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Management of In-Train Forces:

Challenges and Directions

Railroad Safety White Paper

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Disclaimer

The author writes from the point of view of an observer and generalist, albeit one with over 46 years of involvement in rail safety and policy issues, 36 years of which were "in the trenches" at the Federal Railroad Administration. Views advanced here should be tested against the seasoned judgments of qualified engineers, technologists, managers, line employees and data analysts.

The issues described here are not native to any individual area of specialization. Only a dialogue involving transparency and rigor will yield clarifications and real progress.

The author acknowledges being a member of the Bar of the District of Columbia. Although this paper endeavors to shed light on some matters having legal significance, for the purpose of policy context, any views expressed may not be relied upon as legal opinions by any party. Any person desiring authoritative opinions on such matters should consult an agency of appropriate jurisdiction or their own attorney.

Acknowledgements

In its earlier revisions, this paper was reviewed by several very experienced colleagues for general soundness. They provided insights, detailed edits, and informational segments that improved the document; and they saved the writer from acute embarrassment. I am very grateful for their effort and wise counsel, which has included contributions to the current revision. Out of an abundance of caution given the controversy that has already arisen concerning recent developments in the industry, and since this paper inevitably touches on that controversy, I have not recognized them individually.

As always, responsibility for any errors that remain (or that were inadvertently introduced during final editing) rests with the author. Readers are invited to report any errors or engage on any points of disagreement using the e-mail address on the cover.

Introduction to Version 3.0

In January of 2019, I made a presentation to the Railroad Operational Safety Committee of the Transportation Research Board (TRB), of which I was a member, calling attention to the safety issues associated with Precision Scheduled Railroading (PSR). I linked the emerging problems to the longstanding challenges associated with management of in-train forces.

The presentation drew some interest within the Committee, but by the January 2020 meeting my efforts to promote the development of a TRB "research needs statement" had run up against firm opposition from industry representatives. The Federal Railroad Administration (FRA) was initiating some research, referenced below, that dealt with one of the critical issues (i.e., how far can you push existing train air brake systems), but not the broader issues.

Meanwhile, things were not getting better out on the railroad. PSR was driving away customers, aggravating communities with blocked crossings, and adversely affecting the safety of an industry that, previously, had been in a virtuous cycle of continuous improvement. I was retired, both from FRA and the consulting I previously did with Amtrak and Washington's Metrorail system.

It seemed to me that nobody else was clearly declaiming that the Emperor (the PSR Class 1 railroads) had no clothes. Somebody had to say it.

The initial White Paper bore a date of March 3, 2021. I distributed it widely. Version 2.1 was put up on the *Railway Age* website, which I appreciated. I expected lots of criticism, much of which I hoped would be helpful (providing useful corrections to any misperceptions, countering arguments that I may have extended too far, or fixing data).

I did get plenty of help in drafting the initial effort (including full texts of Appendices C and D, which I carry forward here) and in sharpening my focus through the revisions. But I am still waiting for the industry to confront the issues presented here. I have obviously shared my concerns with industry representatives, but it is clear at this point that they feel these issues are best ignored, lest they gain more public traction.

My continuing hope is that this discussion will promote action by the FRA and the Congress. The 2021 Bipartisan Infrastructure legislation did include a mandate for a National Academies study of "long trains"—perhaps because I strenuously cautioned ***against*** that "put it off"-course-of-action in previous versions of this paper.[1]

If the industry comes to its senses before the government can gather itself up, all the better. But industry conduct is being driven by the "almighty operating ratio" and the insistence of investors, including predatory private equity, for big payouts of earnings through stock buy-backs and dividends.[2] All of the analysis in the world cannot counter that set of incentives. Government exists, in part, to restrain irresponsible action by private sector actors.

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[1] Public Law 177-58, §22422.

[2] *See, e.g.*, Stephens, Bill, "Financial Engineers at the throttle," *Trains* May 2020 at 16; Oberman, Martin J., speech before North American Rail Shippers Association, September 8, 2021 (available at https://www.stb.gov/news-communications/testimony-speeches/)

This version has been extensively revised and updated, with reference to intervening accidents that appear to indicate a slow learning curve with respect to management of in-train forces, reporting of accident causes, and investigation of accidents.

It would be unfair to imply that there are no positive signs. Eastern railroads have, however belatedly, added distributed power to some of their already long and heavy trains. Some movement has occurred with respect to technology that might fill gaps in communication within trains. But overall performance appears to be deficient. With proper attention to train marshalling, technology, training, and maintaining communications, risk could be significantly limited. Indeed, just avoiding the gross excesses of train weight and length, particularly among mixed manifest trains, would go a long way toward delivering more responsible train operations.

Disappointingly, there appears to be little or no movement on the deployment of electronically controlled pneumatic brakes, despite ample study, demonstrations in revenue service, and regulatory incentives.

Executive Summary

Effective management of in-train forces has always been important for the safety of railroad operations. Although improvements in braking technology have greatly reduced the incidence of run-away trains, incidents of loss of effective braking still occur, and accidents involving buff and draft forces within trains continue to occur. The development of advanced tools to assist in ascertaining and managing those forces presents an opportunity to reduce derailments. Better control of risks to persons and property can also yield greater confidence in the ability of the railroads to handle a variety of hazardous materials. However, for progress to be realized, railroads must place a priority on proper marshalling and management of their trains.

Unfortunately, short-term financial incentives have driven major railroads away from operating strategies that focus on customer needs, and towards strategies that appear to place operating efficiency alone at the top of priority rankings. Among other impacts, this has resulted in decisions to operate fewer and longer trains and to skip train marshalling practices that limit risk. Initial implementation was not accompanied by appropriate measures to manage in-train forces, even by traditional standards. As this paper was revised in the spring of 2022, some of the railroads were moving toward implementation of more effective measures, but adherence is not assured. At the same time, supported by government research, the railroads claim to be moving toward fully automated operations.

The changes in train operations already implemented may be approaching the point at which train crews will be deskilled and thus wholly reliant on technology that is not yet ready to seize control of train movements. This is a prescription for learning in the field, rather than on the test track, with train crews and communities paying the price.

Review of discrete rail accident data sets bearing most directly on this category of risk indicates that recent safety performance is unacceptable, given the technology available and the strides visible in key categories, principally track safety. Excess risk continues to generate concrete examples of events that have had the potential for catastrophic consequences.

The Federal Railroad Administration has begun documenting exemplary events through its accident investigation program, demonstrating a growth in technical understanding. The National Transportation Safety Board sees the problem, but appears to be a little confused about how to deal with it. From the viewpoint of the outside observer, at least, action in response to documented hazards has not yet been forthcoming.

This paper endeavors to identify some of the actions likely required to nudge or compel the railroads toward a path that is better disciplined and more respectful of the risks associated with operating practices that rely on untested technology or suites of technology that have not been evaluated for proper integration. The following actions are required:

- Moving on an expedited basis, FRA should require railroads to adhere to their own train marshalling and train operation rules.

- The Congress should mandate regulatory action to address management of in-train forces and establish default conditions that would take effect if regulatory action is stalled or obstructed.

- FRA should convene the RSAC to address this need and prepare a proposed rule.

- FRA should update the accident/incident reporting system to gather better focused and refined train accident data.

- Both FRA and the NTSB should redouble their efforts to determine the underlying causes of accidents associated with management of in-train forces.

This paper also urges early adoption of electronically controlled pneumatic brakes, technology crucial to proper control of long trains and heavy trains safely and efficiently.

Taking action on these issues now will both improve safety in the short term and clarify issues with respect to any automated operations proposed to be undertaken in the future. By contrast, exclusive reliance on the new Risk Reduction Program will not materially advance resolution of these issues, because under that program railroads can elect to mitigate hazards at a level they determine and shield from public view important data which should be available to ensure accountability.

Safety Context

American railroads have made major strides in safety by virtually any measure during the 21st Century, building on progress made possible by reform of economic regulation that began in the 1970's and advanced more rapidly after enactment of the Staggers Rail Act of 1980. Innovations in technology, training, practices and regulatory oversight have all played a role, but the good economic health of the industry has been critical to progress. The industry is both capital and labor intensive; and investments in equipment, infrastructure and people must be funded from freight transportation revenues.

However, since about 2010 improvements in safety performance have sometimes seemed to flatline. The AAR presented the following graph to a TRB committee that offers a more encouraging take:

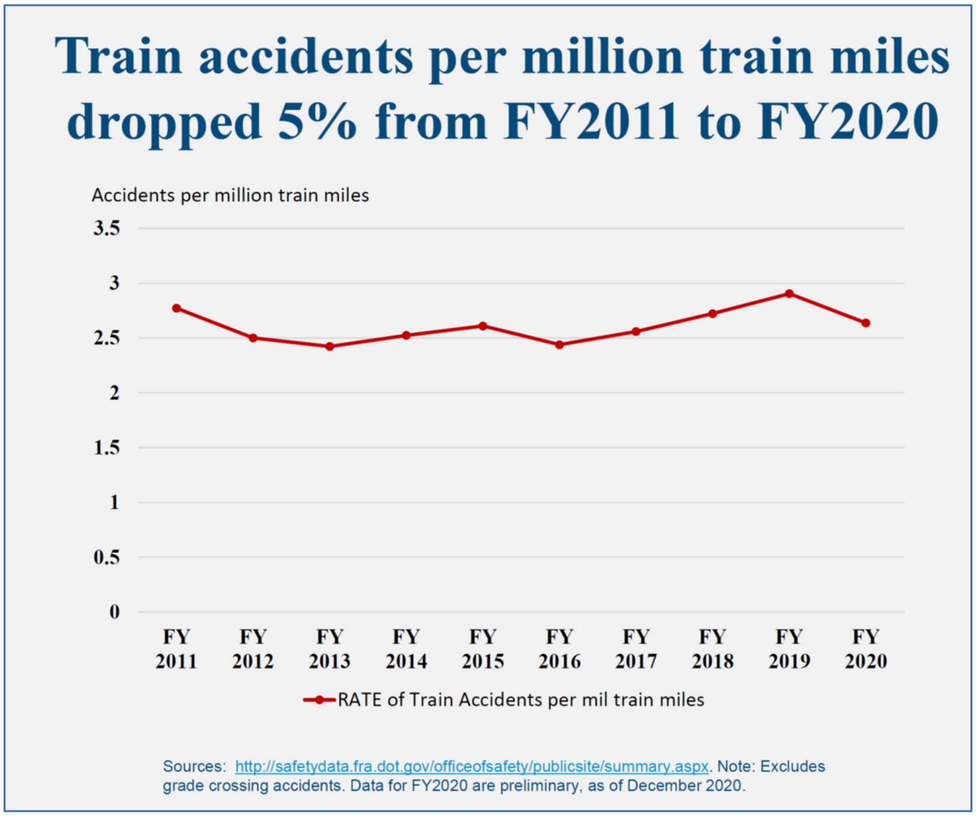

Figure 1 – Train Accident Rate / All Railroads

In Figure 1, AAR displays data for Federal fiscal years, which end September 30th. It includes all railroads.

The AAR also displayed a subset of train accidents, derailments. The chart below from the AAR reflects overall derailment rates.

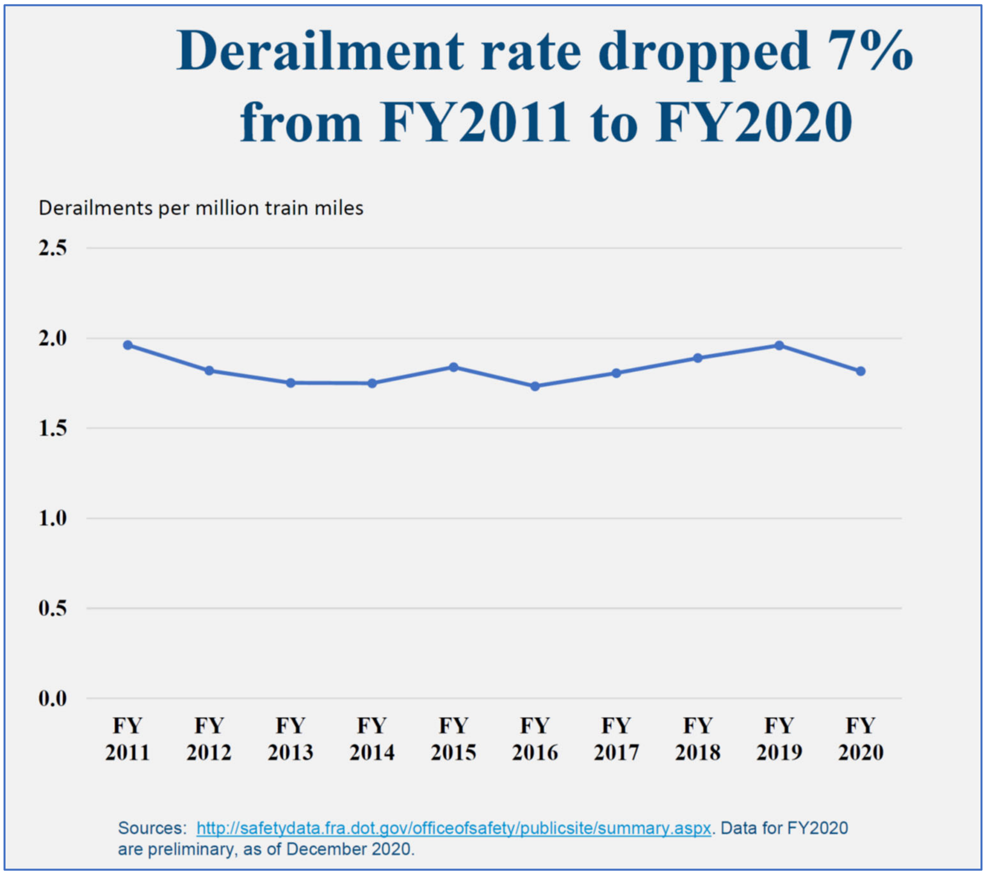

Figure 2 – Derailment Rates for All Railroads

Again, this is data for all railroads. It reflects derailments on all track (including yard and main line).

In earlier versions of this paper, we noted that placing a positive spin on these numbers requires accepting that the 2020 results reflect real progress. Let's happily concede that, at 1.90 the derailment rate for FY2021 was better than the derailment rate for FY2020, which was 1.93. Having said that, FY2016 came in at 1.70.[3]

These are historically very low numbers, with many recent years "best ever" by one or more measures. One would expect that. Railroads have leveraged heavier investments in track and structures (at a rate now apparently diminishing, but with uncertain impacts for the future), improved rail rolling stock, automated track geometry inspections, nondestructive testing of rail, wayside detectors, near-real-time data analysis, and generally good regulatory compliance to drive down risk. These advances benefit safety, efficiency, reliability of service and long-term profitability. The addition of PTC on about half of the major railroads' route miles further promotes safety while providing a technological foundation for further gains across the board

[3] Calculated from data retrieved 4-27-2022 from FRA Safety Data page 1.12 https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/query/TenYearAccidentIncidentOverview.aspx

(although PTC, which can virtually eliminate collisions, cannot significantly impact derailment rates).[4]

To be sure, the railroads face considerable headwinds if they are to achieve further reductions in train accidents. Extreme events driven by climate change pose major issues of resiliency that will be difficult to overcome given the expanse of the network and the limited control railroads can establish over their extended rights of way. Recent events have demonstrated the persistence of vandalism and calculated interference in rail operations that are always difficult to anticipate and mitigate.

Yet, with the steady advance of technology one might still hope for a continuing decline in accidents *related to management of in-train forces*, which should further improve overall outcomes.

This paper explains why this kind of progress has not yet been achieved and offers suggestions for moving forward.

What do we mean by "Management of In-Train Forces"?

Regardless of how hard we try to explain, some will claim this paper is about "long trains." It is true that the advent of much longer and more unwieldy trains associated with "Precision Scheduled Railroading" (PSR) gave impetus to the author's decision to return to this topic, but the truth is that management of in-train forces has been a major safety and efficiency issue for railroads throughout their existence. Means are now available to improve performance in this arena, but instead performance has deteriorated.

The most basic means of controlling in-train forces are motive power (locomotive traction, actuated at the throttle) and braking systems.

Braking systems for current freight operations consist of the—

- Train air brakes ("automatic brake" or "power brakes")
- Locomotive brake ("independent brake")
- Locomotive dynamic brake.

Manually-applied hand brakes are also available to secure individual cars and (most) locomotives when at rest.

Railroads today like to rely as much as feasible on "extended range" dynamic brakes to slow trains. Independent brakes are used to stop trains at very slow speeds. Dynamic and independent brakes apply only on the locomotives in the train consist. In training and through review of data downloads and check rides, locomotive engineers are coached to use these systems, and not the train air brakes, whenever possible.

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[4] See, e.g., Ditmeyer, S., "Network-Centric Railway Operations Utilizing Intelligent Railway Systems," *Journal of Transportation Law, Logistics, and Policy*, Vol. 77, No. 3 (Third Quarter 2010); Cothen, G., "Integration of Railway Electronic Systems to Achieve Safety and Efficiency," *Proceedings of the 2012 Joint Rail Conference*, JRC2012-74025 (April 17-18, 2012).

Train air brakes have the advantage of actuating at the command of the locomotive engineer through brake valves on each car, providing vastly greater adhesion and thus stopping power. However, the system depends on pressure changes in a train air line, a system of pipes and hoses connected through the train to signal each car to apply or release the brakes on that car. This pneumatic system, developed in the 19th Century, has been refined many times since.

But these improvements have reached their maximum effectiveness – no significant improvement in propagation is likely or even possible. The pressure-change signal propagates at only about two-thirds the speed of sound in normal service, and then only when the brake pipe is unobstructed. So, even an emergency brake command from the lead locomotive of a typical100-car train will take several seconds to propagate to the back of the train. The result is that, in the case of a brake application, cars at the front of train begin to reduce speed before cars at the back, leading to "run-in" and build-up of compressive forces that can cause problems if not handled with great skill. The skill is in deciding when and how much brake to apply before you apply the brakes. Once the compressive forces build up, it is too late to do anything but hold on tight!

Just getting started can be a puzzle. The longer the train, the longer it takes for brakes on individual cars to release at the back of the train. If an engineer tries to move a train before all of the air brakes have released in sequence, excessive longitudinal draft (pulling) forces may result.

There is also the problem of "signal" and "noise." An increase in brake pipe pressure is used to signal the release of train brakes. However, air is also pumped into the train line by the "pressure maintaining feature" to compensate for leakage. In general, the longer the train the greater risk that brakes far back in the train will be unintentionally released. As a result, attention must be given to excessive "air flow," 60 cubic feet per minute being the maximum allowed in the absence of a Distributed Power Unit (DPU)—another locomotive with a compressor back in the train—or a supplementary air source.[5] Appendix C provides a more complete explanation of train air brakes.

FRA research ongoing. Many of the limitations of train air brakes are exacerbated by very long trains, at least in the absence of DPUs to help charge and control the brake valves on each car. Results of ongoing FRA research on a test rack (the most favorable case) illustrate the differences. On the positive side, the researchers note that, just for a 200-car train to depart an initial terminal, the leakage at each car would need to be half of that for a 100-car train in order to stay within the maximum air flow allowed (60 cfm).

