



In accordance with NTSB rules and regulations, the Washington Metrorail Safety Commission (WMSC) submits the below findings of fact and conclusions drawn from the evidence obtained during investigation RRD22LR001, the investigation into the October 12, 2021 derailments of a Washington Metropolitan Area Transit Authority (WMATA) Metrorail Blue Line train, including the derailment between Rosslyn and Arlington Cemetery stations.

As a party to the investigation, the WMSC has shared information and input throughout the process. As the entity having direct safety oversight responsibility for Metrorail since March 2019, the WMSC has taken safety action based on the available data and information when necessary, in accordance with the WMSC Compact that created the WMSC in August 2017.

Causes contributing to the accident

The probable cause of the accident was the outward movement of wheels on the seats of an axle of railcar 7200 beyond the design specification limits. The movement of wheels on 7000 Series railcar axles is due to deficiencies related to the 7000 Series railcar design, including with respect to interactions with Metrorail's track infrastructure, that were not identified and acted upon during the railcar design and acceptance process.

When wheel movement was detected prior to the derailment, Metrorail did not take appropriate action to prevent such a derailment due in part to its ineffective safety culture as demonstrated by "shortcomings in WMATA's internal communications, in its recognition of hazards, its assessment of risk from those hazards, and its implementation of corrective actions" and its ineffective use of "past safety investigations and studies to make lasting changes that become incorporated in its organizational safety culture." Metrorail's siloed approach to safety and its inconsistent consideration of available safety data to make safety improvements prevented WMATA leadership outside of the railcar departments (and prevented Metrorail's state safety oversight agency) from learning of and acting upon the wheel spread safety issue prior to the derailment despite an abundance of data indicating that this safety issue was occurring and was being identified more and more frequently, and despite other Metrorail data and reports demonstrating this wheel migration has occurred on other WMATA railcar fleets.

Contributing to the outcome of this siloed approach was Metrorail's inadequate understanding, safety promotion, safety assurance, and safety risk management to ensure that Metrorail systems and identified deficiencies in those systems are considered on a systemic, cross-functional basis, including as the systems and identified deficiencies relate directly to the safety of Metrorail riders, workers, and first responders.

Contributing to the deficiencies in the timeliness of emergency response, Metrorail's training, safety promotion, and information available to personnel are insufficient to prepare personnel to effectively respond to or manage emergencies.

Migration of wheels on axles: Metrorail design deficiencies

The probable cause of the accident was the outward movement of wheels on the seats of an axle of railcar 7200 beyond the design specification limits. The movement of wheels on 7000 Series railcar axles is due to deficiencies related to the 7000 Series railcar design, including with respect to interactions with Metrorail's track infrastructure, that were not identified and acted upon during the railcar design and acceptance process.

- As of February 1, 2023, Metrorail maintenance personnel had identified 83 7000 Series railcar axles with measurements of back-to-back or journal bearing gaps outside of Metrorail's safety requirements. Metrorail stated that this list includes only those instances that were detected by Metrorail personnel through manual or wheel lathe measurements in maintenance shops. This total does not include cars such as the derailed car, car 7200, which Metrorail had not detected as exceeding safety requirements prior to its derailments.
 - Metrorail's list of 83 railcars that were identified by maintenance personnel includes 26 such railcars measured since Metrorail implemented an improved measurement procedure and tool in May 2022. Metrorail conditionally accepted each of these 83 cars between 2015 and 2020. Metrorail first identified axles that exceeded its safety requirements in 2017. There are 748 railcars in the 7000 Series fleet.
- 7000 Series Railcar Design
 - As with all transit railcars, the transit agency, in this case WMATA Metrorail, set the specifications and requirements for the railcar design. WMATA Metrorail reviewed and approved conceptual and final designs from Kawasaki, the car builder.
 - The 7000 Series railcars are designed differently from Metrorail's other existing and past railcars, including differences in truck design. Differences include car weight, truck damping, gearbox mounting, and other elements.
 - Beginning in March 2014, prior to 7000 Series railcars entering service, Metrorail identified wheel migration on other then-active railcar fleets. These inspections were initially triggered by alerts from a Truck Performance Detector. The inspections identified more than 30 "legacy" (non-7000 Series) cars with back-to-back measurement exceedances.
 - Metrorail did not incorporate this hazard into the 7000 Series railcar design and acceptance process, demonstrating a lack of rigor for a comprehensive system safety engineering analysis to consider railcar subsystems and railcars overall in the context of the operating environment including Metrorail's track and structures, real-world operations, and other features (see below elements related to safety certification).
 - Wheelset assembly interference fit and press tonnage for 7000 Series railcars did not account for differences between 7000 Series railcars and prior Metrorail cars, including the 7000 Series railcar weight, power, and other features (Hatch-LTK report, interviews).
 - Kawasaki stated that the original specification was based on Metrorail's 6000 Series railcar manuals.
 - There is no documented review of differences in requirements for 6000 Series axles and 7000 Series axles based on items such as differences in truck design or increased weight of the 7000 Series cars, or differences in requirements for

