July 5, 2023 Railroad Investigation Report RIR-23-08

Derailment of Amtrak Passenger Train 7 on BNSF Railway Track

Joplin, Montana
September 25, 2021

Abstract: This report discusses the September 25, 2021, derailment of Amtrak Passenger Train 7, the *Empire Builder*, carrying 149 passengers and 16 crewmembers, on BNSF Railway track near Joplin, Montana. Three passengers who were riding in the lounge railcar died, and 49 passengers and crewmembers were treated for injuries. The safety issues identified in this report include a combination of track conditions that, when combined, caused the train to derail. This report also addresses the limitations of track inspection practices; the retention of passenger windows in railcar overturn events; and the adequacy of compartmentalization in railcar overturn events. Three recommendations are made to the Federal Railroad Administration, two recommendations are made to BNSF Railway, and one recommendation is made to all Class I and intercity railroads. In addition, Safety Recommendations R-14-74, R-16-35, and R-16-36 are reiterated to the Federal Railroad Administration. Furthermore, Safety Recommendations R-14-75 and R-14-76 to the Federal Railroad Administration are reiterated and given a new classification.

Contents

Figures

Tables

Acronyms and Abbreviations

Amtrak	National Railroad Passenger Corporation
BNSF	BNSF Railway
CFR	*Code of Federal Regulations*
CWR	continuously welded rail
FRA	Federal Railroad Administration
FRMP	Fatigue Risk Management Program
HOS	hours-of-service
LSA	lead service attendant
MAS	maximum authorized speed
MP	milepost
NTSB	National Transportation Safety Board
OBS	onboard service personnel
POD	point of derailment
PTC	positive train control
ROCC	BNSF Police Department Resource Operations Command Center
Volpe	John A. Volpe National Transportation Systems Center
V/TI	vehicle/track interaction

Executive Summary

What Happened

On September 25, 2021, Amtrak's Passenger Train 7, the *Empire Builder*, a passenger train carrying 165 passengers and crewmembers, traveling on track owned and maintained by BNSF Railway, derailed near Joplin, Montana. Three passengers were killed and 49 people were injured. The train consisted of 2 locomotives and 10 railcars. Of the eight passenger railcars that derailed, four derailed on their sides, one derailed leaning, and three derailed upright.

What We Found

The derailment occurred because of a combination of conditions that affected the BNSF Railway track. These conditions included worn rail, vertical track deflection at a four-bolt rail joint, subgrade instability, and track misalignment. Also, we found that had a locomotive equipped with an existing automated vehicle/track interaction monitoring system traveled the derailment curve on the day of the derailment, the deteriorating track conditions could have been identified and BNSF Railway could have been notified, giving it the opportunity to take action to mitigate the dangers of the misaligned track.

We also found that rail wear limit regulations would have required the worn rail to be replaced before there was wheel flange contact with the four-bolt joint bars.

Eight years ago, we recommended that the Federal Railroad Administration revise its Track Safety Standards to require tracks to be repaired if the combination of defects results in a hazardous condition, even if the individual deviations do not constitute a violation.

We also found that walking inspections are important to ensure an understanding of track conditions and that the track inspector's workload likely prevented him from performing a timely walking inspection of the track in the area of the derailment. We found that BNSF Railway's lack of management of workloads for safety-related employees indicates a shortcoming in its safety culture, and that a Fatigue Risk Management Program, as required by the FRA, must account for all job responsibilities, duties, and work hours to mitigate the risk of fatigue.

Furthermore, we found that performance standards are needed for window retention systems to prevent passenger ejections. We also found that the approach of compartmentalization in Amtrak's passenger railcars did not protect the occupants of the overturned railcars from injury during the Joplin derailment.

The National Transportation Safety Board determines that the probable cause of the derailment of Amtrak Passenger Train 7 on BNSF Railway track was the combination of worn rail, vertical track deflection at a four-bolt rail joint, subgrade instability, and track misalignment. Contributing to the severity of the injuries were the occupant protections that did not restrain passengers in the overturn event and the failure of the window retention systems.

What We Recommended

As a result of this investigation, we recommended that the Federal Railroad Administration require limits for rail head wear, as well as require that the regulations on replacement rail joints be applied to all rail joints in continuously welded rail track without exception. We recommended that the Federal Railroad Administration implement a process where certain alerts from vehicle/track interaction devices automatically trigger a slow order that remains in place until an inspection is completed and the issue is remediated. We recommended that BNSF Railway complete a thorough evaluation of the derailment curve to look for the cause of instability in the subgrade and to make the appropriate repairs once the cause is determined. We also recommended that all Class I and intercity railroad trains operating on main tracks be equipped with a technology-based monitoring system to detect track defects earlier, reducing the likelihood of train derailments.

We reiterated existing recommendations to the Federal Railroad Administration regarding occupant protection and reiterated and gave new classifications to existing recommendations to the Federal Railroad Administration to address combinations of track conditions and the protection of occupants within passenger railcars.

1 Factual Information

1.1 The Derailment

On September 25, 2021, at 3:56 p.m. local time, Amtrak (National Railroad Passenger Corporation) Passenger Train 7 (the *Empire Builder*), consisting of 2 front locomotives and 10 railcars, derailed at milepost (MP) 1014.574 on the BNSF Railway (BNSF) Hi-Line subdivision near Joplin, Montana.[1] The train was traveling west at a speed of 77 mph, which was within the authorized speed limit for passenger trains on the BNSF track, when it derailed while negotiating a slight right-hand curve while ascending a slight grade on a single main track.[2] After the train derailed, it traversed the east switch for the Buelow siding and came to rest on both the main and siding tracks. As a result of the accident, 8 railcars derailed, 3 passengers were killed, and 49 passengers were injured.[3] (See figure 1.)

Figure 1. Aerial view of the derailment scene. Photograph courtesy of the *Billings Gazette*.

Table 1 details the train consist and the orientation of the railcars and locomotives after the derailment.

[1] (a) All times in this report are local times. (b) Visit ntsb.gov to find additional information in the public docket for this NTSB accident investigation (case number RRD21MR017). Use the CAROL Query to search safety recommendations and investigations.

[2] According to Title 49 *Code of Federal Regulations* (*CFR*) 213.9, the maximum authorized speed (MAS) for passenger trains on this section of the track was 79 mph for passenger trains. The MAS for freight trains was lower and depended upon the weight of the train.

[3] The rail vehicles in this report are referred to by their equipment type and position in the train. For example, the first railcar behind the locomotives is Railcar 1.

Table 1. Amtrak Train 7 consist, September 24, 2021.

Position	Type	Road Number	Bare Weight (Pounds)	Length (Feet)	Orientation
Locomotive 1 (L1)	GE P42DC	74	268,650	69.0	Not derailed
Locomotive 2 (L2)	GE P42DC	38	268,650	69.0	Not derailed
Railcar 1 (R1)	Viewliner II Baggage	61034	119,000	82.5	Not derailed
Railcar 2 (R2)	Superliner II Transition Sleeper	39019	161,500	82.5	Not derailed
Railcar 3 (R3)	Superliner I Sleeper	32050	154,000	82.5	Trailing two axles derailed
Railcar 4 (R4)	Superliner II Sleeper	32085	160,000	82.5	Derailed upright, first to derail
Railcar 5 (R5)	Superliner II Diner	38058	159,000	82.5	Derailed upright
Railcar 6 (R6)	Superliner I Coach	34059	148,000	82.5	Derailed leaning
Railcar 7 (R7)	Superliner II Lounge	33049	151,000	82.5	Derailed on right side
Railcar 8 (R8)	Superliner I Coach	34077	148,000	82.5	Derailed on right side
Railcar 9 (R9)	Superliner I Coach/Baggage	31036	147,000	82.5	Derailed on right side
Railcar 10 (R10)	Superliner I Sleeper	32007	157,000	82.5	Derailed on right side

There were 149 passengers and 16 Amtrak crewmembers for a total of 165 people on the train. Six passengers who were riding in the lounge railcar (Railcar 7 of the consist) were ejected from the train. Three of those passengers died. In total, 49 passengers and crewmembers, in Railcars 2 through 10, were treated for injuries, 15 of whom required hospitalization. Damage to Amtrak equipment, BNSF track, and BNSF signals was estimated to be $22.5 million.

Shortly before the derailment, the engineer was operating the train, and the assistant engineer had recently stepped away.[4] Event recorder data from Locomotive 1 shows that at 3:55:52 p.m., 1/4 of a mile from the point of derailment (POD), the speed of the train was 79 mph. The engineer told the National Transportation Safety Board (NTSB) that just before his train derailed, he felt a severe jerk to the right, then left, then back to the right. According to the event recorder data, at 3:56:04 p.m., the train experienced a train line–induced emergency

[4] Although the engineers are designated in this report as the engineer and assistant engineer, they were peers with relatively equal training and experience.

application of the air brakes.[5] Audio recordings indicate that about 7 seconds later, the engineer called out on the radio, "Emergency, Emergency, Emergency…."[6] At 3:57 p.m., the engineer then called the BNSF Havre West dispatcher and reported that his train had derailed and requested emergency response.[7]

The fourth railcar in the consist, a Superliner II sleeper railcar, was the first railcar to derail. It remained upright after the derailment. The third and fifth railcars in the consist also derailed and remained upright. The sixth railcar in the consist derailed leaning. The railcars in positions seven through ten all derailed onto their right sides.

Figure 2 is an illustration of the derailment site.

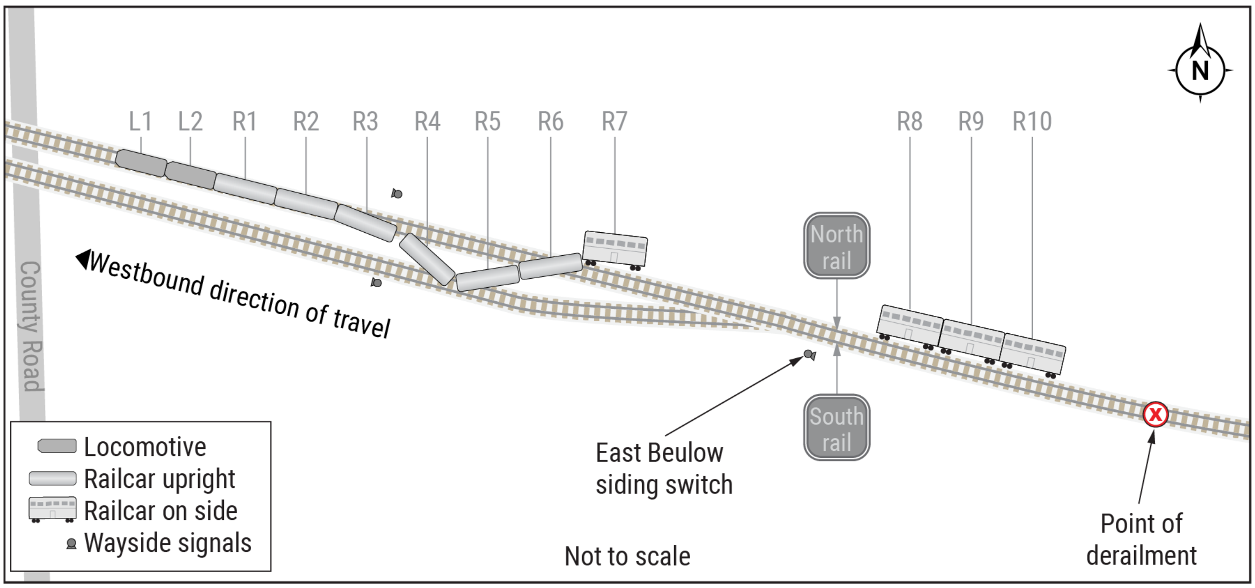

Figure 2. Site drawing of the derailment scene.

[5] When pressure in a train's brake line is reduced rapidly, the entire train's brakes automatically apply.

[6] Rule 2.10 of the *General Code of Operating Rules* requires that train crews broadcast the words, "Emergency, Emergency, Emergency" over the radio to provide initial reports of hazardous conditions which could result in death or injury, damage to property, or serious disruption of railroad operations, such as derailments, collisions, storms, washouts, fires, track obstructions, and emergency brake applications.

[7] The BNSF Havre West dispatcher worked out of the BNSF Dispatch Center in Fort Worth, Texas.

1.2 Amtrak Train 7, *The Empire Builder*

Amtrak Train 7, the *Empire Builder*, departs daily from Chicago, Illinois. The train was 988 feet long and weighed over 2 million pounds. In Spokane, Washington, the rear four railcars of the train were to be removed and would operate as Train 27, with a destination of Portland, Oregon. The remainder of Amtrak Train 7 would continue to Seattle, Washington.

The crew of Amtrak Train 7 consisted of 16 employees, which was typical. The operating crew consisted of an engineer, an assistant engineer, a conductor, and an assistant conductor, and the onboard service personnel (OBS) consisted of 2 lead service attendants (LSA) who supervised 10 service attendants and car attendants. While one of the engineers was operating the train, the other would sit in the operating compartment of the locomotive, communicate the signal indications, and operate the radio. The engineer and assistant engineer would alternate roles about every 2 hours, in accordance with Amtrak procedures.

1.3 Before the Derailment

1.3.1 Amtrak

On September 24, 2021, before the train's initial departure from Chicago, Amtrak mechanics completed the Federal Railroad Administration (FRA)–required Class I air brake test on the train.[8] In addition, FRA requires mechanics to complete other mechanical and operational inspections each day before a train goes into service.[9] The next morning, the train arrived in Minot, North Dakota, for an operating crew change and required safety inspections.

The Amtrak Train 7 operating crew at the time of the derailment went on duty on September 25, 2021, at 8:21 a.m. The crew stated that, upon going on duty, they conducted a safety briefing and communicated with the BNSF dispatcher for general track bulletins.[10] The crew also logged into the positive train control (PTC) system.

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[8] Title 49 *CFR* 238.313.

[9] In addition to the Class I air brake tests, the FRA requires exterior and interior calendar day mechanical inspections of passenger equipment outlined in 49 *CFR* 238.303 and 49 *CFR* 238.305. FRA track classes prescribe the MAS of trains and the associated required inspection and maintenance practices.

[10] According to the *General Code of Operating Rules*, *general track bulletins* are notices that contain information on all conditions that affect safe train or engine movement.

Amtrak Train 7 departed Minot at 9:06 a.m. with the assistant engineer operating the train. At Havre, Montana, the engineer and assistant engineer switched positions and the engineer operated the train toward its next scheduled stop in Shelby, Montana. Figure 3 shows the path of Amtrak Train 7 on the day of the derailment.

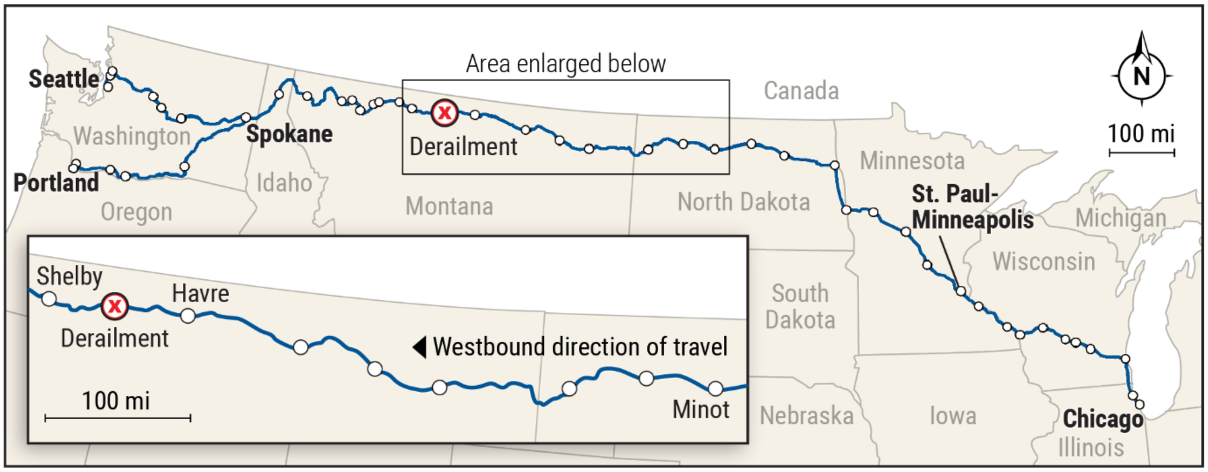

Figure 3. Amtrak Train 7's route.

1.3.2 Train Movements

Ten BNSF freight trains and one other Amtrak passenger train passed through the accident curve on the day of the derailment. The NTSB obtained and examined forward-facing image recordings from the lead locomotives of the last three trains that traversed through the accident curve before the derailment, in addition to the lead locomotive of Amtrak Train 7. Still images from the data and their respective timestamps examined by NTSB showed a progressively worsening track misalignment in the accident curve.

At 12:37 p.m., eastbound Amtrak Train 8, traveling at 81.5 mph, traversed through the misaligned BNSF track at MP 1014.55 about 3 hours 19 minutes before the *Empire Builder*. Forward-facing image recordings show significant right and left rolling, yawing, and swaying of the train as it traveled over the misalignment.[11] A still image captured from Amtrak Train 8 shows the misaligned BNSF track in the curve at

[11] *Yaw* is the twisting or oscillating movement around a vertical axis.