The findings to date, while often expected, are more concerning to this non-expert observer:

- Propagation of brake applications is proportional to train length.
- Restoration of brake cylinder pressure takes considerably longer for 200-car trains.

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[5] Under new FRA regulations following the Canadian example, total air flow of 90 CFM is allowed for trains equipped with at least one distributed power unit (discussed below) or an air repeater unit. 85 FR 80544, 80571 (Dec. 11, 2020); 49 CFR § 232.205(c). *See* Aronian, A., et. al., "Testing and Validation of Long Trains under High Flow and Gradient Conditions," *Proceedings of the 2012 Joint Rail Conference* (JRC2012-74036).

- Brake release is also approximately proportional to train length, meaning engineers need to allow more time before engaging the throttle.

- Recharge time for reservoirs at individual car locations is almost 3 times as long in the 200-car train (compared with a 100-car train), meaning once the brake system is substantially depleted, the air brakes may not be available for a longer period (something to "watch out for under cycle braking conditions").

- The more the application sequence becomes nuanced (stepped braking), the longer it will take for available brake cylinder pressure to be restored for the very long trains.

Perhaps of greatest concern, the probability of ***unintended release*** of the brakes at individual car locations rises quite dramatically with train length during cycle braking. (Unintended release reduces braking effort of the train as a whole while contributing to buff forces that can increase the derailment risk.) The researchers noted that making the subsequent application of the brakes "heavier' by 5 psi would avoid unintended release if the false gradient in the train line was 4 pounds or less, a practice the railroads said was standard. However, so far as the writer is aware, there is no publicly available data regarding the incidence of higher false gradients during normal train handling. Nor do we know to what degree this practice may contribute to depletion of the brake system during heavy blended braking (mountain grades, for instance).

The FRA research is directed at establishing firm benchmarks that provide a point of departure for additional analysis, so of course it cannot tease out all of the factors that could be documented in the field (e.g., initial gradients greater than that allowed with no reasonable opportunity to stop the train and make repairs, "false gradients" in excess of that stipulated, risk of more rapid brake system depletion from heavier successive applications).

Future FRA research will include instrumenting a train in the field, and subsequently testing with DPUs.[6] Meanwhile, some railroads continue to operate 200-car trains without DPUs.

Two-way EOTs. Since 1997, trains exceeding 30 mph and certain trains operating over heavy grade territory have been required by FRA regulation to be equipped with two-way end-of-train (EOT) devices.[7] These devices are connected directly to the brake pipe hose coupling at the end of the train. They are generally set up in the coupler of the last car and are powered by an internal battery. They communicate by data radio (telemetry) with the lead locomotive. When an emergency brake application is initiated at the front of the train, or when directly commanded by the locomotive engineer, the EOT vents the brake pipe from the rear, resulting in an emergency application from the rear of the train as well. Using this method, the train will normally stop in a shorter distance; and the risk of a derailment from run-in is reduced. EOTs also provide the locomotive engineer with a read-out of the train "gradient", or difference in train

[6] Results of FRA research to date have not yet been published widely, but have been disseminated to industry parties as part of the collaborative research program. The summary above was taken from a presentation entitled "Air Brake Performance in Very Long Trains; Review of Test Data from Air Brake Rack Tests" (USDOT/FRA Office of Research and Development, June 1, 2022). *See* Appendix E for FRA contact information.

[7] 62 FR 278 (Jan. 2, 1997); 49 CFR 232, Subpart E. In recent years, railroads have boasted about the use of these devices as "new technology" and claimed that they make electronically-controlled brakes unnecessary. In fact, they were mandated over industry objections after a number of serious run-away accidents.

line air pressure at the front of the train vs. the back (which, by regulation, may not exceed 15 psi in an initial terminal test, but will vary over the road as the brakes are applied and released).[8]

Slack built in. However, the best maintained motive power and braking systems are not sufficient for effective management of in-train forces. Trains experience "buff" (compressive) and "draft" (tensile) forces in normal operation. There is always "slack" between cars and locomotives and between cars. Slack is a design feature originally grounded in the simple need to get a train moving. Locomotive driving wheels could not get sufficient adhesion to start a long, rigid train from a standing start. So, equipment was built to allow the first car to get rolling a little, and then the second, and so on.

More recently, many cars (about 15%) have been built with end-of-car cushioning (EOCC) units on each end to protect the content (lading) of the car from impacts during yard switching and the run-in and run-out of slack during normal train operations. This helps at the level of the individual car, but it also adds length of stroke and more slack action, which may become problematic if several of these cars are entrained together.[9] The unusual arrangements can lead to faulty repairs and kinked train air lines. EOCC units are difficult to maintain, so some may be in service in failed condition.[10] A number of the accidents reviewed in Appendix B involved blocks of cars with EOCC devices contributing to run-in and high lateral over vertical (L/V) forces.

Car combinations. Complications also arise because cars are of different length with draft gear differently arranged. Some combinations of short and long cars, coupled together, can cause excessive lateral forces between connected cars. This can contribute to wheel climb, typically on the outside of a curve.

Route conditions. The track structure can also pose challenges. No railroad lines are entirely straight ("tangent") from origin to destination. Curvature, both horizontal and vertical, is prominent in track layout because of the physical obstacles that must be overcome. So, as an example, the outer rail in a curve is "superelevated" above the inner rail to prevent overturning of cars and locomotives by centrifugal force, and to provide for reasonably equal vertical wheel loads on the inner and outer wheels. The superelevation will provide safe operation at the maximum speed permitted on the curve, but will not be so great as to cause equipment moving at low speed to overturn to the low side. The superelevation will correspond with safe passage at a speed less than the maximum allowable. But if the train is moving at a very low speed, and the rail cars traversing the track segment are unloaded, any excessive drag (e.g., from too much tonnage, brakes that have not released, the back of the train still cresting a hill, etc.) may cause the train to "stringline" (one of those rare railroad terms that means just what it says).

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[8] Some years ago, a major vendor developed an EOT capable of effecting a service reduction of the brakes in coordination with a brake application made by the locomotive engineer. This approach should significantly reduce in-train forces related to use of the air brakes, but so far as the writer can determine the capability has not been employed in actual service.

[9] See, e.g., Klopp, A., "Impact Control with Limited Slack Action," *Railway Age* (July 2020).

[10] A commenter noted that modern EOCC units are equipped with a "go/no go" button that sticks out from the side of the unit if it fails. This should be evident to a carman during a normal freight car inspection, reducing the number of failed units in service.

During the author's time at FRA, the agency, with help from the Volpe National Transportation Systems Center, produced a congressional report[11] that describes the kinds of derailments. Here are illustrations from that report:

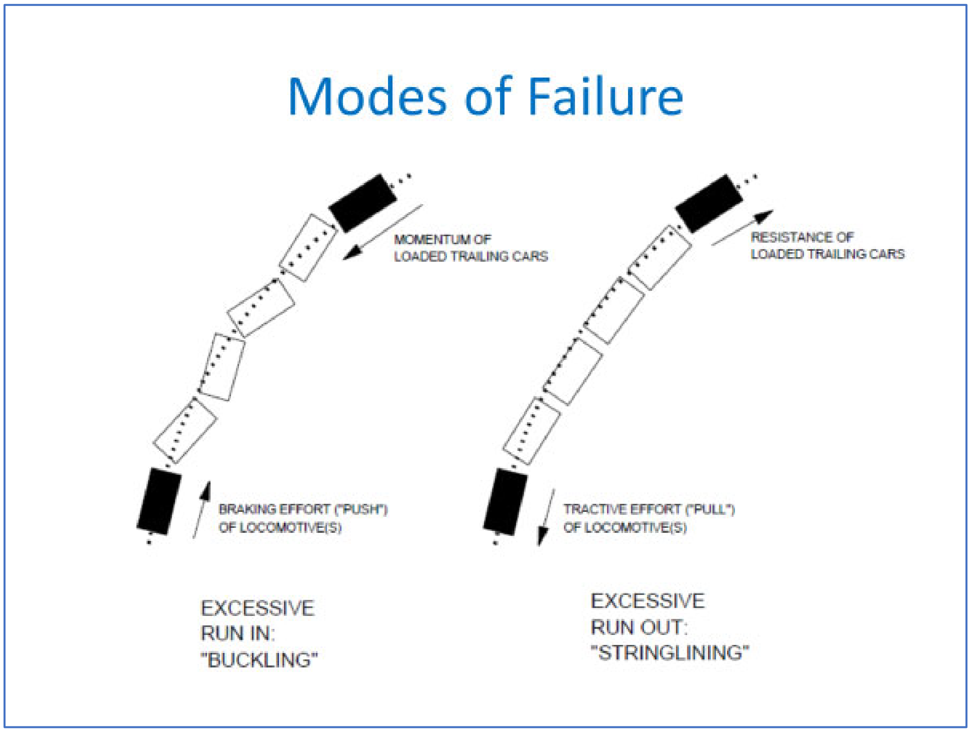

Figure 3 – Buckling and Stringlining Illustrated

[11] Safe Placement of Train Cars: Report to the Senate Committee on Commerce, Science and Transportation and the House Committee on Transportation and Infrastructure (FRA June 2005).

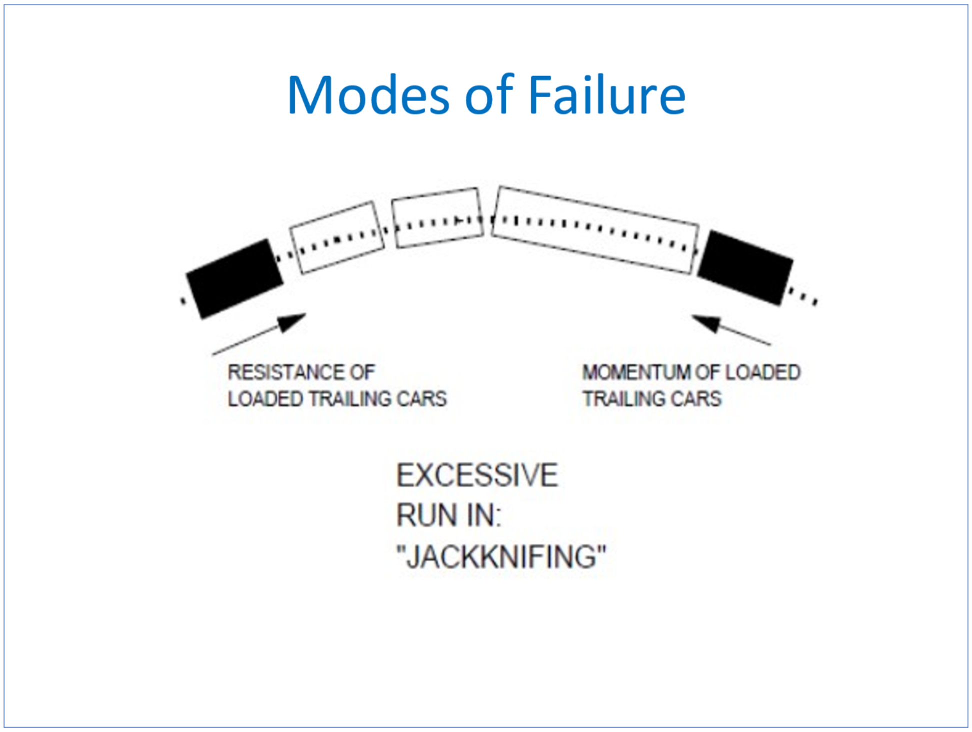

Figure 4 – Jackknifing Illustrated

These classic derailment scenarios, together with run-away trains, have been staples of railroad operations since the beginning. Note that the modes of failure can result from poor use of motive power, poor braking, or poor train make-up. But other initiating causes, such as wide gage, broken rails, broken wheels, stiff trucks, etc., can set up unfavorable in-train forces; and the severity of the resulting events will increase. Even when an engineer deems it necessary to apply the emergency brake to avoid or mitigate a collision with a tanker truck stuck on the crossing ahead, or children on the track failing to respond to the train horn, the result may be a serious derailment.

In order to manage in-train forces properly, the railroad needs to establish appropriate operational limitations, procedures, training and oversight.

Why Now?

There has long been an understanding within the industry and among regulators that management of in-train forces is integral to safe train operations. Accidents related to the design and functioning of brake systems, the make-up of trains, the use of braking systems over mountain grades and undulating territory—all of these have been well understood, individually, in relation to specific accident scenarios. FRA's reporting system includes scores of "cause codes" used to report these events.[12] Unfortunately, the reporting system has never been a completely effective tool for capturing the interaction among various underlying factors. Worse,

[12] See 49 CFR Part 225, and FRA Guide for Preparing Accident/Incident Reports, DOT/FRA/RRS-22 (November 9, 2010) (available at www.fra.dot.gov).

changes in technology and operations over the past decade have left the reporting system badly out of date.

Inevitably, information gets lost in the mountain of data. For instance, a coupler failure that leads to a train separation, emergency brake application, and major derailment might be caused by a crack that grew over time with successive yard impacts. Or it may have been caused by poor train make-up or poor train handling. There are at least three options there for further evaluation, but just as likely as not the accident will be reported as "E30C—Knuckle broken or defective" (or one of several similar codes). Worse, the railroad may utilize any number of miscellaneous codes that leave us no wiser. On occasion, some railroads will add helpful narratives that tease out the underlying causes. Other railroads may not add anything of value to the narrative, even if the particular cause code calls for it.

This is where this writer becomes desperately impatient. Railroad spokespersons are trained to talk about "data-driven" decision making as the key to safety. Yet, despite the fact that FRA's accident data system is the best in ground transportation, it remains inadequate, standing alone, when the purpose is to identify the next big risk to public or employee safety. Even working groups of the Railroad Safety Advisory Committee have found it necessary, repeatedly, to delve below the available train accident data to ascertain underlying causes and related factors. Thus, we need to look at accident investigation reports from public agencies and between the lines of filed railroad accident reports. The material provided in Appendix B is intended to ask many of the necessary questions.

It should be emphasized that both FRA and NTSB have been challenged by the changes in operations and practices, as well. Railway electronic systems now generate abundant data, only part of which is routed to the fire- and impact-resistant locomotive event recorder. Most of the data is available following derailments and run-away train incidents of the kinds discussed in this paper. Yet, based on the content of published reports, it appears that Federal accident investigators do not access most of this data.

Interpretation of the data is a complex process. Translating throttle settings, brake applications, grade, curvature, and other factors into an understanding of track/train interaction in four dimensions (lateral, vertical, longitudinal, time) at multiple locations within a train has always been a challenge. The industry has long employed the Train Operations and Energy Simulator (TOES), which was initially based on Track/Train Dynamics research conducted jointly between the industry and FRA in the 1970s.[13] However, the AAR declined to license TOES for FRA use. Accordingly, for a number of years FRA endeavored to produce a satisfactory replacement.

In 2015, FRA published a validation study for its new model, the Train Energy and Dynamics Simulator (TEDS).[14] FRA has been utilizing TEDS in selected recent accident investigations where track/train dynamics was at issue. Based on the published reports, it appears that TOES and TEDS produce similar estimates of the forces involved in the accidents studied. TEDS has also been made available to the NTSB.

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[13] Track Train Dynamics Guidelines for: Train Handling, Train Makeup, Track & Structure, Engineer Education, FRA, AAR, RPI (1973); *see* Qing Wu, Maksym Spiryagin & Colin Cole, "Longitudinal train dynamics: an Overview," *Vehicle System Dynamics*, 54:12, 1688-1714, DOI: 10.1080/00423114.2016.1228988 (2016).

[14] Validation of the Train Energy and Dynamics Simulator, DOT/FRA/ORD-1501 (January 2015), available at https://railroads.dot.gov .

Even as tools of analysis have improved, the target has been moving.

Nominal freight car cargo capacities have gone from 70, to 100, and to 125 tons (286,000 pounds gross weight on rail) or more. Major railroads, and particularly the western railroads, have long utilized DPUs, embedded mid-train or placed at the end of train consists, to support longer and heavier trains, or to establish better control of in-train forces moving over significant grades. Initial analog radio control systems have given way to data-based telemetry, making these systems (successive versions of LOCOTROL®, originally developed by GE Transportation, which was acquired and refined by Wabtec Corporation) more practical and precise. DPUs can be operated in "synchronous" mode, with power or dynamic braking at the same setting in the controlling locomotive and DPU, or "fenced" mode, with commands to the DPU based on differing requirements (like pushing the back of the train over the hill after the lead locomotives and most cars have begun their descent).

More recently, suppliers adapted train energy management systems (TEMS) to run on board locomotives, using information regarding the train consist and route characteristics. New York Air Brake's LEADER® (originally developed with funding from FRA R&D) and GE Transportation's Trip Optimizer® (now a Wabtec product) were the initial offerings, and they have been deployed on a significant portion of the locomotive fleets. Originally touted as "coaches" for locomotive engineers, so that they could use visual displays to fine tune their use of the throttle and dynamic brakes, their major selling point was fuel conservation. However, they also held promise for reducing derailments associated with excessive in-train forces in properly marshalled trains while permitting crews to rely more heavily on dynamic brakes, rather than the automatic train brake.

Unfortunately, DPUs and EOTs have always relied on radio transmissions using frequencies that are actually, or very nearly, line of sight. So, it is pretty common for communication to be lost when operating in mountain territory or along river routes with a high degree of curvature. The longer the train, the bigger the challenge. How common is it? Well, in the era of big data, we don't really know. The railroads may know, but they are not telling. Some of the sampled accident investigation reports give us a hint that the problem, always troublesome, is much bigger with longer trains. The railroads do (did?) have a plan to deal with this in PTC territory, by leveraging PTC data radio towers.[15] However, there is apparently no timetable, and about half of the Class 1 route miles are not PTC-equipped.

Moving forward, railroads intend to rely on DPUs, TEMS, EOTs, and PTC integrated into automated operation of very long and heavy road trains, with or without crew on board[16]—but with the computer running the train for much or all of the trip. This is Automated Train Operation (ATO).

[15] Newcomb, M.R., TCCO Status Update, Transportation Research Board Annual Meeting (January 2019)

[16] Newcomb, infra. Industry spokespersons run hot and cold on this point. Some see single-person locomotive crews on board to oversee the operation and step in as necessary, with traveling conductors driving to any location where couplers might need replacing, hand brakes might need to be applied, or other exigencies might arise. Others talk about the potential for remote monitoring (like drone piloting, but with less involvement).

What is the Current State of Play?

If automated operations are the industry's goal, how are they doing along the way? We must all walk before we can run. How much do we know about how this is going?

The events summarized in Appendix B suggest that it's not going that well. The mistakes that railroads were making two or three decades ago keep happening, but they may be happening more frequently due to the pressures of PSR. TEMS now actually handle the manipulation of the throttle and dynamic brakes on some trains, but it's not clear how many. Much learning has been integrated into the on-board TEMS platforms, but there is also a good deal that is not understood and thus cannot be modeled.[17] Automated systems depend on highly granular information about route characteristics and train make-up, but we have no idea how effectively that data is being presented to the systems, or with what fidelity.

