of the signal system in those locations for eight-car trains.

While the quality of information collected in response to each of these specific stop signal overrun events varied, and limited data was available to support trend analysis back to 2012, the review of these reports nevertheless provided valuable information regarding the actions of train operators and rail traffic controllers, the physical characteristics of WMATA's stop signal system, the functioning of WMATA's critical safety rules, and the potential consequences involved with these events.

In the course of this investigation, FWSO also conducted observations in the ROCC during revenue service and overnight maintenance operations, reviewed training materials and certification processes for train operators and rail traffic controllers, and interviewed train operators, rail transportation supervisors, and rail traffic controllers regarding their experiences in operating on the WMATA system

Further, while investigating a February 3, 2016 stop signal overrun at Smithsonian, FWSO took the opportunity, to treat this near-miss incident as a major investigation and reviewed all available date to identify the full range of potential concerns related to stop signal overruns, including, but not limited to:

- Radio communication between the ROCC and train operators;
- ROCC records;
- Signal placement;
- Track type and design;
- Work site planning and General Orders and Track Rights System (GOTRS) requests;
- Employee records; and

- Employee fatigue.

Through the course of its investigation of the February 3 incident, FWSO accessed audio and video recordings from the ROCC and the signal system, downloads from rail vehicles, employee training records and work histories, in-depth examination of work zone set-up practices and the GOTRS database, and testing and measurement regarding the location of the signal masts and potential visual obstructions. FWSO also conducted independent interviews with several WMATA employees involved in the incident. Finally, using information gathered during the investigation into the February 3 incident, FWSO conducted observations of train operations, the ROCC and interlocking operators, and interviewed a range of operations and maintenance personnel.

2.3 Frequency of Stop Signal Overruns at WMATA

Working cooperatively, FWSO and WMATA reviewed records and reports in WMATA's Safety Measurement System (SMS) web-based tool and WMATA's Maintenance Management Information System (MMIS). In all, FWSO and WMATA identified 68 stop signal overruns that occurred during the 55-month period between January 1, 2012 and July 31, 2016.

Figure 1 presents the number of stop signal overruns by year and the average monthly rate of occurrence. WMATA experienced more stop signal overruns in 2015 than in either of the two previous years. Through July 31, 2016, WMATA averages 1.43 stop signal overruns per month, its highest average rate since 2012. With 10 stop signal overruns so far in 2016, WMATA is on pace to match or exceed the 2015 stop signal overrun total.

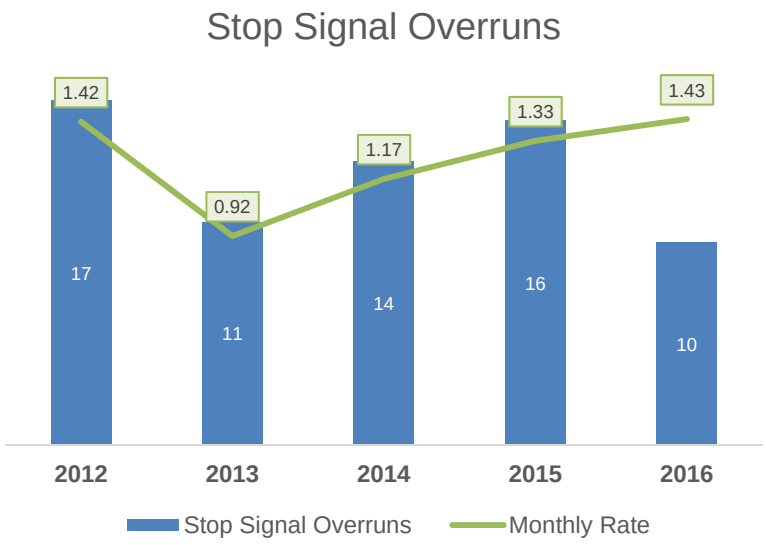

Figure 1: WMATA Stop Signal Overruns and Rate by Year, 2012 through July 31, 2016

Figure 2 identifies the location of all stop signal overruns on the WMATA Metrorail system by year.

Figure 2: WMATA Stop Signal Overruns and Rate by Location and Year, 2012 through July 31, 2016

Figure 3 presents the number of stop signal overruns by month and the cumulative monthly rate since January 1, 2012. The cumulative monthly rate refers to the monthly rate for the period from January 2012 to that month, which is determined by the dividing the number of stop signal overruns by the number of months for the period. Figure 3 illustrates the relative consistency of the occurrence of stop signal overruns on the Metrorail system. The data presented in this figure shows that longest period between stop signal overruns has been 97 days, and the shortest period, one day. Over the 55-month period, WMATA experienced 2 months with 4 stop signal overruns (the highest number), 3 months with 3 stop signal overruns, 16 months with 2 stop signal overruns, 19 months with one stop signal overrun, and 15 months with no stop signal overruns.

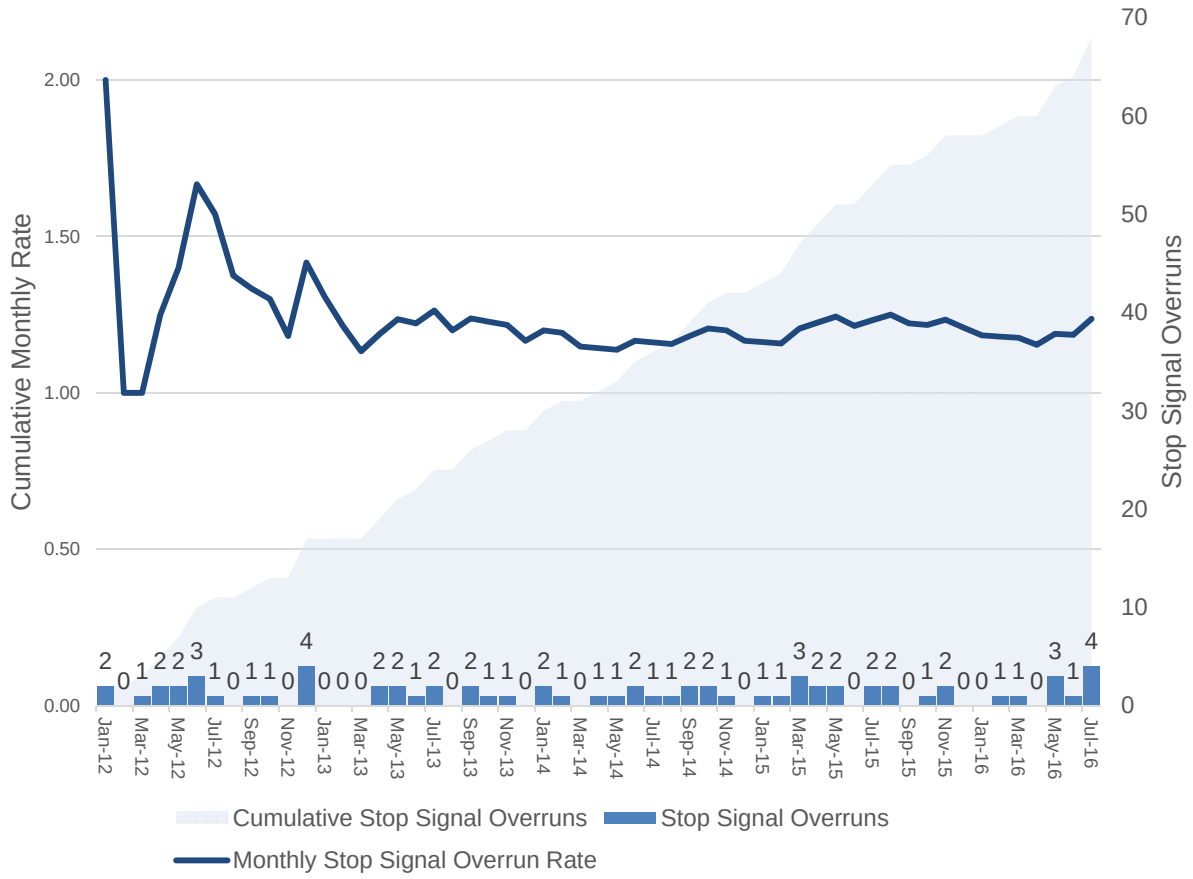

Figure 3: WMATA Stop Signal Overruns Cumulative Rate by Month

These stop signal overrun events occur at all times of day and night, during all months of the year, and take place on all types of track (including mainline track and pocket tracks), in stations and terminals, and in the yards. Both new and veteran train operators and rail maintenance machine operators overrun stop signals. While newer operators are somewhat more likely to experience stop signal overruns than their more senior counterparts, and while more stop signal overruns occur in stations than yards, there are few clearly discernable patterns or trends regarding the occurrence of these incidents on the Metrorail system.

While none of these stop signal overruns resulted in a train-to-train collision, FWSO found that in four (4) cases, dating back to 2012, as a result of a stop signal overrun, trains came closer than 500 feet to each other. And, in three instances since FWSO assumed direct oversight, on October 23, 2015 near Pentagon Station, on February 3, 2016 near Pentagon Station, and on July 5, 2016 near Glenmont Station, trains or maintenance vehicles came within seconds of striking another passenger train or workers on rail transit right-of-way.

FWSO also found that eight (8) of the 68 events resulted in damage to switch components, occurring largely during single tracking operations. These incidents required track to be removed from service for repairs, and could have resulted in a derailment or intrusion into a work zone.