MP 1014.55. (See figure 4.) The north-side running rail (north rail), the inside rail of the curve, in the still image is laterally shifted toward the left.[12]

Figure 4. Still frame from Amtrak Train 8 that shows the misaligned BNSF track.

At 1:31 p.m., eastbound BNSF freight train 4182-ZSSECHC7-24A, traveling about 61 mph, traversed through the misaligned BNSF track about 2 hours 25 minutes before the derailment of Amtrak Train 7. Forward-facing image recordings show significant right and left rolling, yawing, and swaying of the train as it traveled over the misaligned BNSF track. A still image was captured from the recording and shows the misaligned BNSF track in the curve at MP 1014.55. (See figure 5.) Both the north rail and south rail are shown to be laterally shifted toward the left.[13]

[12] The *north rail* was on the engineer's right side.

[13] The *south rail* was on the engineer's left side.

Figure 5. Still frame from BNSF freight train 4182-ZSSECH-24A that shows the misaligned BNSF track.

At 1:42 p.m., eastbound BNSF freight train 7380-QPTLCHC3-23A, traveling about 47 mph, traversed through the misaligned BNSF track about 2 hours 14 minutes before Amtrak Train 7. Forward-facing image recordings show significant right and left rolling and swaying of the train as it traveled over the misaligned BNSF track. A still image from the recording shows the misaligned BNSF track in the curve at MP 1014.55 immediately before the train traveled over the misalignment. (See figure 6.) Both rails are shown to be laterally shifted toward the left.

Figure 6. Still frame from BNSF freight train 7380-OPTLCHC3-23A that shows the misaligned BNSF track.

The forward-facing image recording from Amtrak Train 7 shows about 2.9 inches of lateral movement of the rails about 1 second before the derailment. (See figure 7.) The recording shows the locomotive undergoing a short-duration roll.[14]

[14] The *short-duration roll* was the locomotive's rapid leaning or listing to the side as it operated through the derailment curve.

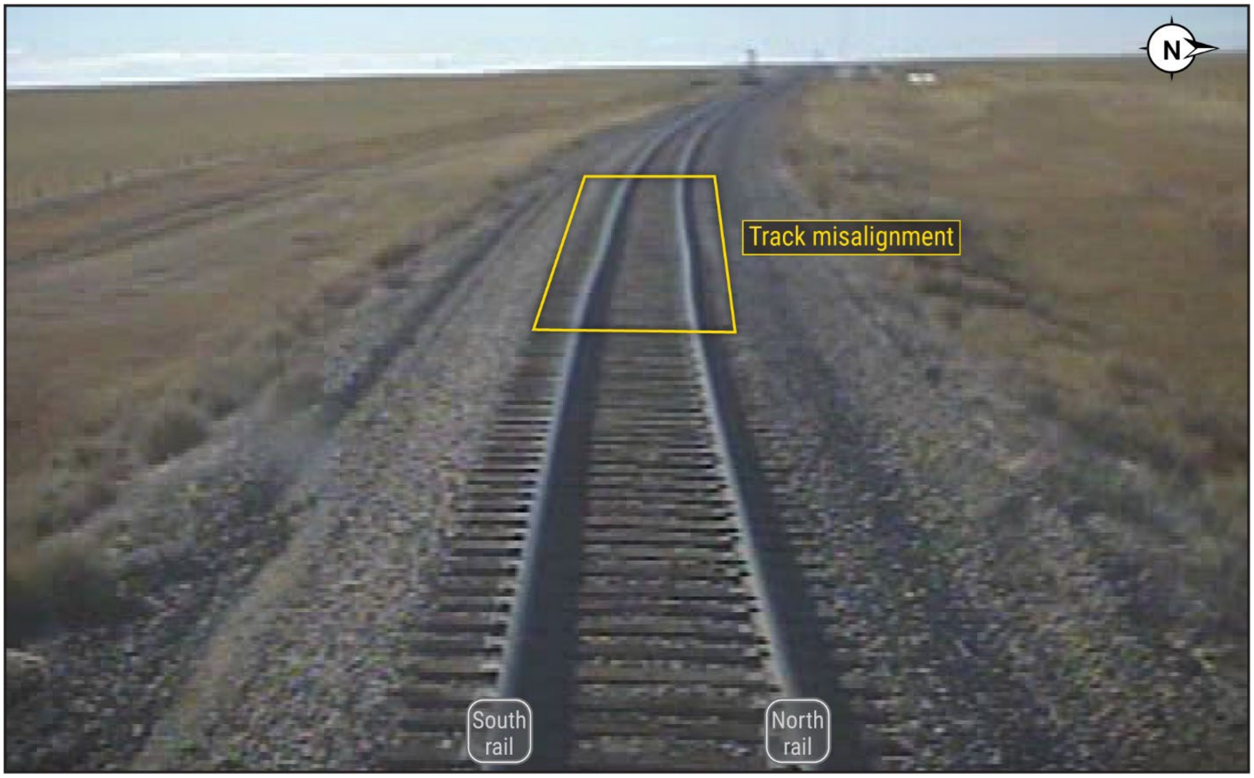

Figure 7. Still frame from Amtrak Train 7 that shows the misaligned BNSF track.

1.4 Emergency Response

1.4.1 Local Response

Joplin, Montana, is an unincorporated community in Liberty County, Montana, near the US/Canadian border. The Liberty County Sheriff's Office operates the 911 emergency communications for the county and dispatches police, fire, and emergency medical services. Table 2 is an excerpt from the Liberty County Emergency Communications Center's incident response log.

Table 2. Excerpts from the Liberty County Communications Center's incident response log.

Time	Response	Remarks
3:57 p.m.	Passenger on board train called 911 and reported derailment	Passenger provided incorrect location of derailment[a]
3:57 p.m.	Passenger called 911 and reported derailment	Passenger reported the location at East Buelow
3:59 p.m.	Amtrak employee reported derailment	Employee was on board eastbound Amtrak Train 8
3:59 p.m.	Witness called and reported derailment	Confirmed location as Buelow crossing
3:59 p.m.	Amtrak called and reported derailment	N/A

Time	Response	Remarks
4:00 p.m.	Liberty County Sheriff's Office dispatched call to emergency responders	Liberty County Sheriff's Office requested mutual aid from adjacent communities/counties
4:14 p.m.	First ambulance arrived on scene	N/A
4:20 p.m.	Mercy Flight air ambulance called	Two additional choppers and crews sent at 5:24 p.m.

[a] The passenger who called 911 did not know the exact location but provided an estimated location that was west of the actual derailment site. However, subsequent calls pinpointed the exact location of the derailment.

1.4.2 Amtrak/BNSF Emergency Communications

As part of a joint agreement between Amtrak and BNSF, emergency communications needs are performed by the BNSF train dispatcher. According to BNSF's internal policies, emergency notifications are turned over to the dispatcher for the BNSF Police Department Resource Operations Command Center (ROCC). The engineer of Amtrak Train 7 reported the derailment to the BNSF train dispatcher, who then notified the ROCC. Table 3 is an excerpt from the ROCC's incident log.

Table 3. ROCC incident log.

Time	Response	Remarks
4:02 p.m.	BNSF dispatcher notified ROCC	BNSF dispatcher reported railcars "on the ground"
4:03 p.m.	ROCC notified Liberty County Sheriff's Office	
4:08 p.m.	ROCC notified Amtrak Police	
4:13 p.m.	ROCC notified of possible injuries	Notified by BNSF dispatcher (likely based on information from *Empire Builder* crew)
4:25 p.m.	ROCC received request for additional ambulances	Requested units from neighboring counties; request made to Liberty County Sheriff's Office at 4:25 p.m.

1.4.3 Amtrak's Emergency Preparedness

Passenger railroads are required under Title 49 *Code of Federal Regulations* (*CFR*) Part 239 to prepare, adopt, and implement emergency preparedness plans and that they be approved by the FRA. The Passenger Train Emergency Preparedness Plan also provides a chain-of-command structure to ensure the orderly flow of information, instruction, and compliance in case of an emergency. Amtrak issued its latest version in conjunction with BNSF on June 28, 2021.

Pretrip safety briefings are not mandated in passenger rail transportation. Although public address system announcements are provided to all passengers, the ability to obtain such safety information is dependent upon whether the public address system is working in the railcar. Passengers were provided with safety instructions that were printed on cards that were left in the pockets on the back of each seat. These cards were placed in response to Safety Recommendation R-83-075 that the NTSB made to Amtrak following a 1982 fire onboard Amtrak Train 11, the *Coast Starlight*, in Gibson, California (NTSB 1983). However, on the day of the derailment, the passengers in the coach railcars had not been informed that safety instructions were available in the seat pockets.

1.4.4 Train Crew Emergency Response

1.4.4.1 Engineers

The engineer immediately contacted the dispatcher following the derailment and began relaying information to be passed along to emergency responders. The engineer stayed in the locomotive about 2.5 to 3 hours after the derailment and monitored the radio for any calls from the dispatcher, conductor, or assistant conductor. Meanwhile, the assistant engineer exited the cab of the head-end locomotive, walked to the rear locomotive, and deenergized the electrical power distribution system to prevent any type of electrical mishap. He also conducted a walkaround inspection of the train and locomotives to assess the damage and to verify there were no fuel leaks or risks associated with damage to the equipment.

1.4.4.2 Conductors

The conductor had the primary responsibility to evacuate the train and oversee the safe egress of passengers in an emergency. At the time of the derailment, the conductor was in Railcar 2. (See figure 2.) In interviews with the NTSB, he said that he did not attempt to make an announcement on the public address system because he could see that the train had uncoupled and tipped over and, therefore, assumed that the communication systems would not be working. The conductor stated that he observed OBS assisting passengers in Railcar 2 and other nonderailed railcars. He then exited the car to assess the emergency. After examining the derailed railcars and assessing the passengers, the conductor radioed the engineer and requested several ambulances.

The assistant conductor was in Railcar 7 at the time of the derailment. When all passengers had evacuated Railcar 7, the assistant conductor began moving to the trailing railcars that were on their sides. By this time, emergency responders had arrived and began entering the railcars.

1.4.5 Postderailment Debrief

On November 13, 2021, Amtrak held a debrief with the emergency responders involved in the derailment. The discussion included topics on the ability to provide accurate information to emergency responders regarding the number of occupants onboard the train, improved communications, and its emergency training program.

1.5 Injuries

Table 4 shows the location in the train of all occupant fatalities and injuries. The three fatalities, almost one-third of the serious injuries, and all of the ejections were located in Railcar 7.

Table 4. Occupant location and injuries.

Railcar[a]	Number of Occupants	Fatal	Serious	Minor	None	Ejection	Entrapment
Railcar 1	0	0	0	0	0	0	0
Railcar 2	11	0	0	3	8	0	0
Railcar 3	27	0	0	4	23	0	1
Railcar 4	26	0	1	0	25	0	0
Railcar 5	3	0	1	0	2	0	0
Railcar 6	9	0	0	1	8	0	0
Railcar 7	25	3	4	7	11	6	2
Railcar 8	13	0	6	4	3	0	2
Railcar 9	7	0	1	2	4	0	1
Railcar 10	15	0	2	9	4	0	7
Unknown	27	0	2	2	23	0	0
Total	163	3	17	32	111	6	13

Note: The location of 27 passengers at the time of the derailment is unknown.

Two of the fatalities in this derailment were passengers who were reportedly walking between Railcars 7 and 8 in the vestibule when the derailment occurred.[15] Both of these passengers were ejected from the vestibule area of the train. The third passenger was ejected from a window in Railcar 7.

Four passengers were ejected out of Railcar 7 when its right-side passenger windows detached from the railcar after the railcar derailed and before it came to rest on its side, creating an opening through which the passengers were ejected. One of these passengers was killed. One surviving passenger ejected from Railcar 7 told the NTSB that he was seated on the left side of the train when the derailment occurred. He was thrown to the right side and out of the window space, although he did not remember striking the window.

Another passenger who sustained serious injuries was located in the middle of Railcar 7 on the right side and told the NTSB that he and his wife ended up on top of a window after the train derailed and overturned on its side as it continued to move forward. He said that the window initially remained in the frame and intact as they

[15] A *vestibule* is an enclosed space at each end of a passenger railcar.

rode on top of the glass; however, the window gave way as the train slowed to a stop, falling out of its frame and dropping the couple to the ground. Railcar 7 came to rest on its side with a gap between the side of the railcar and the ground. Figure 8 shows Railcar 7 in its resting position.

Figure 8. Photograph of overturned Railcar 7 in its position after the derailment.

1.6 Personnel Information

1.6.1 Engineer

The engineer was hired by Amtrak as an assistant conductor in 2010 and was certified as an engineer since 2016. He had worked in the area near the derailment site as both a conductor and engineer for 11 years and his work on Amtrak Train 7 was his regular assignment.

Title 49 *CFR* Part 217 requires that railroads test employees on various aspects of their job to evaluate their ability to perform their jobs correctly and their knowledge of company rules and federal regulations. Records indicate that during the first 9 months of 2021, the engineer was tested 82 times. No discrepancies were documented. No serious medical conditions were noted in his June 2021 company physical.

The engineer told the NTSB that in the moments leading up to the derailment he was not using the radio or distracted by other activities. An examination of the engineer's cell phone records confirmed that there were no phone calls, text activity, or internet activity during this time.

1.6.2 Assistant Engineer

The assistant engineer was hired by Amtrak as an assistant conductor in 2007. He certified as an engineer under 49 *CFR* Part 240 in 2016 after completing Amtrak's engineer training program. He had worked on the Hi-Line subdivision throughout his career. Records show that during the first 9 months of 2021, the assistant engineer was tested 62 times in accordance with 49 *CFR* Part 217 requirements. No discrepancies were documented. No serious medical conditions were noted in his March 2021 company physical. An examination of the assistant engineer's cell phone records confirmed that there were no phone calls, text activity, or internet activity before the derailment.

1.6.3 Toxicology

Postaccident toxicology testing was performed on the engineer, the assistant engineer, and the conductor for alcohol and other drugs in compliance with 49 *CFR* 219.201. The results were negative for all tested-for substances.[16]

1.7 Operations, Signals, and Traffic and Train Control Information

BNSF operates a daily average of 25 freight trains and 2 passenger trains, including Amtrak Train 7, on the BNSF Hi-Line subdivision, which extends westward from MP 964.8 in Havre, Montana, to MP 1217.5 in Whitefish, Montana. The subdivision consists of mostly single main track with multiple passing sidings. The maximum authorized speed (MAS) is 79 mph for passenger trains and 55 mph for freight trains.

The operating crew was governed by the *General Code of Operating Rules, Seventh Edition*, effective April 1, 2021. Specific instructions relating to the Hi-Line subdivision were found in *BNSF System Special Instructions, All Subdivision, No. 2*, effective August 4, 2021; *BNSF Montana Division Timetable No. 2*, effective April 21, 2021; and any general track bulletins specific to that train and that day of operation.

[16] The testing screened for substances including amphetamines, barbiturates, benzodiazepines, cocaine, alcohol and cannabis metabolites, methadone, methaqualone, MDA-analogues, opiates, 6-acetylmorphine, oxycodone, opiates, phencyclidine, and propoxyphene.

BNSF authorizes train movements in the derailment area with a traffic control system, coordinated by the BNSF Havre West dispatcher.[17] The train movements are governed by operating rules, special instructions, timetable instructions, and the signal indications of the traffic control system and are supplemented with an overlaid PTC system.

The NTSB performed testing on the signal equipment and reviewed maintenance, inspection, and testing records for the locations between Control Point Joplin and Control Point West Buelow. The records and testing indicated the equipment was working properly.

1.8 Amtrak Train Information

1.8.1 Locomotives

The two locomotives on Amtrak Train 7 were Genesis P-42s that were built by General Electric in 1997. Amtrak uses the P-42 locomotive fleet as the main motive power for its passenger trains that operate outside of the Northeast Corridor. The locomotive cab contains seats for the operating engineer and two other crewmembers. The locomotives are equipped with a forward-facing image recorder and a permanent core memory event data recorder.

1.8.2 Railcars

Amtrak Train 7 had one Viewliner II baggage railcar positioned behind the locomotives, followed by nine Superliner railcars. According to Amtrak, 343 seats were available for purchase.

Amtrak Train 7 had three Superliner sleeper railcars, two coach railcars, one combination baggage/coach railcar, a transition sleeper railcar, a lounge railcar, and a dining railcar. All Superliners are equipped with two-piece windows located at each seat row or room that are 24 inches tall by 66 inches wide. The side windows in all of these railcars are identical except the curved roof-level windows in the lounge railcars.

All large windows in lounge railcars are emergency egress/access windows, except for the curved roof-level windows that provide increased passenger views. Each section of the emergency egress/access windows is 31.8 inches wide by

[17] A *traffic control* signal system establishes routes to control railroad traffic and is monitored by a dispatcher.

38.12 inches high. The actual frame opening of these windows is about an inch smaller. Figure 9 shows a damaged window from Railcar 7.