The drive toward ATO skips the step of implementing electronically controlled pneumatic (ECP) brakes. The industry has silenced FRA and others with the message that ECP brakes cannot be effectively maintained. At present we must rely on the industry itself for that conclusion, and given the difficulty it had implementing PTC we shouldn't dismiss the concern out of hand. However, the fact that it may be difficult does not exclude the likelihood that it will be necessary.

With or without TEMS electronic control, train air brakes remain an important tool in negotiating mountain grades and undulating territory. Some of the accidents listed in Appendix B confirm that TEMS are basically out of their league under circumstances where train air brakes must be called upon. Crews are required to "blend" the use of air brakes and dynamic brakes, often without—

- sufficient DPUs to manage the resulting forces and recharge individual car air reservoirs, or
- effective communication to the rear of the train to know the current state of charge in the train air line—or even, in an extreme case, to effect an emergency brake application from the rear.[18]

This is about the future, but it is also about the present. The number of accidents that can be traced to management of in-train forces is not large in comparison to the total numbers, but several things must be considered here:

- Only a portion of the accidents involving in-train forces are reported under the relevant codes.
- Even if reporting were pristine, the current accident/incident system is not geared to capture most of the relevant information.
- Excessive in-train forces can and will create problems that manifest themselves at a later time, whether it be wheel wear, damage to draft gear, lateral forces on track structure, or other factors. *Stress on the system drives problems in the system.*

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[17] Klopp, infra.

[18] New York Air Brake is developing its LEADER® technology to control the air brakes and has made at least one demonstration run at the Transportation Technology Center. Vantuono, W.C., "Look Ahead," *Railway Age* (Sept. 2019).

- Societal loss from related accidents is greatly understated by the reporting requirements. Reported damages do not include—
    - Loss of lading or supply chain disruption
    - The cost of wreck clearance
    - Delay and re-routing of trains
    - The cost of environmental remediation
    - The impact on local motorists and businesses of road and grade crossing closures
    - The cost of emergency response and evacuations
    - Damage to third-party property.

Significantly, there is no cost accounting system that captures all of the costs of derailments to the railroads, let alone to society. Shareholders have no way of knowing what this adds up to, and one wonders whether corporate directors track even the cost of catastrophic insurance (which, at least in prior years, had to be sourced off-shore).

Train crews assigned to manage unmanageable trains are also subject to stress that can result in ill effects ranging from distraction to poor decision making, fatigue, and even long-term health effects. These issues may be exacerbated by the blown schedules and pulled-apart trains that go with the current PSR model.

Long and heavy trains still have to be made up and broken up, and the technology that can help manage a train over the road is of little value when the crew has to yard a 170-car train in a facility built for 50-car cuts, at best. Yard derailment and collision data respond to this stress, as well, but in ways that may be difficult to discern. The railroads are making investments in modified facilities to address this mis-match, but the concern here is whether it is at the expense of state-of-good-repair (most of which is included in capital expenditure line items in the railroads' financial statements).

Performance Overview

Despite all of the excellent progress railroads have made in reducing train accident risk, derailments generally for the major railroads have been flat or slightly rising over the past several years, measured against volumes.

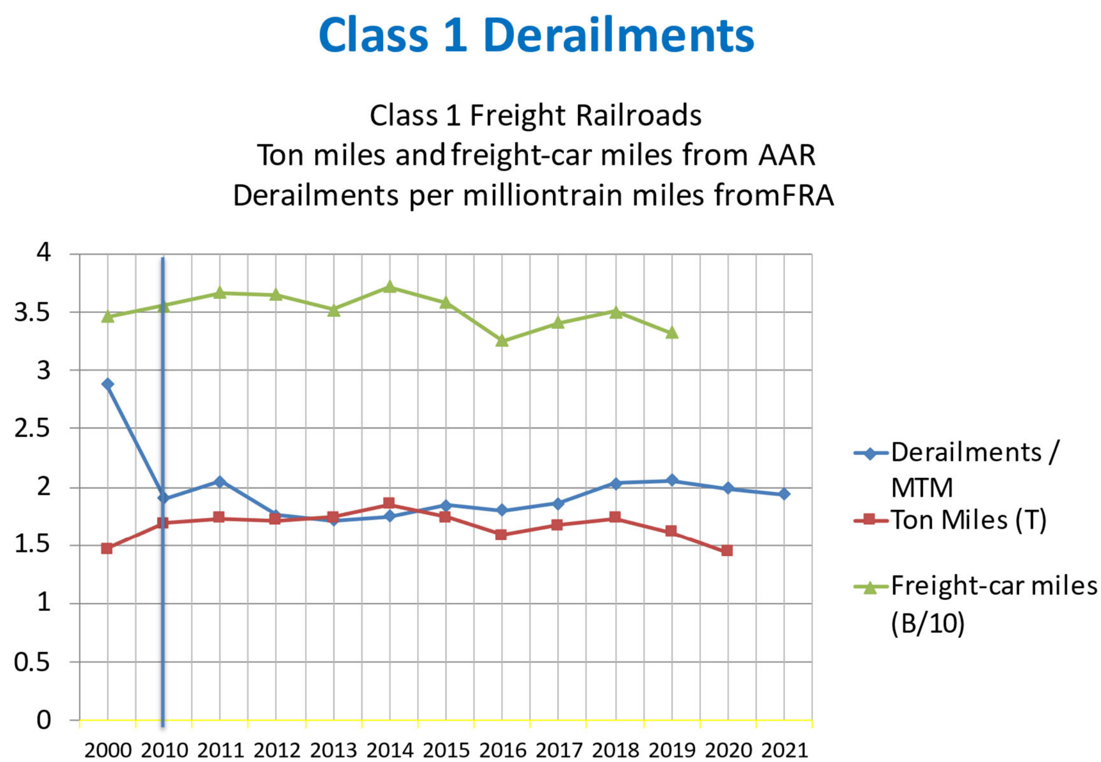

Figure 5 – Class 1 Freight Railroad Derailment Trends (all tracks)

Figure 5 data for ton miles and freight-car miles were taken from AAR Fact Books, and the derailments per million train miles were calculated directly from FRA data.[19] Note that this data varies slightly from AAR's report of FRA data, used in prior versions, perhaps because AAR included all Class 1 railroads (including Amtrak) while the graph above applies to freight railroads only. Temporary increases in coal traffic, and a general recovery of carload traffic, likely pushed ton miles up somewhat in 2021.

There is an ongoing discussion, the resolution of which has not come to the writer's attention, over what kind of normalizing statistic should be used in an era of very long trains. Figure 5 displays the accidents per train mile metric that both FRA and AAR have used in the past to gauge progress. Running fewer trains yields fewer train miles to serve as the denominator, even if this is being done soundly.

It is very true that the railroads made rapid progress in the '80s and '90s, reducing accidents and personal injuries with the benefit of economic deregulation. But it is also true that performance in the train accident arena has flattened out to some extent in the last decade, which deserves scrutiny given the many advances in available capital, technology, and regulatory attention in the intervening period. ***The fact that performance is good when measured against historic standards does not mean further improvement is not warranted.***

[19] 1.12 Ten-year accident/incident overview, retrieved 4-27-2022 and 4-28-2022. Ton-mile data for 2020 was taken from an on-line source, Statistica.

How Should We Read the Data?

Track-caused accidents have declined significantly over the decade for a host of reasons that would be worthy of another white paper, which would be a very favorable portrait—at least for now.[20] As track-caused accidents have declined, "*human factor*" accidents actually increased over the last decade, abating in absolute numbers to some extent in 2020 and 2021. This paper posits that current Class 1 railroad operating plans accept excess risk that can be reduced to a significant extent by better managing in-train forces. This would favorably affect the number of events reported under "human factor" codes and perhaps others, as well.

The term "human factor" is generally taken to mean wrong actions by individuals—and this is the meaning implied when the industry discusses its ambitions for automation and the further drastic reduction of labor costs. However, the accidents that fall under this heading also prominently include choices made with respect to choosing technology, training personnel, configuring track structure in yards and terminals, and marshalling trains. These are best described as involving ***institutional*** or ***organizational*** factors.[21]

As it is today, however, accidents involving deficits in managing in-train forces are generally reported as ***human-factor accidents, equipment accidents*** or under ***miscellaneous causes***. The available cause codes and reporting protocols are deficient. For main line train movements, a variety of cause codes are employed (examples only):

FRA Cause Code	Meaning	Comment
H501	Improper train make-up at initial terminal	Normally not a road crew performance issue
H502	Improper placement of cars in train between terminals	Significant issue given pre-blocking in PSR
H503	Buffing or slack action excessive, train handling	Often attributed to crew in cases where train has insufficient distributed power or other unfavorable chacteristics
H504	Buffing or slack action excessive, train make-up	Normally not a road crew performance issue
H505	Lateral drawbar force on curve excessive, train handling	Determining which of these apply would normally require a TOES (or similar) run, but accident records rarely say if this was done
H506	Lateral drawbar force on curve excessive, train make-up	
H507	Lateral drawbar force on curve excessive, car geometry (short car/long car combination)	Train make-up issue
H508	Improper train make-up	Organizational
H511	Automatic brake, excessive	

[20] The writer is scoping a subsequent white paper devoted to the future of freight railroading in the United States. Concerns include shrinking markets, excessive payouts of capital to drive up stock prices, and assumption of long-term debt that will be difficult to re-finance and pay down as interest rates rise to more normal levels.

[21] *See, e.g.*, James Reason, *Managing the Risks of Organizational Accidents* (Ashgate 1997)

FRA Cause Code	Meaning	Comment
H514	Failure to allow air brakes to fully release before proceeding	Long trains and cold weather present a challenge
H518	Dynamic brake excessive	Often attributed to crew in cases where train has insufficient distributed power
H519	Dynamic brake, too rapid adjustment	Prominent code for trains under circumstances where engineers are told not to touch the air brake (to save fuel)
H520	Dynamic brake, excessive axles	Road crew may receive consist with set up already determined
H524	Excessive horsepower	Should refer to tractive effort available (number of locomotives, etc.), but unclear how code is used
H525	Independent (engine) brake, improper use	The longer the train, the more sensitive use may be, given topography and slack
E00C	Air hose uncoupled or burst	Cited in a report without further explanation
E06C	Brake valve malfunction (car)	Cited in a report involving a stuck brake on a car that was not inspected before being moved because the long train was blocking a crossing providing access
E29C	Other body defects (car) (provide detailed explanation in narrative)	Cited in report without explanation required, other than it was “torn apart”
E30C	Knuckle broken or defective (car)	Cited in reports without underlying cause
E79L	Other locomotive defects (requires explanation in narrative)	Cited in a report involving irregular loading by a mid-train DPU (underlying cause not explained); Cited as primary in a report involving excess in-train forces, revised from “train make-up without further explanation
E06L	Brake valve malfunction (locomotive)	Cited in a report involving excessive buffing or slack action caused by a mid-train DPU (underlying cause not explained)
E09L	Other brake defects (locomotive)	Cited with E0C—Obstructed brake pipe when communication with EOT failed
M405	Interaction of lateral/vertical forces (includes harmonic rock off)	Code appears to be used as a catch-all; harmonic rock off is much less frequent in the era of continuous welded rail
M505	Cause under active investigation by reporting railroad….	Sometimes updated, but sometimes left in place

Note that (i) in many cases these codes tell us *how* something happened but not *why* and (ii) none of these codes call out specific problems associated with marshalling of very long or heavy trains, communication among DPUs, mishandling of the dynamic brake or throttle by TEMs, or insufficient training for crews handling new technology. So, in many cases we have to read between the lines.

How are the major railroads doing, then, in relation to how well they might do? Overall, the Class railroads have a pretty flat record over the past 5 years when it comes to main line derailments:

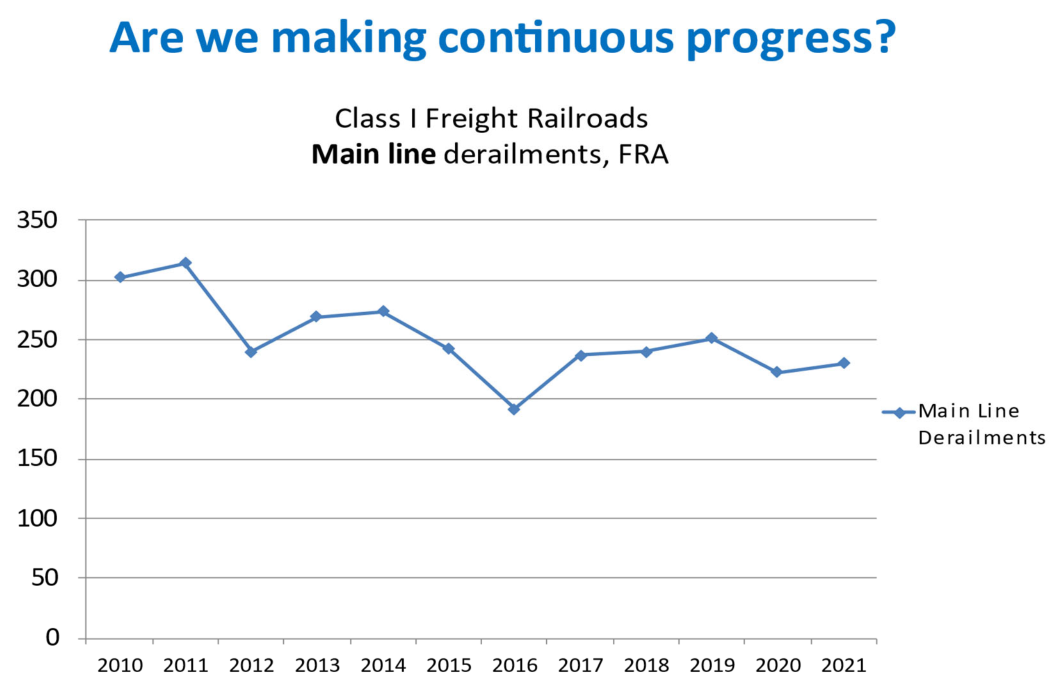

Figure 6 – Class 1 Main Line Derailments (counts only)

While running many fewer trains, the major railroads continue to report a steady or increasing number of main line derailments. What is behind this trend? First, "human factor" derailments having been gradually rising, even as track-caused accidents decline steadily. As would be expected with the rise of in-train forces associated with PSR, equipment caused derailments also remain at a significant level—this, despite all of the advances in wayside detection technologies.

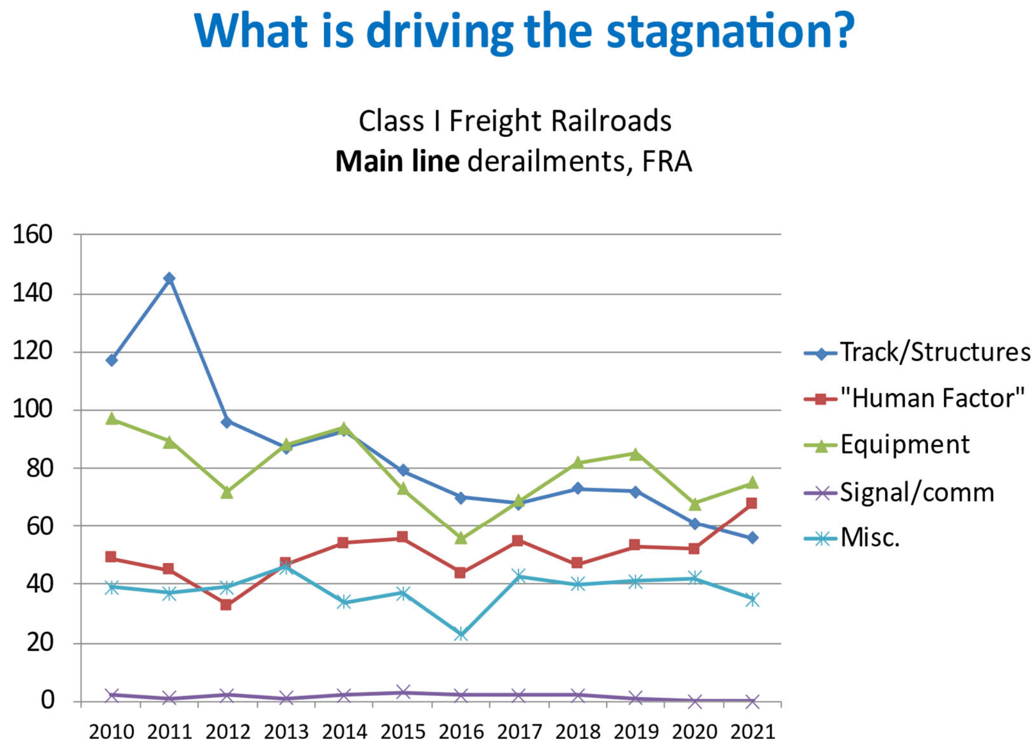

Figure 7 – Class 1 Main Line Derailments by Cause (counts)

Figure 7 shows he gradual increase in human factor derailments, even as the number of trains operated has declined steeply. Track accidents continue to decline, but equipment-caused accidents have remained quite persistent. Miscellaneous causes have also shown persistence.

Even without normalizing for activity, it's plain to see that some of the major railroads have been doing better than others in main line derailments:

Are the railroads doing about the same?

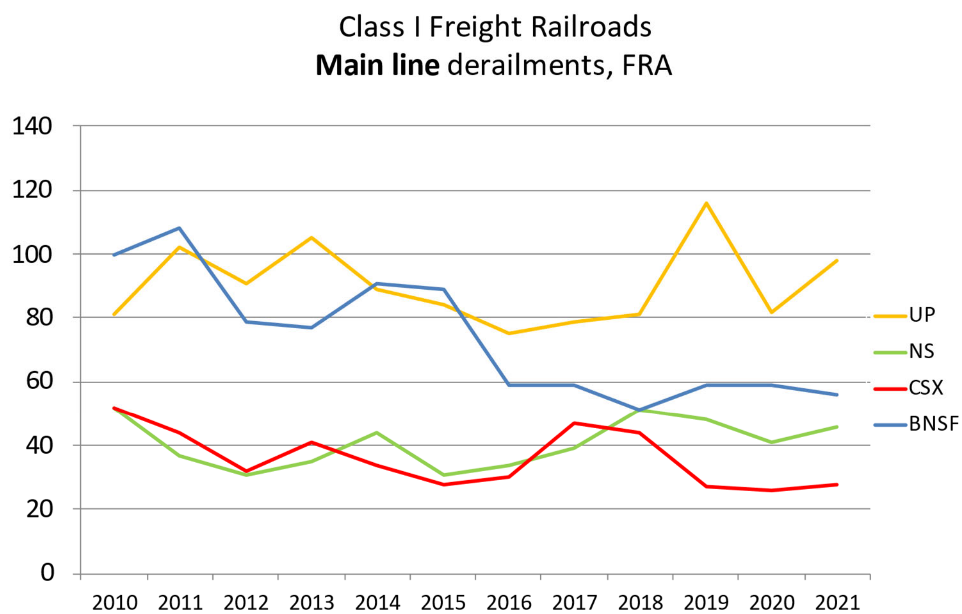

Figure 8 – Class 1 Main Line Derailments by Major Railroads (counts)

In Figure 8, note than BNSF is actually the bigger railroad in the west (by volume), but UP is leading in derailments. CSX, which went through a difficult PSR start, now has fewer main line derailment than NS, which is the smaller railroad in the east. These differences look stark when one searches for accidents likely driven by in-train forces (examples abound in Appendix B).