2.4 Previous FTA Required Actions

On June 17, 2015, FTA issued Safety Directive 15-1, which documented findings and required actions from the Safety Management Inspection (SMI) that FWSO conducted at WMATA between March and June 2015. WMATA has developed and is currently implementing corrective action plans (CAPs) that address a number of FTA findings related to improving the performance of the ROCC; enhanced training for train operators, controllers, and supervisors; efficiency testing and monitoring for operations personnel; new radio protocols requiring 100 percent word-for-word repeat-backs, and expanded accident investigation procedures. While these findings and required actions do not address stop signal overruns directly, many of these activities support improvements that also address issues relevant in stop signal overrun occurrences.

In December 2015, the FTA issued Safety Directive 16-2, requiring WMATA to take corrective action to resolve more than 200 open safety findings previously issued by the Tri-State Oversight Committee. To address outstanding items from previous investigations into stop signal overruns, the FTA required WMATA to develop eight (8) corrective actions, FTA-RED-15-001 through FTA-RED-15-008. WMATA is currently working to implement CAPs for each of these required actions.

On May 7, 2016, the FTA issued Safety Directive 16-3 to re-focus operations and maintenance personnel on the importance of safety over service when responding to events impacting passenger operations, and to require safety standards to review WMATA's rules and standard operating procedures. Safety Directive 16-3 contained four (4) findings requiring action from WMATA.

FWSO continues to monitor WMATA's activity to implement these corrective actions, most of which will be completed by early-to-mid 2017. Updated status regarding WMATA's closure of corrective actions is available on FTA's website at: https://www.transit.dot.gov/regulations-and-guidance/safety/wmata-cap. Required actions issued by FWSO as part of this investigation take into account WMATA action already underway to implement corrective action to address Safety Directives 16-3, 16-2, and 15-1, as well as other actions taken by WMATA since 2012.

3.0 Stop Signal Overruns at WMATA

3.1 Introduction

The WMATA Metrorail system is the second largest rail transit system in the United States with 269.8 total track miles, including 136.6 miles at grade, 18.4 miles on elevated structures, .5 miles elevated on fill, 3.1 miles open-cut tunnel, and 111.2 miles of subway tunnels.[3] It operates over six lines, the Blue, Green, Orange, Red, Silver, and Yellow lines, and services 91 stations. Metrorail provides this service using a fleet of approximately 1,100 vehicles comprised of seven different series (named 1000- through 7000-series). Typical service hours are 5:00 a.m. through midnight on Monday through Friday, and 7:00 a.m. through midnight on Saturday and Sunday.

Through 2015, each weekday, Metrorail provided approximately 730,000 passenger trips. Beginning in June 2016, WMATA implemented its new SafeTrack program, with maintenance "surges" scheduled throughout the year, which requires taking track out of service or instituting continuous single tracking through work zones. This extensive maintenance program is expected to have a substantial impact on ridership and service through the spring of 2017.

3.2 Stop Signal Overrun Definition

As specified in WMATA's Operating Rule 3.67, a stop signal overrun occurs anytime a revenue passenger train or roadway maintenance machine vehicle passes a specific point designated as the location where the train or maintenance vehicle must stop when a particular indication, signal, sign, flag or board is displayed. Stop signal overruns can occur on mainline tracks, at stations, and in rail yards, anywhere WMATA uses signals or flags to direct the movement of trains. Figure 4 presents typical stop signal configurations at WMATA.

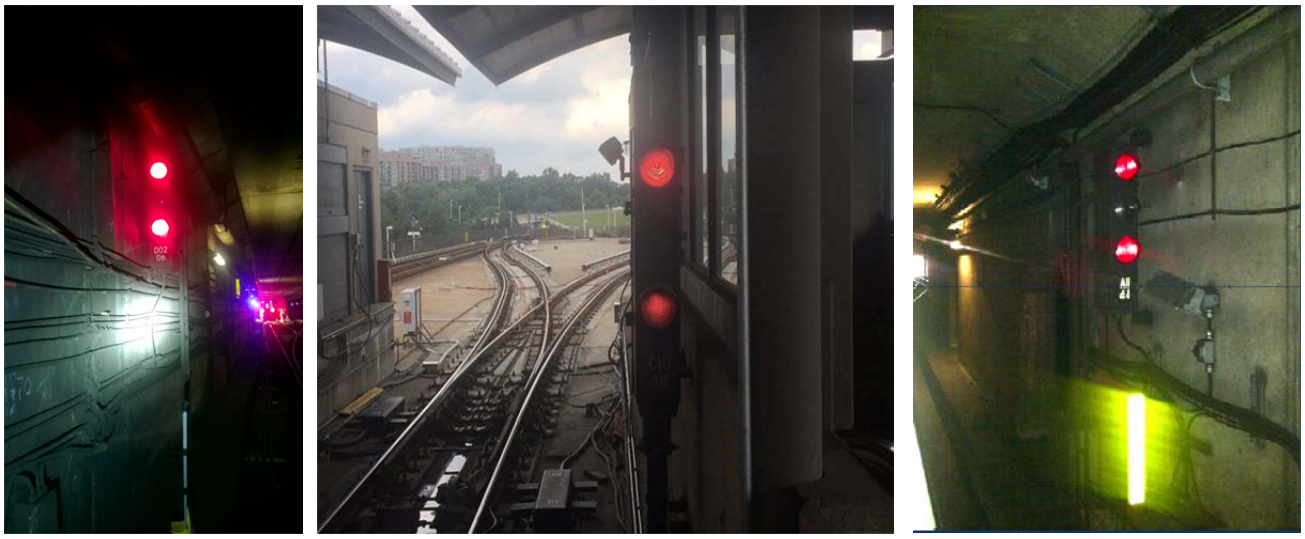

Figure 4: Typical Stop Signal Configurations at WMATA

[3] As reported by WMATA to the National Transit Database.

As depicted in Figure 4, signals are mounted on pedestals alongside the track or mounted on the wall of a tunnel. Figure 5 shows an outdoor signal, fitted with hoods to improve daylight viewing. When the top and bottom lights are red, as indicated in Figures 4 and 5, the train operator is facing a stop signal, and is required by WMATA operating rules to bring his or her train to stop no less than 10 feet in advance of the signal (see section 3.2.1 below).

Figure 5: Typical Outdoor Stop Signal

Each interlocking has a signal associated with it, and all signals are referred to by an alphanumeric code. To identify a particular signal at which a train is standing, the interlocking code and signal number are both used. In Figure 5, the interlocking code is J03 and the specific signal number is 02.

Unauthorized passing of a stop signal is considered a major violation of WMATA's safety rules, and has the potential to result in a range of consequences, including:

- Damage to switch components when operating over a misaligned switch;
- Derailments resulting from operating over a misaligned switch;
- Train-to-train collisions; and
- Collisions with workers or equipment on the right-of-way.

In performing this investigation, FWSO included in its analysis instances in which (1) a rail vehicle violated a stop at a signal interlocking or red lamp and (2) a passenger train or roadway maintenance machine vehicle bypassed the limits of an absolute block.

3.2.1 Signal Interlockings and Absolute Blocks

For revenue passenger trains, WMATA train operators are subject to Operating Rule 3.67 from the WMATA Metrorail Safety Rules and Procedures Handbook (MSRPH), which states:

> Rail vehicles shall not be operated past or closer than a point 10 feet in approach of an interlocking signal or lamp displaying a red aspect, a red flag, or a dark interlocking signal, unless authorized by Rail Operations Control Center (ROCC) or the Interlocking Operator and the move is consistent with customer safety as specified in Rule 3.1.[4]

WMATA's Metrorail system does not use mechanical trip stops for signal enforcement. Instead, signal enforcement is provided by speed commands transmitted to trains through coded track circuits. Prior to 2009, WMATA operated its system in full automatic mode, which meant that

[4] MSRPH Rule 3.1 states: "Customer Safety is the responsibility of every WMATA employee; however, Train Operators have the ultimate and final responsibility for the safety of the customers on their particular trains. If any Train Operator is instructed by any person, regardless of rank, title, or position, to take any action which would adversely affect the safety of customers, the operator shall stop that train, notify ROCC or the Interlocking Operator, and shall not continue until satisfied that is it safe to do so."

train operators only manually moved trains upon the loss of speed commands, in inclement weather, to support unusual train movements, to maintain skills in manual operations, and in rail yards.

Since the collision at Fort Totten in 2009, however, WMATA determined, as an extra safety precaution, to operate its system in manual mode. While many elements of the automatic train protection system remain in effect for trains operating in manual mode, specific manual mode settings allow trains to move at speeds just under 15 miles per hour through stop signals. In these specific circumstances, trains can proceed beyond the signal, potentially over switches into territory that may include another train, a work zone, or workers on the right-of-way, without receiving automatic braking penalties.

Roadway maintenance machine vehicles are not equipped to respond to WMATA's track circuits and do not receive speed commands at signals. Therefore, to protect these vehicles on the mainline, WMATA's ROCC sets absolute blocks. As specified in Standard Operating Procedure (SOP) #15, absolute blocks are used to prohibit trains from entering a specific track segment. Absolute blocks can be imposed anywhere on the WMATA mainline and may include interlockings within their limits. Absolute blocks are used to manage a variety of operational and maintenance situations on the Metrorail system. For example, SOP #15 requires that an absolute block be implemented for any mainline rail vehicle movement in any of the following scenarios:

- Failure of the wayside automatic train protection subsystem;
- Roadway maintenance machine vehicle movement;
- Movement against the established direction of traffic;
- Movement through a protected work area; and
- Whenever, in the judgment of the ROCC supervisor, a circumstance warrants the use of an absolute block.