Figure 9. Postderailment photograph of a damaged window from Railcar 7.

The dining railcar (Railcar 5 in the consist) had seating for 72 people on the upper level. The galley, or kitchen, occupies the entire lower level.

1.8.3 Postderailment Railcar Inspections and Testing

On September 26, 2021, the NTSB conducted an FRA Class I air brake test on the portions of the train (the locomotives and first two railcars) that did not derail. When tested, the brakes applied and released properly from both service and emergency applications.

1.8.4 Occupant Protection

Occupant protection involves providing a protective envelope that can limit the movement of an occupant, known as compartmentalization, and uses energy-absorbing material designed to minimize injury to an occupant colliding with an interior structure during an accident. Window retention and compartmentalization are two primary facets of occupant protection.

Railroad passenger vehicles fall into one of three "tiers." The type of equipment used on Amtrak Train 7 is tier I equipment, designed to operate at speeds not exceeding 125 mph. Tier II vehicles operate up to 160 mph, and tier III vehicles operate up to 220 mph when in exclusive rights-of-way. As tier I vehicles, the applicable minimum federal safety standards for design and construction are found in 49 *CFR* Part 238 "Passenger Equipment Safety Standards" Subparts B and C.

Specifically, in Subpart B, "Safety Planning and General Requirements," minimum standards exist for door emergency egress and rescue access systems, emergency window exits, rescue access windows, emergency lighting, emergency communications, and markings and instructions for emergency egress and rescue access. In Subpart C, "Specific Requirements for Tier I Passenger Equipment," minimum standards exist for crashworthiness such as static-end strength, anticlimbing devices, collision posts, corner posts, rollover strength, interior fittings and surfaces, and glazing (windowpanes).

During the postderailment examinations of the vehicles, the NTSB found the structural elements of the vehicles were not compromised and did not fail. Damage to the exterior of the vehicles was limited to sidewall and running gear damage and did not impact passenger occupant space. However, debris was found to have entered through the window areas and passenger ejections were reported through the window areas. Therefore, NTSB postderailment examinations focused on window and emergency egress, rescue access, and window glazing.

1.8.4.1 Amtrak Train 7 Window Systems

Amtrak Train 7 exceeded the federal minimum standard for the number of emergency window exits and the number of rescue-access windows by making every window a "dual-function window."[18] Dual-function windows meet the requirements for both an emergency exit and rescue-access window. FRA regulations require a minimum of two rescue-access windows on each main level of a passenger railcar and a minimum of four emergency exit windows on each main level. The railcars exceeded this requirement because each window was a dual-function window.

Windows in passenger railcars must meet functional requirements and be transparent, maintainable, and have high optical quality, as well as address safety requirements such as emergency egress, rescue access, fire tolerance, and occupant containment (FRA 2022).

Amtrak Train 7's windows were held together by an aluminum perimeter frame which was held into the railcar body with elastomeric gaskets containing zip strips.

[18] Title 49 *CFR* 238.113 and 49 *CFR* 238.114.

Zip strips are the element that provide both "maintainability" and emergency removal for egress and access. Instructions are provided on the interior and exterior of the railcar for removal of the zip strips. When a zip strip is removed from a railcar, the entire aluminum window frame is designed to be easily removed from the carbody to allow for egress and access through the resulting space. Once the window is removed, it can be placed inside of the railcar or placed outside of the railcar (FRA 2022).

In June 2022, the FRA and the John A. Volpe National Transportation Systems Center (Volpe) issued a report, *Integrity of Rail Passenger Equipment Glazing Systems*. In this report, FRA and Volpe said:

> Over the last 44 years, at least 25 fatalities have been attributed to passenger ejection through window openings during passenger train accidents (FRA 2015). Many of these fatalities have been attributed to the inability of the glazing systems to provide the needed level or resistance to passenger ejection. Reviews of rollover accidents have shown that, more often than not, occupant retention performance (or the lack thereof) has been defined by the capacity of glazing retention gaskets, rather than the strength of the glazing panes. In particular, it appears that these failures are more attributable to the mounting method of the glazing panes, rather than failures of the panes themselves (FRA 2022).

Ensuring that train occupants are not ejected through windows during a crash or rollover, referred to as occupant containment, is a key function of window systems. FRA glazing securement requirements address the forces due to air pressure differences when two trains pass at the minimum separation for two adjacent tracks.[19] Additionally, the glazing portion must meet standards for impact resistance found in 49 *CFR* Part 223. Aside from shatter resistance and the passing of high-speed trains, there are no federal minimum safety standards for the retention of a window frame in the carbody in circumstances where it is undesirable for the window to be removed, such as in a rollover event.

Figure 10 shows the exterior right side of Railcar 7 after it had been righted at the scene. The occupant ejections occurred from the missing windows on the upper level.

[19] Title 49 *CFR* 238.221.

Figure 10. Photograph of the exterior of Railcar 7.

In this derailment, multiple window systems in Railcars 7 through 10 failed. As noted previously, the rear four railcars overturned onto their sides during the derailment. The failure of the window retention system resulted in the loss or displacement of 47 windows in the four overturned railcars. (See table 5.)

Table 5. Window failures in Railcars 7 through 10.

Railcar	Window Failures	Passenger Ejections	Passenger Injuries	Passenger Fatalities
Railcar 7 – upper level[a]	9	4	7	1
Railcar 7 – lower level	3	0	1	0
Railcar 8 – upper level	10	0	3	0
Railcar 8 – lower level	1	0	1	0
Railcar 9 – upper level	1	0	0	0
Railcar 9 – lower level	0	0	0	0
Railcar 10 – upper level	8	0	0	0
Railcar 10 – lower level	4	0	2	0
Total	36	4	14	1

[a] Passenger ejections, injuries, and fatality reported in this table are a result of the failure of the railcar windows. Two ejected passengers are not accounted for in this table because they were ejected from the vestibule area of the railcar.

The gaskets were torn away from the windows as the railcars slid across the ground. (See figure 11.) The windows either detached entirely or became partially dislodged, which allowed dirt and ballast to push into the void spaces and fill the occupied spaces within the railcar.

Figure 11. Exterior photograph of a window from Railcar 9.

The failure of the window retention system resulted in seven passenger entrapments, two of which resulted in serious injuries.

1.8.4.2 Crashworthiness

During postderailment inspections, the NTSB observed that Railcars 3 through 7 derailed and remained attached to the locomotives. Railcar 3 derailed the rear two axles. Railcars 4 and 5 exhibited postderailment damage limited to the underside. Railcar 6 derailed leaning to the right, with damage to the underside of the vehicle.

Railcar 7 derailed onto its right side and exhibited extensive damage to the exterior sidewall, which included 9 of 11 large, side passenger windows that were missing or dislodged. Figure 12 shows the interior of Railcar 7 after the derailment.


Figure 12. Interior of Railcar 7 after the derailment.

Railcar 8 derailed and overturned onto its right side and was located about 830 feet behind Railcar 7. All 14 windows were dislodged from the right side and the window from the side passenger door was missing. Railcar 9 was still coupled to Railcar 8 and was also derailed and overturned onto its right side. All 11 windows were dislodged from the right-side upper level. Railcar 10 lost 12 windows and was derailed and overturned onto its side and still coupled to Railcar 9. The bedrooms in this railcar had dirt and debris inside, and most of the windows were dislodged.

In the railcars that overturned (Railcars 7 through 10), passengers were trapped by dirt and debris when doors became wedged shut, and several passengers were partially trapped by the incoming dirt. In lower-level bedrooms and seating areas, as much as 2 feet of dirt had entered the occupant spaces.

1.9 BNSF Track

The minimum safety standards for railroad track are outlined in the FRA's Track Safety Standards, found in 49 *CFR* Part 213.

The track in the accident area, owned by BNSF, is designated as FRA Class 4 track, which allows passenger trains to operate at a MAS of 80 mph and freight trains to operate at a MAS of 60 mph, unless otherwise restricted, based on the weight of the railcar. The derailment occurred along the single mainline portion of the Hi-Line subdivision in a slight curve. The track was constructed with wood crossties that measured 9 inches wide by 7 inches deep, measuring 8 feet 6 inches long. The crosstie center-to-center spacing was measured to be 19.5 inches in the area of the derailment.

As discussed in section 1.3.2, the main track consisted of a south rail and a north rail. The south rail consisted of 141-pound section rail, manufactured in January 2003.[20] From about MP 1014.60 to about MP 1014.40, the NTSB measured the south rail to have a uniform rail wear pattern on the track curve of about 3/8 inches throughout the length of curve 1014, through the POD located at MP 1014.57, and rail tread wear loss of about 3/8 of an inch. The NTSB noted that the south running rail was observed to be dry with no indication of friction modification (grease) extending along the gauge portion of the rail.[21] The south rail was secured to the crossties using standard double-shoulder tie plates and standard-cut spikes.

The north rail, traveling westbound, consisted of various sections of 136-pound and 132-pound rails. The majority of the north rail from MP 1012.00 to MP 1014.554 consisted of 136-pound rail, manufactured in October 1995. The north rail was secured to the crossties using standard double-shoulder tie plates and standard-cut spikes.

The NTSB noted a replacement rail on the north side with two four-bolt suspended rail joints that measured 19 feet 6 inches long between MP 1014.554 and MP 1014.550. The 19 feet 6 inches plug rail consisted of a 132-pound replacement rail manufactured in January 1982. The NTSB noted that the bolted replacement rail had 1/2 inch of vertical rail wear.[22] The bolted replacement rail was secured to the existing north rail with standard six-hole joint bars measuring 36 inches long. Each replacement rail joint was drilled for in-track welding, and had four 6.5-inch standard bolts, nuts, and locking washers securing the joint bars. The NTSB noted that the east

[20] The rail section refers to the dimension of the rail and the associated rail weight. For example, the rail section on the south rail weighed 141 pounds per yard.

[21] a) Gauge is often spelled “gage.” However, the FRA told the NTSB in November 2022 that the Rail Safety Advisory Committee had recommended the use of “gauge” as the standardized spelling. (b) The *gauge* side of a rail means the side that is facing the other rail.

[22] *Vertical rail wear* is the reduction of rail head height due to wear.

suspended four-bolt rail joint had evidence of train wheel flange contact at the top surface of the gauge-side joint bar.[23]

1.9.1 Point of Derailment

Amtrak Train 7 derailed at MP 1014.57. The NTSB observed the first wheel flange departure marks in a curve on the south rail, about 100 feet west of the bolted replacement rail.[24] The wheel flange departure marks were about 2 inches apart, beginning at the gauge corner of the south rail.[25] The wheel flange departure marks traversed up and across the head portion of the south rail.[26] The markings did not fully extend across the entire rail head portion of the running rail. There were no other derailment witness markings between the misaligned BNSF track and the confirmed POD. Figure 13 shows the first wheel flange departure marks at the POD in a curve on the south rail.

[23] (a) The *wheel flange* is the projecting portion of the rail wheel that extends below the wheel tread. It is designed to help guide the wheel set and keep the wheels on the rail. (b) Under normal circumstances, the flange of a railcar wheel rides below the head of the rail to assist with steering. When the lateral and vertical forces at the wheel/rail interaction are disrupted in such a way as the flange rises, or climbs above the head of the rail, this is known as *wheel climb* and can lead to a derailment of the wheel.

[24] *Wheel flange departure marks* are a unique scar on the surface of a rail due to increased weight concentration at a spot where railcar wheel flanges ride directly on the surface of a rail. This location is used to help determine the first point of derailment. Wheel flange marks on the north rail are identified in figures 16 and 17; however, they are not wheel flange departure marks.

[25] The *gauge corner* is where the top surface of the rail and the gauge face, or inside horizontal portion of the rail, meet.

[26] The *rail head* is the uppermost surface of the rail, which includes the running surface on which the wheels ride on top.

Figure 13. Wheel flange departure marks on the south rail.

1.9.2 Continuously Welded Rail and Four-Bolt Rail Joints

Federal regulations in 49 *CFR* 213.119 define continuously welded rail (CWR) as a continuous rail length that exceeds 400 feet. When rail is installed as CWR, rail joints for replacement rails installed at a later date remain classified as CWR.[27] Generally, rail joints are used to install replacement rails when internal rail defects are

[27] In the railroad industry, replacement rails are referred to as plug rails when installed in CWR track, in accordance with 49 *CFR* 213.119. They can be used either for installation or for maintenance purposes. In its *Track and Rail and Infrastructure Integrity Compliance Manual*, the FRA created a provision to allow replacement rails placed for maintenance purposes to remain in place indefinitely or until there is a service failure (FRA 2018).

identified during inspection. Replacement rails are installed in CWR using one of the following methods:

- Welding.
- Bolting using rail joint bars and four bolts.
- Bolting using rail joint bars and six bolts.

Four-bolt rail joints with two bolts per rail end allows for the joint to be welded in the future. Although having a third bolt hole drilled in a rail end makes the joint more robust, the option to weld the joint is no longer available because of the proximity of the third bolt hole to the end of the rail.

1.9.2.1 Bolted Replacement Rail Joints

Replacement rails or plug rails are sections of rail connected at each end to the existing CWR using bolts and metal bars known as joint bars. Amtrak Train 7 derailed about 100 feet beyond the west joint of two four-bolt rail joints between MP 1014.55 and MP 1014.57. BNSF requires that replacement rails be 18 feet or longer in that area of curved CWR track. Policy set forth in BNSF's *Engineering Instructions* state that temporary rail joints left in place up to and including 90 days need to be inspected quarterly (BNSF 2021). Figure 14 shows an example of a bolted replacement rail. The rail spike is raised in the photograph because of the contact with the joint bar. As the rail and joint bar move vertically under the load of the train, the spike is gradually worked out of the crosstie. This is known as vertical track deflection, which will be discussed further in section 1.9.3.2. The anchor spike (the spike that is not in contact with the joint bar) moves along with the crosstie and is not influenced by the rail/joint bar movement.

Figure 14. Photograph of a bolted replacement rail.

During the postderailment inspection of the BNSF track, the NTSB noted a 19 feet 6 inches bolted replacement rail with two four-bolt rail joints between MP 1014.554 and MP 1014.550, 100 feet east of the POD. The replacement rail was installed using standard six-hole joint bars on each end. Each joint bar was secured with two bolts at each rail end using 6.5-inch standard bolts, nuts, and locking washers securing the joint bars. BNSF records indicate that this rail was installed on July 23, 2021, 64 days before the derailment. The four-bolt rail joint in the area of this derailment was considered maintenance rail, not installation rail. Maintenance rail is used to replace rail determined to be defective. It is a shorter rail section that is cut into larger sections of preexisting CWR when a track defect requires that the rail be replaced.

1.9.2.2 CWR Regulations and Rules

Federal regulations outlined in 49 *CFR* 213.118 require that each railroad with track constructed of CWR have a plan in place that contains written procedures that address the installation, adjustment, and maintenance of CWR; the inspection of CWR joints; and a training program for putting the procedures into practice. Before implementation, plans for CWR programs must be submitted to the FRA for approval.

BNSF's CWR program is outlined in its *Procedures for the Installation, Adjustment, Maintenance, and Inspection of CWR* plan as required by 49 *CFR*

213.118, Effective Date March 4, 2021. This procedure details the railroad's policy on installing, adjusting, maintaining, and inspecting CWR track (BNSF 2021). The procedures apply to CWR on all main tracks, sidings, and other tracks over which trains operate and details how BNSF applies its CWR construction and maintenance standards and procedures to comply with FRA requirements outlined in 49 *CFR* 213.119.

In 49 *CFR* 213.119 (c)(2), the FRA requires that after October 21, 2009, every four-bolt rail joint placed during CWR installation be either welded, installed with six bolts, or have every crosstie within 195 feet in each direction anchored within 60 days of installation.

1.9.3 BNSF Track Conditions

1.9.3.1 BNSF Track Misalignment

Track geometry refers to the gauge, surface, and alignment of the track structure. Changes or deviations in track geometry conditions will affect how a train performs while traversing over these conditions.

In the 10-year period between 2012 and 2022, there were 592 reportable derailments attributed to track geometry in the United States, resulting in 5 fatalities and 75 injuries.[28] A comprehensive review of accident data revealed that track geometry accounted for 35 of the 97 derailments in the United States in 2021, and was the second leading cause of track-caused derailments in the country. Of the track geometry-caused accidents, 48 percent were related to a track alignment irregularity. Each month, about two reportable train accidents occur due to the similar conditions that caused the Joplin derailment. In 2021, 35 derailments in the United States were attributed to reportable track geometry conditions, 3 on BNSF track.

Just before the derailment, a track misalignment condition was observed in the forward-facing image recording from Amtrak Train 7. The track misalignment condition was estimated to have about 2.9 inches of lateral displacement of both rails and was about 40 feet long. The misalignment could have met the minimum FRA Track Safety Standards but possibly exceeded the allowed lateral displacement of 1 1/2 inch. The misalignment was calculated by a video study with a margin of error

[28] The FRA generally investigates accidents and incidents that meet specific criteria. The criteria for derailments includes any derailment resulting in at least one fatality or serious injury; the derailment of a locomotive, 15 or more railcars, and extensive property damage; derailments resulting in a fire, explosion, evacuation, or release of regulated hazardous materials, especially if it exposed a community to these hazards or the threat of such exposure; derailments involving a train transporting nuclear materials; most Amtrak derailments; and any other derailment likely to generate considerable public interest.

of ± 1 inch. The track was disturbed during the derailment and the alignment deviation could not be confirmed because the track shifted to the right in the derailment.