- 7000 Series axles from prior Metrorail railcar series that Metrorail's 6000 Series requirements were based on.
 - Bending forces are introduced by Metrorail's wheelset assembly design that were not effectively accounted for in the context of Metrorail's operating environment and the overall 7000 Series railcar design.
 - Metrorail and other parties involved in the 7000 Series program did not conduct or cause to be conducted engineering failure analysis of wheel migration on 7000 Series axles prior to the October 12, 2021 derailments.
 - Metrorail did not have documentation of any requests for failure analysis from Kawasaki on back-to-back issues.
 - Metrorail did not share the report on wheel migration on older railcars with Kawasaki until after the derailments.
 - As part of a Metrorail corrective action plan to address a WMSC finding, Metrorail has identified issues related to vibrations and possible resonance as being linked to the prevalence of wheels out-of-round on 7000 Series railcars (Out of Round Study). MxV identified vibrations as relevant to this investigation through its dynamic testing data analysis (MxV report).
 - Metrorail is proceeding with additional work related to engineering assessments and modeling of designs for increased damping options for 7000 Series cars, investigation of frequency components and axle bending resonance and associated design changes, any external vibration frequencies that enter the system, and the potential need for Metrorail to institute tighter tolerance for out of round.
- Vehicle-Track Interaction, track conditions
 - Kawasaki communications with Metrorail beginning in 2017 and dynamic testing data analysis, including Kawasaki's analysis report, indicate a relationship between wheel migration and Metrorail's track infrastructure.
 - Metrorail reports in 2014 (restraining rail study), 2015 (LTK wheel migration report on legacy fleet), and in 2020-21 (QICO report) identified safety issues related to Metrorail's restraining rails. Prior to the derailment, mitigations or correction for these issues were not incorporated into vehicle or track design.
 - Metrorail's 2014 restraining rail study identified concerns related to lubrication and to the flangeway width that WMATA had set, noted differences in the design of current railcars compared to the original 1000 Series railcars that were part of Metrorail's original track standard considerations, and recommended wayside measurements and computer modeling specific to WMATA's vehicle characteristics. However, Metrorail did not conduct that modeling.
 - Actual conditions, not just design criteria, are a factor in vehicle-track interaction forces. A location where dynamic testing identified a high lateral load had a spacer sticking out from under the rail head and did not meet Metrorail's track standard.
 - The NTSB investigation team's walking inspections identified "various locations of flangeway width outside of the measurements set forth in WMATA's maintenance standard." The narrowest flangeway noted was 1-1/2 inches. The widest flangeway noted was 2-3/4 inches."