To enforce the absolute block, both rail vehicle operators and vehicle flag persons are responsible for compliance with verbal instructions and limits from the ROCC or rail transportation supervisor, regardless of wayside signal indications or speed readouts. Further, operators of railway maintenance machines are also responsible for checking rail alignment when given permission to pass any signal set to stop. Additionally, SOP #15 Section 15.5.8.6 requires that, "with a lunar aspect[5], rail vehicle operators and flag persons shall not operate their vehicle beyond the established limits of the assigned absolute block." This requirement further reinforces the primacy of complying with ROCC verbal instructions when operating under an absolute block.

3.2.2 WMATA Signal and Train Control System

WMATA's train operations are governed by a train control system designed during Metrorail's original construction in the early 1970's for train movements in both directions on two main tracks, in pocket tracks, and in the rail yards. Although rehabilitation and upgrade programs are

[5] Lunar aspect means a lunar white signal that generally indicates the train should proceed through the interlocking.

underway to replace train control components, the original train control equipment remains in use in many locations throughout the system.

When fully engaged, WMATA's Automatic Train Control (ATC) system uses automatic train protection (ATP), automatic train supervision (ATS) and automatic train operation (ATO) to automatically route trains and enforce train separation, train speeds, and train operation between stations. Manual control, however, overrides specific ATC subsystem elements, and introduces a greater opportunity for operator error and inconsistency.

In response to the 2009 Fort Totten collision, Metrorail suspended use of the ATO control subsystem, operating trains in manual control with ATS and ATP control subsystems. WMATA also completed an extensive safety analysis and engineering evaluation of the performance of the ATC system. As a result of this analysis and evaluation, WMATA replaced track circuits suspected of causing "parasitic oscillations," an electrical malfunction impacting the ATC system's ability to appropriately detect train locations.

WMATA is in the process of upgrading its train control system. Completion of a major track circuit replacement has enabled WMATA to restore automatic operations to the Red Line for eight-car trains during peak hour service. Additional work is underway to potentially restore other lines to automatic operation for eight-car trains in 2017 and 2018. As WMATA's operations shift to 100 percent eight-car trains, the agency will continue to evaluate its options regarding the reinstatement of full automatic operations.

Whether in manual or automatic mode, WMATA's train control system employs "go/no-go" signals located at interlockings and speed read-outs to direct train operation. Interlockings are places where tracks join together and include track switches, associated signals and the control machinery that connects them and enables their operation. Speed read-outs set a maximum train speed for moving through a particular track block or location. Penalty brakes are applied to trains moving at excessive speeds.

A stop signal serves as the "no go" indication used by WMATA's signaling system. Metrorail mainline routes are divided into blocks between the terminal stations at the ends of each route. Each block is checked for train occupancy utilizing audio frequency track circuits. Tuned impedance bond devices are installed at block boundaries. The impedance bonds transmit onto the rails the coded signals generated in the train control room that are used to detect the presence of a train in a block and to signal speed commands to trains.

In certain manual operating modes, settings for speed read-outs allow train operators to operate trains at speeds under 15 miles per hour when the signal system requires "zero" speed commands without brake penalties being applied. Under these circumstances, trains can violate stop signals and enter blocks occupied by other trains or cross over switches without being automatically stopped by the ATP system. Appendix B provides additional detail regarding WMATA's operating modes.

3.2.4 Yard Operations

An interlocking operator, who is a Rail Transportation employee assigned to a yard control room or tower, operates the yard locking control panel and oversees all yard operations. Due to yard configuration complexity and the significant number of potentially moving vehicles, the interlocking operator coordinates all yard movements.

Prior to movement in the yard, train operators must contact the interlocking operator and request a path for train movement. When safe to do so, the interlocking operator sets a lead for the train to make the required move prior to granting the operator permission to move the train by establishing a path using lunar signals. WMATA Rule 3.84 states, "the maximum authorized speed in the yard is 15 miles per hour, except for curves, switches, roadway crossings, and storage track entrances, which require a 10 mile per hour maximum speed…" Operators in the yard must also be prepared to stop within half the range of vision (within half of the distance they can see in their line of sight from the cab or equipment), short of any train, obstruction, broken rail, or improperly aligned switch.

4.0 Results of Investigation

4.1 Investigation Process

In the public transportation industry, the unauthorized passing of stop signals can occur for any number of reasons, including employee error or inattention, deficiencies in the design and performance of the signal system or the placement of signal masts, ineffective or insufficient employee training and supervision, overly aggressive train routing and scheduling practices, confusing or incorrectly set-up work zone and single-track configurations, and poor communications and/or radio discipline. In general, investigations into stop signal overruns typically address a number of items, including:

- General information (location of stop signal overrun, date, time of day)
- Train operator information (name, badge number, years of experience, hours on duty, recent work history, etc.)
- Train operator training and qualification information (most recent re-certification, scores, results of efficiency testing, performance record, etc.)
- Rail traffic controller information (name, badge number, years of experience, hours on duty, recent work history, etc.)
- Rail traffic controller training and qualification information (most recent re-certification, scores, results of efficiency testing, performance record, etc.)
- Train information (train consist configuration, inspection results, data downloads, etc.)
- Physical environment information:
    - System information (track and signal type and configuration, etc.)
    - Weather (temperature and visibility, rain, fog, snow, etc.)
    - Signal visibility (sun on signal, lights of another train, obstruction (e.g., behind a wall), around a curve, train pulled up ahead of signal at platform, signal condition [missing bulb, etc.], presence of other lights, etc.)
    - Signal interpretation (non-standard location that may have caused confusion regarding applicability of signal, complexity of location or sequencing of moves, train operator reading through to subsequent signal, etc.)
    - Signal markings (contrast, size, reflectivity, reaction to sunlight and train lights, etc.)
- Situational information (e.g., what happened immediately prior to the stop signal overrun, time pressure/stress, mental state of train operator, tenor of communication from ROCC or supervisor, etc.)
- Signal system performance (dropped signal, etc.)
- Communication information (quality of radio communication, dropped communication, accuracy of repeat-backs, clarity of directions, radio protocol followed, etc.)
- Distractions for train operator (radio communications, paperwork, communication with another employee or passenger, cell phone, newspaper, etc.)
- Distractions for rail traffic controller (number of radio communications, number of activities being performed, level of ambient noise, paperwork, cell phone, conversations with employees, newspaper, etc.)
- Train operator expectations (anticipated signal/route, anticipation of clear signal, anticipation of previous signal, anticipated switch points, etc.)

- Train operator's experience with train move (familiarity with train, line and signal, familiarity with operating schedule, unusual train movement, etc.)
- Fatigue (hours on duty, work history)
- Drug and alcohol (results of testing, as appropriate)

4.2 Investigation Findings

For this investigation, FWSO reviewed stop signal overrun investigation reports and supporting materials collected by WMATA and FWSO investigators between January 1, 2012 and July 31, 2016 to identify prevalent and recurring contributing factors associated with the stop signal overruns. FWSO generally agrees with WMATA that the probable cause of these events is the failure of the train operator and/or rail traffic controller to follow critical safety rules and procedures. However, FWSO also identified additional contributing factors, which were apparent in multiple stop signal overruns that occurred under this period of review. These contributing factors include systemwide issues that can be managed or improved to reduce the probability of inadvertent violation of WMATA's safety rules and procedures.

Historically, dating back to 2012, WMATA has not collected sufficient information that allows the agency to systematically identify current risks of stop signal overruns or the sources of these risks. WMATA's new leadership is working actively to enhance the quality and comprehensiveness of accident investigation.

Interviews conducted with train operators as part of these early stop signal overrun investigations provide some insight into specific issues experienced by train operators, equipment operators, rail traffic controllers, and others related to stop signal overruns. In reviewing these results, FWSO has specific concerns relating to:

- The quality of radio communication,
- Train operator route knowledge and signal familiarity,
- Radio protocol and professionalism,
- Signal visibility,
- Train operator and rail traffic controller training,
- Train schedules and breaks, and
- Operating rules.

More recently, WMATA has instituted a process for conducting more detailed investigations, including review of radio communications and recordings, signal system and rail transit vehicle downloads, recreations of conditions at certain signal locations, and engineering review of signal performance. These later investigations have broadened the spectrum of issues under consideration, and pointed out specific challenges with eight-car trains in center pocket tracks, with approaches to left-hand signals, and with communications regarding the movement of roadway maintenance machines under certain conditions.

In 2014, WMATA also commissioned a study[6] to analyze eleven (11) stop signal overruns occurring in 2014 to identify causes and make recommendations to proactively prevent future stop signal overruns. While this report was never finalized, it provides additional detail on each of these events, and also includes follow-up interviews with train operators. This report emphasizes the importance of train operator personal readiness for train movements through signals and discusses the importance of strategies for managing pressure and "unintentional" rushing to meet on-time performance demands. This report also reinforces the importance of physical characteristics training, and sharing with operators the locations of past signal overruns and emphasizing non-standard signal locations and signal "hot spots" with limited visibility or unusual approach requirements.