1.9.3.2 Vertical Track Deflection

Vertical track deflection is the up and down movement of the track that occurs when the train's weight is applied to the track as it moves over the track. When vertical track deflection is encountered, unloading of the wheels occurs on the opposite diagonal corner of the railcar.[29]

Since Amtrak Train 7 was traveling west, it encountered the east joint first. During the investigation, the NTSB observed that the east joint of the bolted replacement rail had a vertical gap of about 1 inch between the rail base and the crosstie plates. There was also visible evidence of an additional 1 inch of vertical track deflection of the crosstie that would have occurred when a train was traversing/loading the rail, resulting in a vertical track deflection totaling about 2 inches.[30] The west joint of the bolted replacement rail had a gap of 5/8 inch between the rail base and the crosstie plate with an additional 1/2 inch of vertical track deflection noted, totaling about 1 1/8 inch. (See figure 15.) Title 49 *CFR* 213.13 "Track Safety Standards" states that when unloaded track is measured to determine compliance with the requirements, the amount of (vertical) rail movement, if any, that occurs while the track is loaded must be added to the measurement of the unloaded track. This regulation is in place so that when track geometry is measured for the purpose of inspection, it is representative of the conditions that a train will encounter while traversing the track.

[29] *Wheel unloading* occurs when there is a variation in the elevation of the parallel rails. If there is a low spot or dip on one of the rails, this causes the ridged railcar body to twist, unloading weight from a wheel on the opposing corner of the railcar.

[30] Measurements were made from witness marks, which were consistent with the loaded condition of vertical displacement. The exact condition before the derailment is unknown.

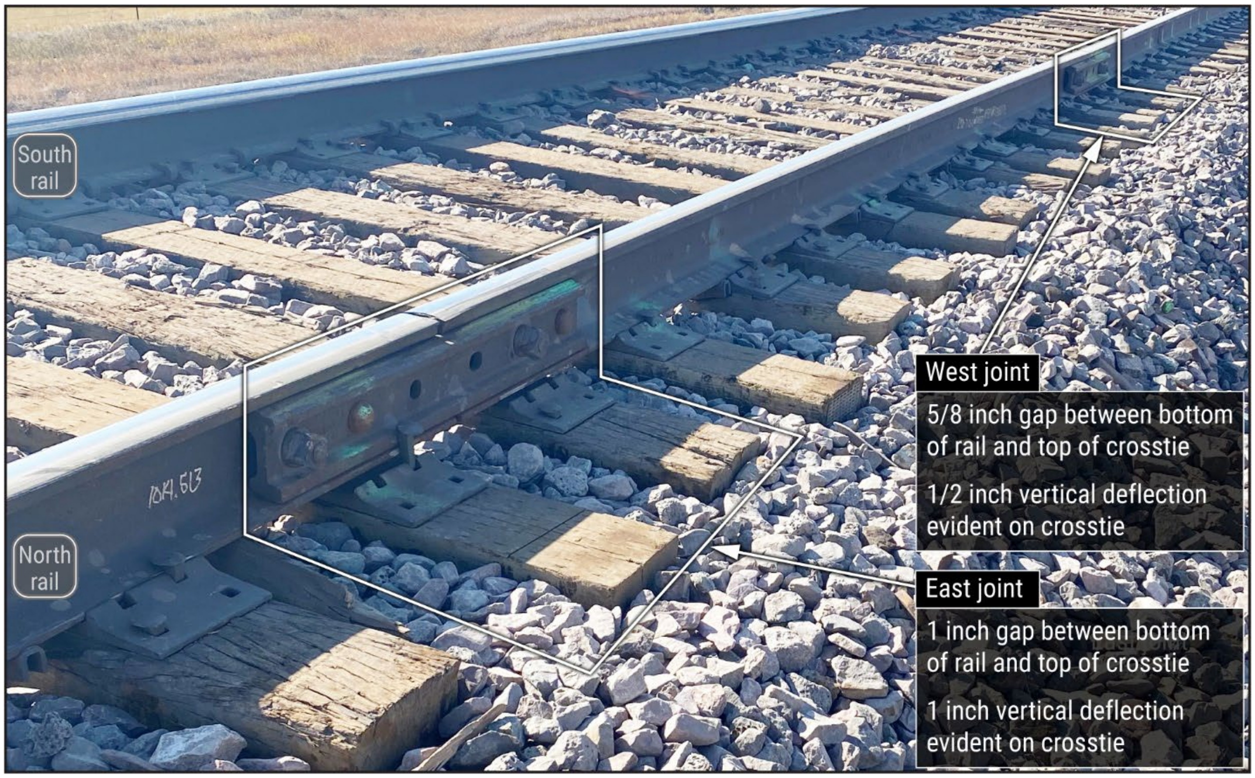

Figure 15. Vertical track deflection evidence at the derailment curve.

Note: The image has been lightened to show better detail of the gap.

In the NTSB's examination of the forward-facing image recordings from the derailment train and the three trains immediately before it, the NTSB estimated the vertical track deflection of the north rail when a locomotive was passing over the vertical deflecting area based on the roll angle of the locomotive.[31]

Table 6 lists the vertical track deflections and the lateral deviations that were estimated based on the forward-facing image recordings studied.

[31] The vertical track deflection estimation is described in detail in the NTSB Video Study, found in the docket for this accident.

Table 6. Vertical track deflections and lateral deviations of trains passing the POD on September 25, 2021.

Train	Time	Direction	Speed (mph)	Lateral deviation (inches)	Estimated vertical deflection (inches)
Amtrak 8	12:37 p.m.	East	81.5	Less than 1	2-3
BNSF 4182-ZSSECHC7-24A	1:30 p.m.	East	61.0	Less than 1	2-3
BNSF 7380-QPTLCHC3-23A	1:42 p.m.	East	48.0	2.9 (±1.0)	2-3
Amtrak 7	3:47 p.m.	West	77.0	2.9 (±1.0)	2-3

1.9.3.3 Vertical Worn Rail and Joint Bar Contact

The NTSB noted that several replacement rails along the north side of the derailment curve had 1/2-inch vertical worn rail. Vertical worn rail is calculated as the difference when compared to a new rail section of the same weight or dimensions. As shown in figure 16, there are grooves and grease on the joint bar, which is consistent with wheel flange contact. This indicates the wheel's flange had made contact with the joint bar as it traveled over the worn rail, thus departing from the normal wheel–rail interface. As rail head wears, the clearance between the joint bar and a wheel's flange is reduced. If the wear is severe enough, then the wheel's flange will make contact with the joint bar, creating an unsafe condition.

Figure 16. Photograph showing a north four-bolt rail joint with wheel flange contact on the joint bar.

In 1998, the FRA published a report titled *Estimation of Rail Wear Limits on Rail Strength Investigations* (FRA 1998). The FRA report, developed by Volpe, concluded that for safe operations on railroad tracks, allowable rail-wear limits should be established on the basis of fracture strength. With some exceptions, the limits could be summarized as (1) maximum allowable head-height loss of 0.5 inch, or (2) maximum allowable gauge-face wear of 0.6 inch. FRA has not enacted any regulations on rail wear limits based on the findings of the report. However, BNSF outlines in its *Engineering Instructions* the limits of vertical worn rail allowed based on the weight of the rail (BNSF 2021a). The north rail had 1/2 inch of vertical rail wear, which was the maximum amount allowed for 132-pound rail under the BNSF standards. The north rail also showed significant vertical worn rail metal flow.[32]

As illustrated in figure 17, the rail ends were chipped and broken, and there is evidence of wheel flange contact on the rail joint bar impacting the four-bolt rail joints.

[32] *Metal flow*, or plasticity, is a result of vertical loads imparted on the rails during train movements. It causes deformation of the metal that forms a lip or overflow.

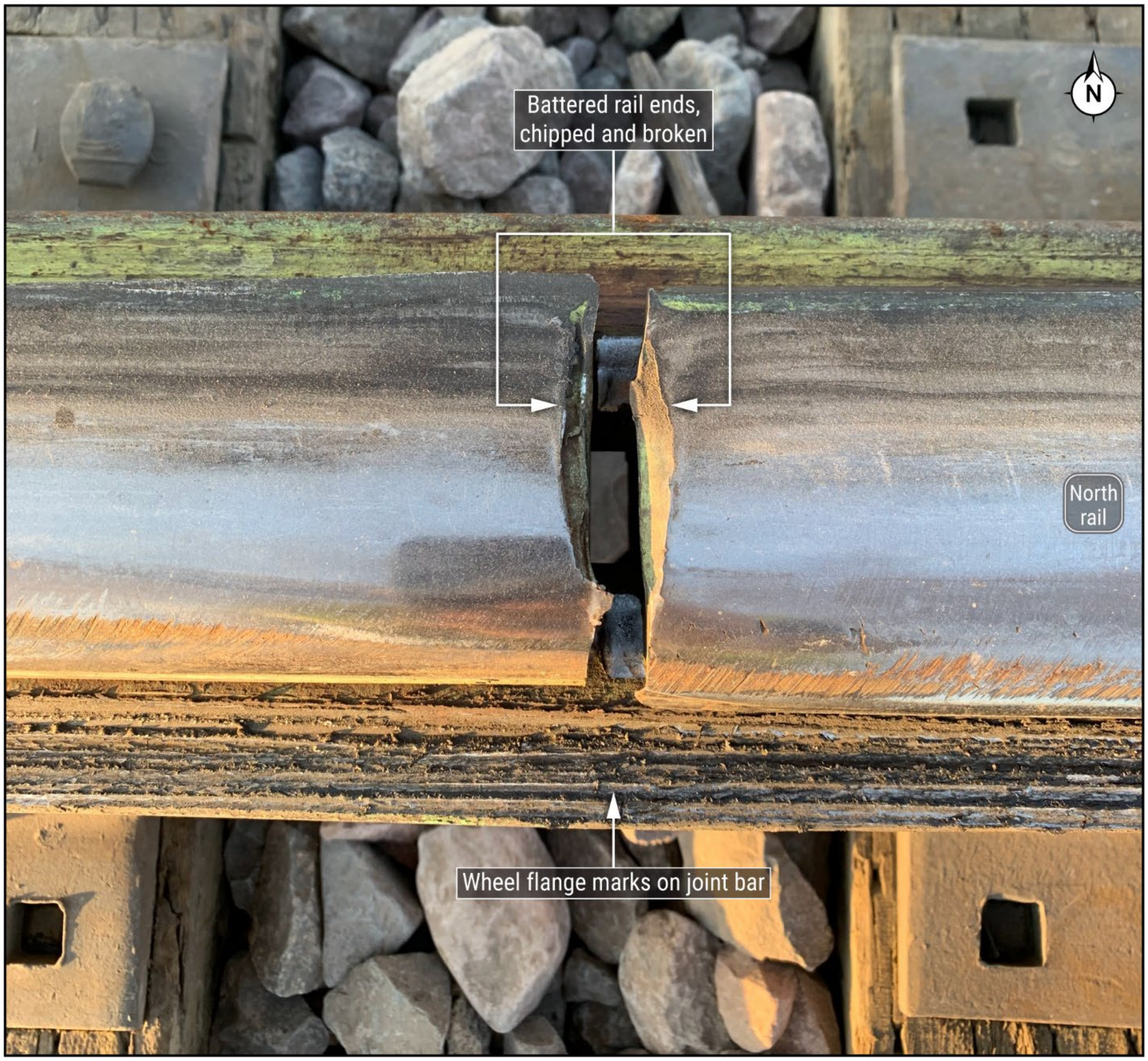

Figure 17. Photograph of the four-bolt rail joint with wheel flange contact on the joint bar. The top of this photograph shows the battered rail ends.

1.9.3.4 Subgrade Instability

During the review of satellite images and BNSF track records of the derailment area, the NTSB identified what appeared to be a culvert for allowing water to pass through the earthen fill that supported the track structure.[33] On September 15, 2022, the NTSB and representatives from BNSF's engineering department returned to the derailment curve to examine the 30-inch diameter culvert and gather additional

[33] A *fill* is a part of the roadway built by mounding material to carry the roadbed and track at the designated elevation or grade.

information. The culvert had not been visible during the on-scene phase of the investigation and the BNSF representatives told the NTSB they had to use excavating equipment to remove dirt and debris to locate the culvert in preparation for the NTSB's site visit.

From the POD at MP 1014.57, the area of vertical moving track extended about 78 feet west and about 200 feet east. The NTSB observed this area exhibited abnormally disturbed ballast in the space between the crossties that was not uniform. In addition, the ballast surrounding the crossties showed evidence of movement which is an indication of vertical deflection of the track under loads imposed by the weight of trains.

Although there is always some vertical movement in track, the NTSB observed a freight train traversing the fill during the inspection and noted that the track was moving more significantly in a vertical direction under the loads put on the track by the train wheels than on the other areas of the track. (See figure 18.)

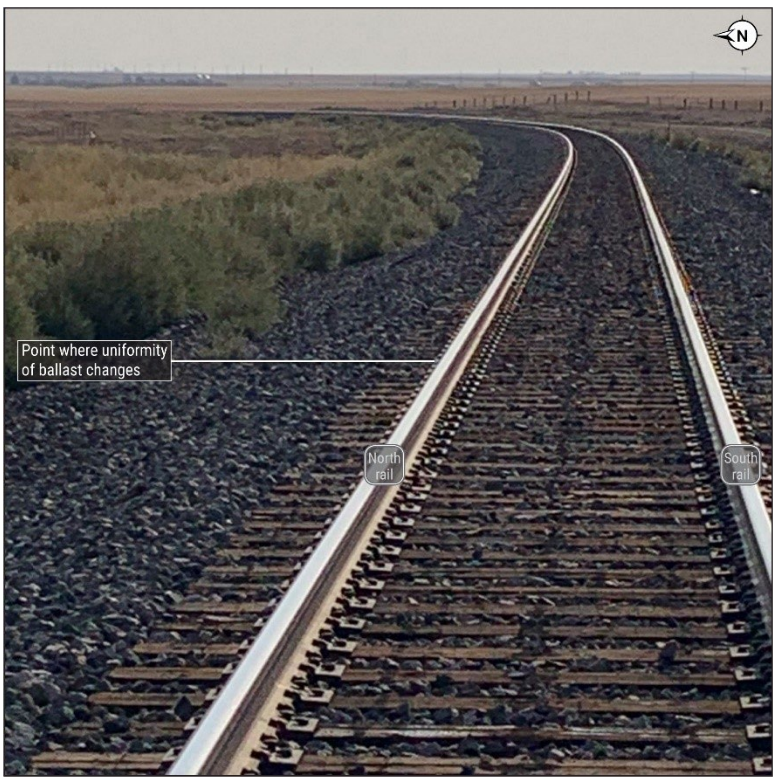

Figure 18. Photograph of the derailment curve.

While on scene on September 15, 2022, the NTSB observed a white survey marker driven in the roadbed, on top of the fill, adjacent to the track. A representative for BNSF stated that the marker denoted the location of a core drill sample that BNSF had conducted to gather information on the track subgrade in the area. This core drill sampling and analysis had been performed during the ongoing investigation without notifying the NTSB. The NTSB subsequently requested the core samples and any analysis or assessments completed regarding them. On October 5, 2022, BNSF provided the NTSB with a document with a stated purpose to assess whether subgrade instability is a factor impacting track performance at four sites on the Hi-Line subdivision and if those sites were viable candidates for subgrade stabilization. The report recommended, in part, that "BNSF continue to monitor for embankment instability" (Shannon & Wilson 2022).

1.9.4 Recent BNSF Track Maintenance

1.9.4.1 Crossties

On August 26 and 27, 2021, less than 1 month before the derailment, a BNSF crosstie production gang installed about 700 standard crossties between MP 1014.00 and MP 1015.00, including the area of the derailment. The work also included tamping and adjustment of the rail anchors, but only for the newly installed crossties. On the morning of August 27, 2021, the gang foreman placed a 30-mph slow order speed limit on the affected areas of the BNSF track, since the track surfacing work was not complete.[34]

1.9.4.2 Track Surfacing

Track surfacing is the process of tamping and stabilizing the track structure to remove track surface irregularities. It also assists in maintaining the track to proper geometry requirements for the designated class of track.

After completion of the track surfacing work on the evening of September 2, 2021, in accordance with BNSF rules, the surfacing foreman issued a 30-mph slow order over the affected area of BNSF track to compact or settle into the ballast.[35] The next day, the speed was increased to 45 mph. On September 14, 2021, the slow order was removed.

[34] *Slow orders* are speed restrictions placed on trains traveling over a certain area.

[35] BNSF's Maintenance-of-Way department, of which surfacing is a component, is responsible for issuing speed restrictions for any condition that might prevent trains from operating safely at the MAS.