- MxV identified a horizontal restraining rail between Metro Center and McPherson Square stations on March 8, 2022 that did not have a flare in the normal direction of traffic, and that demonstrated conditions consistent with oxidation from reactions with water after impact or sliding, as well as indications of a torch cut and fatigue cracks. Metrorail personnel found a picture from 2016 showing the rail had a flare at that time.
- “TTCI provided WMATA personnel with additional information about how the wheels on the railcar perform on the running rail. This information, along with WMATA track designs and specifications, and the apparent safety risk gave the team additional reasoning to escalate this finding to the Senior Vice President Level. WMATA will issue a Service Bulletin to its Track Inspection to include designs and specifications of horizontal and vertical curves”
- Metrorail is conducting new frog and restraining rail studies, and has now identified and is addressing track-related issues through the 7000 Series railcar VTI data (see below)
- 7000 Series Railcar Safety certification
 - The FTA Handbook for Safety and Security Certification was published in 2002. Metrorail established a safety certification program the following year, in July 2003.
 - As documented in investigative interviews, safety certification was not fully valued and adopted for 7000 Series railcars in the comprehensive fashion specified in Metrorail procedures from scope and design development through commissioning of vehicles.
 - Metrorail’s safety department was not involved in 7000 Series contract and initial specification development.
 - Information was not proactively shared with the personnel attempting to carry out safety certification activities.
 - According to the interviews, this was emblematic of Metrorail’s use of safety certification program generally, including Metrorail proceeding with projects such as turnout changes without following its safety certification process that is designed to ensure hazards are identified and mitigated, reducing the risk of unintended consequences.
 - As further noted in other interviews, compliance with specifications does not achieve hazard identification and mitigation requirements, and “compliance in system elements in isolation does not necessarily mean that the system itself as a whole is safe.” This process is intended to account for a systemic approach that includes interactions among different systems and subsystems, human factors, and operational and maintenance processes and procedures.
 - Deficiencies in the safety certification process reduced the opportunity to proactively mitigate hazards and contributed to the high number of issues those involved in the 7000 Series program were facing on an ongoing basis. An effective safety certification process could have reduced the number of issues, which could have better allowed the opportunity for appropriate preoccupation with failure, rather than concern only about items that had already directly impacted passenger service or led to serious injury. For example:
 - Ground brush issues that had been identified were systemically addressed after a mechanic was injured.

- Those involved in the work believed they were “chasing other more catastrophic failure modes” at the time changes were made to wheelset assembly requirements for the final 7000 Series railcars.
 - Issues raised to the Chief Operating Officer’s level were generally due to safety events or service disruptions that had already occurred.
- The known hazard of wheel migration identified on the older “legacy” railcars was not effectively communicated to the safety certification team for incorporation into the 7000 Series railcar safety certification process
- The known condition of wheel migration identified on 7000 Series railcars was not effectively communicated to the safety certification team for incorporation into the 7000 Series railcar safety certification process.
 - Metrorail personnel stated in interviews that this (and other reviews and communication) should have occurred.
 - Metrorail did not implement mitigations to systematically address this safety issue such as changes to measurement tools and measurement frequency or engineering changes for railcars already delivered or near delivery.
- As explained in interviews with QICO and SAFE personnel, fragmented responsibilities, roles and meetings related to 7000 Series railcar project oversight and implementation contributed to a belief that someone else was focused on, checking on, and acting upon safety items.

Allowing known wheel migration to progress to derailment of a train carrying passengers: a culture of siloed approaches to safety, inaction on available safety data

When wheel movement was detected prior to the derailment, Metrorail did not take appropriate action to prevent such a derailment due in part its ineffective safety culture as demonstrated by “shortcomings in WMATA’s internal communications, in its recognition of hazards, its assessment of risk from those hazards, and its implementation of corrective actions” and its ineffective use of “past safety investigations and studies to make lasting changes that become incorporated in its organizational safety culture.” Metrorail’s siloed approach to safety and its inconsistent consideration of available safety data to make safety improvements prevented WMATA leadership outside of the railcar departments (and prevented Metrorail’s state safety oversight agency) from learning of and acting upon the wheel spread safety issue prior to the derailment despite an abundance of data indicating that this safety issue was occurring and was being identified more and more frequently, and despite other Metrorail data and reports demonstrating this wheel migration has occurred on other WMATA railcar fleets.