In 2016, FWSO and WMATA worked together to conduct an extensive investigation of the stop signal overrun near Smithsonian Station on February 3, 2016. This investigation focused on the quality of communication between the train operator and the ROCC, and the level of activity and distraction in the ROCC. Since February 3, 2016, FWSO has overseen and directed the collection of extensive information regarding the occurrence of each stop signal overrun.

4.3 Investigation Analysis

Working with available information, including in-depth review of accident investigation reports and supporting attachments, FWSO identified several prevalent and recurring contributing factors associated with the stop signal overruns experienced on the WMATA's Metrorail system. Some of these factors were present at more than one incident, while some incidents had none of these factors readily discernible. For sixteen (16) stop signal overruns, insufficient information was available to conclusively identify causal or contributing factors.

The four primary categories of causal and/or contributing factors identified by FWSO include:

- **Lack of train operator familiarity with Mainline or Yard Territory**: Lack of train operator familiarity with mainline track and yard territory played a role in 30 percent of the stop signal overruns, including 12 events involving an operator with less than one year of experience. In these incidents, train operators indicated that they were not expecting the signal, were not familiar with the line or yard, or were unfamiliar with the schedule for train departures.

- **Train operator inattention or confusion when departing from a station or terminal or moving under zero speed commands**: Thirty-four percent of stop signal overruns occurred while the operator departed a station or terminal and operated under zero speed commands. In these instances, WMATA and FWSO investigations generally found inattentiveness, lack of preparation, and failing to follow established procedure for leaving terminals, failure to read speed commands, signal indication or switch alignment prior to train movement, and violation of cardinal operating rules for approach to stop signals and zero speed commands (Operating Rules 3.1, 3.67, and 3.79).

[6] The study was performed by Atticus Consulting Group LLC, Preliminary Report was issued April 29, 2015; "Investigation and Analysis of WMATA 2014 Stop Signal Violation Incidents." The report was not finalized.

- **Poor or incomplete communication between the train operator and the Rail Operations Control Center (ROCC) and others regarding unusual train movements**: Deficient communications infrastructure or poor understanding or direction from the ROCC, interlocking operator, or rail transportation supervisor played a factor in 36 percent of stop signal overruns. In these instances, radio communications were difficult to hear, communications did not follow required protocols, and radio repeat-backs were not properly issued or authorized.

Other factors, such as fatigue, signal configuration (left-hand signals versus traditional location), and improper storage in yard were also identified by FWSO, but were not sufficiently prevalent across the investigation period to make conclusive findings.

FWSO also found the need for more effective event reporting and analysis regarding stop signal overruns. WMATA does not currently collect a sufficiently broad or consistent set of data to enable the agency to identify trends and create targeted mitigations. Encouraging more open and complete reporting of stop signal overrun incidents and performing additional field and even simulator-based research will allow WMATA to better understand why stop signal overruns occur and identify more effective and targeted corrective actions to address them.

Table 1 below provides a complete list of the 68 stop signal overruns, and also indicates the presence of one or more key contributing factors identified by FWSO during its review of the investigation reports. Stop signal overruns with insufficient information available to draw conclusions are also identified.

#	Date	Location	Causal Factors
1	1/10/2012	Mount Vernon Square/7th St.-Convention Center	Departing Station/Zero Speed Commands
2	1/17/2012	Farragut North	New/Unfamiliar Operator
3	3/6/2012	Farragut North	New/Unfamiliar Operator, Communication, Fatigue
4	4/16/2012	Vienna-Faifax/GMU	Departing Station/Zero Speed Commands, Communication
5	4/22/2012	Van Dorn Street	Communication
6	5/5/2012	DuPont Circle	Insufficient Information
7	5/10/2012	West Falls Church Yard	Communication, New/Unfamiliar Operator
8	6/20/2012	Grosvenor-Strathmore	Insufficient Information
9	6/21/2012	C+A Connector	New/Unfamiliar Operator
10	6/27/2012	Grosvenor-Strathmore	Insufficient Information
11	7/23/2012	Alexandria Yard	Insufficient Information
12	9/25/2012	Twinbrook	Insufficient Information
13	10/19/2012	Foggy Bottom	Departing Station/Zero Speed Commands, Left-hand Signal
14	12/6/2012	Silver Spring	Departing Station/Zero Speed Commands, Visibility
15	12/10/2012	L'Enfant Plaza	New/Unfamiliar Operator, Departing

#	Date	Location	Causal Factors
			Station/Zero Speed Commands
16	12/26/2012	New Carrolton Yard	Interlocking Operator Error
17	12/28/2012	Mount Vernon Square/7th St.-Convention Center	New/Unfamiliar Operator, Departing Station/Zero Speed Commands
18	4/4/2013	Prince George's Plaza	Prime Mover Operating outside work zone
19	4/22/2013	Van Ness-UDC	New/Unfamiliar Operator, Departing Station/Zero Speed Commands
20	5/13/2013	Van Ness-UDC	Communication, Departing Station/Zero Speed Commands
21	5/28/2013	McPherson Square	Communication, New/Unfamiliar Operator, Left-Hand Signal
22	6/2/2013	Van Dorn Street	Communication, Departing Station/Zero Speed Commands
23	7/15/2013	West Falls Church Yard	Interlocking Operator Error
24	7/20/2013	West Falls Church Yard	Interlocking Operator Error, Improper Storage
25	9/4/2013	Franconia-Springfield	Communication, New/Unfamiliar Operator
26	9/15/2013	Ballston	New/Unfamiliar Operator, Left-Hand Signal
27	10/1/2013	Smithsonian	Communication, New/Unfamiliar Operator
28	11/24/2013	DuPont Circle	Departing Station/Zero Speed Commands, Fatigue
29	1/8/2014	Shady Grove	Communication, Departing Station/Zero Speed Commands
30	1/13/2014	Greenbelt	Communication, Departing Station/Zero Speed Commands, Visibility
31	2/15/2014	Brentwood Yard	Communication
32	4/28/2014	New Carrolton Yard	Improper Storage
33	5/28/2014	Anacostia	Departing Station/Zero Speed Commands
34	6/24/2014	Brentwood Yard	Communication, New/Unfamiliar Operator, Visibility
35	6/30/2014	Greenbelt	New/Unfamiliar Operator, Departing Station/Zero Speed Commands
36	7/4/2014	Shady Grove Yard	Communication, New/Unfamiliar Operator, Interlocking Operator Error
37	8/16/2014	Ronald Reagan Washington National Airport	Departing Station/Zero Speed Commands, Left-Hand Signal
38	9/16/2014	Largo Town Center	Departing Station/Zero Speed Commands
39	9/24/2014	U Street/African American Civil War Memorial/Cardozo	New/Unfamiliar Operator

#	Date	Location	Causal Factors
40	10/12/2014	Shady Grove Yard	Insufficient Information
41	10/30/2014	Braddock Road	Communication, Departing Station/Zero Speed Commands, Visibility
42	11/3/2014	Shady Grove Yard	Insufficient Information
43	1/23/2015	Shady Grove	Communication, Departing Station/Zero Speed Commands
44	2/19/2015	Alexandria Yard	New/Unfamiliar Operator
45	3/7/2015	Foggy Bottom	Insufficient Information
46	3/17/2015	Silver Spring	Communication, New/Unfamiliar Operator
47	3/23/2015	Vienna	Departing Station/Zero Speed Commands
48	4/10/2015	West Falls Church Yard	New/Unfamiliar Operator
49	4/19/2015	Alexandria Yard	Visibility
50	5/8/2015	Judiciary Square	Communication, Departing Station/Terminal
51	5/10/2015	Wiehle-Reston	Insufficient Information
52	7/22/2015	Brentwood Yard	Insufficient Information
53	7/27/2015	Shady Grove Yard	New/Unfamiliar Operator, Left-Hand Signal
54	8/20/2015	Alexandria Yard	Communication, Interlocking Operator Error
55	8/30/2015	Ronald Reagan Washington National Airport	Insufficient Information
56	10/23/2015	Pentagon	Communication, New/Unfamiliar Operator
57	11/2/2015	Brentwood Yard	Insufficient Information
58	11/11/2015	New Carrolton Yard	Insufficient Information
59	2/3/2016	Smithsonian	Communication
60	3/3/2016	Silver Spring	ATO in Pocket Track
61	5/7/2016	Brentwood Yard	Communication
62	5/13/2016	C and J Junction	Communication
63	5/26/2016	Shady Grove Yard	Insufficient Operation
64	6/21/2016	Eastern Market	Departing Station/Zero Speed Commands
65	7/5/2016	Glenmont	Departing Station/Zero Speed Commands
66	7/13/2016	Ronald Reagan Washington National Airport	Insufficient Information
67	7/19/2016	Alexandria Yard	Departing Station/Zero Speed Commands
68	7/27/2016	Ronald Reagan Washington National Airport	Insufficient Information

Table 1: Stop Signal Overruns with Common Causal Factors

Appendices present maps regarding the locations of stop signal overruns in each of the three main categories identified by FWSO:

- Appendix C: Locations of Stop Signal Overruns with Lack of Familiarity with the Mainline Track or Yard,
- Appendix D: Locations of Stop Signal Overruns with Train Operator Inattention or Confusion when Departing a Station, Terminal or Operating Under Zero Speed Commands, and
- Appendix E: Locations of Stop Signal Overruns with Poor Communications between the Train Operator and the ROCC.