1.9.5 Track Inspections

1.9.5.1 BNSF Track Inspections

Class 4 track is required by 49 *CFR* 213.233 to be inspected twice weekly with a 1-day interval between track inspections, either on foot or by traversing the track in a vehicle at a speed that allows the person making the inspection to visually inspect the track structure for compliance. FRA regulations do not specify speeds at which these inspections should occur.

The procedures outlined in the BNSF CWR document provides a list of conditions for inspectors to watch for and appropriate remediation actions. In particular, for rail joints, after the inspection is complete, the inspector initials and dates the web of the rail at the joint and then documents the inspection in BNSF's electronic track records system.

BNSF's track inspection policy states that track inspection is used to detect, correct, and protect variations from BNSF track standards and to ensure safe train operations at authorized speeds and to assist in prioritizing track maintenance (BNSF 2019).

BNSF inspects and maintains tracks, switches, sidings, and yards in accordance with its engineering instructions and FRA Track Safety Standards. BNSF inspections may be performed on foot, by hi-rail, or by riding in a train or geometry car.[36] Automated track geometry measurement systems provide information for a railroad's inspectors about track conditions, which must then be verified by an inspector, thus augmenting the overall track inspection program. Visual inspections by foot or hi-rail cannot reveal all track defects internal to the rails or stemming from precise measurement deviations. All methods of track inspection are necessary and provide actionable information to inspectors in different circumstances—one mode of inspection should not be considered superior to another mode for all track inspection needs. For example, automated track inspections by geometry cars or railcar-attached devices provide detailed information on specific track parameters, but they do not capture the diverse array of unique track hazards detectable to human inspectors. They are intended to supplement an inspection program and should not be used to supplant an inspector physically examining a track.

BNSF provided the NTSB with geometry car inspection data for the five most recent geometry car inspections of the derailment area before the accident date: July 17, 2021; July 24, 2021; August 19, 2021; August 25, 2021; and September 1,

[36] *Geometry cars* measure track to determine compliance with maintenance standards and provide data to inform planning of routine maintenance.

2021. The September inspection data were collected after BNSF installed crossties between MP 1014.4 and MP 1014.60 on August 25, 2021, but before BNSF surfaced the curve on September 2, 2021. No geometry car inspections were performed in the derailment area between September 1, 2021, and the derailment. The NTSB's review of all track geometry car inspection data showed no BNSF or FRA defects.

BNSF track inspection records show that the last inspection of the curve before the derailment took place from a hi-rail vehicle at MP 1014.57 on September 23, 2021, 2 days before the derailment. There were no defective track conditions noted in the record.

The FRA requires in 49 *CFR* 213.119 (h)(6)(i) that rail joints in CWR territory be inspected by walking the area when the track is Class 2 with passenger trains or Class 3 and above for all types of trains. For this area of BNSF track, that meant that the walking inspections were required to be made quarterly. The four-bolt rail joints were installed and inspected July 23, 2021, and were not due to be inspected until October 2021.

1.9.5.2 FRA Track Inspections

FRA's Office of Railroad Safety promotes and regulates safety throughout the nation's railroad industry. The office executes its regulatory and inspection responsibilities through a diverse staff of railroad safety experts. The staff includes nearly 400 federal safety inspectors who specialize in one of six technical disciplines focusing on compliance and enforcement. An FRA track inspector serves in an external oversight role to assure that the railroad track network within the assigned geographical territory complies with federal regulations by conducting periodic compliance inspections on the railroad that owns the track. Track inspectors' activities are prioritized using the FRA's Focused Inspection Program, which along with its Asset Inventory of Railroads and Shippers database, was implemented to replace its National Inspection Program and Regional Inspection Points.

FRA track inspectors filed seven reports with BNSF on the subdivision in 2021, up to the day of the derailment. However, none of these inspections included the area of the derailment.

In 2020, FRA railroad safety inspectors filed 13 activity reports with BNSF for inspections on its Hi-Line subdivision. A review of those reports showed that in a 3-day period from February 18 through February 20, 2020, the FRA inspector filed eight reports covering portions of the Hi-Line subdivision. The derailment area was only inspected twice in 2020. These inspections were conducted from the lead locomotive of an Amtrak passenger train.[37]

Following the derailment, the NTSB reviewed FRA track inspection records for the Hi-Line subdivision for the years 2019, 2020, and 2021. On August 22, 2019, an FRA railroad safety inspector performed a walking inspection on the Hi-Line subdivision between MP 1006.9 and MP 1022.0, which included the derailment area. This is the last recorded walking inspection of the derailment area by the FRA before the derailment occurred 25 months later. In these inspection reports, the FRA inspector noted 36 defective conditions, none of which were in the derailment curve. Two were locations where BNSF failed to comply with written CWR procedures. Further, a defective condition of a spike and tie plate under the rail base was identified at MP 1014.8; this was the defect nearest the POD at MP 1014.57.

The FRA conducted two track inspections using an unmanned track geometry car on August 25, 2021, and September 1, 2021. The inspections identified no track defects that required any follow-up action.

1.9.5.3 Track Inspections and System Safety

The NTSB's review of the BNSF Hi-Line subdivision track inspector's work history showed he worked about 224 hours over 17 days from September 1 through September 25, 2021. This averaged a little over 13 hours per work day. BNSF records indicate that in the week before the derailment, the track inspector was off duty for the first 3 days of the week, but then worked more than 57 hours over the next 4 days.

In his interview with the NTSB, the track inspector indicated that the track inspector positions were "awarded" based on seniority through a bidding process. However, there were open positions that had not been filled, as no one had bid on them, thus leaving vacancies.

The track inspector provided the following description of his method of inspecting the track for which he was responsible over the summer:

> I would look at the—it took some trial and error too because—well, for most of the summer the Great Falls was a four-times-a-week inspection. And so, that was a 4-to-5-hour part of your day that you knew was going to be obligated to that branch line. So, you would have to—I'd do a part of the Hi-Line and then the Great Falls sub, and then I'd do the other part of—half of the Hi-Line and the Great Falls sub. And then I'd do the Sweet Grass and the Great Falls sub, and then I would try to do the

[37] FRA requires track inspectors to periodically inspect track from lead locomotives to examine train ride quality. This is known as a head-end inspection.

> entire Hi-Line in 1 day and then the Sweet Grass and Great Falls on the last day. And that was how I found best to break it up through trial and error.

The NTSB asked the track inspector if working long hours impacted his ability to adequately inspect track. He said, "I wouldn't place my hours at work as an excuse to not protect the railroad and protect our commodities and the people on it." He indicated that he continued to report defects, repair defects, and implement protective measures as needed.

The track inspector said that he had been inspecting the derailment curve since May 2021. He said the derailment curve "historically, rides a little over elevated." He said that he had noticed a rougher ride through the derailment curve after the rail joints had been installed in July 2021. He said that the joints "get beat up pretty bad because they're in the low side of the curve as trains go over it." He indicated that it would be "good" to have them "welded up…sooner than later." He said that he did "point out the joints" to a roadmaster who was riding with him during his September 23, 2021, inspection, but they "didn't stop and look at the joints." He said that he had problems with "other plug rails in that low rail where they either have a mismatch…in the rail or…they just ride it rough because they're on the low side of that curve." He said that the "low rail is pretty thin and then the high rail has got a pretty good gauge face wear to it."

1.9.6 Slow Orders

BNSF's slow order policy requires that temporary slow orders be used on track where certain maintenance activities, like surfacing, disturb the track's supporting ballast structure (BNSF 2020). These temporary slow orders allow the continued movement of trains and other equipment over the BNSF track at lower operating speeds. The train traffic compacts and aids in the settlement of the track's supporting ballast structure. BNSF policy instructs employees to check the restrictions daily, if necessary, to ensure that they are the proper speed.[38]

BNSF's speed restriction policy also has other requirements:

> Qualified personnel must inspect locations covered by temporary speed restrictions and remove the restrictions as soon as possible. Periodically check the superelevation of curves within slow order limits to detect any

[38] Restrictions are checked by having the employee inspect the area of track under the slow order and checking for compliance with FRA Track Safety Standards.

increases in superelevation.[39] The weight of trains moving slowly through curves can cause increased superelevation, which can cause wheel climb, especially if track alignment or cross level is irregular. Check restrictions daily, if necessary, to ensure that they are at the proper speed.

BNSF's Hi-Line subdivision track inspector told the NTSB in a postderailment interview that he had not walked the curve (referring to the derailment curve) since the fall of 2020.

As shown in table 7, in the 2 months before the accident, BNSF placed temporary slow orders seven times in the area around the POD.

Table 7. Slow orders at the POD in the 2 months before the derailment.

Dates	Location	Restriction	Reason
July 22-23, 2021	MP 1014.4 – MP 1014.60	50 mph	Rail replacement (bolted)
August 26, 2021–September 2, 2021	MP 1014.00 – MP 1015.20	30 mph	Crosstie replacement
September 2-3, 2021	MP 1014.00 – MP 1015.20	30 mph	Track surfacing
September 3-4, 2021	MP 1014.00 – MP 1015.20	45 mph	Track surfacing
September 3-9, 2021	MP 1012.10 – MP 1014.30	30 mph	Crosstie replacement
September 9, 2021	MP 1013.3 – MP 1014.3	15 mph	Disturbed track
September 10-14, 2021	MP 1013.3 – MP 1014.3	45 mph	Crosstie replacement

1.10 Autonomous Track Monitoring Systems

Autonomous track monitoring systems, such as a vehicle/track interaction (V/TI) onboard component monitoring system, are designed to detect issues with superelevation, as well as measure ride quality, wheel/rail impacts such as battered and broken joints, and short-chord track surface conditions, such as track geometry conditions. These systems are intended for the early detection of deteriorating track conditions and to monitor the overall health of the track and track structure using trains in revenue service. They have the ability to give railroads real-time notification when track conditions exceed a predefined set of alert criteria.

Autonomous monitoring systems can be installed on both passenger and freight rail vehicles (Pedrag, Jovanovic, and Dick 2018). Amtrak introduced the first systematic use of an autonomous monitoring technology in the United States when it installed autonomous ride-monitoring systems on the Acela trainsets on the

[39] *Superelevation* of railroad track refers to the elevated relationship between the outer and inner rails of a curve.

Northeast Corridor in 2000 in response to FRA-introduced regulatory requirements.[40] This monitoring system was based on technology developed by a partnership between an equipment manufacturer and the FRA and allowed remote, autonomous monitoring of the Acela trainset performance through the measurement of truck and carbody accelerations.

As of October 2022, autonomous monitoring systems, such as V/TI, are used on all Class I railroads. Of these, 47 are on locomotives operated by BNSF and 39 are on Amtrak rail equipment.

1.11 Postderailment Actions

Following the derailment, BNSF made repairs to put the track back into service. In addition to the crosstie and surfacing work performed before the derailment, BNSF replaced both the north and south rails with 141-pound CWR, thereby eliminating all joints in the accident curve. BNSF then resurfaced the area for proper track conditions.

Amtrak also took action in several areas to address issues that arose from this derailment, some of which were discussed in its November 13, 2021, debrief with emergency responders. Amtrak addressed occupant protection to include the mitigation of potential entrapment within the railcars. In addition, Amtrak included enhanced briefings to provide passenger awareness of the availability of safety information. Amtrak also worked to provide better maintenance oversight on safety systems, such as emergency lighting and the public address system. Amtrak also addressed passenger accountability, which includes the ability to provide accurate information to emergency responders regarding the number of occupants aboard the train and providing additional training to OBS. Also, Amtrak took measures such as training to improve communication between the crewmembers, the crew and passengers, and the crew and emergency responders in emergency situations. Furthermore, Amtrak initiated revisions to its emergency training for its employees and provided additional resources and training to emergency responders.

[40] Title 49 *CFR* 213.345.

2 Analysis

2.1 Introduction

On September 25, 2021, Amtrak Train 7, also known as the *Empire Builder*, a passenger train carrying 165 passengers and crewmembers, traveling on track owned and maintained by BNSF, derailed at MP 1014.574 near Joplin, Montana. Six people were ejected, three of whom were killed. Forty-nine people were injured. The train consisted of 2 locomotives and 10 railcars. The locomotives and first two railcars remained on the track. Of the eight railcars that derailed, four derailed on their sides, one derailed leaning, and three derailed upright. Forty-seven side passenger window systems in the four railcars on their sides failed.

This analysis discusses the derailment and the following safety issues:

- The combination of track conditions that, when combined, caused the train to derail. (See section 2.2.)
- The treatment of maintenance rails installed with four-bolt rail joints in CWR. (See section 2.4.)
- The limitations of track inspection practices. (See section 2.5.)
- The retention of passenger windows in railcar overturn events. (See section 2.7.1.)
- The adequacy of compartmentalization in railcar overturn events. (See section 2.7.2.)

Having completed a comprehensive review of the circumstances that led to the derailment, the investigation established that the following factors did not contribute to its cause:

- *BNSF's signal and train control systems.* The NTSB reviewed BNSF's PTC system and traffic control signal system and found that both were functioning as designed and did not cause or contribute to the derailment. Additionally, the NTSB found that BNSF's dispatching activities were appropriate in the use of the traffic control signal system.
- *Performance, training, or experience of the Amtrak engineers.* The NTSB reviewed the forward-facing image recordings from Amtrak Train 7 and found that there was insufficient time for the operating engineer to detect and respond to the track defect. Both engineers were fully qualified and familiar with the route.
- *Mechanical condition of the Amtrak locomotives and railcars.* The NTSB examined the train and found that it was in the expected condition for its

age and time since overhaul. Mechanically, the vehicles were compliant with all applicable standards and regulations and were fit for service at the intended speeds on the intended route.

Therefore, the NTSB concludes that none of these contributed to the derailment of Amtrak Train 7: BNSF's signal and train control systems; the performance, training, or experience of the Amtrak engineers; or the mechanical condition of the Amtrak vehicles.

2.2 Track Conditions

The NTSB observed three track conditions in the area of the POD that were of concern: worn rail, vertical track deflection at a four-bolt rail joint, and track misalignment. While none of the three conditions individually could be confirmed to be a condemnable defective condition because the measurements were conducted postderailment, their presence in combination led to the conditions that caused the derailment.

Each condition is discussed below, followed by a discussion of the combination.

2.2.1 Worn Rail

Worn rails are more susceptible to defects that lead to rail failures. In addition, as rail is worn, the overall strength of the rail is reduced, and the dimensions of the rail have changed. In this accident, the north rail at the accident area had vertical rail wear of 1/2 inch at the east four-bolt rail joint. The two four-bolt rail joints (east and west) had notable chipping (small breakouts) of the rail at the adjoining rail ends. Furthermore, both four-bolt rail joint bars had longitudinal grooving that extended across the top surfaces of the joint bars, which is consistent with wheel flange contact. As rail head wears, the clearance between the joint bar and a wheel's flange is reduced. If the wear is severe enough, then the wheel's flange will make contact with the joint bar, creating the unsafe condition.

Four-bolt joint bars in joined rail are not designed to support the loads imparted by wheel flanges as a train moves over top while fully loaded. In this accident, because of the wear on the rail, the NTSB observed evidence that the wheel flanges were riding on top of the joint bar. This type of contact creates nonuniform forces that result in unequal load distributions into the rail system. In addition, rail joints that are loose and not strongly attached to the crossties will cycle up and down as trains move over them, further disturbing track conditions. When a wheel flange departs the normal wheel–rail interface and rides up onto a joint bar in curved track, the forces the train experiences while negotiating the curve can be excessive and nonuniform, resulting in a wheel climb derailment (Wu and Wilson 2006). The NTSB concludes worn rail at the four-bolt rail joints allowed wheel flange contact; this created a condition that resulted in nonuniform and excessive forces on the train and unusual load distributions into the rail, contributing to the wheel climb derailment.

Wheel flange contact is not the only risk of worn rail to a railroad system. The NTSB has long recommended the FRA create standards related to rail wear. In July 1980, tank cars carrying hazardous materials derailed in Muldraugh, Kentucky. Two tanks carrying vinyl chloride were punctured and their contents burned. An examination of the track curve leading to the derailment disclosed excessive wear. As a result of that investigation, the NTSB recommended the FRA create regulations that designate the limit of acceptable rail wear (NTSB 1981). In November 1982, the recommendation, Safety Recommendation R-81-35, was classified Closed—Unacceptable Action because the FRA said that it believed proposed rules at the time adequately addressed the recommendation and that it did not intend to promulgate additional standards on rail wear.

In 1998, the FRA published *Estimation of Rail Wear Limits on Rail Strength Investigations,* a rail wear study conducted by Volpe under FRA sponsorship (FRA 1998). In its report, Volpe said that for safe operation on railroad tracks, allowable rail-wear limits should be established on the basis of fracture strength. Since the overall strength of the rail is proportional to the amount of material present, the less material present, the lower the overall strength. Volpe further stated that for most rail sections, the allowable rail wear limit was estimated to be 1/2 inch. To date, the FRA has not taken any action to implement regulatory requirements for rail wear. Had the FRA established regulations for rail wear limits in response to previously issued NTSB recommendations or the FRA-sponsored Volpe study, the rail wear seen in this accident would have required replacement. Therefore, the NTSB concludes that had the FRA established rail wear limit regulations, that likely would have required replacement of the worn rail before there was wheel flange contact with the four-bolt joint bar. Therefore, the NTSB recommends that the FRA require a limit for maximum acceptable rail wear.

