National Aeronautics and Space Administration

Loss of Detection:

D.C. Metro Railway Collision

Leadership ViTS Meeting

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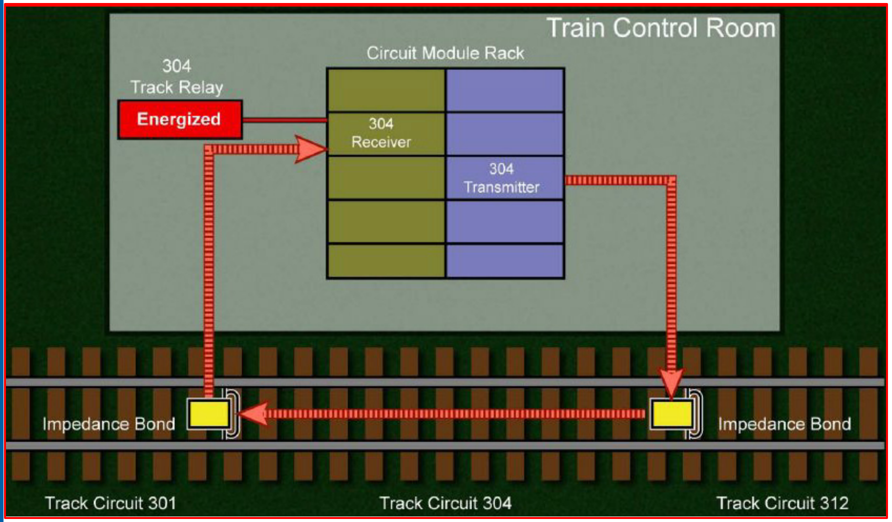
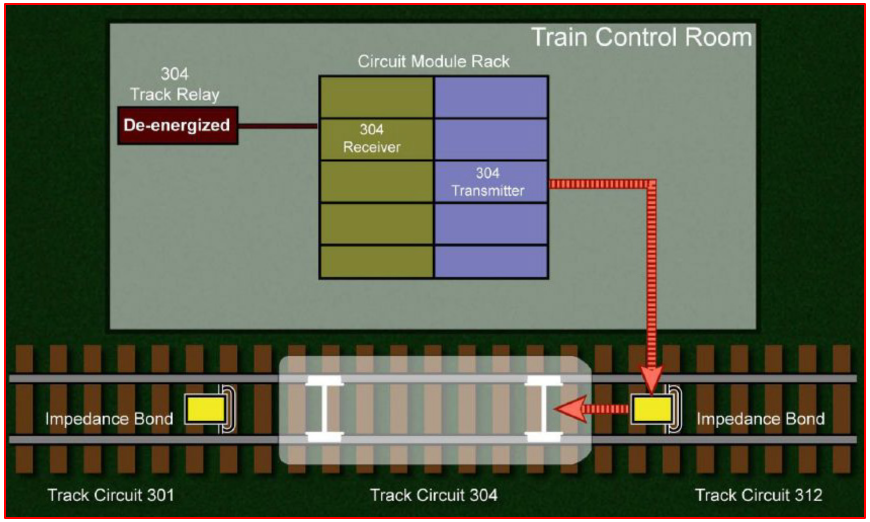
THE MISHAP

At the beginning of the evening rush hour on June 22, 2009, the Washington Metropolitan Area Transit Authority (WMATA) experienced the most devastating accident in its 30 year history. That day, the lead car of train 112 collided with the end car of stopped train 214 between the Fort Totten and Takoma "Metro" rail stations. The operator of train 112 and eight passengers died in the accident, and at least fifty more suffered injuries related to the crash. Damages to train equipment cost $12 million.

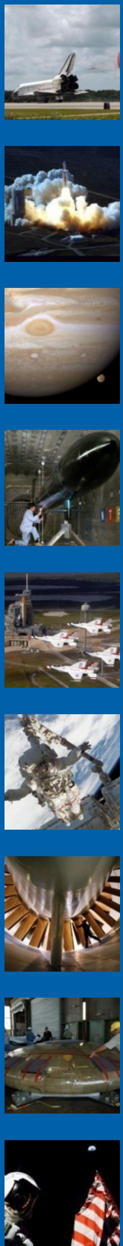
Automatic Train Detection

- The DC Metro rail system uses an Automatic Train Control (ATC) system composed of a series of track circuits that can be either energized or de-energized. When a track circuit is energized, it indicates the track circuit is unoccupied.
- An unoccupied track circuit remains energized until a train passes over it. The circuit then becomes de-energized because the train's wheels create an alternate path for the electrical signal, preventing it from reaching the receiver.
- To maintain safe separation between trains, track circuits transmit speed commands based upon detection of occupied and unoccupied tracks. If a track circuit loses detection of a train, that train will default to a speed of 0 mph.