5.0 Mitigations in Place and Previous Findings

5.1 WMATA Efforts to Address Stop Signal Overruns

Stop signal overruns present an ongoing challenge that WMATA Metrorail continues to try to effectively address and resolve. Since 2009, WMATA has instituted a variety of corrective actions in an effort to mitigate the occurrence of stop signal overruns. As discussed previously, these mitigations include operator interviews and reinstruction, administrative action, distribution of maps and lessons learned materials, safety talks and stand-downs, stickers on the operator's console to re-focus operator attention on approach to stop signals, and revisions to operating rules. In addition to these system wide solutions, WMATA is also modifying its signal system at two pocket tracks to prevent stop signal overruns at these locations for 8-car trains.

Since moving to manual operations in 2009, compliance with operating rules provides the primary method of mitigating stop signal overruns.

WMATA Rule 3.67 states:

> Rail vehicles shall not be operated past or closer than a point 10 feet in approach of an interlocking signal or lamp displaying a red aspect, a red flag, or a dark interlocking signal, unless authorized by ROCC or the Interlocking Operator and the move is consistent with customer safety as specified in Rule 3.1.
>
> ROCC or Interlocking Operator shall give permission to pass a stop signal or dark aspect after the switches have been blocked or clamped for the required move in accordance with SOP #35. Once this has been verified the train or track unit will be given permission to pass the stop signal or dark aspect at a speed no greater than 5 miles per hour.
>
> Upon hearing or seeing the activated overrun alarm at Grosvenor interlocking, Train Operators shall immediately bring their trains to a stop, advise ROCC of the alarm condition, and not attempt to resume train movement until specifically instructed to do so by ROCC.

In addition to WMATA Rule 3.67, two additional rules address common problems associated with stop signal overruns. WMATA Rule 3.79 governs movement with zero speed commands. When approaching a stop signal, or when stopped at a platform or stop signal, trains receive zero speed commands, alerting the operator that they need to stop. WMATA Rule 3.79 states:

> Train Operators shall not move trains with zero speed commands except after notifying ROCC and being given permission to move with zero speed commands and either a permissive block for the move going with traffic or an absolute block for the move going against traffic.

In order to address terminal station stop signal violations, WMATA implemented Permanent Order T-15-04, issued on January 27, 2015, which revised Operating Rule 3.13 by adding a new set of requirements for Terminal Supervisors:

> 3.13.3 At Staffed Terminals Train Operators shall contact the Terminal Supervisor for permission to depart the terminal.
>
> 3.13.3.1 Terminal Supervisors shall ensure that the train has a lunar signal, correct alignment before giving the operator permission to depart the terminal with speed commands.

In order to address stop signal violations within pocket tracks, WMATA issued Permanent Order T-15-06 in April 3, 2015:

> All trains are to be operated manually when entering and exiting pocket tracks unless ROCC or a terminal supervisor grants permission for them to be operated in ATO. If conditions exist where a train must be operated in ATO into a pocket track, ROCC or the terminal supervisor must ensure a lunar signal is set on the exiting end of the interlocking to prevent a stop signal overrun.

In addition to the added rules, WMATA developed two visual aids for operators. As a result of a stop signal overrun in the Shady Grove Yard in January 2014, WMATA developed a sign notifying train operators of signals placed to the operator's left. WMATA surveyed each yard and installed signage to indicate locations where a signal occurs in that atypical location.

Figure 6: Picture of Installed Signage at Shady Grove Yard

Following a stop signal overrun at the Van Dorn Street interlocking, and in response to a recommendation in the 2014 stop signal violation report commissioned by WMATA, "point-of-power" stickers have been developed to encourage train operators to focus on five (5) points before moving their trains forward from any stopped position.

These stickers are being placed on the console of WMATA's train operating cabs, and provide a visual reminder to encourage train operators to verify signals, get permission from the Terminal

Supervisor or ROCC or Interlocking before moving their trains, check their speed commands, and ensure correct switch alignment prior to moving their trains.

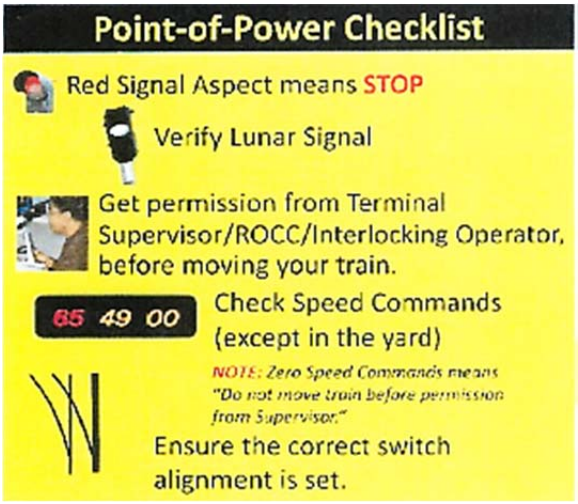

Figure 7: Sticker Installed in Operating Cabs

Also, following a stop signal overrun at a pocket track in 2012, WMATA installed a sign to remind train operators of the manual mode restriction in and out of all pocket tracks and connector tracks.

Figure 8: Sign installed near D&G Junction

WMATA also conducts "safety stand downs" to discuss stop signal overrun causes and potential mitigations, posts reminders and tips on bulletin boards visible to train operators and roadway maintenance machine pilots at various locations, and has distributed rail system maps and lessons learned flyers to all Metrorail operations personnel.

In two pocket track locations, WMATA has modified its signal system to better accommodate 8-car trains. At the Silver Spring Pocket Track, the speed commands, which were initially temporarily disabled, have now been removed from the track circuit to enforce manual operation. At the Grosvenor-Strathmore Station Center Pocket Track, WMATA has established an Engineering Modification Instruction (EMI) to modify the track circuit to send an open door left command to act as a positive stop to prevent trains from moving past a red signal. Developed in response to two signal overruns that occurred in June 2012, this EMI has not yet been fully implemented pending a software upgrade and completion of a formal hazard analysis to ensure that the integration of this modification does not conflict with other applications in the signal and train control system. As of July 31, 2016, WMATA has completed field wiring and equipment installation for the override button at this location, and is developing a scope of work for the hazard analysis.

New leadership at WMATA has expressed particular interest in the modification at the Grosvenor-Strathmore Station Center Pocket Track, as potentially having widespread application throughout the WMATA system. WMATA is in the process of commissioning a white paper on global positive stop as a potential engineering solution to address red signal violations.

In addition, FWSO understands that WMATA is considering an eventual return to system-wide automatic train operation, which will reduce many of the opportunities for stop signal overruns on the mainline, and that costs and activities focused on near-term enhancements to prevent stop signal overruns must be balanced against the work scope and schedule for restoration of fully automatic train control.

Finally, on July 19, 2016, after reviewing an earlier version of this report, and in response to the conditions surrounding a stop signal overrun that occurred in July 5, 2016, WMATA issued Permanent Order T-16-10 Radio Protocols, Modification to General Rule 1.79. This Permanent Order modifies General Rule 1.79 to clarify and require specific radio protocol, including 100 percent, word-for-word repeat backs for speed restrictions, including blanket announcements. Positive identification is now required prior to transmitting a message.

5.2 Previously Issued FTA Findings and Required Actions

Since the FTA's Safety Management Inspection (SMI) in June 2015, and even more recently under the FTA's direct safety oversight, WMATA has taken a number of critical steps to improve the safety of its train operations.

WMATA has made considerable progress in addressing findings previously issued by the FTA and recommendations resulting from WMATA's own internal assessments and evaluations. Many of these actions also address factors commonly considered to contribute to stop signal overruns, such as speeding, lack of familiarization with the location of stop signals, lack of

operational testing, and ineffective communications between supervisors and train operators regarding safety rules and performance.

On June 17, 2015, FTA issued Safety Directive 15-1, which documented findings and required actions from the SMI that FWSO conducted at WMATA between March and June 2015. WMATA has developed and is currently implementing CAPs that address a number of FTA findings related to improving the performance of the ROCC; enhanced training for train operators, controllers, and supervisors; testing and monitoring for operations personnel; and accident investigation.

In December 2015, the FTA issued Safety Directive 16-2, requiring WMATA to take corrective action to resolve more than 200 open safety findings previously issued by the Tri-State Oversight Committee. To address outstanding items from previous investigations into stop signal overruns, the FTA required WMATA to implement eight (8) required actions. WMATA is currently working to implement CAPs for each of these required actions.

On May 7, 2016, the FTA issued Safety Directive 16-3 to re-focus operations and maintenance personnel on the importance of safety over service when responding to events impacting passenger operations, and to require safety standards to review WMATA's rules and standard operating procedures. Safety Directive 16-3 contained four (4) findings requiring action from WMATA.

These previous findings and required actions support improvements that address issues relevant in stop signal overrun occurrences. For example:

In Safety Directive 16-2, FTA issued a required action stating:

> FTA-RED-15-004: WMATA must provide Train Operators and Pilots with physical characteristics training for the lines they operate on and associated yards, including regular familiarization and testing of the rail system to include control points, junctions, stations, restricted sight curves, etc. This training must be provided whenever Rail Operators make a bid to another line, and must emphasize non-standard signal wayside placement and other route irregularities.

Additionally, FTA issued required action FTA-RED-15-003, to specifically address equipment operators stating, "All Equipment Operators and Pilots must include in their job briefing all control points, junctions, stations, restricted sight curves, etc. that will be operated through during their tour of duty." FWSO's investigation reaffirms these required actions, which WMATA is working to implement by early to mid 2017.