2.2.2 Vertical Track Deflection

Vertical track deflection, the up and down movement of the track when the train's weight is applied to the track, is present in small amounts in all track designs. In curved track, undesirable vertical track deflection can create disproportional forces, nonuniform loading conditions imparted into the rail, and undesirable train performance.

Forward-facing image recordings of Amtrak Train 7 moving through the curve showed that the train exhibited sudden, abnormal movements such as rolling, yawing, and swaying consistent with poor track conditions. The NTSB's investigation found that the east joint on the north rail had a vertical track deflection of 2 inches and the west joint had a vertical deflection of 1 1/8 inch. This type of track condition would contribute to the sudden, abnormal movements that were observed in the forward-facing image recordings. As Amtrak Train 7 traveled over the vertically deflecting four-bolt rail joint bars, the load distributions would have changed, imparting undesirable loading conditions into the track. Both four-bolt rail joints exhibited notable deterioration at their rail ends. As a result of these conditions, Amtrak Train 7 rocked and swayed, ultimately unloading the wheels on the south rail in a wheel climb derailment. The NTSB concludes that the vertical track deflection at the east and west four-bolt rail joints contributed to wheel unloading and the wheel climb derailment.

2.2.3 Track Misalignment

Data captured from the forward-facing image recordings of the three earlier trains, beginning 3 hours and 19 minutes before Amtrak Train 7, showed right and left rolling, yawing, and swaying of the trains as they traversed the track. Further, data from these trains showed a progressively worsening track misalignment in the derailment curve with the north and south rails shifting further to the left as each train traversed the track.

The NTSB reviewed the forward-facing image recordings from Amtrak Train 7 to observe how the misalignment had progressed. By using the still images from the recordings, the NTSB estimated that as the train traversed the derailment area, the track had laterally shifted in the curve between 2 and 4 inches.

Forward-facing image recordings show abnormal train performance as Amtrak Train 7 traveled through the misalignment, after having just traveled over vertically deflecting four-bolt rail joints while its wheel flanges rode atop a joint bar. These recordings show the locomotive shifted violently to the left and then to the right, then back to the left, and the train derailed as this motion progressed back through the train. Therefore, the NTSB concludes that Amtrak Train 7 derailed immediately after traveling through a track misalignment in the accident curve.

2.2.4 Subgrade Instability

On September 15, 2022, NTSB investigators and representatives from BNSF's engineering department returned to Joplin for additional evaluation of the accident curve, including a walking inspection. The NTSB noted that since the derailment, BNSF had conducted extensive track renewal in the curve, in addition to the crosstie and surfacing work that had been done before the derailment.[41] BNSF replaced both the north and south rails with 141-pound CWR, which eliminated all rail joints in the curve, and reinforced some of the crossties. BNSF then surfaced the track after this work to obtain proper track geometry.

As discussed in section 1.9.3.4, the NTSB noted a segment of track that exhibited vertical movement and subgrade instability near the earthen fill that contained the culvert that encompassed the POD and extended about 78 feet west and about 200 feet east. This area had been identified because of the disturbed ballast between the crossties that had showed signs of movement. Track always demonstrates some degree of vertical movement. However, during the September 15, 2022, walking inspection, the NTSB noted that while a freight train was traversing the fill, the track was moving more significantly in a vertical direction under the loads put on the track by the train wheels than on the other areas of the track. The NTSB concludes that there was an ongoing unresolved subgrade instability issue on the derailment curve.

Stable subgrade is critical in maintaining proper track geometry which allows the safe operation of trains. This is even more important in CWR territory, as unstable track is more prone to track buckling or mechanical misalignment.

During the 2022 inspection, the NTSB also noted evidence of a core drill sampling and analysis that was performed without its notification during the ongoing investigation and requested the core samples and any associated analysis or assessments. On October 5, 2022, BNSF provided a document titled *Hi Line Embankment Stability Assessment Geotechnical Evaluation*, dated September 22, 2022 (Shannon & Wilson 2022). The geotechnical evaluation conducted on the derailment curve was inconclusive and did not determine the cause of the subgrade instability that was witnessed on September 15, 2022. The NTSB concludes that additional geotechnical study of the derailment curve is necessary to ascertain the cause of the subgrade instability and to prevent future derailments at the same location. Therefore, the NTSB recommends that BNSF conduct additional comprehensive geotechnical evaluations throughout the derailment curve fill area to determine the cause of the subgrade instability. Furthermore, the NTSB recommends that once the geotechnical evaluation has been successfully completed and the cause of the subgrade instability has been determined, BNSF make appropriate repairs to stabilize the track and prevent excessive movement of the track structure.

[41] *Track renewal* is the replacement of a particular track component, such as crossties, over a segment of track.

2.2.5 Combination of Track Conditions

The NTSB has a long history of investigating accidents involving a combination of track conditions that are acceptable under current FRA Track Safety Standards. The FRA regulations found in 49 *CFR* 213.1 "Scope of Part" calls on railroads to address a combination of track conditions, none of which individually amount to a deviation from the requirements, to remediate the condition and provide for safe operations. This regulation was part of FRA's Notice of Proposed Rulemaking in June 1971 for Track Safety Standards (*Federal Register,* 1971, 11974). In that same year, the NTSB commented to the FRA that the Scope of Part was nonspecific and essentially unenforceable.

In June 1978, the Conferees of the House and Senate Appropriations Committees directed the NTSB to conduct a thorough review of hazardous materials rail shipments and the applicable track standards as well as determine how the FRA could more effectively prevent the occurrence and reduce the severity of derailments of hazardous materials. As a result of that review, the NTSB issued Safety Recommendation R-79-19, which called for requirements to be more explicit to ensure the detection and correction of all combinations of track conditions that cause derailments (NTSB 1979).[42] In its investigation of the July 1980 train derailment involving the Illinois Central Railroad Company in Muldraugh, Kentucky, the NTSB determined the probable cause was tipping (rolling) of the outside rail and widening of track gauge in the curve because of the combined effects of defective crossties, excessively worn rail, irregular alignment and gauge, and the lateral forces produced by the train's speed. Many of the track irregularities found at the time of this derailment were acceptable deviations under the established federal standards. As a result of this investigation, the NTSB reiterated Safety Recommendation R-79-19 (NTSB 1981). In March 1982, the FRA responded that it planned no further amendments to the Track Safety Standards. Therefore, on November 10, 1982, Safety Recommendation R-79-19 was classified Closed—Unacceptable Action.

In its investigation of a July 2013 derailment that occurred on the Metro-North Railroad in Bronx, New York, the NTSB determined that the probable cause was excessive track gauge due to a combination of fouled ballast, deteriorated concrete crossties, and profile deviations resulting from Metro-North Railroad's decision to defer scheduled track maintenance (NTSB 2014). The NTSB found that without defined parameters for determining a defective condition, measurement analysis is based on experience and opinion, and compliance is inconsistent throughout the

[42] Safety Recommendation R-79-19 was issued March 1979 in NTSB's report on *Safety Effectiveness Evaluation of the FRA's Hazardous Materials and Track Safety Programs* SEE-79/02 (NTSB 1979).

industry.[43] As a result, combinations of track conditions that could present risk to safe operations are more likely to be missed.

As a result of the Bronx investigation, in Safety Recommendation R-14-75, the NTSB recommended the FRA define specific allowable limits for combinations of track conditions, none of which individually amounts to a deviation from FRA regulations that require remedial action, but which, when combined, require remedial action.[44] The FRA's only response to this recommendation was in April 2015 when it said that as part of a rulemaking to revise its Track Safety Standards, FRA had already reviewed various track conditions to determine which combinations of track conditions were unsafe and require remedial action to ensure safe operations. Following this review, in 2013 the FRA published a final rule in 49 *CFR* Part 213 on V/TI Safety Standards that established new requirements to address unsafe combinations of track alignment and surface conditions (*Federal Register*, 2013, 16052). In developing its V/TI rule, FRA sought to include revisions that would "serve as practical standards with sound physical and mathematical bases," and arrived at its proposals "through the results of computer simulations of vehicle/track dynamics, consideration of international practices, and thorough reviews of qualification and revenue service test data." On January 8, 2016, the NTSB replied that we were disappointed to find that the same changes had not also been incorporated into Subparts A through F. Pending incorporation of the revisions into Subparts A through F, Safety Recommendation R 14-75 was classified Open—Acceptable Response. The FRA has not provided any updates in the 8 years since its only response.

The derailment of Amtrak Train 7 is another example of combined track conditions, none of which individually amount to a deviation from the FRA Track Safety Standards. The track conditions in this accident—rail wear, vertical track deflection at a four-bolt rail joint, track misalignment with the added condition of wheel flange contact on a joint bar—all combined to result in the derailment of Amtrak Train 7. As of the publication date of this report, the FRA has no regulation that defines specific allowable limits for combinations of track conditions, which would require remedial action. The NTSB concludes that had the FRA defined specific allowable limits for combinations of track conditions, the conditions on the BNSF track in Joplin would likely have been identified and warranted remediation before the derailment occurred. Therefore, the NTSB reiterates Safety Recommendations R-14-75 and -76. Because the FRA has not taken any action to address Safety Recommendations R-14-75 and -76 in the past 8 years, they are classified Open—Unacceptable Response.

[43] Letter from the NTSB to the FRA, December 30, 2014.

[44] Letter from the NTSB to the FRA, December 30, 2014.

2.3 Autonomous Track Monitoring Systems

In this derailment, a combination of track conditions rapidly worsened under multiple trains, culminating in the derailment of Amtrak Train 7. These track conditions, especially in combination as discussed in section 2.2, can lead to wheel unloading and the subsequent derailment of a train.

Class 4 track is required by 49 *CFR* 213.233 to be visually inspected twice weekly with a 1-day interval between track inspections. The infrequency of these inspections did not provide the monitoring needed for the early detection of the conditions before the derailment.

The track in the derailment area was ballasted track supported by an earthen fill. As trains traverse tracks, dynamic loads from the rail equipment and cargo are transferred from the wheels onto the rails and then imparted onto the other track components.[45] The track structure functions as a system, and the dynamic loads are dispersed from the rails to the crossties, from the crossties to the ballast, and from the ballast to the subgrade. The rail surface condition, vertical track deflection, and wheel flange contact noted in the derailment area leading up to the derailment would have increased this dynamic loading, thus increasing the rate of track deterioration.

Table 6 in section 1.9.3.2 shows that while the vertical track deflection was present when Amtrak 8 passed the location at 12:37 p.m., the lateral deviation was less than 1 inch until 1:42 p.m., when BNSF 7380-QPTLCHC3-23A passed that location. This suggests that the lateral rail deviation developed on the day of the derailment. However, according to FRA regulations found in 49 *CFR* 213.233, Class 4 track, such as that on the Hi-Line subdivision, are required to be inspected twice weekly with a 1-day interval between track inspections. The NTSB concludes that given the rapid degradation of track conditions on the day of the derailment, it is unlikely that the track surface deviations at the track would have been detected through the current periodic track inspection process required under FRA regulations.

Although it is unlikely that the track deviations would have been detected through the current track inspection process, autonomous monitoring systems that are in limited use on passenger and freight rail vehicles have the ability to monitor track conditions and provide real-time condition monitoring that could be used for early identification and mitigation of unsafe track conditions. Both BNSF and Amtrak already have such systems in limited use. These autonomous monitoring systems provide a technology-based approach to enhance the inspector's ability to identify

[45] *Dynamic loads* are the changing forces on the track when trains traverse.

track defects that are difficult or improbable to find through direct visual inspection and are not intended to replace or supplant the inspector.

The last BNSF V/TI-equipped locomotive went through the Joplin derailment area on September 20, 2021, 5 days before the derailment. The V/TI system did not identify any problematic track conditions because they were not at a detectable level. However, had the multiple trains traversing the track on the day of the derailment been equipped with V/TI technology, there would have been a greater likelihood that the deteriorating track conditions could have been identified in real time and that an alert notifying BNSF of the issues could have been sent before the derailment, affording BNSF the opportunity to address the rapidly deteriorating track conditions. Therefore, the NTSB concludes that had trains with a V/TI-equipped locomotive traversed the accident curve on the day of the derailment, the deteriorating track conditions could have been identified and real-time notification provided to BNSF, affording the opportunity for BNSF to take action to mitigate the danger of the misaligned track. The NTSB recommends that the FRA establish interoperability requirements among railroads to implement a process in which a predetermined critical alert from a V/TI system would require an immediate slow order that remains in place until a walking inspection is performed and, if needed, subsequent repairs are completed.

According to the FRA Office of Safety Analysis safety accident database, over one-third of track geometry-caused accidents in the past decade were related to a track alignment irregularity, which are among the same conditions seen in the Joplin derailment.[46] Further, the database shows that every month, about two reportable train derailments occur due to track geometry issues such as the misalignment present in the Joplin derailment. In calendar year 2021 alone, there were 97 total track-caused reportable derailments on main tracks in the United States. A comprehensive review of accident data revealed that track geometry accounted for 35 of the 97 derailments and was the second-leading cause of track-caused derailments in the country. Forty-eight percent of the track geometry–caused accidents were related to a track misalignment. Most of the time, the trains involved in these derailments are freight trains, carrying a variety of commodities throughout the country. However, on the rare occasions when the derailments involve passenger trains, the results can be catastrophic.

The concern is further compounded if trains are carrying hazardous materials, as was the case in 2015 when the NTSB investigated the derailment of a BNSF train carrying ethanol in Lesterville, South Dakota (NTSB 2017). During that investigation, the NTSB found that conditions similar to those present in the Joplin derailment,

[46] The safety accident database is a website from the FRA that allows railroad safety data to be accessed by the public.

excessive vertical rail wear and issues with the track alignment, caused the derailment.

The NTSB concludes that the expanded use of V/TI monitoring systems across Class I and intercity railroads to detect track geometry conditions earlier could reduce the likelihood of train derailments. Therefore, the NTSB recommends that all Class I and intercity railroads with trains operating on main tracks equip all trains with an autonomous monitoring system, such as V/TI, to detect track geometry defects.

2.4 CWR Replacement Rails

During the NTSB's postderailment inspection of the track, the NTSB noted a replacement rail that was 19 feet 6 inches long with two four-bolted rail joints installed for maintenance purposes on CWR track 100 feet east of the POD. BNSF records indicate that this maintenance rail was installed 64 days before the derailment. The FRA's existing regulations, found in 49 *CFR* 213.119 (c)(2), require that every four-bolt rail joint installed during CWR installation be either welded, installed with six bolts, or have every crosstie within 195 feet in each direction anchored within 60 days of installation. However, because the CWR near the POD was considered maintenance rail, the FRA regulations requiring action within 60 days did not apply to these rail joints.

The NTSB believes the risk of four-bolt CWR joints to track structure is the same, whether for installation or maintenance, and all four-bolt CWR joints should receive the same safety considerations. In this derailment, the maintenance rail joints contributed to the vertical and lateral movement of the track structure. Further, a 2013 FRA safety advisory noted that track components at maintenance rail joints contribute to track movement in the vertical, lateral, and longitudinal planes (*Federal Register*, 2013a, 47486). The NTSB concludes that the CWR installation requirements of 49 *CFR* 213.119 (c)(2) should apply to all CWR joints. Therefore, the NTSB recommends that the FRA require that the CWR installation requirements of 49 *CFR* 213.119 (c)(2) be applied to all CWR joints, including those added to install maintenance rail.

2.5 Track Inspections and System Safety

During the 30 days leading up to the accident, the track inspector was responsible for inspecting between 32.9 and 132.5 miles of track, averaging about 73 miles per day. On September 23—his last inspection of the derailment curve before the derailment—he was responsible for inspecting 126.8 miles of track, which matched the most miles to be inspected during that 30-day period.

The track inspector's work schedule was as follows: he was off duty September 17 through September 20. He then worked the following 3 days. Specifically, on September 21, he worked 16 hours; on September 22, he worked 12 hours 45 minutes, and on September 23, he worked 13 hours 30 minutes.

Railroads need to ensure that inspection territory assignments are sized to allow sufficient time for quality track inspections. Allowing one track inspector to be responsible for such an extensive amount of track results in reduced performance proficiency.

As outlined in 49 *CFR* Part 213, Subpart F, the FRA has inspection frequency requirements that vary by track type. Track carrying regularly scheduled passenger trains must be inspected twice weekly. Generally, these inspections can be made while traversing the track in a vehicle. The track inspector reported spending many hours per week inspecting track in a hi-rail vehicle to meet the requirements. He described how a typical work week over the summer was largely structured around how he would navigate his hi-rail vehicle to meet the inspection intervals. Records show that the track inspector had driven his hi-rail vehicle over the portion of track where the accident occurred twice in the week of the accident, meeting the federally mandated minimum inspection frequency requirement for that section of track.