If we continue to focus on the four major Class 1 railroads, and further focus on main line derailments adjusted by million train miles, the picture clarifies further.

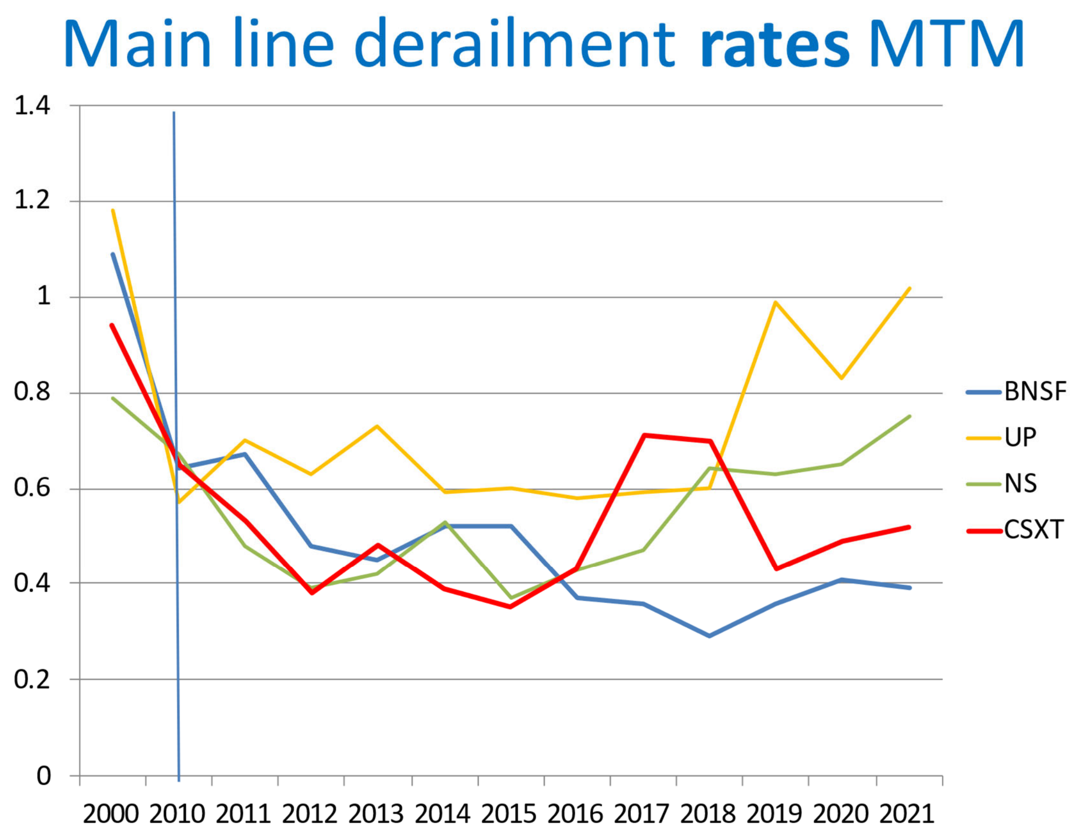

Figure 9 – Main Line Derailment Rates per Million Train Miles

Again, Figure 9 data drawn from the FRA web site shows the rate of main line derailments per million train miles.[22] These four railroads account for the majority of trains operated and train miles in the United States. All four railroads have extended their train lengths and tonnages over the past half-decade, although BNSF has done so to a lesser extent.

Note the significant decrease in derailments as the industry became truly profitable in the mid-2000's. Since 2010, however, the picture has become less clear.

Three of these railroads, CSX, NS and UP have embraced Precision Scheduled Railroading (PSR), a doctrine associated with the late Hunter Harrison, which emphasizes asset utilization and cost reduction. PSR has been criticized for shorting customers and safety (though the various advocates of the doctrine reject the criticism).[23] The beauty of PSR is that, at least for a while, it drives cash to the bottom line that can be used to reward investors handsomely.

[22] As of February 3, 2021, except 2011-2012 data and 2020-2021 data. The latter were retrieved from FRA page 2.09 on 4-28-2022.

[23] E.g., former FRA Deputy Administrator Bruce Flohr recently provided a fulsome defense of PSR (available at https://www.railwayage.com/freight/everyone-wins-with-psr/)

PSR was fully deployed initially on CN and then CP, which struggled with its effects on operations, customer satisfaction, and safety.[24] Tension with regulators ensued, and some remedial actions were taken. Among the issues was management of in-train forces. Canada's Transportation Safety Board (TSB) chose a rather minor accident, albeit on a subdivision that had experienced 353 pull-aparts in the 2 and ½ years prior to the accident, to express its concerns over the growing number of issues with longer and heavier trains. [25] The TSP has returned to this issue, noting in one report the relationship between train length and weight and marginal track conditions on risk of derailment, with exacerbation of derailment severity when communications are lost between the front and end of the consist[26]

CN and CP have apparently since adjusted to a more balanced approach, although the recent TSB report on the fatal Field Hill, B.C., run-away has renewed concerns.[27]

In Figure 9 above, note that the values for NS and UP are relatively high through 2021. NS faced a hostile takeover bid by investors aligned with CP that ended in April of 2016, but its derailment performance overall seems not to have recovered. Each of the PSR railroads has maintained a low operating ratio while using much of its cash for stock buybacks and dividends. *Review of the granular derailment data for UP and NS, in particular, suggests casual attention to train make-up and the challenges presented for crews drawing very long and heavy trains.* The other major railroads continue to struggle with management of in-train forces, but to a lesser extent.

CSX responded to a pending and actual takeover in the period 2016 through 2017 by plunging into the PSR craze with very long trains and other cost cutting, initially without any appreciable use of distributed power, and with bad results for safety and service. However, it seems to be moving back in the right direction.

BNSF, which avoided the private equity whiplash by virtue of its acquisition by Berkshire Hathaway in 2010, had performed pretty well over the last several years but may be trending in the wrong direction for reasons that are unclear.[28]

It is reasonable for industry advocates to note that longer and heavier trains have more cars that may be problematic. They will challenge switch points more frequently that shorter trains, and they can expect at least the same experience with track anomalies. Fewer trains may also reduce conflict with motor vehicles at highway-rail crossings (though that has yet to be demonstrated on a practical level).

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[24] Hunter Harrison had previously used elements of this strategy on the Illinois Central, and of course he had previously been an officer on the Burlington Northern.

[25] "Mid-Track Train Derailment, Canadian National Train Number M36231-20, Brighton, Ontairo, March 21, 2009" (Railway Investigation Report R09T0092).

[26] . "Main Track Derailment, Canadian National, Freight Train G84042-09, Nickel Lake, Ontario, Nov. 10, 2013" (Railway Investigation Report R13W0257).

[27] The bulk of the CN and CP networks is in Canada, which employs a safety reporting system not directly comparable to the U.S. For the Field Hill B.C. (Yoho) derailment report, go to http://www.bst-tsb.gc.ca/eng/enquetes-investigations/rail/2019/R19C0015/R19C0015.html

[28] *See* Stevens, Bill, "Going Long: BNSF Railway jumps on the long train bandwagon, but with only one foot" (*Trains*, November 2021).

The question is whether that's all that is going on, or whether in-train forces (always an issue in railroading, as discussed above) are not being properly managed. To determine that, particularly given the reporting system, it is necessary to examine performance at a more granular level.

Consequences and Probabilities

The author has reviewed recent train accident data, with emphasis for this paper on the period 2018-February 2022. Examples drawn from the raw data and accident investigations, described in Appendix B, include accidents caused by—

- Train make-up in violation of carrier standards or without reference to those standards
- Train make-up that was in accord with carrier standards, leading to changes for the entire railroad or the subdivision, or resulting, so far as we know, in no change
- Train handling, but with significant question about the reported cause based on the circumstances
- Failure of TEMS system to properly control in-train forces
- Combination of train handling and train make-up
- Based on the railroad's accident report (FRA Form 6180.54), undetermined factors, ambiguous factors, or still under investigation
- Loss of communication between head end and EOT or DPU
- Use of hand brakes to control speed on a downgrade after the train stalled out
- Excessive axles of dynamic brakes for train tonnage; and
- Mechanical or track defects that may very well have resulted from excessive in-train forces

Engineering insight: In the case of track defects that may have resulted from in-train forces, a recent engineering presentation called attention to the effect of rolling resistance on the build-up of heat in the rails, contributing to the potential for "sun kinks" (misaligned track)—*a factor that increases with train length and weight*. Gary Wolf, "Essential Strategies for Derailment Elimination in Today's PSR Environment" (power point presentation, William Hay Lecture, University of Illinois Urbana Champaign, p. 23, April 2021).

Most of these accidents resulted only in railroad property damage, so far as we know from the reports on file. Where available, local media often adds detail, including emergency response, blocked grade crossings, highways shut down, Amtrak delays or nullification, and so forth. Other categories of cost are listed above (p. 19); however, beyond the railroad damages required to be reported, dollar values are usually unknown.

However, a number of these events involved damage to hazardous materials (hazmat) cars, evacuations, and casualties.

After more than three years of careful study, NTSB reported on the CSX *Hyndman, Pennsylvania* derailment of August 2, 2017 (Item 5, Appendix B), which resulted from a litany of errors caused by a stalled train that was likely too long and heavy, as configured, for the route. The accident derailed 32 cars. It cost the railroad $2.2 million plus wreck clearance, as well as $1.5 million for remediation and clean-up. The accident caused the evacuation of 1,000 people, destroyed or damaged two homes, and cost $5 million in emergency response. The accident punctured a propane car and a molten sulfur car, causing a fire that persisted for days.

The UP rear-end collision at *Granite Canyon, Wyoming* on October 4, 2018 (Item 11) resulted in fatal injury of two crew members, as well as $3.2 million in damages. The 12,147-ton train ran away on a grade when a kinked air hose obstructed the brake pipe and the locomotive could not communicate with the EOT device. The railroad responded by installing a large number of "repeaters" after surveying the territory and realizing that loss of "comm" was a frequent problem.

A UP switching incident at *Dupo, Illinois*, on September 10, 2019 (Item 27) involved a movement to assemble a train of four locomotives and 183 cars. The 140-car cut was being shoved during the marshalling process and derailed 14 cars, puncturing a flammable liquid tank car and resulting in an explosion and fire. Some 1,147 people were evacuated initially, and when the fire spread underground through a storm drain, it ignited the holding pond next to a chemical plant. At that point, 1,011 students were evacuated from a local school.

The NS accident at *Perry (Hayneville), Georgia*, on October 9, 2019 (Item 28) involved a train equipped with a TEMS[29] in automated mode, controlling the throttle and brake. The FRA report indicates that the railroad was having trouble with TEMS trains producing undesired emergencies over the territory. In addition to $5 million in damages ($6.5m in the updated NS report), the derailment resulted in the rupture of natural gas pipeline, releasing 2.3 million cubic feet of natural gas.

On March 4, 2021, an NS train with either 2 manual locomotives or 2 DPUs mid-train (the report says both) and either 8,461 trailing tons or 12,928 trailing tons (the report says both) derailed near *Front Royal, Virginia*, resulting in damages of $1.2 million (Item 50). ***Only by referencing a local news account do we learn that a worker involved in the wreck clearance operations was fatally injured.*** It must be emphasized that most wreck clearance and remediation activities are inherently hazardous, and casualties may be credited to industrial activities by the contractors employing the workers.

On May 16, 2021, a UP train derailed 15 loads and 32 empties near *Sibley, Iowa*, resulting in $3.4 million in railroad damages, release of product from 9 hazmat cars, and a significant fire

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[29] This was Trip Optimizer (TO), the GE/Wabtec product, even though NS crews may be more familiar with LEADER.

which was allowed to burn out over several days (Item 61). Local news reported a precautionary evacuation of "homes and businesses", but the railroad's report did not indicate that any persons were evacuated.

On June 24, 2021, a 20,331-ton UP train derailed 27 cars in *Ames, Iowa*, with $2 million in railroad damages (Item 66). From local media reports, there was a concern that LPG had been released, and 12-15 residences were evacuated.

On June 28, 2021, an NS train derailed 33 cars near *Royalton, Pennsylvania*, with 18 hazmat cars damaged or derailed, but with no release (Item 67). The potential for release of hazmat brought 12 state and local agencies to the scene. The railroad's initial and most recent report to FRA contained notably contradictory information on trailing tonnage and locomotive configuration, but the railroad did confess improper train make-up at the initial terminal.

These are the more prominent examples of the consequences flowing from a failure to manage in-train forces. We skipped the two derailments on the Horseshoe Curve from the same cause in a single month, the two derailments in downtown Roanoke at virtually the same location within 12 months (with security cameras rolling), and other interesting examples that the reader can pursue in Appendix B.

The point here from the standpoint of consequences is that they will depend on circumstances not anticipated when the train is built. Catastrophic consequences are probable at some point, but the risks are stochastic.[30] We know the potential, so we should not wait for event to take action.

The overall lesson we draw from the data is that, when it comes to management of in-train forces, major railroads continue to experience problems with trains of "normal" size (e.g., manifest trains of ~80 cars, unit trains of 100-110 cars, smaller trains over heavy mountain grades). Those problems become predictably worse when even longer and heavier trains are marshalled.

One of the major tactics for PSR railroads is running trains just as long as needed to handle the available traffic. A good-sized train is expected to pick up a good-sized cut at the next terminal in the forward direction, and perhaps the next and the next, until the train reaches its ultimate destination or interchange. Yard crews and supervision are cut to the bone, because switching cars is disfavored. What this means in practice is that assembling a train is an awkward exercise, and train make-up rules are likely to be ignored. If the crew is unable to get a DPU identified with the lead locomotive, it may be left behind. Although a DPU might best be placed mid-train, if it's easier to put it at the back, so be it. If the train pulls apart enroute, in most cases that's not a reportable event, and no lesson is learned. If the TEMS is not working properly on the territory, cut it out. If there is a requirement to pick up cars at an industry enroute, and the train is already quite big, blame the crews for any problems.

[30] "Stochastic" is a description that refers to outcomes based upon random probability.

Context: Modern railroads have long maintained instructions for braking systems, train make-up and train handling. However, as the data points presented in this paper illustrate, they have not always followed the instructions. As train consists have become heavier, longer and more diverse (with conscious movement away from use unit trains in some cases), former guidance has failed to constrain in-train forces. Some railroads have stayed on top of these issues more than others, using proprietary systems to cabin risk during train marshalling. *See* Yi Wang et al., "Multiscale Simulation-Based Mixed Train Derailment Analysis: A Case Study," JRC2021-58311 (April 20-21, 2021). Some may be scrambling to catch up. *See* Jeff Stagl, "For UP, More is More," *Railway Age* (March 2021), p. 8.

Before long, railroads will want to be trusted to fully automate their operations. They argue that autonomous truck-trains will soon appear on the highways, and they need the same flexibility. This kind of reasoning, of course, could lead to progress; but it could also lead to the lowest common denominator in terms of surface transportation safety—or worse.

FRA must hold the railroads to basic good practices in the application of current, service-tested technology. Railroads must be required to justify the application of technology that is not fully fail-safe to safety-critical operations.

Importantly, railroads need to implement sound braking technology before any thought of moving to ATO. The discussion of ECP brakes, below, further explains why.

So, What Do We Need to Do?

The first step here is a decision, in the Executive and in the Congress, to tackle the problem. The dimensions of the problem are well understood within the industry, at least at the working level. Regardless of the source of initiative, the general direction that needs to be taken is clear:

1. Regulations are required to place countervailing pressure on railroads, balancing the extreme expectations of the financial markets to produce rivers of cash to the bottom line for short-term gain. This balance can be accomplished with limits that are essentially performance-based, giving significant latitude for creativity and innovation when the physics and human-machine integration are sufficient.

2. The agencies responsible for judging outcomes, chiefly FRA and NTSB, need to redouble their efforts to determine the performance of the train operation system, as a whole. That will require further refinement in accident investigation protocols and greater clarity in calling out deficiencies in the system.

3. Railroads must be held to the standard operating procedures that they establish, subject to FRA review and disapproval when basic metrics are omitted or outcomes are wanting.

> Intermediate measures of success will need to be monitored—not waiting for the catastrophic event that portends years of legislative and regulatory struggle before remedies are in place.

This sounds simple. Of course, it is not.[31] But it is achievable, and now overdue. We often discuss transportation of liquified natural gas, crude oil, ethanol, poison inhalation hazards or flammable compressed gases as if these were entirely discrete problems; and certainly, they have their own dimensions in terms of packaging, emergency response, etc. But the overarching issues of safe infrastructure, well-designed and maintained equipment, and proper "command and control" apply to all of these. Crew and community safety are implicated, as well, with or without involvement of hazardous materials.

What is *not* warranted is further study by an expert body comprised of "experts" with no skin in the game because they really have nothing to do with railroads. That path has already been explored, and has led only so far.[32] FRA is conducting research that should be helpful, but not sufficient (Appendix E).

The requisite knowledge of these issues resides only among the regulatory agency, the railroad industry, the supply industry, and rail labor. FRA and its RSAC partners need to sit down and get this done. If they can't reach consensus, FRA should issue appropriate requirements forthwith.

Railroads will explain that this will cost more than the benefits support, but this will be disingenuous. Railroads are returning billions of dollars to shareholders every year, and the major fear among those watching closely is that they are pushing PSR too hard. They are succeeding for now with very low operating ratios but setting themselves up for leaner times ahead. They are creating a climate in which new business is discouraged while shedding existing traffic that is impossible to retain using the current "service" model.

This is a dynamic situation. Railroads need to be able to plan and execute "precisely" if they are to succeed over the long term. That includes operational planning and execution—including keeping trains out of residents' back yards. It means staging technology that was properly vetted before it is relied upon. It's good business, and good stewardship of franchises that flourish from a financial standpoint because they have significant market power.[33]

Should the railroad industry not agree this is prudent because of the "costs," inquiry could be made to shippers whose supply chains have been disrupted by the delays and derailments associated with PSR.

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[31] Transport Canada may have a considerable head start. *See* Liu, Y., et al., "Development of Guidelines for Safe Operation of Long Trains in Canada," International Heavy Haul 2015 (Perth, Australia).

[32] "Freight Trains Are Getting Longer, and Additional Information Is Needed to Assess Their Impact," GAO-19-443 (May 2019).

[33] Major railroads have been left largely unchecked from a legal/regulatory point of view. Certainly, they are constrained to some extent by geographic and product competition, but there is little head-to-head competition among the Class 1s. The Surface Transportation Board's mandate is limited, and that is fine as long as the railroads act like they wish to serve customers, as well as short-term investors.