Track circuit modules are located in a control room at the nearest train station. The module transmitter sends a signal to the corresponding impedance bond, which passes the signal through the rails to the adjacent impedance bond. From there, the signal travels back to the control room to the module receiver, energizing the track circuit. When trains occupy the track, the signal never reaches the module receiver, and the track circuit de-energizes, indicating it is occupied (Credit: NTSB)



BACKGROUND

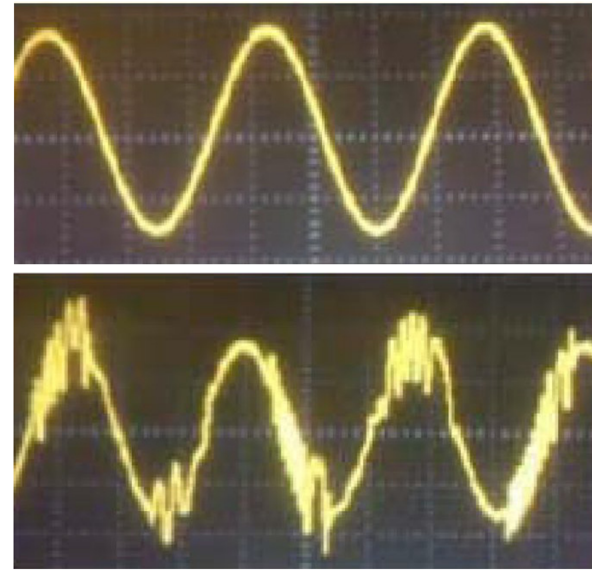
Parasitic Oscillation

•WMATA followed a manufacturer-recommended maintenance plan for upkeep of the track circuit modules, but the tests could not detect the presence of parasitic oscillation, where a track circuit transmitter module emits a spurious signal that mimics a valid track circuit signal.

•During a rush hour backup in 2005, WMATA experienced two near-collisions between the Rosslyn and Foggy Bottom stations. In both instances, the oncoming train's operator was able to override the ATC and apply emergency brakes.

•Later, ATC engineers discovered that the Rosslyn near-collisions had actually occurred because track circuit C2-111 had stopped detecting trains due to parasitic oscillation in the track circuit modules.

•After the near-miss, WMATA amended its procedure for testing track circuits and issued a safety bulletin that detailed the new testing process which involved placing a shunt (a simulated set of train wheels) in the center of each track circuit, as opposed to just at the ends, as the previous procedure instructed.



Top: Valid track circuit signal. Bottom: Parasitic oscillation (credit NTSB).

Impedance Bond Replacement

•The original impedance bonds and transmitter/receiver modules were manufactured by General Railway Signaling Company (GRS, now Alstom Signaling, Inc.), but in 2006, WMATA intended to replace the impedance bonds with Union Switch and Signal (US&S, now Ansaldo STS USA) equipment.

•WMATA would retain the GRS modules.

•On June 17, 2009, a WMATA crew replaced the impedance bonds on track circuit B2-304, located between the Fort Totten and Takoma metrorail stations.

•Since the impedance bonds and track circuit modules were manufactured by different companies, engineering crews needed to adjust transmitter power settings to compensate for differing resistances between the old and new impedance bonds.

•While the team made these adjustments, the track circuit transitioned from "vacant" to "occupied" and back even though no trains were present.

•After leaving the site, the crew leader opened a work order to address this issue, but no action was taken regarding the work order from the time it was opened until the day of the accident (5 days later).

WHAT HAPPENED?

Collision

•At approximately 5:00 pm EST on June 22, 2009, WMATA Metrorail train 214 travelled slowly along the Red Line inbound to Fort Totten station as it entered track circuit B2-304.

•That track circuit failed to detect the train's presence and therefore did not transmit any speed commands. As a result, train 214 defaulted to a speed of 0 mph and stopped completely within the bounds of track circuit B2-304.

•Meanwhile, Metrorail train 112, which was following train 214, was receiving 55 mph speed commands.

•If track circuit B2-304 had been working properly, train 112 would have received speed commands to slow or stop due to the presence of train 214 ahead. Since the system read the track circuit as vacant, it allowed the train 112 to travel at the maximum allowable speed of 55 mph.