The track inspector had not completed a walking inspection of the derailment curve since the fall of 2020. Walking inspections are critical to developing a deep understanding of the state of the track—beyond what can be achieved through hi-rail inspections or automated systems. Had the track inspector performed a recent walking inspection at the derailment curve, he likely would have identified the deterioration and pumping action at the two low rail bolted replacement rail joints. With this information, he might have advised BNSF that safety-critical repairs be implemented, which may have prevented the derailment.

Generally, track inspectors decide when to conduct walking inspections. Through training and experience, they know when it is necessary to pause a hi-rail inspection, get out of the vehicle, and inspect the track on foot. Automated systems are enhancements to the overall inspection program for guiding and focusing the visual inspection process. Over time, track inspectors become familiar with problematic areas of track, may complete minor repairs themselves, and advise their supervisors when major repair work is necessary.

The derailment curve was located on a portion of track that required greater scrutiny. The track inspector was aware of the replacement rail joints in the curve, had concerns about them, and believed it would have been beneficial to have them "welded up"—in other words, removed. On September 23, 2021, the track inspector conducted a hi-rail inspection with a roadmaster through the derailment curve. He indicated his concerns about the replacement rail joints in the curve to the roadmaster, but they did not exit the vehicle and conduct a walking inspection.

The most likely reason that the track inspector did not perform a walking inspection of the derailment curve in about a year is that he did not have time. In comparison to hi-rail inspections, walking inspections are time intensive and the track inspector was already pushing the limit of hours that could be physically worked in a week just to meet the FRA minimum inspection requirements for the hundreds of track miles he was responsible for inspecting. Thus, the NTSB concludes that the track inspector likely could not perform a required walking inspection of the derailment curve due to his assigned workload to inspect an excessive amount of track.

In the month before the accident, the track inspector routinely worked long hours, often more than 12 hours at a time. Generally, except for emergencies, a railroad carrier and its officers and agents may not require or allow train, signal, and dispatching service employees to remain on duty for more than 12 consecutive hours. However, track inspectors are not included in this regulation. Accordingly, the hours worked by the track inspector did not violate any federal safety regulations. Nonetheless, given his safety-critical role, his work schedule is concerning from a fatigue risk-management perspective because of the possibility of reduced performance proficiency. Safety would be improved by limiting the hours that can be worked by track inspectors. Moreover, a new FRA regulation on Fatigue Risk Management Programs (FRMP) should lead to railroads implementing fatigue risk-management policies that go above and beyond what is required by the hours-of-service (HOS) regulations.

BNSF had not mitigated the potential effects on performance associated with working an excessively demanding schedule for employees responsible for inspecting and maintaining railroad tracks. BNSF has stated that it "monitors the hours worked" by its team members very closely "to ensure that employees are receiving an adequate amount of time to rest and adjusts work assignments accordingly." The hours worked by the track inspector were excessive. It is concerning that BNSF asserts that his hours were being monitored "very closely" as this suggests that his hours were considered to be acceptable. An organization with a positive safety culture would not allow a safety-critical employee to routinely work more than 12 hours in a day. BNSF currently has no rules or policies that limit the hours that their track inspectors can work. Thus, the NTSB concludes that BNSF's lack of proactive management controls to prohibit work assignments likely to cause fatigue and workload risks for safety-related employees is an indication of a shortcoming in its safety culture.

The freight railroad industry, in large part, has not taken the necessary measures to mitigate the risk of errors that are due to working excessive hours. Because employees who are responsible for inspecting and maintaining track are not regulated by scientifically based HOS laws, the onus is on individual railroads to establish the allowable schedules for these employees. Few railroads, however, have formally restricted the number of hours or consecutive days they can work. For instance, in the NTSB's investigation into the Long Island Rail Road roadway worker fatality in Queens Village, New York, on June 10, 2017, the NTSB concluded that the watchman/lookout and the foreman, who had worked continuous on-duty shifts, were likely fatigued because their overtime shifts did not allow for adequate periods of restorative sleep during the 2 nights before the accident (NTSB 2020). As a result, the NTSB made the following safety recommendation to the FRA:

> Promulgate scientifically based hours of service requirements for roadway workers. (R-20-7)

In its August 17, 2022, response letter to the NTSB's recommendation, the FRA stated, "FRA does not have the legal authority to implement this safety recommendation because roadway workers are not defined as covered employees under the HOS laws."

The FRA further stated, "FRA is also concerned about the difficulty in establishing scientifically based hours of service regulations, as research may not conclusively establish that a particular number of hours is the exact appropriate limitation."

FRA discussed a recently published FRMP final rule (87 *FR* 35660 (June 13, 2022)) that would require railroads to identify and develop plans to mitigate fatigue risks in their operations. The rule would include fatigue risks affecting roadway workers, even though they are not subject to HOS limitations.

In NTSB's October 3, 2022, response to the FRA, the NTSB classified R-20-7 as "Open—Unacceptable Response" pending the FRA seeking authority and enacting HOS limitations for roadway workers or an alternative action that addresses the safety risks of fatigued roadway workers. Our letter further discussed that the FRA recently issued the FRMP final rule. The rule requires railroads to develop plans to mitigate fatigue risks in their operations, including fatigue risks affecting roadway workers. We noted that railroads are required to submit their FRMP plans to the FRA for approval by June 23, 2023. We stated that a requirement for FRMP plans to address HOS risks to roadway workers and obtain FRA approval may be the basis for an alternative response to R-20-7 without the need to revise the HOS law. We also asked the FRA to describe how approval of FRMP plans would consider the mitigation of risks that are due to HOS to roadway workers.

The FRA is requiring Class I railroads to submit an FRMP plan as a component of the railroad's Risk Reduction Program Plan. This new regulation should reduce the fatigue and fatigue-related consequences experienced by all safety-related employees. Railroads will be required to systematically identify and evaluate fatigue-related safety hazards, determine the degree of risk associated with each hazard, and manage those risks to reduce the fatigue that its safety-related railroad employees experience. Persons who inspect, install, repair, or maintain track are among those employees defined as safety related. Hence, track inspectors are defined as safety related in the regulation, and railroads must develop structured, proactive processes and procedures to manage fatigue in these employees; these processes and procedures will reduce the risk of railroad accidents, incidents, injuries, and fatalities.[47]

The NTSB supports FRA's requirement for railroads to implement an FRMP. The NTSB believes that an effective FRMP will identify areas where HOS requirements may not adequately mitigate the risk of fatigue and will prompt a railroad to develop and implement work schedules that mitigate these risks. The NTSB concludes that a comprehensive FRMP must fully recognize all the demands placed on employees to perform their jobs, including the tasks, responsibilities, duties, and hours worked, and must make necessary modifications to the job and/or scheduling to mitigate associated risks.

2.6 FRA Compliance Inspections

Unlike a railroad track inspector, an FRA track inspector provides a compliance inspection to ensure that the railroad complies with federal regulations. In a restructuring of its inspection program, the FRA has implemented the Asset Inventory of Railroads and Shippers database as well as the Focused Inspection Program tool, which helps FRA track inspectors prioritize their activities.

The FRA conducted an automated track inspection using a track geometry car twice within a month of the Joplin derailment. The track geometry car did not find any track exceptions and, thus, did not prompt FRA inspectors to visit the site. Had FRA inspectors conducted a walking inspection of the track in the area of the derailment, the conditions that led to the derailment might have been identified. Although automated track inspections using geometry cars or other railcar-attached devices can supplement an inspection program, they should not supplant an oversight program that includes on-the-ground inspections. The NTSB concludes that the FRA's restructured Focused Inspection Program would benefit from both automated and walking inspections to ensure an improved understanding of the condition of the track beyond what can be known by only automated inspections.

[47] The final rule requires that FRMP plans shall be filed within a year of the effective date of this rule, July 13, 2022. Therefore, the FRMP plans should be submitted by July 13, 2023.

2.7 Occupant Retention

2.7.1 Window Retention

A major principle in occupant protection is the retention of the occupant within the passenger compartment. Ejection of the occupant is an important factor in determining both the individual's ability to survive the event and the severity of injuries that an individual sustains. The higher the speed of the vehicle from which the occupant is ejected, the greater the potential for sustaining more serious injuries. Once ejected, the occupant is at further risk of injury from striking the ground at a high speed or being crushed by the rolling vehicle.

In this accident, six passengers were ejected from the train during the derailment, all from Railcar 7. Two passengers had just exited Railcar 7 and were walking through the vestibule area between Railcars 7 and 8 when the derailment occurred. They were ejected out of the vestibule space due to the overturning and uncoupling of Railcars 7 and 8. One of these passengers was found a significant distance away from the final resting position of Railcar 7, while the other apparently became entangled with a piece of equipment and traveled a significant distance before coming to rest underneath Railcar 7. The remaining four passengers were ejected from Railcar 7's side passenger windows. Only the three passengers who were ejected from Railcar 7 just before it came to a stop, who had the least exposure outside the railcar, survived.

The most significant loss of windows occurred in Railcar 7 because of the failure of the window retention system to hold the windows in place. All the missing windows were on the right side of the railcar and were subjected to loads from the derailment that resulted in their failure after the railcar overturned and the side of the railcar slid across the ground. In postderailment interviews with the NTSB, two passengers said that as Railcar 7 was sliding along, they found themselves standing on top of a windowpane. As the railcar came to a halt, the window gave way and the two passengers fell to the ground underneath the stopped railcar. The slowing of Railcar 7 as it was sliding along the ground limited the speed and distance traveled by the ejected passengers and their exposure to the ground. Another passenger was ejected from the railcar as it slowed to a stop. The failure of the window retention system permitted the windows to fall from the window frame and created an opening through which four passengers were ejected from Railcar 7.

In December 2013, the NTSB investigated the passenger train derailment that occurred in Bronx, New York (NTSB 2014). During the investigation, the NTSB found that the loss of window glazing, resulting in the ejection of four passengers, contributed to the severity of the injuries. The NTSB noted that window glazing systems are expected to perform safety-critical functions. In addition to providing essential occupant protection by keeping passengers within the railcar structure, which increases the likelihood of survival, the windows are designed to allow for rapid egress in an emergency and provide access by emergency responders.

As a result of the investigation, the NTSB made the following recommendation to the FRA:

> Develop a performance standard to ensure that windows (glazing, gaskets, and any retention hardware) are retained in the window opening structure during an accident and incorporate the standard into 49 *Code of Federal Regulations* (*CFR*) 238.221 and 49 *CFR* 238.421 to require that passenger railcars meet this standard. (R-14-74)

In March 2015, the FRA told the NTSB that it was developing a research program to test all aspects of window glazing systems, including glazing retention, passenger containment during potential accident scenarios, emergency egress, responder rescue access, and impact resistance. The FRA advised that it could not determine what regulatory changes were required until after the research was completed. At the time, the expected completion date for the research was October 2016.

The NTSB's investigation of the May 12, 2015, derailment of Amtrak passenger train 188 in Philadelphia, Pennsylvania, again identified window retention as a contributing factor to the severity of the accident.

In this accident, the NTSB found that several passengers were partially or fully ejected from a railcar during the derailment, leading to their deaths. The NTSB concluded that if the passenger railcar windows had remained intact and secured in the railcars, some passengers would not have been ejected and would likely have survived the accident. As a result, the NTSB reiterated Safety Recommendation R-14-74.

The study that the FRA described in March 2015 was conducted by Volpe. In June 2022, almost 6 years after the expected completion date, the FRA published the final report, *Integrity of Rail Passenger Equipment Glazing Systems* (FRA 2022).

In this report, Volpe acknowledged that additional testing would be needed to quantify the expected retention performance and to determine alternatives that could also accommodate two other safety concerns: emergency egress and responder accessibility. The report examined several potential solutions; however, each of them could adversely impact another factor in the survivability chain.

Volpe said that applying the results of the simulations in a quantifiable manner over the length of the project was impractical because of uncertainties in modeling the material properties associated with glass, elastomer, and plastic elements and because key modes of failure could not be modeled.

Ultimately, the report suggests the FRA collaborate with industry to draft a set of performance standards into specific specifications to consider which glazing system configuration should be used. However, FRA offered no timeline for when that collaboration would be completed or even begin.

The FRA has not communicated with the NTSB regarding Safety Recommendation R-14-74 since March 2015, and the FRA is currently reviewing the results of the Volpe research. Based on the FRA's publication of the final report, Safety Recommendation R-14-74 remains classified Open—Acceptable Response. The Volpe research shows the need for the recommended performance standards for window retention. However, in the months since the report was released, FRA has not moved forward with the required additional testing, nor has it provided a timeline for when such testing would occur. In addition, the Joplin derailment is now the third derailment that the NTSB investigated in the last 10 years in which a failure of window glazing led to passenger fatalities when they were ejected. The NTSB concludes that this derailment demonstrates that there is a need for performance standards for window retention systems to prevent passenger ejections from railcars during derailments. Therefore, the NTSB reiterates Safety Recommendation R-14-74.

2.7.2 Compartmentalization

One key strategy of occupant protection is compartmentalization, which is a strategy to limit the movement or travel distance of an occupant within a space to minimize injury and providing adequate padding of surfaces likely to be struck. In compartmentalization, the occupant would likely strike the seat back in front of them and remain close to their seating area (NTSB 2016). In the preamble to the final rule that promulgated the Passenger Equipment Safety Standards codified at 49 *CFR* Part 238, the FRA noted that compartmentalization could be relied on as a passenger protection strategy (*Federal Register,* 1999, 25540). Compartmentalization assumes that the seat back immediately in front of the occupant is high enough to restrict forward motion and that the railcars remained upright and in line after the accident (FRA 2002). Although compartmentalization counteracts front-to-back movements in an accident, it does not counter side-to-side movement. As a result, compartmentalization is ineffective in an overturn event.

The primary objectives of crashworthiness are to preserve space for occupants to ride out the accident and to limit, to survivable levels, the forces imparted to those occupants. Train seats are placed reasonably close and at a distance to reduce the occupant's amount of fore and aft travel within the railcar during an accident. By limiting how far occupants can travel within the interior and by providing strategic padding, the forces imparted to a train passenger could be survivable. By comparison to highway crashes, the deceleration experienced by a train occupant is generally far less than that experienced by passengers in automobiles.

A paper published by Volpe titled *Reducing the Harm in Rail Crashes: Analysis of Injury Mechanisms and Mitigation Strategies* examined crashworthiness and passenger injuries (Wilson and Tyrell, 2016). Volpe determined that compartmentalization and the application of an energy-absorbing material to the seatbacks in the railcars increased passenger safety. The paper found that many nonfatal injuries were caused by passengers striking the seatbacks with significant force or failing to remain upright in their seats. Maintaining the integrity of the railcar interior, to include the position of the train seats, provides significant occupant protection.

In the Joplin accident, longitudinal forces were generated as the train traveled in a straight line. The use of compartmentalization is more effective in this kind of derailment because the forces generated move fore and aft, and the occupant is more likely to remain confined in the small space between the occupant and the forward seatback. Limiting the distance an occupant can travel lessens the amount of force generated and dissipates the potential for injuries. The NTSB focused on issues such as the injuries related to the overturn event, passenger ejection, window retention, and occupant entrapment in its postderailment examination of Amtrak Train 7's railcars to determine the overall crashworthiness of the railcars and the effects on occupant protection and survivability.

The NTSB learned that most of the injuries occurred in the four railcars (Railcars 7 through 10) at the rear of the train consist that derailed and overturned in the accident. Many of the injured occupants were thrown laterally across the width of the railcar and came to rest on the opposite side of the railcar.

Injuries were particularly prevalent in Railcar 7, which was the lounge railcar. Of the 25 documented occupants in Railcar 7, 3 occupants died, 4 occupants sustained serious injuries, and 7 sustained minor injuries. Unlike those in passenger coach railcars, the seats in lounge railcars are canted with no restraining barrier or structure to limit the ability of the occupant to travel a longer distance during an accident. The compartmentalization strategies incorporated into the design of the lounge railcar did not prevent the occupants from being thrown or ejected, resulting in injuries during the derailment.

In November 2018, the FRA published a final rule titled, *Passenger Equipment Safety Standards; Standards for Alternative Compliance and High-Speed Trainsets* (*Federal Register*, 2018, 59182). These regulations incorporated seat standards outlined by the American Passenger Transportation Association that established the crashworthiness and occupant protection performance requirements for certain types of passenger rail equipment, but not the conventional equipment involved in this accident. The new standard requires seats in railcars to undergo dynamic testing to demonstrate the ability to provide the required occupant protection. The railcar seatbacks are designed to deform during an accident to dissipate the energy and protect occupants by limiting the amount of energy capable of causing injury. However, the seatbacks are only protective against front-to-back movements and are not helpful in preventing side-to-side movements. When Railcars 7 through 10 rolled over onto their sides, lateral forces threw passengers in a side-to-side direction, therefore, the passengers were not compartmentalized. The NTSB concludes that the use of compartmentalization did not protect the occupants in the overturned railcars from injury during the derailment and overturning of the railcars in the Joplin derailment.