The Biden Administration should welcome the chance to address this need.[34]

What are the Elements of the Regulatory Response?

The first action FRA needs to take is to mandate adherence to existing carrier rules and instructions governing the subject matter. This could be done by emergency order (not recommended) or through an expedited rulemaking. FRA would need to specify adherence to rules and instructions in place as of a fixed date prior to any proposal (e.g., January 1, 2021) to avoid "dumbing down" pre-existing requirements in reaction to the initial proposal. Obviously, the carriers would be free to implement improvements simply by notifying FRA; and FRA could disapprove any changes deemed to involve a reduction in safety after an inquiry.

The elements of a more robust regulatory response should be tailored to the need, of course. It should rely where possible on strategies that track performance, provide flexibility to fit the circumstances, and lead to programmatic adjustments within the structure of the regulations (e.g., automatically within the structure of the regulations or through "special approval procedures" as incorporated in a number of FRA regulations). Here is an estimate of the needed elements:

1. ***Top-level principles and metrics*** that set standards for evaluation of railroad plans. They should address such basic issues as:

    - The requirement that systems used to brake trains have sufficient fail-safe characteristics to limit train speeds *to designated maximums* and to stop short of targets on the route, *without creating the possibility for depletion of train line air pressure due to successive applications in blended braking.*

    - The requirement that trains marshalled by weight and/or length with reliance on remote devices accessed only by telemetry (DPUs, EOTs) be supported by *adequate data radio links* (signal strength, receptivity of devices), with sufficient supplementary data paths as needed based on the geography of the route and the length of pertinent train segments.

[34] See, e.g. Executive Order 13992 (86 FR 7049; Jan. 25, 2021); Presidential Memorandum on "Modernizing Regulatory Review" https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/modernizing-regulatory-review/, and Sunstein, C.R, "On Neglecting Regulatory Benefits, *Administrative Law Review*, Vol. 72, No. 3 (Summer 2020).

> **Update:** Loss of communication with mandated EOTs, in particular, has been known to be a problem in certain territories, and PSR has accentuated the problem. Recently, in unrelated research at the FRA, several railroads attempted to maintain communications with EOTs, on routes of their choosing, for test purposes, using the standard 900 MHz data radio setups employed for EOTs. The result was a conclusion that, beyond about 0.8 miles, communication loss was sufficiently serious to challenge the integrity of the program being tested (positive train location, front and rear). Many trains operated today under PSR exceed this length. [See "Positive Train Location—Supporting Next-Generation Methods of Train Control and Operations," William W. Hay Engineering Seminar Series, University of Illinois Urbana-Champaign, April 30, 2021.]

- The requirement that trains be built to limit buff and draft forces so that equipment will not be subject to excessive impacts or stresses and that, over the intended route, excessive lateral forces will not be generated.

- The requirement that all systems used to perform safety-critical functions without direct intervention or continuous oversight by trained and skilled crew members be shown to be sufficiently robust, accurate and reliable to substitute for experienced, qualified personnel before they are deployed in the field.[35]

2. ***Railroad plans*** that bring together the elements of major carrier documents like power brake rules, train make-up rules, operating procedures and the like as adapted to the territory. For simplicity, perhaps call them Train Operation Plans for Safety (TOPS).[36] A major railroad might decide to have TOPS for each of its subdivisions, taking into consideration—

   - The types of trains operated over the territory. (A territory with mostly unit coal or grain trains and a few local trains switching industry could be subject to a much simpler plan than a trans-continental route with all sorts of traffic. Allowable tonnages and train lengths are also salient factors.)

   - The physical characteristics of the territory. (Think of grades, curves, turnouts to sidings, industries, extremes of weather, crew change locations, etc. In addition, security of voice and data radio communications, including supplementary telemetry to support EOTs and DPUs.)

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[35] This was supposed to be addressed by Subpart H of the signal and train control regulations (49 CFR Part 236, Subpart H). The requirements appear to have been ignored by FRA and the railroads, although there may have been waivers issued over the last decade that the writer missed. As the writer left the field, the agency had conceded that TO could be used to operate the throttle over the road subject to override by the engineer. It was made clear that Subpart H would need to be satisfied if there was any thought of touching the dynamic or air brake. The writer does not doubt that Subpart H is quite strenuous in its requirements. How it got that way would be the subject of another White Paper.

[36] A commenter on Revision 1.0 noted that the Southern Pacific Transportation Company used "TOPS" for its "Total Operations Processing System." The writer was not aware of this previous usage. Presumably such rail spirits as may still haunt the building at 1 Market Street, San Francisco, will forgive us this unintentional appropriation.

- The method of operation, to the extent it includes a system for limiting train speed (assuming available braking capacity).

- Qualifications of personnel, to the extent they differ within the territory. (For instance, in joint operations where an operating railroad may receive foreign units positioned as controlling locomotives, crews should be fully qualified to interface with electronic systems on board before being called for duty.)

- Limitations on tons per operative brake and specific dynamic brake requirements, tied to MAS over the specific territory (and intended train handling strategies).

- Requirements to secure hand brakes on stalled trains, etc.

- *Special requirements for cold weather operations.*[37]

- Other special instructions.[38]

To emphasize, many if not all of these provisions will already be in place in the lengthy instructions already published. Clearly, there are many subdivisions (or other track segments) for which the TOPS could be pretty standard. So those might take "TOPS A." The idea is not to repeat whole rule books, but to bring everything together in an acceptable manner for the type of operation.

[37] Cold weather operations can extend as far south as south Texas, as recent events have illustrated. North American railroads have not always mastered these challenges, even when they were fully expected.

[38] In the past, mention of retainers, which are designed to hold pressure against the wheels when manually set, would be appropriate here. They were formerly used in mountain grade territory to ensure against run-away trains. Retainers are still available, but are not used by Class I railroads in the U.S. (so far as we know) because of the inefficiency associated with setting and releasing them at the top and bottom of the grade, on each car.

Update: A highly experienced commenter on Revision 1.0 of this paper offered the following suggested requirements, emphasizing that tailored, railroad-owned plans would be superior to prescriptive requirements issued by FRA:

a. Tonnage ratings for each district for each class of loco
b. TPOB [tons per operative brake] for each district
c. Maximum number powered and DB axles per loco class
d. Definitions of:
   i. Long car
   ii. Short car
   iii. Empty spine platform (empty/loaded container question)
   iv. Empty doublestack platform
e. Maximum train lengths
f. Maximum train tonnages
g. Instructions on placing contiguous blocks of loads and empties, say over a block of 20 cars together
h. Maximum block size of coupled commodity cars
i. Mass distribution limits in each quartile of the train
j. Maximum tonnage behind a long car/short car combo
k. Maximum coupled EOC equipped cars
l. And others too numerous to mention

Again, the goal of the TOPS would be to ensure secure handling of the train from the point of view of motive power and braking, such that the train is handled in accordance with authorized speeds for the category of train, the buff and draft forces within the train are limited to acceptable levels, and no unacceptable lateral coupler forces are generated as a result of poor marshalling.

In preparing each TOPS, the railroad should review its rules and training of crews such that excessive reliance is not placed on use of dynamic brakes under circumstances where train brakes are essential to safely negotiate grades, and where use of air brakes to keep trains stretched are required to moderate in-train forces.

Update: Comments on Revision 1.0 of the paper emphasized that, where safe and practicable, sole reliance on dynamic brakes is preferred to avoid the inherent limitations of air brake systems, including fuel consumption, equipment wear, the increased potential for undesired emergency brake applications, stuck brakes, etc. The intent of the writer is not to dismiss train handling strategies that emphasize use of dynamic brakes, but to question whether in some instances this emphasis is pressed too far.

As experience in aviation has taught, introduction of technology does not reduce the need for effective training of crew members entrusted with decision-making for the operation of transportation systems. Rather, the need for training is increased. Crew members need to know how systems on board function, and they need to become familiar with those systems before they begin operations over the road. Training must include how to respond to system failures and unusual circumstances. If crews are required to cover a variety of territories or operate foreign line equipment, they need to know what systems will be relied upon and any variations in expected applications.

3. ***Performance measures*** would include train accident metrics, of course. However, in this regard it should be noted that a number of pitfalls will be involved:

- As noted above, catastrophic accidents have a likelihood of occurrence usually described as "stochastic." A derailment or collision involving failure to manage in-train forces may typically be disruptive, but there is the potential that it will be catastrophic. In good safety practice, this is a risk we cannot attach a firm statistical probability to, but we know it is possible. In the case of railroad accidents, we do not have to imagine what can happen. Our preliminary hazard analysis might rate the frequency of high consequences being low for any average event, but the severity of an event once it occurred could certainly be catastrophic. This is why high-hazard industries deserve close attention.[39]

- For more typical events, accident reporting must become more transparent with respect to management of in-train forces. It might be all well and good, for instance, to report that the derailment was caused by a truck trailer high-centered on the crossing. However, if that led to more serious derailment than would otherwise have occurred because the train was not configured in accordance with the train make-up element of the TOPS, we would need to know that too.

- The response to an obvious misstep needs to become nimbler. If an accident involves a violation of the TOPS or a clear deficiency in the TOPS, remedial actions need to be prompt; and a report should be provided to FRA.

4. Because accidents are lagging indicators of safety risk in the system, ***intermediate performance measures*** will also be required.

- Unacceptable in-train forces (excessive buff or draft forces) are most likely to result first in (i) equipment damage, which from an inspection standpoint may either be latent or difficult to trace to an over-the-road event or (ii) train separations (sometimes referred to as "pull-aparts" and signaled by an emergency brake application). Every traceable event should be recorded in the TOPS tracking log, and supervision should be responsible to determining the cause (initially, perhaps, by reviewing the event recorder data; as needed, asking for a TOES run).

- Trains can stall on ascending grades because of insufficient power or brakes far back in the train that will not release. These need to be logged and examined.

- Trains can become unstable from the point of view of braking on downgrades, and crews may find the need to stop and set handbrakes. To the extent this is a matter of a simple

[39] There is a good discussion in "Designing Safety Regulations for High-Hazard Industries," National Academy of Science, Transportation Research Board, Special Report 324 (2018).

leaking air hose replaced by the conductor, that can be logged and referred to the mechanical department. To the extent air flow or gradient issues have arisen that interfere with the normal operation of the train, the problem should be carefully followed up. (A train so unwieldy that it cannot be recharged and handled safely down a grade, without use of hand brakes, should never be dispatched.)

- With or without PTC active on board and responsive to the wayside, overspeed events need to be addressed. This may be a matter of crew inattention, failure of an automatic system controlling the throttle and dynamic brake, or a poor decision to discourage use of the air brakes given train make-up. These events need to be logged and examined.

5. ***FRA oversight*** is critical. Today, trains are being marshalled that present unacceptable risks. From the accident records reviewed it appears that authorized speeds on some grades can be reliably observed only by reliance on both the air brakes and dynamic brakes (as opposed to the train air brakes alone, as should be the case).[40] TEMS are being relied upon without rigorous field testing to ascertain their limitations. To the extent crews become excessively reliant on these systems and then find themselves, occasionally, on territories where the systems have to be cut out, the risk of deskilled crews making mistakes is present. FRA needs to provide consistent oversight, reviewing accident records, TOPS logs, and responsive actions. Railroads need to get report cards, and if necessary, more stern reminders.

It may be argued that there are many judgments involved here upon which we don't all agree, and perhaps that's so. However, the railroads need to agree among themselves (most have extensive agreements for joint use), and FRA and the railroads need to agree as well. It will not do for railroads desperate to drive cash to the bottom line to sacrifice safety, and they need to be checked. Railroads already operating with more discipline should have little to complain about.

Simultaneous with initiating the rulemaking advocated immediately above, FRA will need to commence a rulemaking to revise its Accident/Incident Reporting Guide to capture more completely and clearly the dimensions of the issues under study here.

Update: As suggested by a commenter, FRA should include a requirement that simulation analysis be performed, and results reported, for significant events where management of in-train forces may have been a factor. That should include any accident designated by FRA on review of the filed accident report.

[40] A colleague who investigated the event for FRA cites the NTSB for the lesson: "No reliance cannot be had on the effect of the dynamic brake in controlling the speed of a train on a downgrade. The dynamic brake is not a fail-safe system. If a train exceeds a speed in a downgrade that requires more than 26 horsepower per wheel to maintain that speed, and the dynamic brake should fail, the train WILL run away on the grade. The wheels and brake shoes can only dissipate heat at or below that rate. Exceeding it will cause the wheels to overheat and the brake shoes to burn off." NTSB RAR 90/02, Southern Pacific Transportation Co., San Bernardino, CA May 12, 1989.

Why not Risk Reduction?

Major railroads will respond that they will be doing all of this, albeit not in the same form, under the "new" Risk Reduction Program,[41] which was mandated in 2008 and only now is coming on line. There are three basic reasons not to leave it there.

First, implementation of a safety management system (same essential concept as an RRP) is left largely to the railroad. The idea is to tease out risks that are not well understood, at which point the railroad may elect to "accept" the risk or mitigate it. Management of in-train forces at the scale discussed in this paper is, *per se*, fraught with unacceptable risks. There should be a floor imposed by minimum standards, below which the railroad may not go.

Second, addressing these issues wholly within the framework of the RRP will lack the necessary transparency. Under an RRP, the railroad will undoubtedly treat the RRP and implementing hazard analysis, remediation programs, etc., as confidential business information. FRA has said it will release RRP information only under what will undoubtedly be very narrow circumstances.[42] Railroads unhappy with FRA for proposing to release information will feel free to sue, alleging that the information is confidential, subject to treatment as Security Sensitive Information, or otherwise barred from release. Given the broad policy language that FRA has included in its RRP final rule, the agency may be "hoist[ed] with [its] own petard." Without a separate regulatory mandate, the fact that the public will lack access to key documents would only heighten the likelihood that railroads will continue to lack discipline in managing these risks.

Third, by law and regulation, evidence derived from an RRP will be inadmissible in an action for damages against the railroad. Now, this writer is not a big fan of the idea that large corporations structure their business to avoid liability. However, the fact remains that if a major accident occurs that involves harm to a railroad employee or a member of the public, all of the underlying facts need to be available to determine whether the harm was foreseeable and, indeed, whether under standards of the railroad's own program the railroad was grossly negligent. This may not be required to assign liability; but, for sure, it will be pertinent to exemplary damages (and, for employees, the value assigned to pain and suffering).

Let me emphasize that this need not wall off management of in-train forces from analysis and evaluation under an RRP. But once we have a TOPS accepted (or not yet disapproved) by FRA, adherence or deviation should be discernable from records maintained through FRA oversight.

[41] 85 FR 9262 (Feb. 18, 2020); 49 CFR Part 271.
[42] Ibid, 85 FR 9263.

Why ECP Brakes?

Railroads and suppliers have worked on the concept of ECP Brakes since the mid-1990s and completed a standard supported by an FRA-funded safety analysis in 1999. During his time as a regulator, the writer commissioned the Booz Allen Hamilton ECP brake report (August 2006), which was founded on analysis reviewed by an expert industry panel. Thereafter, FRA created regulatory incentives for introduction of ECP Brakes,[43] and the George W. Bush Administration made a major effort to encourage the deployment of test trains in revenue service to demonstrate the viability of the technology. Initial results were very positive, but the railroads involved declined to participate in data collection that might have illustrated the economic as well as safety benefits of the systems, even though the Transportation Technology Center Inc.[44] had provided a data collection protocol.

Over time, impetus was lost, and the issue did not recur until FRA and PHMSA sought to fashion special safety requirements for certain "high-hazard trains," such as those transporting large blocks of crude oil or ethanol cars. FRA's attempt to include ECP Brakes in the requirements was opposed by the rail industry, and the Congress mandated a National Academy study to resolve a narrow issue presented in DOT's cost/benefit analysis, i.e., the extent to which ECP brakes mitigate derailment consequences after an emergency application of the brakes had been initiated. The NAS committee was unable to resolve the issue outright, but suggested further analysis, test rack exercises, and field tests that might prove dispositive.[45] The NAS findings were received by some as having undermined the ECP requirement. Meanwhile, tank cars were being retrofitted and built to new, more robust standards. Accordingly, FRA/PHMSA withdrew the requirement.[46]

Meanwhile the NTSB completed its report on the Granite Canyon collision, which cited the 2006 ECP report at length and stated that, had the striking train been equipped with ECP technology, the accident would have been prevented.[47] Curiously, NTSB has yet to recommend the introduction of ECP technology by regulatory or voluntary action.

In conjunction with DPUs, good marshalling practices, and good train handling, ECP brakes can respond to virtually all of the shortcomings of current braking strategies. The Booz Allen Hamilton report and the industry's own briefing materials explain how. This is territory that needs to be revisited, with a view toward applying ECP brakes first to unit trains (high hazard trains, intermodal trains) and then (if necessary, by "overlay") to the general fleet.

There is another argument for ECP brakes that is seldom expressed directly. Advocates of ECP brakes have hesitated to open this discussion, largely out of respect for railroads' status as victims of highway-rail crossing accidents and other obstruction accidents involving events beyond their control. Further, there is legitimate anxiety that the point will be overblown.

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[43] 73 FR 61512 (Oct. 16, 2008); 49 CFR Part 232.

[44] Wholly-owned subsidiary of the Association of American Railroads.

[45] "A Review of the Department of Transportation Plan for Analyzing and Testing Electronically Controlled Pneumatic Brakes," National Academies Press (February 2017), available at http://nap.edu/24698.

[46] 83 FR 48393 (Sept. 25, 2018).

[47] "Collision of Union Pacific Railroad Train MGRCY04 with a Stationary Train, Granite Canyon, WY, October 4, 2 018," NTSB/RAR-20/05 at 33-34.

Nobody wants to make the situation worse for the railroads, but they have had over two decades to move forward on ECP brakes, and the transition will take another decade or two. Perhaps it's past the time to pull punches.

The point is this: with ECP brakes, some crossing and obstruction accidents, and some trespassing incidents, could be prevented or mitigated in severity. The writer is not aware of any quantitative risk assessment that has been conducted on this point, but that should occur.

As background, locomotive engineers are reluctant to call on train air brakes for an emergency application, because they can sometimes cause derailments (and are more likely to do so when the train is stretched, a common case when approaching crossings). Further, if the vehicle clears after the emergency application has been made, the train air line has been emptied anyway ("vented to atmosphere"). That means the train will stop and long delays will ensue (often with multiple crossings blocked) while the train is inspected, hand brakes are set if necessary, the air brake system is recharged, and any hand brakes are released.

Consider—

- In the anxious seconds a locomotive engineer is likely experiencing while viewing a motor vehicle on a crossing some distance ahead, the most likely scenario by far is that the vehicle will clear the crossing before the arrival of the train.

- In those cases where the engineer becomes concerned that the vehicle might not clear the crossing, but the outcome is not certain, the most effective step that can be taken is to slow the train by backing off the throttle and using the train brakes in service mode.