•Evidence proved that train 112's operator activated the emergency brakes, but there was not enough distance to stop before impact. Train 112 barreled into train 214 at significant speed.

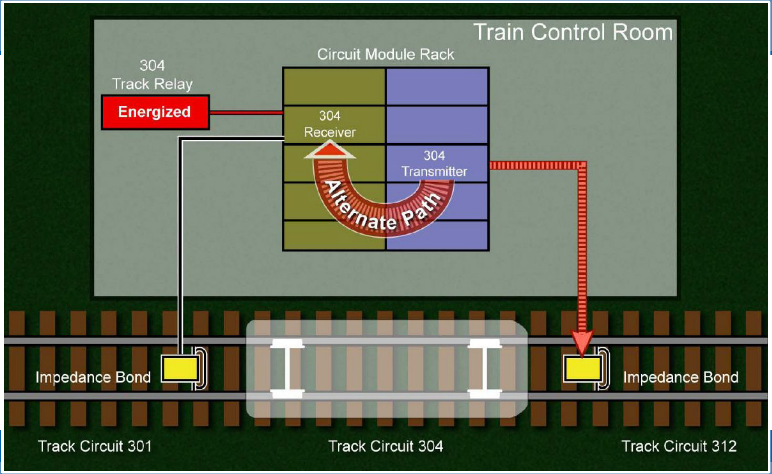
•Upon impact, the end car of train 214 telescoped into the lead car of train112, eliminating passenger survival space inside train 112 for a distance of 63 feet. Nine people aboard train 112, including the train operator, died in the crash. More than 50 passengers were injured, and damage to train equipment was estimated to cost $12 million.

AP photo by Gerald Herbert of accident

A scene of devastation followed the metrorail collision near the Fort Totten station in Washington D.C.

PROXIMATE CAUSE

The NTSB found that the accident occurred because of parasitic oscillation in the track circuit module. This oscillation travelled from the module transmitter to the module receiver through the equipment racks on which the modules were mounted. When the maintenance crews replaced the impedance bonds for circuit B2-304, they calibrated an increase in the power of the output transistors. The adjustment increased the amplitude of the spurious signal, giving it sufficient strength to drive the receiver module. This energized the track circuit and caused it to read as vacant.



UNDERLYING ISSUES

Failure to Implement Procedures

•Four years before the Fort Totten accident, WMATA engineers became aware that the current testing procedures could fail to identify malfunctioning track circuits, so they issued a bulletin detailing a process change – not to hunt down parasitic oscillation but simply to locate sections of track that failed to detect trains.

•After the Fort Totten accident, none of the engineers NTSB interviewed were aware that the bulletin existed. NTSB cited this fact as an indication that WMATA failed to ensure that its technicians received, understood, and acted upon critical safety information.

Absence of Effective Safety Culture

•NTSB's analysis of WMATA's safety initiatives concluded that the language, oversight, and enforcement methods pointed to a safety model that placed the responsibility for preventing accidents on its employees – an approach that excludes situations such as the Fort Totten accident, which NTSB considers to be an "organizational accident" that could not have been prevented by individual workers.

•NTSB found deficiencies in the way WMATA approached safety concerns, including propagating a climate that placed schedule over safety throughout the organization.

•WMATA ineffectively distributed safety-critical information throughout the organization and then failed to assess whether or not the new protocols were being followed. The poor internal communication prevented WMATA from adequately applying lessons learned from past failures to prevent future accidents.

FOR FUTURE NASA MISSIONS

•Dr. James Reason, author of *Managing the Risks of Organizational Accidents*, writes that organizations with effective safety cultures continually collect, analyze, and disseminate safety critical information; adapt based on lessons learned from the past; and encourage employees to report safety-related information while fostering both individual and organizational accountability.

•Per NTSB, WMATA exhibited deficiencies in all of these areas, but the Fort Totten accident was most directly impacted by WMATA's failure to adapt after identifying the circuit malfunction that caused the Rosslyn near-collisions.

A sign of mourning. Credit: WMATA

•Cultivating an informed safety culture at NASA requires action on multiple fronts – not just on information sharing and learning – but NASA can use this incident as a reminder of how mission success rests partly on the degree to which management ensures that lessons from failures are published and integrated into planning and operations.

•We can prove we've learned from failure when we can trace the rationale for how we work to such learning.

•Dr. Reason wrote in *Managing the Risks of Organizational Accidents*, "the two characteristics most likely to distinguish safe organizations from less safe ones are, firstly, top-level commitment and, secondly, the possession of an adequate safety information system."