Contributing to the outcome of this siloed approach was Metrorail’s inadequate understanding, safety promotion, safety assurance, and safety risk management to ensure that Metrorail systems and identified deficiencies in those systems are considered on a systemic, cross-functional basis, including as the systems and identified deficiencies relate directly to the safety of Metrorail riders, workers and first responders.

- Metrorail first identified 7000 Series railcars in 2017 with wheelsets that exceeded “back-to-back” and journal bearing gap requirements set for safe operation, identified additional such cars in 2018 and 2019, and identified growing numbers of cars with wheelsets exceeding these

requirements in 2020 and 2021. Metrorail did not as an organization identify and act upon this trend.

- Culture
 - “Shortcomings in WMATA’s internal communications, in its recognition of hazards, its assessment of risk from those hazards, and its implementation of corrective actions” and its ineffective use of “past safety investigations and studies to make lasting changes that become incorporated in its organizational safety culture” are evident from investigative interviews and documentation.
 - Above noted items related to safety certification
 - Above noted items related to Metrorail’s lack of pre-occupation with failure, including prior Metrorail data and reports that Metrorail did not act on in relation to making safety improvements to track design and 7000 Series railcar axle assembly requirements, and:
 - Responses to a Federal Transit Administration safety advisory indicated that this wheel migration is not occurring at other transit agencies.
 - Such wheel migration is unusual in the industry, with ORX describing even the initial identified migration in 2017 as “a big deal” and Kawasaki describing it as something “obviously, that raised alarms for us since we don’t normally see this.”
 - Metrorail’s Chief Mechanical Officer stated “We weren’t really all that concerned because the wheels didn’t move all that much. And again, it was only onesies and twosies. It was later on when more and more axles started to come out of spec that we really became concerned.”
 - Metrorail personnel stated that they allowed axles known to be beyond Metrorail safety specifications to operate in service as a deferred maintenance activity to be checked again later depending on “how far it was out of spec, we deferred it and monitored it, or we had to replace it.”
 - A January 29, 2021 letter from Kawasaki to Metrorail disputing the chargeability of these wheel migration issues under the contract expressed a conclusion that “other forces within the WMATA system are causing the wheels to move,” indicating that this safety issue related to the interaction of Metrorail systems such as vehicles and track. The letter also stated “WMATA did not inform KRC of a tighter turnout on WMATA tracks until after original wheel press tonnage was finalized.” Metrorail responded that “Per the noted letter chain WMATA did not specify any press tonnage in the TS [technical specification] or contract documents. WMATA only requested that KRC investigate increasing the press tonnage after an observed failure,” suggesting that even after identifying a deficiency related to its older railcars, Metrorail was not planning to proactively consider the same safety improvement for 7000 Series cars.
 - This is further supported by WMATA’s approval on March 6, 2017, in response to a December 22, 2016 letter from Kawasaki – each date is after the September 15, 2016 LTK final report

related to older railcars that led to changes for those railcars – approving a revision of the 7000 Series wheelset drawing, which still noted a press tonnage requirement of 55-80 tons.