- ECP brakes in service mode reduce stopping distances by up to 60%, depending on such factors as tonnage, grade, etc. That is because the brake valves on all of the cars are activated quickly (speed of light) and at once. Use of ECP brakes in this scenario will substantially reduce collision forces, even if it becomes necessary to invoke an emergency application should it become evident that the vehicle will not clear.

ECP brake systems will operate in graduated release (rather than direct release) and charge the brake pipe and air reservoirs continuously. That means that an engineer is able to modulate the brakes at will without stopping to charge the train or concern for "running out" the air supply. All this can happen without inducing significant in-train forces (buff and draft) that has led to many a derailment with conventional brakes.

There is, of course, controversy over the relative advantage of ECP brakes in stopping a train in emergency mode, vs. an emergency application of today's automatic train brakes. However, the better argument here is that the ECP train will stop in up to 20% less distance than conventional brakes. As demonstrated in the few cases available, ECP trains will also stop more uniformly (with less chance of derailment). So, if our locomotive engineer in the example above needs to go to full service or emergency on an ECP train, the engineer will be able to do so with greater confidence. Further, even with an emergency application (commanded through the electronic train line), there will be no need to empty the pneumatic train line, so recovery will be faster.

Railroad crew member safety could also be enhanced with ECP brakes. Consider the case of a train crew with reasonable preview of a crossing where a heavy truck (trash or concrete truck, propane tank truck, gasoline truck) appears to be stalled or stored on the crossing. Employees continue to die or sustain significant injuries in these incidents. Again, the proportion of events that might be prevented or mitigated deserves study, but giving the locomotive engineer the confidence to go to the train brake early without fear of derailment would certainly make a difference in some cases.

The same sort of arguments, with nuances, pertain to an engineer who is facing a trespasser on the right of way. Most trespassers clear the track structure after seeing or hearing the train, and some also taunt the train crew up to the point of near collision. If trains are going to get over the railroad, stopping or slowing for trespassers will seldom be an attractive course of action.

However, a train approaching a known area of risk (e.g., bridge over a swimming hole or fishing spot) might give children spotted on the bridge the few seconds more they need to get clear. Railroads ***cannot*** make the right-of-way safe for trespassers, but crews potentially traumatized by strikes involving young or disabled persons would no doubt welcome as many options for avoiding these events as might be reasonable.

The advantage of stopping short of obstructions such as washouts, rock slides and downed trees with reduced chances for a serious derailment is obvious (which will not always be possible either, but might be mitigated).

Again, using ECP brakes approaching a highway-rail crossing where danger is detected, or in the case of what appears to be an imminent trespasser strike, or in the case of an obstruction can only reduce the number of fatal accidents and mitigate the severity of those collisions that cannot be avoided. But how much benefit would be derived, as a practical matter? After all, even passenger trains (with much shorter and tighter brake pipes, and in some cases with electric train lines) are involved in lots of crossing collisions. There are inherent limitations on wheel/rail adhesion. Many vehicles unfortunately enter the crossing, and trespassers enter the right-of-way, long after any opportunity is provided for train crews to react.

The FRA needs to document all of the benefits of ECP brakes, including safety, efficiency, fuel savings and reduced emissions. The benefits studied should also include reducing and mitigating highway-rail crossing accidents, obstruction accidents, and trespasser train incidents, with the full benefit of a quantitative risk assessment.

Appendix D provides a description of ECP brake technology and its advantages.

How Can We Ensure It Will Get Done?

Federal law requires that "[t]he Secretary of Transportation, as necessary, shall prescribe regulations and issue orders for every area of railroad safety supplementing laws and regulations in effect on October 16, 1970 (49 U.S.C. § 20103). This general authority is supplemented by emergency powers. One would think that this would settle the matter, particularly given that railroads are engaged in interstate commerce.

However, these issues are set against a background of renewed judicial conservatism, a conservatism that can only be described as strident and activist, with clear indications that administrative actions, including issuance and revision of regulations under generic statutes such as the Federal Railroad Safety Act of 1970 (as codified), will be given strict scrutiny approaching the days of "non-delegation" and "substantive due process". These were doctrines used for parts of last century to protect business from regulation, and their renewal comes through the "major questions" test.[48]

However, a sufficiently direct mandate from the Congress could limit judicial interference and sweep away some spurious objections related to exercise of agency discretion. The Congress should act to require regulatory action addressing the management of in-train forces.

[48] See, e.g., Sunstein, Cass R., "Who Should Regulate?" (reviewing The Chevron Doctrine: Its Rise and Fall and the Future of the Administrative State by Thomas W. Merrill) (New York Review of Books, May 26, 2022).

Conclusion

Railroads play a critical role in the national economy and have a footprint that touches most of the communities in the contiguous United States. Over the past several decades, economic deregulation, an aggressive embrace of technology, and regulatory compliance have contributed to a much safer industry. However, given the nature of railroad operations and the commodities transported, significant areas of risk remain. Recent events have suggested that excess risk is now tolerated in the system due to economic incentives and lack of regulatory constraints. Consider—

- Financial markets have introduced distortions in Class I railroad behavior that redound to the short-term benefit of investors but fail to confer benefits on employees or customers.

- Over the past decade train accidents, and particularly derailments, have failed to demonstrate a reliable downward slope. Among Class I railroads, significant differences in accident performance have been notable.

- Accidents reviewed for this paper revealed alarming practices related to train marshalling and train operation that have had consequences already for communities and that pose the kind of risk that could result in catastrophic events.

- Railroads are already pushing the phased transition to automated operations for over-the-road trains, and it is clear from the data that they are not ready.

- The regulator, FRA, has begun documenting this unfolding situation through its accident investigations and should be poised to address it.

- Unfortunately, because of unreasonable expectations in the financial markets, railroads will reflexively push back against any meaningful attempt to regulate.

For the reasons stated in this paper, it is important to take the following actions:

- As an interim action, FRA should conduct an expedited rulemaking to require that railroads adhere to their existing rules and instructions governing the subject matter, with provision for adjustments in the interest of safety.

- The Congress should mandate regulatory action along the lines described above, ensuring that industry parties and the public get to play a role but also ensuring that final action is taken without delay. Given the "this too shall pass" attitude of the major railroads, as displayed in the 35-year struggle for PTC (including 12 years under legislative mandate), the Congress may wish to specify particular restrictions that will apply by law in the absence of final regulatory action that has been made effective, say, within 3 years of the legislation's passage. Legislation should specifically direct FRA to consider requirements for the phased implementation of ECP brakes.

- Without waiting for legislative direction, FRA should convene the RSAC in the spirit (and with the format) of interest-based bargaining, to begin addressing management of in-train forces. As the regulator, FRA would of course have the right and obligation to impose action after notice and comment in the absence of consensus.

- Separately, FRA should initiate a fresh study and rulemaking for the phased introduction of ECP brakes.

- FRA should include a specific focus on strengthening the Accident/Incident Reporting System to better capture related events. *Railroads should be required to conduct simulation analysis for significant events that may have involved management of in-train forces, including any events designated by FRA following the filing of an accident report.*

- To support the most efficient and effective regulatory program, the NTSB and FRA should redouble their efforts to document the *underlying causes* of accidents associated with management of in-train forces.

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Appendix A—Acronyms and Abbreviations

AAR	Association of American Railroads
ATO	Automated Train Operation
BNSF	BNSF Railway
CFM	Cubic feet per minute (air flow)
CSX	CSX Transportation
DPU	Distributed power unit, a locomotive placed in the middle or at the end of the train and managed from the controlling locomotive via telemetry
ECP	Electronically controlled pneumatic brakes
EOCC	End-of-car cushioning unit or device
EOT	End-of-train device (also referred to elsewhere as ETD)
FRA	Federal Railroad Administration, U.S. Department of Transportation (USDOT)
LEADER	TEMS from New York Airbrake
L/V	Lateral over vertical, pertaining to forces that may cause wheel climb or rail roll-over
NS	Norfolk Southern Railway
MAS	Maximum authorized speed
PHMSA	Pipeline and Hazardous Materials Safety Administration, USDOT
PSI	Pounds per square inch (air pressure)
PSR	"Precision Scheduled Railroading"
PTC	Positive Train Control
RRP	Risk reduction program (49 CFR part 271)
RSAC	Railroad Safety Advisory Committee
TEDS	Train Energy and Dynamics Simulator (FRA)
TEMS	Train Energy Management System (acronym is the author's, industry sometimes uses just EMS)
TO	Trip Optimizer, the TEMS from GE/Wabtec
TOES	Train Operations and Energy Simulator (AAR)
TOPS	Train Operation Plan for Safety
TRB	Transportation Research Board
UDE	Undesired emergency application of the train air brakes[49]
UP	Union Pacific Railroad

[49] Some have noted that this term has both proper and questionable usages. A UDE can be caused by a malfunction of an emergency valve on an individual car that empties the train line, in which case it is truly undesired. The term is often used, as well, for an emergency application resulting from a train separation, which is an "as designed" action intended make the brakes as "fail safe" as possible. A UDE can result in a derailment if there is excessive run-in and the situation is ripe, but normally the result is that the train stops.

Appendix B – Train Accidents

Introduction: In most cases, the listed accidents were selected initially from train accident records (6180.54s) as filed with the FRA (downloaded 12/21/2020 or thereafter). The author endeavored to search for and review published NTSB and FRA accident investigations for the events the agencies investigated that appeared relevant to the topic. Some accidents remained under FRA or NTSB investigation as this paper was produced.

The listed accidents are neither all of the accidents reported under suspect cause codes nor necessarily those demonstrably resulting from ineffective management of in-train forces. The selected accidents are intended to be illustrative with respect to the challenges presented from the point of view of safety by current practices in train marshalling and train operation.

This White Paper was developed over a period of over 2 years. During that time, some railroad reports have been updated or amended. In March/April 2022, the writer endeavored to capture the railroads' edits in this table. The date below "6180.54" is the date the most recent record was retrieved.

	Event / Sources	Train consist / speed	Consequences	Cause(s)
1	BNSF 11/7/2015 Alma, Wisc. 6180.54 (6/6/2022) & FRA HQ-2015-1094	Loads, empties (total): 58, 54 (112) Power: 3 front Tons:[50] 9,719 Length: 8,188 ft. Speed 28 mph	Train derailed on descending grade when dynamic brakes were applied prior to bunching the train Cars derailed: 25 Damages:[51] $2.1m 75 evacuated, 20K gallons of alcohol N.O.S. released from 5 cars	FRA and BNSF: H-519 Dynamic brakes, too rapid; buffing or slack action, and H-504 train make-up
	Explanation: This was not a particularly long train, but it was a relatively heavy mixed consist. Both air brakes and dynamic brakes were in use. FRA noted "buffing action caused by train makeup" as a secondary cause, account placement of a heavy block of loaded cars behind empty auto racks. The engineer's management of the dynamic and air brakes did not match the sequence in the carrier's rules, but FRA noted that its analysis indicated the engineer was likely fatigued and that this may have contributed to the accident.			

[50] This is reported as trailing gross tons, excluding locomotives under power.

[51] In this table, "damages" refers to *railroad property damage only*, including such items as track and structures damage, equipment damage, and signal system damage. It does not include the cost of clean-up, loss of lading, or consequent delays for freight (and where pertinent) passenger traffic. Damage to non-railroad property and environmental damage are not included in this figure.

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">2</td><td>UP
Malakoff, TX
3/29/2017

6180.54
(4/4/2022)
&
FRA HQ-2017-1196</td><td>Loads, empties (total): 126, 6 (132)

Power:
2 front, 2 DPU--rear

Tons: 15,603
Length: 7,479 ft.

Speed: 46 mph</td><td>Train derailed, beginning at 75th car, on descending grade, with head end coming out of dynamic and rear DPUs in notch 7 [undulating terrain], DPUs fenced

Cars derailed: 38, 5 of which released diesel fuel

Damages: $1.9m</td><td>FRA: H501—train make-up

UP: M599-Other misc.</td></tr>
<tr><td colspan="4">Explanation: FRA's report was useful, and confirmed no loss of communication with the DPUs at the rear of the train (although it was an issue on the subdivision). The report notes: "The undulating grades and multiple curves in the track segment occupied by the train at the time of the derailment, made it difficult to control a train with these dimensions. Examination of the event recorder downloads revealed the Engineer making an excessive demand for power on the rear of the train with near full power pushing and simultaneous heavy braking (approximately 50 percent) at the head-end of train." UP's narrative included the following:
<blockquote>NOTE: THIS INCIDENT IS BEING MODELED WITH THE TOES PACKAGE FOR IN-TRAIN FORCES. THE TRAIN SYMBOL HAS BEEN CORRECTED TO REFLECT THE MPBMX-28. AT THIS TIME, THE INCIDENT WILL BE GIVEN THE M599 CODE UNTIL COMPLETION OF THE MODELING, MRE. 5 CARS SPILLED DIESEL FUEL. AFTER SIMULATION AND REVIEW, THE CAUSE OF THE DERAILMENTIS DUE TO TRAIN MAKE-UP. THE SIMULATION DID NOT HIGHLIGHT ANY TRAIN HANDLING ISSUES AND NO MECHANICAL ISSSUES WERE NOTED. AS A RESULT, THE SUBDIVISION IS UNDERGOING AN UNDULATING TOPOGRAPHICAL REVIEW, WITH OPERATING PRACTICES, TO DETERMINE A BETTER SET OF TRAIN HANDLING RULES GOVERNING THE TERRITORY AND SIMILAR TRAIN MAKE-UPS.</blockquote>
UP TOES analysis apparently confirmed the crew had no chance given the make-up of the train, agreeing with the FRA conclusion. UP was planning train make-up changes for the subdivision. But the meaningless M599 code remains in the database.</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>3</td><td>UP
Mason City, IA
5/18/2017

6180.54
(4/7/2022)
&
FRA HQ-2017-1204</td><td>Loads, empties (total):
121, 25 (146)

Power:
4 front, 1 DPU-rear

Tons: 17,112
Length: 8,590 ft.

Speed: 33 mph</td><td>Empty cars mid-train squeezed off by buff forces from behind.

Cars derailed: 32

Damages: $1.9m</td><td>FRA: H-504 – Buffing or slack action excessive, train make-up

UP: M-599 – Other misc. causes</td></tr>
<tr><td></td><td colspan="4">Explanation: Following TOES/TEDS analysis, the railroad altered train make-up rules for EOCC cars. The useless cause code was never corrected in the database.

Per FRA, “The train make-up was such that most of the empty cars, including the derailed portion, were followed by a group of loaded cars and a DPU locomotive on the rear of the train. This grouping of empty cars equipped with EOCC devices followed by loaded cars and a DPU produced the excess of 300 Kilopounds (KIPs) experienced, which is well over the 250 KIP threshold allowed by UP.” Placement of 42 cars with EOCC in mid-train was cited as crucial to the TEDS outcome.</td></tr>
<tr><td>4</td><td>NS
Pell City, AL
5/19/2017

6180.54
(4/4/2022)
&
FRA HQ-2017-1207</td><td>Loads, empties (total):
107, 14 (121)

Power: 5 front, 1 DPU—rear (but coded as helper in 6180.54)

Tons: 13,207
Length: 6,903 ft.</td><td>Derailed at 45 mph on 1.13% grade; DPU was being operated in “fenced” (independent) mode contrary to NS rules; DPU squeezed off cars 78-109 on curve

Cars derailed: 30

Damages: $1.7m, release of hazmat with minor evacuation

Amtrak train delays</td><td>FRA: H503 – Buffing or slack action excessive, train handling.

NS: H503</td></tr>
<tr><td></td><td colspan="4">Explanation: This was a heavy train being operated at significant speed on a significant downgrade, with derailment on a curve. Although a DPU was provided, it was evidently not throttled back after the lead locomotives were placed in dynamic braking. FRA’s report does not specify whether TEMS coaching was provided to the crew, nor does it provide detail regarding use of air brakes. There were 5 locomotives up front: were there too many axles of dynamic brakes cut in? Was communication (telemetry) between the head end and the DPU continuous?</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
5	CSX Hyndman, PA 8/2/2017 6180.54 (4/7/2022) FRA HQ-2017-2018 NTSB/RAR/20/04	Loads, empties (total): 128, 50 (178) HazMat cars: 70 Power: 5 front (2 in tow) Note: From the FRA report, a helper locomotive had pushed from the rear until the train crested the grade and began its descent. Tons: 18,252 Length: 10,612 ft. Speed: 24 mph (per FRA)	Train stopped on grade due to air brake leak. Second crew dragged train with 33 hand brakes set until derailment beginning at 35th car. Cars derailed: 32 (3 releasing HazMat) Damages: $2.2m, ~1,000 evacuated due to propane and molten sulfur release and fire, 6 injuries per CSX report (6180.54). NTSB reported slightly lower damage and no injuries, with three homes damaged. FRA noted two homes destroyed, calculated railroad damage at ~$2.2 million. Lost lading was $650K, local property $250K, response $5m, and remediation and cleanup $1.5m. Amtrak trains bussed for several days.	CSX: H019 – Failure to release hand brakes on cars FRA cited E67C (built up tread) and H019 as contributing NTSB found inappropriate use of hand brakes and placement of blocks of empty cars at front of consist, etc.

Explanation: The NTSB report was issued 11/23/2020, over 3 years and 3 months after the accident. It ignores the larger issue (pun intended) of train length and the absence of mid-train distributed power to assist in maintaining brake pipe pressure without resulting in excessive air flow and gradient, the factor that apparently led to the initial stop and subsequent reliance on hand brakes. Rather, the Board relapses into a general discussion of risk analysis and safety management.

Comment: Contrary to the Board's implication that a risk reduction program would have led to an identification of the risks attendant to this train movement, the risks involved were already well understood in the railroad industry (not *just* by the train crews, although clearly by them, as noted).

On first impression, the writer had provided the following:

> From the account in the NTSB report, FRA report and docketed materials, it appears to the writer that this accident was ordained by poor train make-up (including too long and heavy for a ~2% grade) and the carrier's failure to provide a DPU mid-train to assist in maintaining brake pipe pressure and provide additional checks on in-train forces. Minor specific leaks contributed to the unreliability of the air brake system, causing the first crew to stop on the grade and the second crew to utilize hand brakes to negotiate the grade, resulting in wheel tread build-up. Train make-up, with 90% of the tonnage behind 42 cars at the front, of which 36 were empty, may also have contributed; but FRA did not analyze this factor.

Update: One commenter on Revision 1.0 indicated that, at the time of the derailment, in-train forces were likely unexceptional. The commenter further noted that there was insufficient explanation in the official reports to explain why the first car derailed.