In its investigation into the May 2015 derailment of Amtrak Train 188 in Philadelphia, Pennsylvania, the NTSB determined that the inadequate requirements for occupant protection in the event of a train overturning contributed to the severity of the injuries sustained in that derailment (NTSB 2016). Therefore, the NTSB made the following safety recommendations to the FRA:

> Conduct research to evaluate the causes of passenger injuries in passenger railcar derailments and overturns and evaluate potential methods for mitigating those injuries, such as installing seat belts in railcars and securing potential projectiles. (R-16-35)
>
> When the research specified in Safety Recommendation R-16-35 identifies safety improvements, use the findings to develop occupant protection standards for passenger railcars that will mitigate passenger injuries likely to occur during derailments and overturns. (R-16-36)

The NTSB reiterated and classified the FRA's response to these safety recommendations as Open—Unacceptable Response following the investigation into the December 18, 2017, derailment of Amtrak Train 501 in DuPont, Washington (NTSB 2019). The NTSB reiterated these recommendations again following the investigation into the head-on collision between an Amtrak passenger train and a stationary CSX Railroad freight train in Cayce, South Carolina (NTSB 2019a).

In a 2020 response to the NTSB, the FRA advised that it had previously conducted research into occupant protection standards and believed that the potential use of seat belts (as Safety Recommendation R-16-35 suggests) on trains were unlikely to be effective and may "do more harm than good." [48] In addition, the FRA said that the use of seat belts could possibly present a hazard to unbelted

[48] Letter from the FRA to the NTSB, January 23, 2020.

occupants because seat attachments to the railcar body would have to be strengthened to make seat belts effective. This would, in turn, create a more hostile impact on seats by unbelted passengers. FRA advised us that the mandatory dynamic seat testing and the use of compartmentalization provided adequate protection for passenger rail occupants. Furthermore, the FRA claimed that it believed no further action was required, stating that the deceleration rate of railcars was one-quarter of that experienced by highway vehicles and that the current occupant protection standards were sufficient.

Over the years, the NTSB has conducted many investigations involving passenger train derailments and overturn events. These types of accidents are more likely to result in the injury or death of train occupants due to the inadequate occupant protection provided by compartmentalization in accidents involving nonlongitudinal forces, such as those forces experienced in an overturn event, like what occurred in this derailment in Joplin, Montana. The NTSB concludes that the FRA's occupant protection standards do not provide adequate protection from passenger injuries likely to occur during derailments and overturns due to their reliance on compartmentalization as the basis for the standards. Therefore, the NTSB reiterates Safety Recommendations R-16-35 and -36 to the FRA.

3 Conclusions

3.1 Findings

1. None of these contributed to the derailment of Amtrak Train 7: BNSF Railway's signal and train control systems; the performance, training, or experience of the Amtrak engineers; or the mechanical condition of the Amtrak vehicles.

2. Worn rail at the four-bolt rail joints allowed wheel flange contact; this created a condition that resulted in nonuniform and excessive forces on the train and unusual load distributions into the rail, contributing to the wheel climb derailment.

3. Had the Federal Railroad Administration established rail wear limit regulations, that likely would have required replacement of the worn rail before there was wheel flange contact with the four-bolt joint bar.

4. The vertical track deflection at the east and west four-bolt rail joints contributed to wheel unloading and the wheel climb derailment.

5. Amtrak Train 7 derailed immediately after traveling through a track misalignment in the accident curve.

6. There was an ongoing unresolved subgrade instability issue on the derailment curve.

7. Additional geotechnical study of the derailment curve is necessary to ascertain the cause of the subgrade instability and to prevent future derailments at the same location.

8. Had the Federal Railroad Administration defined specific allowable limits for combinations of track conditions, the conditions on the BNSF Railway track in Joplin would likely have been identified and warranted remediation before the derailment occurred.

9. Given the rapid degradation of track conditions on the day of the derailment, it is unlikely that the track surface deviations at the track would have been detected through the current periodic track inspection process required under Federal Railroad Administration regulations.

10. Had trains with a vehicle/track interaction–equipped locomotive traversed the accident curve on the day of the derailment, the deteriorating track conditions could have been identified and real-time notification provided

to BNSF Railway, affording the opportunity for BNSF Railway to take action to mitigate the danger of misaligned track.

11. The expanded use of vehicle/track interaction monitoring systems across Class I and intercity railroads to detect track geometry conditions earlier could reduce the likelihood of train derailments.

12. The continuously welded rail installation requirements of Title 49 *Code of Federal Regulations* 213.119 (c)(2) should apply to all continuously welded rail joints.

13. The track inspector likely could not perform a required walking inspection of the derailment curve due to his assigned workload to inspect an excessive amount of track.

14. BNSF Railway's lack of proactive management controls to prohibit work assignments likely to cause fatigue and workload risks for safety-related employees is an indication of a shortcoming in its safety culture.

15. A comprehensive Fatigue Risk Management Program must fully recognize all the demands placed on employees to perform their jobs, including the tasks, responsibilities, duties, and hours worked, and must make necessary modifications to the job and/or scheduling to mitigate associated risks.

16. The Federal Railroad Administration's restructured Focused Inspection Program would benefit from both automated and walking inspections to ensure an improved understanding of the condition of the track beyond what can be known by only automated inspections.

17. This derailment demonstrates that there is a need for performance standards for window retention systems to prevent passenger ejections from railcars during derailments.

18. The use of compartmentalization did not protect the occupants in the overturned railcars from injury during the derailment and overturning of the railcars in the Joplin derailment.

19. The Federal Railroad Administration's occupant protection standards do not provide adequate protection from passenger injuries likely to occur during derailments and overturns due to their reliance on compartmentalization as the basis for the standards.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the derailment of Amtrak Train 7 on BNSF Railway track was the combination of worn rail, vertical track deflection at a four-bolt rail joint, subgrade instability, and track misalignment. Contributing to the severity of the injuries were the occupant protections that did not restrain passengers in the overturn event and the failure of the window retention systems.

4 Recommendations

4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations:

To the Federal Railroad Administration:

1. Require a limit for maximum acceptable rail wear. (R-23-1)

2. Establish interoperability requirements among railroads to implement a process in which a predetermined critical alert from a vehicle/track interaction system would require an immediate slow order that remains in place until a walking inspection is performed and, if needed, subsequent repairs are completed. (R-23-2)

3. Require that the continuously welded rail installation requirements of Title 49 *Code of Federal Regulations* 213.119 (c)(2) be applied to all continuously welded rail joints, including those added to install maintenance rail. (R-23-3)

To all Class I and Intercity Railroads Operating on Main Tracks, including Amtrak and the Alaska Railroad:

4. Equip all trains with an autonomous monitoring system, such as vehicle/track interaction, to detect track geometry defects. (R-23-4)

To BNSF Railway:

5. Conduct additional comprehensive geotechnical evaluations throughout the derailment curve fill area to determine the cause of the subgrade instability. (R-23-5)

6. Once the geotechnical evaluation has been successfully completed and the cause of the subgrade instability has been determined, make appropriate repairs to stabilize the track and prevent excessive movement of the track structure. (R-23-6)

4.2 Previously Issued Recommendations Reiterated in This Report

The National Transportation Safety Board reiterates the following safety recommendations:

To the Federal Railroad Administration:

> Develop a performance standard to ensure that windows (glazing, gaskets, and any retention hardware) are retained in the window opening structure during an accident and incorporate the standard into 49 *Code of Federal Regulations* (*CFR*) 238.221 and 49 *CFR* 238.421 to require that passenger railcars meet this standard. (R-14-74)

> Conduct research to evaluate the causes of passenger injuries in passenger railcar derailments and overturns and evaluate potential methods for mitigating those injuries, such as installing seat belts in railcars and securing potential projectiles. (R-16-35)

> When the research specified in Safety Recommendation R-16-35 identifies safety improvements, use the findings to develop occupant protection standards for passenger railcars that will mitigate passenger injuries likely to occur during derailments and overturns. (R-16-36)

4.3 Previously Issued Recommendations Classified and Reiterated in This Report

The National Transportation Safety Board classifies and reiterates the following safety recommendations:

To the Federal Railroad Administration:

> Revise Title 49 *Code of Federal Regulations* Part 213 to define specific allowable limits for combinations of track conditions, none of which individually amounts to a deviation from Federal Railroad Administration regulations that requires remedial action, but, which when combined, require remedial action. (R-14-75)

Safety Recommendation R-14-75 previously classified Open—Acceptable Action is classified Open—Unacceptable Action in section 2.2.5 of this report.

> Once you have completed the actions specified in Safety Recommendation R-14-75, program your geometry inspection vehicles to detect combinations of conditions that require remedial action. (R-14-76)

Safety Recommendation R-14-76 previously classified Open—Acceptable Action is classified Open—Unacceptable Action in section 2.2.5 of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JENNIFER HOMENDY Chair	**MICHAEL GRAHAM** Member
BRUCE LANDSBERG Vice Chairman	**THOMAS CHAPMAN** Member

Report Date: July 5, 2023

Appendixes

Appendix A: Investigation

The National Transportation Safety Board (NTSB) was notified on September 25, 2021, of the derailment in which the Amtrak (National Railroad Passenger Corporation) *Empire Builder* derailed in a right-hand curve at milepost 1014.57 on the BNSF Railway (BNSF) Hi-Line Subdivision near Joplin, Montana. The train was carrying 165 passengers and crew. Three people died and 15 other people required hospitalization.

The NTSB launched Vice Chairman Bruce Landsberg, an investigator-in-charge, and a team to investigate track, signals and train control, railroad operations, crashworthiness, and mechanical functions. NTSB investigators from Washington, D.C.; Montana; Colorado; Maryland; and Virginia assisted in the investigation.

Parties to the investigation included the Federal Railroad Administration; Amtrak; BNSF; the Brotherhood of Locomotive Engineers and Trainmen; the Brotherhood of Maintenance of Way Employes Division; and the International Association of Sheet Metal, Air, Rail and Transportation Workers–Railroad Division.[49]

Appendix B: Consolidated Recommendation Information

Title 49 *United States Code* 1117(b) requires the following information on the recommendations in this report.

For each recommendation–

(1) a brief summary of the Board's collection and analysis of the specific accident investigation information most relevant to the recommendation;

(2) a description of the Board's use of external information, including studies, reports, and experts, other than the findings of a specific accident investigation, if any were used to inform or support the recommendation, including a brief summary of the specific safety benefits and other effects identified by each study, report, or expert; and

[49] The Brotherhood of Maintenance of Way Employes Division spells the word "Employes" in its name with only one e.

(3) a brief summary of any examples of actions taken by regulated entities before the publication of the safety recommendation, to the extent such actions are known to the Board, that were consistent with the recommendation.

To the Federal Railroad Administration:

R-23-1
Require a limit for maximum acceptable rail wear.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.1. Information supporting (b)(1) can be found on pages 42 and 43; (b)(2) can be found on pages 42 and 43; and (b)(3) is not applicable.

R-23-2
Establish interoperability requirements among railroads to implement a predetermined critical alert from a vehicle/track interaction system would require an immediate slow order that remains in place until a walking inspection is performed and, if needed, subsequent repairs are completed.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3. Information supporting (b)(1) can be found on pages 48-50; (b)(2) can be found on pages 48-50; and (b)(3) is not applicable.

R-23-3
Require that the continuously welded rail installation requirements of Title 49 *Code of Federal Regulations* 213.110 (c)(2) be applied to all continuously welded rail joints, including those added to install maintenance rail.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4. Information supporting (b)(1) can be found on page 50; (b)(2) can be found on page 50; and (b)(3) is not applicable.

To all Class I and Intercity Railroads Operating on Main Tracks, including Amtrak and the Alaska Railroad:

R-23-4
Equip all trains with an autonomous monitoring system, such as vehicle/track interaction, to detect track geometry defects.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3. Information supporting (b)(1) can be found on pages 48-50; (b)(2) can be found on pages 48-50; and (b)(3) is not applicable.

To BNSF Railway:

R-23-5
Conduct additional comprehensive geotechnical evaluations throughout the derailment curve fill area to determine the cause of the subgrade instability.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.4. Information supporting (b)(1) can be found on pages 44 and 45; (b)(2) can be found on pages 44 and 45; and (b)(3) is not applicable.

R-23-6
Once the geotechnical evaluation has been successfully completed and the cause of the subgrade instability has been determined, make appropriate repairs to stabilize the track and precent excessive movement of the track structure.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.4. Information supporting (b)(1) can be found on pages 44 and 45; (b)(2) can be found on pages 44 and 45; and (b)(3) is not applicable.

References

AREMA (American Railway Engineering and Maintenance-of-Way Association). 2022. *2022 Manual for Railway Engineering*. Lanham, Maryland: AREMA.

BNSF (BNSF Railway). 2021. *Procedures for the Installation, Adjustment, Maintenance, and Inspection of CWR as Required by CFR 213.118*, effective date March 4, 2021. Fort Worth, Texas: BNSF Railway.

-----. 2021a. *Engineering Instructions*, Revision: June 1, 2021. Fort Worth, Texas: BNSF Railway.

-----. 2020. *Engineering Instructions*, Revision: June 1, 2020. Fort Worth, Texas: BNSF Railway.

-----. 2019. *Engineering Instructions*, Revision: June 1, 2019. Fort Worth, Texas: BNSF Railway.

FR (*Federal Register)*. Vol. 83, no. 225 (November 21).

-----. 2013a. Vol. 78, no. 150 (August 5).

-----. 2013. Vol. 78, no. 49 (March 13).

-----. 1999. Vol. 64, no. 91 (May 12).

-----. 1971. Vol. 36, no. 121 (June 23).

FRA (Federal Railroad Administration). 2022. *Integrity of Rail Passenger Equipment Glazing Systems*. DOT/FRA/ORD-22/21. Sharma and Associates for the Federal Railroad Administration. Washington, DC: FRA.

-----. 2019. *Joint Bar Failure Study – Field Investigation.* DOT/FRA/ORD-19/20. ENSCO, Inc. for the Federal Railroad Administration. Washington, DC: FRA.

------. 2018. *Track and Rail and Infrastructure Integrity Compliance Manual*, Volume II, Chapter 1. Washington, DC: FRA.

-----. 2015. *The Integrity of Rail Passenger Equipment Glazing Systems Request for Proposal.* Washington, DC: FRA.

-----. 2002. *Commuter Rail Seat Testing and Analysis*. DOT/FRA/ORD-01/06. Simula Technologies, Inc. for the Federal Railroad Administration. Washington, DC: FRA.

-----. 1998. *Estimation of Rail Wear Limits Based on Rail Strength Investigations*. DOT/FRA/ORD-98/07. John A. Volpe National Transportation Systems Center for the Federal Railroad Administration. Cambridge, Massachusetts: FRA.

NTSB (National Transportation Safety Board). 2019. *Amtrak Passenger Train 501 Derailment, DuPont, Washington, December 18, 2017.* NTSB/RAB-19/01. Washington, DC; NTSB.

-----. 2019a. *Amtrak Passenger Train Head-on Collision With Stationary CSX Freight Train, Cayce, South Carolina, February 4, 2018.* NTSB/RAR-19/02. Washington, DC: NTSB.

-----. 2017. *BNSF Railway Unit Ethanol Train Derailment, Lesterville, South Dakota, September 19, 2015.* NTSB/RAB-17/07. Washington, DC; NTSB.

-----. 2016. *Derailment of Amtrak Passenger Train 188, Philadelphia, Pennsylvania, May 12, 2015*. NTSB/RAR-16/02. Washington, DC: NTSB.

-----. 2014. *Organizational Factors in Metro-North Railroad Accidents*. NTSB/SIR-14/04. Washington, DC: NTSB.

-----. 1983. *Fire Onboard Amtrak Passenger Train No. 11,* Coast Starlight, Gibson, California, June 23, 1982. NTSB/RAR-83/03. Washington, DC: NTSB.

-----. 1981. Illinois Central Gulf Railroad Company Freight Train Derailment Hazardous Material Release and Evacuation, Muldraugh, Kentucky, July 26, 1980. NTSB-RAR-81/01. Washington, DC: NTSB.

-----. 1979. Safety Effectiveness Evaluation of the Federal Railroad Administration's Hazardous Materials and Track Safety Programs. NTSB-SEE-79/02. Washington, DC: NTSB.

Predraig, Tesic, Stanislav Jovanovic and Matthew Dick. 2018. "Analysis of vehicle/track interaction measurement data using the V/TI monitor system," *Gradevinar,* 70(2), March 2018.

Shannon & Wilson. 2022. *Geotechnical Evaluation: Hi Line Embankment Stability Assessment, Hi Line Subdivision, Montana*, Shannon & Wilson No: 108788-001. Revision: September 29, 2022. Seattle, Washington: Shannon & Wilson.

Wilson, Bruce and David Tyrell, 2016, *Reducing the Harm in Rail Crashes: Analysis of Injury Mechanisms and Mitigation Strategies,* ASME JRC2016, Proceedings of the ASME IEEE ASCE 2016 Joint Rail Conference, April 12-15, 2016, Columbia, South Carolina.

Wu, Huimin and Nicholas Wilson. 2006. *Handbook of Railway Vehicle Dynamics*. Chapter 8, "Railway Vehicle Derailment and Prevention." Boca Raton, Florida: CRC Press.

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