- The wheelset drawing was next revised in May/June 2017 to increase the 7000 Series requirement to 65-95 tons, in line with the changes Metrorail had implemented for its older railcar fleets.
- Metrorail identified and confirmed wheel migration on 7000 Series railcar axles. This was identified and confirmed with increasing frequency from 2017 through the time of the October 12, 2021 derailments. However, Metrorail did not investigate 7000 Series wheel migration prior to the derailments, and did not communicate regarding this safety issue.
 - Metrorail did not share the report on wheel migration on older railcars with Kawasaki until after the derailments.
 - 7000 Series specifications and contracts focused on programs for addressing failures related to delays to passenger service, not to failures related to safety or high hazard items.
 - Metrorail did not respond to Kawasaki’s request for direction on whether changes were needed to cars delivered with axles built to the original design requirements
 - Metrorail took no action to improve its measurement practices until after the derailments.
 - According to interviews, prior to the derailments, Metrorail had used existing gauges and measured wheelsets as passing inspection that were identified by other means such as the wheel lathe as exceeding safety requirements.
- Information regarding this known wheel migration was held by a small group of personnel. This prevented WMATA senior vice presidents and the general manager from learning of the issue.
 - Despite frequent meetings between Metrorail railcar personnel and the WMSC railcar team with both specific and open-ended questions at least from July 2020, and despite further questions and document requests during the 2020 WMSC’s Revenue Vehicle (Railcar) Audit, Metrorail also did not share this safety information with the WMSC.
- Interviews indicated that Metrorail personnel did not understand, or dismissed the safety critical significance of, the documented wheel migration, despite Metrorail’s requirements identifying back-to-back measurements as necessary for a train to be allowed to safely operate, and that there are gaps in Metrorail’s culture related to valuing safety processes and procedures.
 - These interviews included information that there are perceptions that information should not be referred to other groups, that professional judgement is applied in place of documented safety processes, and that there is a perception that if an item does not directly impact the ability to provide service then it does not impact safety.

- Interviews noted the challenges of improving the safety culture of such a large organization and the next stages required to overcome Metrorail’s history and deliver a future “just culture” approach through middle management.
- Safety data not acted upon, and necessary track adjustments
 - Since approximately 2015, Metrorail has had access to Vehicle Track Interaction (VTI) data collected by a sample of 7000 Series railcars. Prior to the derailment, and prior to the WMSC’s focus on Metrorail including such data in a holistic ongoing evaluation of Metrorail systems, Metrorail had not effectively used this data.
 - Following the derailment, review of this data identified track maintenance and safety issues requiring repair that had not been identified and addressed through other sources.
 - Following the derailment, Metrorail also conducted special frog inspections, which identified several new frog point conditions that had not been noted during the previous month’s inspections.
 - During Metrorail’s Return to Service Plan process, after the WMSC held Metrorail to its plan, Metrorail has been able to effectively utilize this data to identify track locations, most commonly in special track work, requiring maintenance and repair.
 - Further, during Metrorail’s Return to Service Plan process, after the WMSC held Metrorail to its plan, Metrorail effectively utilized this data to identify in January 2023 deficiencies in frog inspection practices, and then to make the necessary changes to improve these practices.
 - Metrorail had not addressed safety issues in a systemic fashion, and had evaluated failures in isolation.
 - Metrorail has since, at the WMSC’s suggestion during development of return to service plan revisions, created a multi-disciplinary vehicle-track working group
 - As documented in Metrorail’s change management procedures, the systemic evaluation of track is necessary in concert with any proposed changes to vehicles or other related systems.
- Actions outside of safety procedures
 - Metrorail conducted a special inspection of the 7000 Series railcar fleet in the days after the derailments and identified additional wheelsets with wheel spacing that exceeded Metrorail’s back-to-back requirements.
 - The WMSC identified that Metrorail returned a trainset to service in the days after the derailment that contained such wheelsets that Metrorail had documented did not meet safety requirements, communicated this to Metrorail, and, following Metrorail declining to remove 7000 Series railcars from service, ordered Metrorail later on October 17, 2021 to do so until Metrorail developed a plan with data-driven safety mitigations.
 - After Metrorail developed such a plan, the WMSC identified that Metrorail had returned 7000 Series railcars to service that did not meet the requirements of its plan, and ordered Metrorail on December 29, 2021 to develop a plan with additional protections.
 - Metrorail began developing such a plan several months later, with a final version of this revision completed in May 2022. Subsequent revisions were made in September 2022 and October 2022 based on available data.

Emergency and Operational Response

Contributing to the deficiencies in the timeliness of emergency response, Metrorail's training, safety promotion, and information available to personnel are insufficient to prepare personnel to effectively respond to or manage emergencies.