	Event / Sources	Train consist / speed	Consequences	Cause(s)
6	CSX Atlanta, GA 10/5/2017 6180.54 (4/4/2022) & FRA HQ-2017-1231	Loads, empties (total): 68, 129 (197) Power: 3 front Tons: 12,911 Length: 12,420 ft. Speed: 15 mph	Derailed beginning at 60th car (empty) on 1.2% grade with slight curve and turnout, at 2:48 a.m. Cars derailed: 14 Damages: $245K Derailed car struck residence, 1 injury to occupant (non-fatal)	FRA: H503—Buffing or slack action excessive, train handling; and H504—Buffing or slack action, train makeup CSX: M405 – Interaction of lateral and vertical forces
	Explanation: This was a very long and somewhat heavy mixed manifest train with no DPUs (apparently typical for CSX during the period). FRA noted that of the 12,911 trailing tons, 10,429 trailing tons was behind SOXX 5950, the first car to derail. The sequence of commands from the locomotive involved releasing air brakes after a stop at 2:37 a.m. and relying on dynamic brakes to slow the train as it descended the short grade—resulting in a run-in that took 19 seconds to reach the locomotives. FRA noted that the engineer was likely affected by fatigue, which could have affected his judgment in handling the (very difficult) train. Comment: In a situation such as this, release of the air brakes to proceed would have left the train reliant on dynamic brakes during the period individual cars were recharged from the train line. ECP brakes are designed for graduated release, permitting the engineer to leave a minimum set and keep the train stretched; and charging of the individual car reservoirs is continuous.			

	Event / Sources	Train consist / speed	Consequences	Cause(s)
6A	NS Knoxville, TN 10/21/2017 6180.54 (4/4/2022)	Loads, empties (total): 68, 0 (68) Power: 1 front, 1 rear manual [*sic*: see explanation] Tons: 9,752 Length: 9,211 feet Speed: 28 mph	Derailed 42nd through 48th cars when rail rolled due to compressive forces within the consist Cars derailed: 7 Damages: $1m *USA Today* reported that containers were embedded in buildings on both sides of the tracks, but no injuries were reported. https://www.usatoday.com/story/news/nation-now/2017/10/22/police-norfolk-southern-train-derails-knoxville/788290001/	NS: H519—Dynamic brake, too rapid adjustment
	Explanation: This was actually a train with two locomotives up front and one mid-train DPU, so this power coding[52] is *wrong three ways*. The reported cause suggests a train handling error by the engineer. Later analysis suggested that this was a train-makeup issue, with a block of EOCC cars affected by run-in from a heavier, more rigid block driven in part by the DPU. At the time of the derailment, the DPU was moving at 3 mph faster than the lead unit, which had reached the bottom of the grade, adding to the compressive forces. *See* https://www.wheel-rail-seminars.com/archives/2018/hh-papers/presentations/HH01.pdf (automatic pdf download). Analysis using TOES appeared to show that the same train handling would not have produced the derailment had the placement been different. The railroad exercised due diligence to determine the true cause, then failed to update the report filed with FRA.			
7	CSX Sewanee, TN 3/7/2018 6180.54 (4/4/2022)	Loads, empties (total): 90, 87 (177) Power: 5 front Tons: 14,837	Derailed at 19 mph Cars derailed: 13, plus 3 engines Damages: $507K	CSX: H520, dynamic brake, excessive axles
	Explanation: This is a train with excessive power at the front, too many dynamic brake axles cut in, with no DPU to moderate in-train forces or ease the charging of the train air line. Note derailment of 3 locomotives, which suggests a powerful run-in. Again, use of ECP brakes might have enabled the crew to handle the train without concern for sticking brakes or depletion of the brake pipe.			

[52] The writer confesses that the use of "coded" and "coding" in these pages is potentially misleading. The intended meaning is that the submitting railroad has entered in the proper box a numeric value that somehow is at odds with other numeric values, including values provided in the railroad's narrative (as applicable). My apologies if this is confusing.

	Event / Sources	**Train consist / speed**	**Consequences**	**Cause(s)**
8	CSX Jacksonville, FL 4/6/2018 6180.54 (4/4/2022)	Loads, empties (total): 150, 60 (210) Power: 7 front Tons: 21,157 Length: 14,141 ft. Speed: 4 mph	Derailed beginning at position 51 (empty) in terminal area Cars derailed: 3 Damages: $18K	CSX: M405—Interaction of lateral/ vertical forces (includes harmonic rock off)
	Explanation: This is clearly a minor derailment, but it is offered for the extreme size and poor make-up of the train. The CSX narrative claims that the “TRAIN WAS BUILT IN ACCORDANCE WITH TRAIN PLACEMENT RULE, AND NO EXCEPTIONS TAKEN WITH TRAIN HANDLING....” Further, “SEQUENCE NUMBERS 51 - 54 WHICH WERE EMPTY INTERMODAL FLATS STRUNG OUT AROUND THE HONEYMOON WYE.” This was not likely a harmonic rock off at 4 mph, so what happened? It sounds like a stringline due to drag from the much heavier portion of the consist to the rear.			
9	NS Eden, AL (Pell City) 7/5/2018 6180.54 (4/4/2022) & FRA HQ-2018-1279	Loads, empties (total): 43, 29 (72) Power: 3 front Tons: 8,631 Length: 10,194 ft. Speed: 36 mph	Derailed 41st car, at 3:15 a.m., on descending grade Cars derailed: 25 Damages: $2.1m	FRA: H504 – Buffing or slack action excessive, train makeup NS: H504
	Explanation: As usual, the NS narrative is spare and unhelpful. The FRA report notes placement of auto racks with long slack in the middle of the train, which consisted of a number of articulated intermodal platform cars ahead and behind. Placement complied with NS rules. No indications whether NS changed its rules. No information on whether the lead locomotive was equipped with TEMS.			
10	CSX Atmore, AL (Wawbeek) 7/11/2018 6180.54 (4/4/2022)	Loads, empties (total): 148, 66 (214) Power: 3 front Tons: 19,329 Speed: 34 mph	Derailed beginning at position 161 Cars derailed: 6 Damages: $412K	CSX: E00C—Air hose uncoupled or burst
	Explanation: Air hoses can come uncoupled for any number of reasons and will come uncoupled if the train separates. This was a very heavy train more than 2 miles long with no mid-train or rear DPU. Was this simply a mechanical defect?			

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>11</td><td>UP
Granite Canyon, WY
10/4/2018

6180.54
&
NTSB RAR-20/05</td><td>[Striking train]
Loads, empties (total): 95, 10 (105)

Power: 3 front

Tons: 12,147
Length: 6,581 feet

Speed: 55 mph (per NTSB)</td><td>Rear-end collision in PTC territory.

Cars derailed: 59, and 3 locomotives in striking train, 8 cars in struck train

Fatalities: 2 (striking train crew)

Damages: $3.2m</td><td>NTSB: See explanation

UP:
E03C—Obstructed brake pipe and
EO9L – Other brake defects (rear-end telemetry device "failed")</td></tr>
<tr><td></td><td colspan="4">Explanation: Crew lost control on grade, apparently due to kinked air hose; and 2-way EOT (ETD) failed to activate an emergency application account out of communication. The NTSB issued an alert on 9/16/2019 regarding "Train Emergency Brake Communication" that found, in part that "Radio telemetry between ETDs and HTDs can be interrupted by natural obstructions, changes in track grade, and track curvature during normal operations. Notifications to the train crew of such communication interruptions do not initiate until there has been a loss of communication for a minimum of 16 minutes and 30 seconds. Therefore, train crews may not be aware of communication interruptions between the HTD and ETD in a timely manner." The Board made recommendations regarding monitoring of brake pipe pressure and verifying ETD communications cresting a grade.

The Board's final report was issued on 1/25/2021. Quoting the report:
"The National Transportation Safety Board determines that the probable cause of the collision was the failure of the Union Pacific train MGRCY04 air brake system due to an air flow restriction in the brake pipe and the failure of the end-of-train device to respond to an emergency brake command. Contributing to the accident was the failure of Union Pacific Railroad to maintain the railcars in accordance with federal regulations, including regularly performing single railcar air brake tests. Further contributing to the accident were communication protocols, set by Federal Railroad Administration regulations and industry standards, that allowed extended time intervals for loss of communication notification between the head-of-train device and the end-of-train device without warning the train crew of the loss of communication."[53]

After addressing the potential of ECP brakes in some detail, the Board said (p. 33):
"The NTSB concludes that had the striking train been equipped with ECP technology, the emergency brake commands would have been received through the entire train, thereby applying the brakes on each railcar of the train, likely preventing the accident."</td></tr>
</table>

[53] The deficient interval for crew notification of loss of communication with the EOT was based on the technology and industry standards of the time the requirements were issued. Since that time developments in technology (including technology successfully demonstrated under waivers signed by the author) have made plausible more timely notice. However, FRA's recent amendments to the Power Brake Regulations failed to address the known deficiencies. 85 FR 80544 (Dec. 11, 2020).

<table>
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<tr><td rowspan="2">12</td><td>UP
on NOPB
Jefferson Parish, LA
10/5/2018

6180.54
(4/4/2022)</td><td>Loads, empties (total): 73, 33 (106)

Power: 3 front

Tons: 10,411

Speed: 4 mph</td><td>Derailment behind lead power when rear of train ran in coming off of Huey P. Long Bridge

Cars derailed: 5

Damages: $221K</td><td>UP: H503—Buffing or slack action excessive, train handling</td></tr>
<tr><td colspan="4">Explanation: This was a transfer move over a shared highway/rail bridge owned by the NOPB. The approaches to this bridge have a significant grade, and the area around the north (TTE) approach is highly populated. One of the 34 placarded hazmat cars was compromised, but given the nature of the product no evacuation was required. The UP narrative does not comment on use of train air brakes, which might have helped to dampen run-in. An apparently similar (and minor) accident coming off the bridge occurred on 12/5/2020.</td></tr>
<tr><td rowspan="2">13</td><td>UP
Houston, TX
1/1/2019

6180.54
(4/4/2022)</td><td>Loads, empties (total): 80, 16 (96)

Power: 2 front

Tons: 11,104</td><td>Derailed at 18 mph. First car derailing was the 70th

Cars derailed: 29

Damages: $803K</td><td>UP: T403 – Engineering design or construction (NO EXPLANATION IN NARRATIVE)</td></tr>
<tr><td colspan="4">Explanation: The writer has no explanation for the accident, and the carrier has provided no explanation that would be useful in preventing a similar event. Is it possible the heavy train found a track anomaly only at the 70th car? Are there other possible explanations?</td></tr>
<tr><td rowspan="2">14</td><td>UP
Stockton, CA
1/2/2019

6180.54
(4/5/2022)</td><td>Loads, empties (total): 84, 36 (120)

Power: 3 front

Tons: 12,861</td><td>Derailed at 13 mph. First car to derail was the 4th (empty)

Cars derailed: 18

Damages: $428K</td><td>UP: H525 – Independent brake, improper use</td></tr>
<tr><td colspan="4">Explanation: Again, the writer can discern little explanation. The independent (locomotive) brake is normally used at the end of a stop sequence to bring the movement to a complete stop.</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>15</td><td>UP
Fremont, NE
2/8/2019

6180.54
(4/5/2022)</td><td>Loads, empties (total): 196, 0 (196)

Power: 6 front

Tons: 27,685</td><td>Derailed at 20 mph. First car to derail was the 181st

Cars derailed: 12

Damages: $704K</td><td>UP: T207 – Broken rail, detail fracture</td></tr>
<tr><td></td><td colspan="4">Explanation: This accident is included largely as an example of the sort of trains being marshalled by UP during the period. Note no DPUs, 27K tons.

Comment: Why it would have been the 181st car to find the broken rail is again, curious, although of course it can happen.</td></tr>
<tr><td>16</td><td>CSX
Baltimore, MD
3/15/2019

6180.54
(4/5/2022)</td><td>Loads, empties (total): 72, 90 (162)

Power: 3 front, 1 DPU mid-train

Tons: 11,724</td><td>Derailed at 4 mph when crew hooked locomotives to STALLED TRAIN and pulled without properly releasing air brakes

Cars derailed: 9

Damages: $261K</td><td>CSX: H514 – Failure to allow air brakes to release before proceeding; and H523 – Throttle (power), too rapid adjustment</td></tr>
<tr><td></td><td colspan="4">Explanation: This is a train that stalled for a reason, but we are not told why. When movement resumed after two locomotives were added to the front, the train evidently stringlined, with the first car off in position 17 (empty). Note CSX has added a mid-train DPU.

The damages to railroad property are modest, but the railroad was not required to report that the Baltimore Trolley Museum substation was destroyed by the derailment, which occurred on an elevated track in downtown Baltimore. According to a web page, the Museum did resume trolley operations on 7/3/2019.</td></tr>
</table>

	Event / Sources	**Train consist / speed**	**Consequences**	**Cause(s)**
17	UP Lynndyl (Eureka), UT 3/30/2019 6180.54 (4/5/2022) & FRA HQ-2019-1329	Loads, empties (total): 139, 26 (165) Power: 5 front, 2 mid-train DPUs Tons: 19,019 Speed: 35 mph	Derailed beginning at position 19 (empty, car causing) Cars derailed: 25 Damages: $2.14m Hazmat: Of 18 hazmat cars, 12 were damaged and 4 released, including propane	FRA: E06C—Brake valve malfunction (stuck brake) and H995—Human factor, equipment, H999—Other train operations, human factors UP: E06C—Brake valve malfunction (stuck brake, etc.)

NOTE: This entry has been revised from earlier versions, since the FRA report has been published and adds detail.

Explanation: In the narrative, the railroad identified tread build-up on the first car derailing as the cause of the derailment. FRA agreed, but FRA noted that the brake defect had been identified at the Salt Lake City North Yard, the point at which a short pool crew was relieved by the long pool crew, but not properly diagnosed and remedied. The excuse for not having an inspection by a carman at Salt Lake was the inaccessibility of the car due to the (long) train blocking a crossing. The car in question had a history of brake issues, but wayside detectors were not triggered on this occasion after the train left Salt Lake.

FRA reports that the long pool crew, headed for Milford from Salt Lake, operated with Trip Optimizer engaged until the speed of the train dropped down to 19 mph. The general derailment, signaled by a UDE, occurred at 685.7, with the train operating at 35 mph down a .80% grade—the train having dragged the first car off for over 10 miles. Is there a human factors issue here, related to reliance on technology and de-skilling, that may have played a role in the severity of the general derailment?

ECP brakes would likely have given the crew notice (confirmation) of the stuck brake.

	Event / Sources	Train consist / speed	Consequences	Cause(s)
18	UP Wells, NV 6/19/2019 6180.54 (4/5/2022) & FRA HQ-2019-1344	Loads, empties (total): 120, 56 (176) Power: 3 front, 2 DPUs mid-train Tons: 16,501 Length: 11,866 ft. Speed: 38 mph	Derailed cars 59 to 85 on 1.4% grade with train traversing multiple curves Cars derailed: 27 Damages: $1.24m I-80 closed for over 90 minutes	FRA: H504—Buffing or slack action excessive, train makeup. UP: H504
	Explanation: FRA prepared a precise and emphatic report detailing the train make-up issues. The train was equipped with mid-train DPUs (synchronous) and the engineer followed train handling instructions. However, the presence of 56 cars with cushioning between the headend power and mid-train power, together with a large block of light cars followed by 21 heavy cars, resulted in the lighter cars being squeezed and producing lift on the derailing car, which climbed out. FRA commended UP for amending their system order regarding the placement of auto-racks equipped with end-of-car cushioning, but took exception to the fact that other cars so equipped were not treated similarly.			
19	BNSF Ash Hill, CA 7/4/2019 6180.54 (4/5/2022)	Loads, empties (total): 80, 19 (99) Power: 6 front, 1 DPU rear Tons: 10,015 Speed: 14 mph	Derailed beginning at position 56 (empty) Cars derailed: 1 Damages: $66K	BNSF: M405—Interaction of lateral/ vertical forces (includes rock offs)
	Explanation: This is a very minor derailment that was saved from being worse by a wayside detector that alerted the train to stop. Strange to be a rock-off on a very high-density corridor with continuous welded rail. Was the consist evaluated for train placement?			
20	NS Tunnelhill (Horseshoe Curve), PA 7/5/2019 6180.54 (4/5/2022)	Loads, empties (total): 49, 91 (140) Power: 3 front Tons: 8,920 Speed: 22 mph	Derailed beginning at position 1 (behind locomotive consist) ascending Horseshoe Curve Cars derailed: 11 (empties) Damages: $751K	NS: H506—Lateral drawbar force on curve excessive, train makeup
	Explanation: This appears to be simple case of putting light cars up front on a heavy train and with track grade and curvature doing the rest. NS did this again 3 weeks later, to the amazement of railfans, at the same milepost, in the same direction of travel. See NS item below for 7/26/2019.			

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">21</td><td>UP
Caliente (Elgin), NV
7/10/2019

6180.54 (4/5/2022)
&
FRA HQ-2019-1350</td><td>Loads, empties (total): 179, 3 (182)

Power: 3 front, 2 DPU mid-train

Tons: 20,572
Length: 12,927 ft.

Speed: 35 mph</td><td>Derailed beginning at 47th car on descending grade with curvature

Cars derailed: 32

Damages: $3m</td><td>FRA: H504—Buffing or slack action excessive, train makeup.

UP: H504</td></tr>
<tr><td colspan="4">Explanation: FRA's report provides useful detail. This was heavy grade territory with significant curvature. "[D]ue to the train length and undulating terrain, the TO [Trip Optimizer] could not maintain speed control and was disengaged." The engineer was balancing the train with the air brake and dynamic braking, and the DPUs were in synchronous mode. No exception to train handling; however, the train was in full dynamic braking to control speed. (The train had cut-in PTC, but the speed was within limits.) The derailment involved lighter (though loaded) auto-rack cars with end-of-car cushioning followed by a block of heavier cars. Compression of the auto-rack cars led to wheel lift and derailment.

UP further modified its rules on placement of auto-rack cars following the accident.

Comment: The writer could add that possibly contributing to the derailment were two factors. Operations down the mountain were permitted to 35 mph, which created a challenge with respect to managing the descent. From the reports, it appears UP should, among other things, have reduced the MAS for trains of this category over the territory.