In addition to territory familiarity, FWSO notes that 34 percent of the reviewed stop signal overruns occurred when the operator departed a station or terminal or moved under zero speed commands. These overruns are frequently the result of violating multiple rules, including Rule 3.67 governing stop signal overruns, Rule 3.79 governing movement without speed commands,

and Rule 3.13 governing departure from the terminal. An additional required action in Safety Directive 16-2 requires:

> FTA-RED-15-001: While WMATA is completing its program to address FTA's SMI findings R-2-18-a and R-2-19-a (regarding operational testing programs), WMATA must immediately improve its testing and observation of Train and Equipment Operators, including regular review of track circuit downloads for speeding and speed gun testing for manual vehicle operations on the mainline and in yards.

FWSO's investigation into the 68 stop signal overruns reaffirms this required action, which WMATA is working to implement by the end of 2017.

Finally, communications issues played a factor in 36 percent of the reviewed stop signal overruns. These issues include instances where the train operator and/or ROCC controller, interlocking operator, or rail transportation supervisor misunderstood each other or did not perform required repeat-backs or other communication, and communication infrastructure issues, such as malfunctioning radios. In Safety Directive 16-2, FTA issued a required action stating:

> FTA-RED-15-002: While WMATA is completing its program to address FTA's SMI finding R-6 (regarding radio discipline), WMATA must immediately require proper read back from vehicle operators for vehicle movement instructions from ROCC, Interlocking Operators, and Supervisors. Also, for equipment movements, employees piloting equipment must call out the signal aspect and indication ahead on the radio and the vehicle operator must repeat back.

WMATA has implemented new rules and training to implement this required action.

FWSO continues to monitor WMATA's activity to implement these corrective actions, most of which will be completed by early-to-mid 2017.

Updated status regarding WMATA's closure of corrective actions is available on FTA's website at: https://www.transit.dot.gov/regulations-and-guidance/safety/wmata-cap. Required actions issued by FWSO as part of this investigation take into account WMATA action already underway to implement corrective action to address Safety Directives 16-3, 16-2, and 15-1, as well as other actions taken by WMATA since 2012.

6.0 New Findings and Required Actions

FWSO believes that findings previously issued as part of Safety Directive 15-1 and Safety Directive 16-2, and discussed in this report, address many of the most the most pressing issues that contribute to stop signal overruns. FWSO also recognizes WMATA's commitment to reducing stop signal overruns, and acknowledges that some of the programs and efforts remain under development. However, FWSO finds that WMATA must increase its efforts to prevent stop signal overruns beyond those steps already taken and in progress.

FWSO's investigation identified continuing deficiencies and operational concerns that limit WMATA's effectiveness in preventing and mitigating these events. Further, FWSO finds that WMATA's approach in key areas must be improved to reduce the frequency of stop signal overruns. This report outlines six (6) findings and eleven (11) required actions to address these concerns.

FWSO groups the findings and required actions from its investigation into four categories:

- Category 1: Mainline and Yard Familiarity;
- Category 2: Departure from Stations and Terminals and Movement with Zero Speed Commands;
- Category 3: Communication with ROCC and Interlocking Operators; and
- Category 4: Stop Signal Overrun Investigations.

6.1 Category 1: Mainline and Yard Familiarity

FWSO found that mainline and yard familiarity played a role in 30 percent of the stop signal overruns reviewed as part of this investigation. These overruns include instances where the operator acknowledges a lack of familiarity with the territory, as well as overruns experienced by operators with less than one-year employment as a train operator. As a result of its investigation, FWSO issues one finding and three required actions regarding mainline and yard familiarity.

6.1.1 Category 1 Findings

An effective training program for new and existing employees is critical for safe operations. FWSO's stop signal overrun investigation identifies a need for improved mainline and yard initial and refresher territory familiarization training, including general awareness of the presence of left-hand signals, complex yard alignments, and operations beyond the limits of absolute blocks.

- **Finding 1:** WMATA does not ensure train and equipment operator familiarity with mainline and yard characteristics, including signal placement, interlocking locations, and track numbers.

FWSO's stop signal overrun review identifies specific and potentially serious issues related to territory familiarization training for both mainline and yard alignments. While WMATA provides retraining to operators following stop signal overruns, it does not provide a standard familiarization training program to train equipment operators to ensure that they have adequate

knowledge of the unique characteristics they may encounter. This lack of experience leads to mistakes such as missed left-hand signals, operating vehicles beyond limits of absolute blocks, and movement of trains on incorrect tracks in the yard.

In response to Safety Directive 16-2, WMATA is developing a physical characteristics training program for frontline operations and maintenance personnel. As part of its investigation, FWSO identified two areas of focus to support this training and assist operators who are unfamiliar with the territory in which they are operating.

Interviews demonstrate that some train operators are unfamiliar or uncomfortable with the alphanumeric naming convention for signals on the mainline and in yards. This convention is particularly important for absolute blocks. As a result, these operators did not recognize the signal at which they were directed to stop, and operated past it.

Currently, WMATA uses a black plate with white numerals to identify the signal number. This marker is not retro-reflective and is difficult to see, especially at night. Increasing the visibility of these markers would lead to an improvement in operator awareness while operating through unfamiliar territory, especially in yards with many signals, or when operating under an absolute block.

Especially in the tunnel environment, WMATA has also experienced stop signal overruns stemming from situations where an operator is unsure regarding the track he is operating on or the direction in which she is supposed to move the train. WMATA's signage is limited in tunnels. Signs are wall mounted and typically include station marker, chain marker, No Clearance, and Turnback signs. At certain intervals, signs are mounted on the tunnel walls to indicate the direction and distance to the emergency exit or the name and distance to the nearest station. For the most part, WMATA currently places wayside signs at the end of each platform indicating track number and direction. WMATA also issued, and requires equipment operators to carry, system maps, as well as added increased signage in yards where signals are on the left hand side.

However, these efforts are not a sufficient substitute for formal and routine territory familiarization training that enables train operators to experience and master the physical characteristics of their routes and yards. FWSO finds that WMATA should do more to orient its train operators in tunnels and to promote physical characteristics in its newly developed operator familiarization training program.

6.1.2 Category 1 Required Actions

The table below presents the FTA's finding and required actions in this category.

Stop Signal Investigation Category 1: Mainline and Yard Familiarity			
Finding		**Required Actions**	
FTA-RED-16-001	WMATA does not ensure train and equipment operator familiarity with mainline and yard characteristics, including signal placement, interlocking locations, and track numbers.	FTA-RED-16-001-A	To support train and equipment operator identification of signals, WMATA must improve the visibility of signal markers. (Example actions include replacing existing black and white markers with retro-reflective markers, and taking steps to ensure that the color of the marker cannot be mistaken for signal aspect.)
		FTA-RED-16-001-B	To support train and equipment operator orientation on the Metrorail system, WMATA must increase the availability of location information. (Examples actions include the provision of additional detail on wayside signage at the end of station platforms, including the direction of travel, line, and location of any interlockings prior to the next station.)
		FTA-RED-16-001-C	To enhance train and equipment operator familiarity with the Metrorail system, WMATA must increase opportunities for visual observation of the system as part of its program to address FTA-RED-15-004. (Examples include incorporating the use of video or simulation technologies for each line and yard, as part of the new physical characteristics training program.)

Table 2: Findings and Required Actions for Category 1

6.2 Category 2: Station Departure and Movement with Zero Speed Commands

FWSO finds that 34 percent of the reviewed stop signal overruns occurred during station or terminal departure or under movement with zero speed commands. Although WMATA has multiple rules that govern stop signals, operation with zero speed commands, and departure from stations and terminals, they are not sufficient to prevent stop signal overruns. FWSO issues two findings regarding train departure from stations and terminals.

6.2.1 Category 2 Findings

WMATA has three main operating rules in place to prevent stop signal overruns upon departure of stations and terminals or when moving under zero speed commands. WMATA Rule 3.67, the main Rule governing stop signals, states:

> Rail vehicles shall not be operated past or closer than a point 10 feet in approach of an interlocking signal or lamp displaying a red aspect, a red flag, or a dark interlocking signal, unless authorized by ROCC or the Interlocking Operator and the move is consistent with customer safety as specified in Rule 3.1.
>
> ROCC or Interlocking Operator shall give permission to pass a stop signal or dark aspect after the switches have been blocked or clamped for the required

> move in accordance with SOP #35. Once this has been verified the train or track unit will be given permission to pass the stop signal or dark aspect at a speed no greater than 5 miles per hour.
>
> Upon hearing or seeing the activated overrun alarm at Grosvenor interlocking, Train Operators shall immediately bring their trains to a stop, advise ROCC of the alarm condition, and not attempt to resume train movement until specifically instructed to do so by ROCC.

WMATA Rule 3.79 governs movement with zero speed commands. When approaching a stop signal, or when stopped at a platform or stop signal, trains receive zero speed commands, alerting the operator that they need to stop or remain stopped. Rule 3.79 states:

> Train Operators shall not move trains with zero speed commands except after notifying ROCC and being given permission to move with zero speed commands and either a permissive block for the move going with traffic or an absolute block for the move going against traffic.

Finally, in order to address stop signal violations that have occurred at terminal stations at the end of each rail line, WMATA implemented temporary order T-15-04, adding Rule 3.13.3 that states:

> At Staffed Terminals Train Operators shall contact the Terminal Supervisor for permission to depart the terminal.
>
> > 3.13.3.1: Terminal Supervisors shall ensure that the train has a lunar signal, correct alignment before giving the operator permission to depart the terminal with speed commands.