- After the final derailment between Rosslyn and Arlington Cemetery Stations, Metrorail personnel focused on troubleshooting and train movement even after riders reported smoke to the Train Operator and reported the derailment, a railcar contacting the tunnel wall, and smoke to the Security Operations Control Center, the WMATA Metro Transit Police dispatch center.
 - Moments after the final derailment, a passenger on the train called Metrorail's Security Operations Control Center to report the derailment and apparent smoke. The WMATA employee receiving this call took no action to address the reported emergency and did not communicate this safety event to the Rail Operations Control Center or other personnel who could take action to immediately respond to the derailment and prevent further train movement. Metro Transit Police were also not immediately dispatched.
 - Following the initial rider report of the derailment, the rider then further described several minutes later the hazard being created by moving and dragging the derailed train. This report was also ignored.
 - As evidenced by further conversation approximately 10 minutes after the initial rider report when the employee was speaking with an individual from the Rail Operations Information Center who called to report the accident train as a disabled train with a brake issue, the employee had summarily dismissed the direct, accurate, and clear reports of this accident, delaying emergency response and introducing additional hazards.
 - Metrorail procedures require that, upon report of smoke, the smoke is to be investigated and riders are to be assisted to another part of the train. The Rail Traffic Controller directed the Train Operator to attempt to override what they believed to be a stuck holding brake, and to attempt to move the train. Neither the Train Operator nor personnel in the Rail Operations Control Center understood the train had derailed.
 - As a result of this lack of shared situational awareness and inaction on available safety information, the derailed train was further dragged approximately 1,200 feet.
- The Train Operator then reported they could not move the train up the incline.
 - At approximately 5:02 p.m., approximately 11 minutes after the final derailment, the Train Operator, having been directed to go to car 7200 to cut out trucks (bypass braking), identified the derailment.
 - Third-rail power was de-energized at 5:03 p.m.
- Metrorail's emergency response did not identify that the train was in a tunnel, which contributed to the delayed activation of ventilation fans following reports of smoke.
 - Metrorail's Advanced Information Management System screens do not ensure personnel in the Rail Operations Control Center understand the physical characteristics of the location where an emergency is occurring.

- The Buttons Rail Traffic Controller was not familiar with the physical characteristics of the system to know that the location of the train was underground.
- Ventilation fans were activated at 6:44 p.m., nearly two hours after the derailment.
 - This is not in conformance with Metrorail procedures requiring activation upon report of smoke.
- Rail Operations Control Center managers and other personnel did not utilize available checklists governing derailment response during the event.
- The Rail Operations Control Center was not fully staffed during the event, with one managerial position vacant during the shift. This reduced communication and coordination during the event.
- Rail Operations Control Center managers did not effectively communicate with the jurisdictional Fire Liaison Officer or Metrorail's Incident Management Official that there was a report of smoke.
- Metro Transit Police Department personnel arrived at the train approximately 44 minutes after the derailment.
- The jurisdictional Fire Liaison stationed in the Rail Operations Control Center ensured that electrical safety equipment, warning strobe and alarm devices (WSADs), were placed in the necessary locations after identifying deficiencies in the safety setup.
- Passenger evacuation did not begin until approximately 6:20 p.m. and did not conclude until approximately 7:16 p.m.

The WMSC has already taken actions related to this investigation, including the October 17, 2021 and December 29, 2021 orders related to 7000 Series railcars that required Metrorail to develop and implement a plan to provide for the safe return to passenger service of each 7000 Series railcar. The WMSC continues to oversee Metrorail's 7000 Series Return to Service Plan, including overseeing Metrorail's work in accordance with Metrorail's change management procedures to make safety improvements as a result of this investigation. The WMSC has separately completed audits, issued other findings requiring Metrorail to develop and implement corrective action plans, and conducted other oversight activities that will help prevent or mitigate future safety events. Other information related to this investigation, such as track frog and restraining rail studies, are pending at the time of this submission.