- **Finding 2:** WMATA train operators do not consistently verify lunar signal aspect and speed commands prior to taking a point of power.
- **Finding 3:** WMATA has not fully implemented sufficient protections against the unauthorized movement of trains with zero speed commands

FWSO's review of stop signal overruns identified 23 events that occurred as a train was departing a terminal, station or was moving with zero speed commands. In these scenarios, operators have violated multiple rules by both moving with zero speed commands and overrunning stop signals. To reduce occurrence of these events in terminal stations, WMATA has instituted Rule 3.13.3 in which a terminal supervisor must verify that a train has a lunar signal and correct alignment prior to granting permission for the operator to depart a terminal station.

In addition to this rule, WMATA is modifying its signal system at two pocket track locations, including a proposed modification at the Grosvenor-Strathmore Station Center Pocket Track, in planning since 2012, to send an open door left command to the train to create a positive stop that can be overridden by the ROCC. WMATA’s new leadership team is in the process of

commissioning a white paper on global positive stop as an engineering solution to address red signal overruns.

As part of the study in stop signal overruns in 2014, WMATA's contractor developed a point-of-power checklist to be installed in each cab to remind train operators regarding the importance of complying with MSRPH Operating Rule 3.67, MSRPH Operating Rule 3.79, and MSRPH Operating Rule 1.79 before undertaking any train movement. WMATA has almost completed installing these stickers, shown in Figure 7 above, in all cabs.

While WMATA's management clearly emphasizes the importance of complying with critical safety rules, FWSO's observations of WMATA's train operations, combined with the review of WMATA's accident investigation reports and FWSO's own investigation activities, indicate a lack of targeted rules checks and operational testing specifically focused on the critical rules that prevent stop signal overruns. FWSO finds that a sustained campaign of random testing and observation of train operator performance, conducted by transportation supervisors, safety officers and quality officers, combined with a dedicated review of train performance from signal system downloads, would provide additional emphasis on this critical issue.

6.2.2 Category 2 Required Actions

The table below identifies two findings and five required actions to be taken by WMATA to address stop signal overrun concerns related to departure from stations and terminals.

Stop Signal Investigation Category 2: Departure from Stations and Terminals and Movement with Zero Speed Commands			
Finding		**Required Actions**	
FTA-RED-16-002	WMATA train operators do not consistently verify lunar signal aspect and speed commands prior to taking a point of power.	FTA-RED-16-002-A	WMATA must increase rules checks, including random testing for conformance with stop signals, to ensure WMATA operators are complying with Rule 3.67 and 3.79, and must incorporate these additional checks and random testing program into the agency's response to FTA-RED-15-001.
		FTA-RED-16-002-B	WMATA must formalize its program for conducting a dedicated review of signal system downloads to monitor train operator performance and must incorporate this program into they agency's response to FTA-RED-15-001.
FTA-RED-16-003	WMATA has not fully implemented sufficient protections against the unauthorized movement of trains with zero speed commands	FTA-RED-16-002-C	WMATA must review its Fatigue Risk Management System (FRMS), available to all WMATA employees via the Metroweb, to ensure that this program provides train operators with sufficient information and training to assist them in the managing of their mental state and attention as required when engaged in train operations, including topics such as personal readiness and the use of the point-of-power stickers installed on the consoles of the operating cabs.

	FTA-RED-16-002-D	WMATA must complete a hazard analysis regarding the positive stop option at the Grosvenor-Strathmore Station Center Pocket Track, and any other options, currently under review to prevent trains from operating with zero speed commands without authorization from the ROCC system wide.
	FTA-RED-16-002-E	Once the modification at the Grosvenor-Strathmore Station Center Pocket Track is fully implemented, WMATA must establish a program to monitor its performance.

Table 3: Findings and Required Actions for Category 2

6.3 Category 3: Communication with ROCC and Interlocking Operators

FWSO finds that radio transmission quality and communications between the ROCC and the train operator played a role in 36 percent of reviewed stop signal overruns. These overruns included situations with poor radio quality, as well as situation where the train operator and controller did not communicate clearly, did not follow radio protocol, or did not perform and/or correct radio repeat-backs. FWSO issues two findings regarding the quality and effectiveness of radio transmissions.

6.3.1 Category 3 Findings

WMATA's ROCC serves as the command and control facility that directs all aspects of the Metrorail system, including operations occurring under normal, abnormal, and emergency situations. The ROCC also serves as the primary point of coordination for all operational decisions affecting rail service. This coordination includes both internal WMATA departments and external emergency response agencies.

The ROCC provides positive control for all train movements, station activities, and subsystems (power, ATC, automatic fare collection, and communications) following operating Rules and SOPs set forth in WMATA's MSRPH, supporting Operations Administrative Procedures, and temporary and permanent orders. ROCC controllers communicate with train operators by radio to ensure conformance with policies and procedures, to inform train operators and personnel of unusual Metrorail occurrences, and to communicate with supervisors and maintenance personnel in the field.

The ROCC employs a central computer system to implement train control strategies as necessary to regulate traffic flow. These control strategies may be preprogrammed strategies carried out automatically by the central control mainframe computer, or they may be strategies implemented manually by ROCC line controllers. Between stations, the ROCC can manually control train movements by changing signal aspects or switch alignments at interlockings at certain control points or through direct communication with train operators via a two-way radio system.

- **Finding 4:** WMATA does not ensure consistent understanding among train and equipment operators and the ROCC or Interlocking Operators.

FWSO identified 36 percent of stop signal overruns with radio repeat back or communication or understanding issues ranging from a train operator misinterpreting instructions from interlocking operators to depart a terminal station to operators in the yard moving trains on incorrect tracks. FWSO noted similar concerns during its SMI, confirming in interviews and observations at the ROCC that radio discipline is not actively enforced to reduce radio congestion and miscommunication. The FTA's SMI team observed confusion in communication resulting from lack of proper protocol for language and terminology used over the radio, notably, a failure to include 100 percent word-for-word repeat-backs for safety-related instructions and unusual train movements, such as absolute blocks. Interviews and observations in rail yards and on trains confirmed the difficulty of understanding radio communications in certain situations.

To address this issue, WMATA issued Permanent Order T-16-10 July 19, 2016 which modifies rule 1.79 and establishes new radio protocols, including standard verbiage. WMATA must audit its own implementation of this critical new permanent order.

- **Finding 5:** WMATA must continue to improve radio quality, as identified previously in the FTA's SMI report.

FWSO identified several events in which radio communications quality played a role, including the recent stop signal overrun at the C and J Junction on May 13, 2016. This issue was also identified during FTA's SMI, which found that, while WMATA's digital radio system is clearer than the analog version major distortion and feed-back still occurs, and a significant number of radio dead spots still exist. Many WMATA employees throughout the agency ranked poor radio performance as their top safety concern. The WMATA's Capital Improvement Plan 136 is underway to address some but not all of the needed enhancements. For example, this project replaces most below-ground radiating coaxial cable with higher capacity, bigger cable for better radio frequency propagation and greater capacity. WMATA must continue to monitor how radio quality impacts the effectiveness of its communications and the safety of its operations.

6.3.1 Category 3 Required Actions

The table below identifies two findings and two required actions to be taken by WMATA to address deficiencies related to communication.

Stop Signal Investigation Category 3: Communication with ROCC and Interlocking Operators			
Finding		**Required Actions**	
FTA-RED-16-004	WMATA does not ensure consistent understanding among train and equipment operators and the ROCC or Interlocking Controllers.	FTA-RED-16-004-A	WMATA must develop and implement a procedure for auditing radio protocol, radio communications, and for ensuring conformance with Permanent Order T-16-10 Radio Protocols, Modification to General Rule 1.79.
FTA-RED-16-005	WMATA must continue to improve radio quality, as identified previously in the FTA's SMI report.	FTA-RED-16-005-A	WMATA must provide FTA with a quarterly report documenting its assessments and findings regarding radio quality, and planned corrective actions.

Table 4: Findings and Required Actions for Category 3

6.4 Category 4: Stop Signal Overrun Investigation

FWSO finds that WMATA conducts investigations into each stop signal overrun as required, but does not collect a sufficiently broad or consistent set of data to enable the agency to identify trends and create targeted mitigations. FWSO issues one finding regarding stop signal overrun investigation.

6.4.1 Category 4 Findings

WMATA is required to report all stop signal overruns to FWSO as part of the safety oversight program. As part of this process, WMATA is required to conduct a full investigation into the incident and provide a formal accident report to FWSO for approval. WMATA reports all events as required by FWSO and, previously, by TOC. However, WMATA's reports do not provide a standard set of data that can be used to identify trends related to stop signal overruns.

- **Finding 6:** WMATA does not conduct sufficient investigations into stop signal overruns to identify trends and implement effective mitigations.

FWSO finds that stop signal overruns provide valuable, data-rich opportunities to assess: 1) the mitigations in place to keep trains and workers safe, 2) the level of conformance with safety rules and procedures, 3) the quality of operations training, and 4) potential actions required to further reduce risks to passengers and employees.

By establishing a set list of factors to analyze for each stop signal overrun, WMATA can establish trends to better understand the root causes of these events. Information such as operator experience, since last operator training, mainline or yard location, time, weather, and visibility, can provide a large-scale picture and help identify meaningful trends in events. These trends can be used to develop more effective mitigations, such as more focused training, infrastructure improvements, and changes to operating procedures.

6.4.2 Category 4 Required Actions

The table below identifies one finding and required action required action to improve investigation or stop signal overruns.

Stop Signal Investigation Category 4: Stop Signal Overrun Investigation			
Finding		**Required Actions**	
FTA-RED-16-006	WMATA does not conduct sufficient investigations into stop signal overruns to identify trends and implement effective mitigations.	FTA-RED-16-005-A	SAFE must create, either as a standalone document or as part of its own accident investigation procedure, an enhanced stop signal overrun investigation process with standardized data fields for trending and analysis.

Table 5: Findings and Required Actions for Category 4

Appendix A: Stop Signal Overrun Findings and Required Actions Tracking Matrix

Stop Signal Investigation Category 1: Mainline and Yard Familiarity			
Finding		**Required Actions**	
FTA-RED-16-001	WMATA does not ensure train and equipment operator familiarity with mainline and yard characteristics, including signal placement, interlocking locations, and track numbers.	FTA-RED-16-001-A	To support train and equipment operator identification of signals, WMATA must improve the visibility of signal markers. (Example actions include replacing existing black and white markers with retro-reflective markers, and taking steps to ensure that the color of the marker cannot be mistaken for signal aspect.)
		FTA-RED-16-001-B	To support train and equipment operator orientation on the Metrorail system, WMATA must increase the availability of location information. (Examples actions include the provision of additional detail on wayside signage at the end of station platforms, including the direction of travel, line, and location of any interlockings prior to the next station.)
		FTA-RED-16-001-C	To enhance train and equipment operator familiarity with the Metrorail system, WMATA must increase opportunities for visual observation of the system as part of its program to address FTA-RED-15-004. (Examples include incorporating the use of video or simulation technologies for each line and yard, as part of the new physical characteristics training program.)
Stop Signal Investigation Category 2: Departure from Stations and Terminals and Movement with Zero Speed Commands			
Finding		**Required Actions**	
FTA-RED-16-002	WMATA train operators do not consistently verify lunar signal aspect and speed commands prior to taking a point of power.	FTA-RED-16-002-A	WMATA must increase rules checks, including random testing for conformance with stop signals, to ensure WMATA operators are complying with Rule 3.67 and 3.79, and must incorporate these additional checks and random testing program into the agency's response to FTA-RED-15-001.
		FTA-RED-16-002-B	WMATA must formalize its program for conducting a dedicated review of signal system downloads to monitor train operator performance and must incorporate this program into they agency's response to FTA-RED-15-001.
FTA-RED-16-003	WMATA has not fully implemented sufficient protections against the unauthorized movement of trains with zero speed commands	FTA-RED-16-002-C	WMATA must review its Fatigue Risk Management System (FRMS), available to all WMATA employees via the Metroweb, to ensure that this program provides train operators with sufficient information and training to assist them in the managing of their mental state and attention as required when engaged in train operations, including topics such as personal readiness and the use of the point-of-power stickers installed on the consoles of the operating cabs.

		FTA-RED-16-002-D	WMATA must complete a hazard analysis regarding the positive stop option at the Grosvenor-Strathmore Station Center Pocket Track, and any other options, currently under review to prevent trains from operating with zero speed commands without authorization from the ROCC system wide.
		FTA-RED-16-002-E	Once the modification at the Grosvenor-Strathmore Station Center Pocket Track is fully implemented, WMATA must establish a program to monitor its performance.
Stop Signal Investigation Category 3: Communication with ROCC and Interlocking Operators			
Finding		**Required Actions**	
FTA-RED-16-004	WMATA does not ensure consistent understanding among train and equipment operators and the ROCC or Interlocking Controllers.	FTA-RED-16-004-A	WMATA must develop and implement a procedure for auditing radio protocol, radio communications, and for ensuring conformance with Permanent Order T-16-10 Radio Protocols, Modification to General Rule 1.79.
FTA-RED-16-005	WMATA must continue to improve radio quality, as identified previously in the FTA's SMI report.	FTA-RED-16-005-A	WMATA must provide FTA with a quarterly report documenting its assessments and findings regarding radio quality, and planned corrective actions.
Stop Signal Investigation Category 4: Stop Signal Overrun Investigation			
Finding		**Required Actions**	
FTA-RED-16-006	WMATA does not conduct sufficient investigations into stop signal overruns to identify trends and implement effective mitigations.	FTA-RED-16-005-A	SAFE must create, either as a standalone document or as part of its own accident investigation procedure, an enhanced stop signal overrun investigation process with standardized data fields for trending and analysis.

Appendix B: WMATA Operating Modes and Zero Speed Commands

WMATA's train control system provides operating speed commands to the train in order to control train movement. These commands vary based on conditions such as space between vehicles, speed restrictions, and location. WMATA utilizes "zero speed commands" to restrict train movement when a vehicle is stopped or must stop, such as at a platform or on approach to a stop signal. In this condition, the train does not receive speed commands from the train control system, which the train interprets as a restriction of zero miles per hour, or a “zero speed command.”

Operations with zero speed commands are governed by WMATA Rule 3.79, which states:

> Train Operators shall not move trains with zero speed commands except after notifying ROCC and being given permission to move with zero speed commands and an absolute block for the move.
>
> Upon losing speed commands on the platform, the operator may adjust the train in the same direction of traffic to service the station without contacting ROCC for permission. After servicing the station, the operator must contact ROCC for permission to leave and an absolute block for the move if speed readouts do not return (See Rules 3.20, 3.21, 3.22 and 3.31).

While WMATA Rule 3.79 prohibits train movement with zero speed commands without approval, WMATA trains in certain manual operating modes are physically capable of moving move up to 15 mph without a penalty brake application under zero speed commands.

WMATA operates in several operating modes, which are governed by Rules 3.20 through 3.23:

> Rule 3.20: Mode 1 (automatic train operations) is the normal operating mode for passenger vehicles in revenue service. Mode 1 shall be used when carrying revenue customers except as authorized by ROCC or as specified in the current General Order.
>
> Rule 3.21: Mode 2 – Level 1 (manual operations) operation shall not be used on the mainline unless specifically authorized by the Operations Control Center, or as specified in the General Orders.
>
> Rule 3.22: Mode 2 – Level 2 (manual yard operations) is the normal operating mode in yards. On the mainline, vehicles shall not be operated in Mode 2-Level 2 unless specifically authorized by ROCC to “operate in Mode 2 with zero speed commands.” The exception to this rule is stated in 3.79. Operators shall move vehicles in either Position “P1” or Position “P2” settings while moving in the yards or with zero speed commands on the mainline unless directed otherwise by the Interlocking Operator in the yard or by ROCC while on the mainline.

> Rule 3.23: Mode 3 operation shall be treated by all employees as a serious and potentially hazardous condition, which must only be used as a last resort when absolutely necessary to move a revenue passenger vehicle.

The table below provides a definition of each of these operating modes. WMATA currently operates revenue trains in Mode 2: Level 1 on the mainline, except for some rush hour trains on the Red Line, which operate in Mode 1.

WMATA Operating Modes	
Mode	**Description**
Mode 1: Operating Mode	Train operation in ATO with ATP.
Mode 1: Terminal Mode	Automatic signal mode for turnback moves at a terminal, which routes outbound trains to Track 1 and turns inbound trains back from Track 1.
Mode 2: Operating Mode	Train operation in manual (train operator) control with ATP.
Mode 2: Terminal Mode	Automatic signal mode for turn-back moves at a terminal, which routes outbound trains to Track 2 and turns inbound trains back from Track 2.
Mode 2: Level 1	Manual with Speed Commands: Train operation under manual control with ATP monitoring and protection.
Mode 2: Level 2	Manual with Zero Speed Commands: Train operation under manual control with partial ATP monitoring and protection. Train is operated at restricted speed (15 mph or as directed by ROCC) and an absolute or permissive block must be established on mainline. This is the normal operating mode in yards.
Mode 3: Operating Mode	Train operation under manual control without ATP monitoring and protection. Only permitted when passengers are off-loaded at the first available station and under an absolute block or permissive block to allow train movement.
Mode 3: Terminal Mode	Automatic signal mode for turn-back moves at a terminal, which crosses over outbound trains and turns back inbound trains straight through. If the exit of the preferred outbound route is occupied, Mode 3 can route outbound trains straight through to the vacant track and cross over the train on its inbound move.

Table C-1: WMATA Operating Modes

The train operator must contact the ROCC for permission to change modes while operating on the mainline, as required by Rule 3.31:

> Train Operators shall not change operating modes on the mainline without authorization from ROCC or as instructed in the General Orders, except when changing from Mode 1 to Mode 2 in order to adjust a train within the platform limits.

Currently, trains operating in manual mode can overrun stop signals at low speeds (less than 15 miles per hour). Once above 15 miles per hour, penalty brakes are released with zero speed commands. While this configuration provides WMATA the ability to move trains with zero speed commands under the permission of the ROCC, this configuration also presents a significant hazard in situations where trains are operating at low speeds, such as departing a station or entering a pocket track.

Appendix C: Category 1 Stop Signal Overruns – Mainline and Yard Familiarity

Appendix D: Category 2 Stop Signal Overruns – Departures and Zero Speed Commands

Appendix E: Category 3 Stop Signal Overruns – Communications