ECP brakes would have made it possible to modulate the train brake and avoid run-in entirely.</td></tr>
<tr><td rowspan="2">22</td><td>NS
Tunnelhill (Horseshoe Curve), PA
7/26/2019

6180.54 (4/5/2022)</td><td>Loads, empties (total): 9, 82 (91)

Power: 3 front

Tons: 662 [<u>sic</u>]

Speed: 10 mph</td><td>Derailed empty centerbeam flat cars, just behind the locomotives, ascending Horseshoe Curve, near viewing platform

Cars derailed: 6

Damages: $355K</td><td>NS: H506—Lateral drawbar force on curve excessive, train makeup</td></tr>
<tr><td colspan="4">Explanation: This is a major east-west route, made more difficult by grade and curvature. The train had presumably come out of or through Altoona, and there would have been multiple opportunities to note the poor configuration. Like the derailment 3 weeks prior at the same location, this was preventable.</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
23	UP Strasburg, MO 8/6/2019 6180.54 (4/5/2022)	Loads, empties (total): 116, 84 (200) Power: 3 front, 1 DPU mid-train Tons: 15,679[54] Length: 9,920 feet Speed: 33 mph	Derailed cars damaged track Cars derailed: 2 Damages: $44K	UP: H504—Buffing or slack action excessive, train makeup
	Explanation: The UP narrative indicates that its train makeup rules were followed, but were amended after this event.			
24	UP Hillsboro, TX 8/19/2019 6180.54 (4/5/2022) & FRA HQ-2019-1359	Loads, empties (total): 129, 19 (148) Power: 3 front, 2 DPU rear Tons: 17,817 Length: 8,282 ft. Speed: 48 mph	Derailment on tangent track with fenced DPUs pushing from behind while cresting hill, cars squeezed off Cars derailed: 32 cars Damages: $1.6m	FRA: H504—Buffing or slack action excessive, train make-up UP: H504
	Explanation: In this accident, the head-end power was evidently in dynamic braking to avoid overspeed while the DPUs that had just crested the hill behind the body of the train continued in T4. We are told nothing about the instructions to the crew for this situation or whether a TEMS was available to coach. Both FRA and UP blamed train make-up, but there was no finding regarding placement of individual cars or blocks of cars. From what we presume to have been TOES simulations, UP concluded that lowering the speed over humpback to 35 or 40 mph might have prevented the accident. A bulletin was issued for the territory, but we are not told what it said.			
25	UP on KCT Independence, MO 8/19/2019 6180.54 (4/5/2022)	Loads, empties (total): 110, 40 (150) Power: 5 front Tons: 11,197 Speed: 13 mph	Derailed beginning at position 31 (empty) Cars derailed: 10 Damages: $1.1m	UP: H508—Improper train make-up
	Explanation: UP narrative says no train make-up rules were violated and changes were made. Unclear why H508, rather than H504 was selected.			

[54] A lesser value is provided in the narrative.

	Event / Sources	Train consist / speed	Consequences	Cause(s)
26	CSX Martinsburg, WV 8/29/2019 6180.54 (4/5/2022)	Loads, empties (total): 116, 87 (203) Power: 5 front, 1 mid-train (see explanation) Tons: 18,557 Speed: 30 mph	Derailed beginning at position 102 beginning ascent of hill with front and mid-train power in notch 8 Cars derailed: 12 Damages: $180K MARC Brunswick Line trains were annulled, per local press	CSX: E30C—Knuckle broken or defective
	Explanation: This is one of those events we would like to know more about. It's a big, heavy train. The CSX narrative says the mid-train locomotive was a "DP MOTOR," but it is coded as a mid-train manual unit. Where was the mid-train locomotive placed? Was the broken knuckle a previous crack, or did the slack run out sharply as the train went into notch 8? Did the engineer call for the DPU throttle, or was it controlled by TEMS? Comment: This will go down as an equipment-caused accident, and indeed the coupler undoubtedly broke. But why?			
27	UP Dupo, IL 9/10/2019 6180.54 (4/5/2022) & FRA HQ-2019-1363	Loads, empties (total) 64, 76 (140) Power: 2 [shoving] Tons: 10,206 Length: 8,008 ft. Speed: 11 mph plus unknown speed of free-rolling cut	Shoving move in terminal led to separation from broken knuckle and roll-back, with collision Cars derailed: 14 Damages: $816K Punctured flammable liquid tank car, which resulted in explosion and fire; 1,147 evacuated; in addition, 1,011 students were evacuated after fire spread underground through a storm drain and ignited the holding pond next to a chemical plant	FRA: H503—Buffing or slack action, train handling; contributing E30C—Knuckle broken UP: H503
	Explanation: This was a *yard movement* to assemble a train with 4 locomotives and 183 cars. The 140-car shoving move, which broke in two and then collided with itself, had no train air brakes. No doubt the engineer bears some responsibility for an abrupt use of the locomotive independent brake; however, the accident is illustrative of the potential additional risk associated with assembling extremely long trains in a constrained area using only locomotive brakes. The coupler knuckle that broke was not defective (new break)			
	Note for readers: The following item 27A is new for v3.0			

	Event / Sources	Train consist / speed	Consequences	Cause(s)
27 A	NS Atlanta, GA 10/4/2019 6180.54 (5/11/2022) & FRA HQ-2019-1367	Loads, empties (total): 50, 140 (190) Power: 3 front Tons: 10,957 Length: 10, 958 feet Speed: 7 mph	Derailed in two steps due to a complex series of events and organizational expectations Cars derailed: 32 (33 by FRA’s count) Damages: $466K; 2 residue chlorine cars derailed but did not release product	FRA: See below NS: E05C—Brake valve malfunction (undesired emergency)

Explanation: This complex incident occurred at Inman Yard, with the consist initially positioned on the signaled run-around track, with a .46% descending grade. The engineer proceeded before full charging the train line at the EOT device, but when the train reached 7 mph experienced a PTC fault caused by faulty wiring common only to a series of NS locomotives. This caused a penalty (full service) brake application. Instead of letting the train just “sit down,” dynamic brakes were applied on the lead locomotives, which may have contributed to run-in that evidently caused one car to derail with (*apparently*) a temporary break in the train air line. This, in turn, caused an undesired emergency brake application. The presence of end-of-car cushioning on some of the cars toward the rear of the long train line may have contributed. (FRA’s multiple explanations of this sequence appear not to add up, so we have tried to make sense of it.)

The proper next step was to walk the train, but since the train air line pressure was recovering the crew was instructed to proceed (in violation of NS rules, as the engineer pointed out to the dispatcher) to a forward location where the train would be inspected by another crew in a “roll-by” inspection. When the engineer tried to restart the movement, using the dynamic brake to control the descent, the general derailment commenced.

The NS cause code blames to whole mess on the PTC malfunction (equipment cause).

Here are FRA’s summary conclusions:

> FRA determined the probable cause for the initial derailment was H503 – Buffing or slack action excessive, train handling.
> FRA determined the contributing factors for the initial derailment were the following:
> H514 – Failure to allow air brakes to fully release before proceeding (H005).
> H521 – Dynamic brake, other improper use (H013).
> In addition, FRA determined the contributing factors for the 32 additional cars that derailed were the
> following:
> H305 – Instruction to train/yard crew improper.
> H999 – Other train operation/human factors (Failure to comply with NS Rules 113 and L-245).

Comment: FRA did its best to explain this, even doing a TEDS run. The writer still finds the various explanations in the FRA report to be less than satisfying. What seems missing here is an acknowledgement that the train was too long and heavy to be operated without a mid-train DPU to keep the brake pipe properly charged and manage in-train forces. Put that together with the dispatcher’s demand to clear the run-around track without a proper inspection, and the situation progressed from a minor event to a significant derailment. This was an organizational accident in which improper train marshalling was followed by steps to move the train in violation of a carrier rule. We can blame the PTC fault, the dispatcher or the engineer, but in truth one bad decision begets another. The single NS cause code tells a small fraction of the true story, and all of the FRA codes added up remain short of the full picture.

<table>
<tr><th></th><th>Event /
Sources</th><th>Train consist /
speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">28</td><td>NS
Perry, GA
(Hayneville)
10/9/2019

6180.54
(4/5/2022)
&
FRA HQ-2019-1368</td><td>Loads, empties (total): 124, 6 (130)

Power: 2 front, 1 DPU mid-train

Tons: 14,651
Length: 8,544 ft.

Speed: 42 mph

TEMS: Yes, in automated mode</td><td>Derailed in undulating terrain when DPU squeezed off cars as front end was just coming out of dynamic braking—AUTOMATED OPERATION

Cars derailed: 32, and the DPU

Damages: $5.1m (amended to be $6.5m in the most recent railroad report)

Derailment resulted in loss of diesel fuel into stream and rupture of natural gas pipeline with loss of 2.3m cubic feet of gas. Rail line (30 mgt) was out of service 2 days</td><td>FRA: E7AL—On-board computer, failure to respond; H504—Buffing or slack action excessive, train makeup

NS: H504</td></tr>
<tr><td colspan="4">Explanation: The crew involved received their training in operation of distributed power from the Road Foreman at the initial terminal, having not previously used it (a factor that appears not to have been causal). The lead locomotive was equipped with Trip Optimizer (TO), which was in automatic mode, controlling the head-end locomotives and the DPU unit in fenced mode. According to FRA—explicating as best one can—the DPU keep pushing at the time it should have throttled down (accentuating buff force from run-in and causing wheel lift). We have no explanation why that would be the case, since TO is supposed to know the train consist and route profile and be capable of handling the DPU. FRA believes the train crew would not have handled the DPU in the same manner, suggesting that the experienced engineer would have been superior to the automated system. NS blames train makeup, with no explanation. End-of-car cushioning on some cars may have been a factor.

Comment: Note that FRA uses a primary cause code that was intended for a unit failure, rather than a system failure, probably because there was no suitable code available. The NS cause code does at least reflect distaste for train makeup (it originated at a major yard), but from the NS report we would have no indication that the train was in automatic operation. In the most recent record retrieved, NS further confuses the matter with entry of 2 head-end locomotives derailed (clearly not the case from the FRA report and NS narrative).</td></tr>
<tr><td rowspan="2">29</td><td>UP
Smithville, TX
10/9/2019

6180.54
(4/5/2022)</td><td>Loads, empties (total): 122, 49 (171)

Power: 3 front, 2 DPUs rear

Tons: 17,388

Speed: 15 mph</td><td>Derailment from climb-out on curve beginning at position 46 (empty)

Cars derailed: 11

Damages: $368K</td><td>UP: H504—Buffing or slack action excessive, train makeup</td></tr>
<tr><td colspan="4">Explanation: UP narrative suggests no violation of make-up or train handling rules. No reference to mitigation. No indication whether the locomotive was equipped with a TEM system.</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>30</td><td>UP
Henefer, UT
11/22/2019

6180.54
(4/6/2022)</td><td>Loads, empties (total): 149, 77 (226)

Power: 3 front, 2 DPUs mid-train

Tons: 20,825

Speed: 1 mph</td><td>Derailed while resuming movement descending grade

Cars derailed: 1

Damages: $29K</td><td>UP: H503—Buffing or slack action excessive, train handling</td></tr>
<tr><td></td><td colspan="4">Explanation: This is a minor derailment, involving a very heavy, long train, selected because it illustrates the mis-application of cause codes that often occurs. The UP narrative follows:
MNPRO-20 WAS STOPPED ON A DESCENDING GRADE AND STRETCHED OUT DUE TO ENGINEER COMING INTO POWER AND PULLING TRAIN THROUGH. THE CREW THEN LET UP AND THERE WERE AIR ISSUES FROM THE REAR OF TRAIN AND THE REAR END STARTED SETTING UP. AT THIS POINT THEY BROUGHT THE TRAIN TO A STOP. THE CREW TIED 70 HAND BRAKES ON THE HEAD END, TO HELP HOLD THE TRAIN. THE CREW THEN BACKS THE TRAIN IN POWER TO HOLD THE TRAIN ON THE HILL AND THEN RELEASED THE AIR TO RECHARGE. THE TRAIN WAS TOO HEAVY AND STARTED PUSHING THEM DOWN THE HILL, RESULTING IN THE TRAIN GOING INTO EMERGENCY. THE DERAILMENT WAS THE RESULT OF THE SHOCK WAVE SENT BACK THROUGH THE TRAIN. THIS GENERATED A SHOCK WAVE SENT FROM THE REAR END WHEN THE AIR BRAKES WERE RELEASED AND THE SHOCK WAVES MET AT THE EMPTY CAR THAT DERAILED. RAILROAD VERIFIED 226 CARS IN THE CONSIST.

Comment: Without further explanation, one would have to conclude that the railroad gave the crew a train so long and heavy it could not be handled over the territory, thereafter blaming the crew for the inherent limitations of the automatic air brake.

Note that, with ECP brakes, the train likely would not have gotten into trouble to begin with; and, with continuous charging the train could have been managed down the hill, no problem.</td></tr>
<tr><td>31</td><td>NS
Altoona, PA
2/13/2020

6180.54
(4/6/2022)</td><td>Loads, empties (total): 32, 158 (190)

Power: 4 front, 3 helpers rear

Tons: 9,284

Speed: 13 mph</td><td>Derailed beginning at position 148 due to broken knuckle

Cars derailed: 3

Damages: $27,160</td><td>NS: H504—Buffing or slack action excessive, train makeup</td></tr>
<tr><td></td><td colspan="4">Explanation: This accident yielded two records, the second being the manual helper units (3) attached to the train at the time of the derailment. The derailment was minor, but note that NS is operating an unwieldy train over the Pittsburg line, which includes the famous Horseshoe Curve (in the direction of travel).</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">32</td><td>UP
Smithton, MO
2/28/2020

6180.54
(4/6/2022)</td><td>Loads, empties (total): 84, 35 (119)

Power: 3 front

Tons: 9,145

Speed: 2 mph</td><td>Derailed 24 cars at 2 mph?

Cars derailed: 24

Damages: $542K

Of the 9 hazmat cars in the train, 4 were damaged; but there was no release</td><td>UP: H518—Dynamic brake, excessive
H508—Improper train make-up</td></tr>
<tr><td colspan="4">Explanation: The UP narrative adds nothing to the cause codes.</td></tr>
<tr><td rowspan="2">33</td><td>NS
Helena, AL
3/7/2020

6180.54
(4/6/2022)</td><td>Loads, empties (total): 113, 52 (165)

Power: 3 front

Tons: 9,834

Speed: 12 mph</td><td>Derailed beginning at position 7

Cars derailed: 10, plus one caboose

Damages: $193K</td><td>M505—Cause under active investigation</td></tr>
<tr><td colspan="4">Explanation: The accident report shows one caboose entrained and one derailed. Was it placed near the front of this relatively heavy consist, as appears? Why was the cause of this low-speed accident still under active investigation as of 4/6/2022?</td></tr>
<tr><td rowspan="2">34</td><td>NS
Hunt, NY
(Formerly Nunda)
6/3/2020

6180.54
(4/6/2022)</td><td>Loads, empties (total): 182, 31 (213)

Power: 4 front

Tons: 15,381
Length: 13,527 feet

Speed: 25 mph</td><td>Derailed beginning at position 42 (empty)

Cars derailed: 13

Damages: $641K (revised downward in latest filing)

Five state and local agencies responded (per local press)</td><td>NS: H521—Dynamic brake, improper use</td></tr>
<tr><td colspan="4">Explanation: This train was built to fail. Did the crew have the benefit of TEMS coaching? If so, how did they deviate? The accident happened at 4:04 a.m., when the crew would have been least able to respond appropriately.

Comment: When the record was last retrieved, it coded 2 head-end locomotives, both of which derailed. From the narrative, this is patently wrong. The nearest town or city was also changed. What else is wrong with this revised report?</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
35	NS Martinsville, VA 6/9/2020 6180.54 (4/6/2022)	Loads, empties (total): 109, 6 (115) Power: 3 front Tons: 6,562 Speed: 11 mph	Derailed at 5th position on 6 degree curve and 1.32 percent ascending grade Cars derailed: 6 (5 unloaded) Damage: $51K	NS: H508—Improper train make-up
	Explanation: A local news photograph shows the stringline derailment which started with an unloaded car.			
36	UP 6/17/2020 Bancroft, ID 6180.54 (4/6/2022)	Loads, empties (total): 105, 76 (181) Power: 2 front, 1 DPU mid-train, 1 DPU rear Tons: 15,560 Speed: 35 mph	Derailed beginning at position 34 (empty) Cars derailed: 31 (30 of which were empty) Damages: $3.8m	UP: E79L—Other locomotive defects (requires explanation in narrative), *revised from* H504—Buffing or slack action excessive, train make-up
	Explanation: This is a big train, but it had DPUs mid-train and at the end. Perhaps it was built from blocks picked up a several locations, with no adjustments in terms of train placement. We do not know whether the engineer was handling the train or if was being operated by a TEMS. The railroad changed the cause code prior to the most recent retrieval, but the narrative remained as follows: MNPPD-16 DERAILED 31 CARS AT G156 ON THE POCATELLO SUB DUE TO AN EXCESSIVE KIP FORCE CREATED BY THE TONNAGE PROFILE, WHICH CAUSED THE HEAVY REAR-END TO INCREASE SPEED WHILE DESCENDING ON UNDULATING GRADE. NO TRAIN HANDLING EXCEPTIONS WERE TAKEN. Comment: Here's another record that will go down as equipment-caused. But there is no explanation as to why the code was selected. It is possible, of course, that the railroad concluded after modeling that the TEMS was not capable of handling the train given its make-up; or perhaps carrier instructions should have called for more effective use of the air brake.			
[37]	[omitted following carrier's update of its cause code]			
[38]	[omitted after review]			

	Event / Sources	Train consist / speed	Consequences	Cause(s)
39	UP Bosler, WY 8/22/2020 6180.54 (4/6/2022)	Loads, empties (total): 220, 2 (222) Power: 2 front, 3 mid-train, 1 rear Tons: 30,113 Speed: 47 mph	Derailed beginning at 10th position (load) Cars derailing: 57 (all loads) Damages: $4.5m	UP: M204—Improperly loaded car
	Explanation: The UP narrative is completely unhelpful. This was a unit grain train (corn). The configuration is unusual, with 3 DPUs mid-train. Was this a shifted load issue (and, if so, how was that determined in the midst of the 57-car pile-up with corn everywhere), or did the DPUs squeeze off the cars in front of them?			
40	NS Limestone (Telford), TN 8/23/2020 6180.54 (3/26/2022)	Loads, empties (total): 80, 36 (116) Power: 4 front Tons: 6,737 Speed: 28 mph	Derailed at position 27 (empty gondola) Cars derailed: 10, plus a caboose Damages: $478K	E21C—Draft sill broken or bent *formerly* NS: M505—Cause under active investigation
	Explanation: The cause was under "active investigation" in the FRA database when checked on 5/3/2021. Since then, the railroad has discovered an *equipment defect* in a car likely destroyed in the derailment. Comment: Like many of these kinds of events, there was an emergency response to check on the 23 hazmat cars in the train (only 1 damaged, no leaks) and several grade crossings were blocked for an extended period (local news story).			
41	UP Nipton, CA 9/19/2020 6180.54 (4/6/2022)	Loads, empties (total): 66, 73 (139) Power: 3 front Tons: 11,150 Speed: 15 m.p.h.	"DERAILED DUE TO EXCESSIVE BUFF FORCES, CAUSED BY UNINTENTIONAL RELEASE. TRAIN WENT FROM STRETCHED TO BUNCHED, AND DERAILED 9 CARS." Cars derailed: 9 Damages: $267K	UP: H503—Buffing or slack action excessive, train handling
	Explanation: Material quoted in caps from UP narrative seems to indicate the brake release was not commanded from the brake stand (writer's hypothesis, subject to expert revision). Why coded as train handling? Was the release masked by high flow associated with the length of the train? Did the engineer fail to respond with a further reduction? Why?			

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">42</td><td>NS
Rocky Gap, WV
11/8/2020

6180.54
(4/6/2022)</td><td>Loads, empties (total): 33, 197 (230)

Power: 3 front

Tons: 3,046 [?]

Speed: 17 mph</td><td>Derailed starting at the head 14 cars, also 156th through 159th cars

Cars derailed: 18

Damages: $1m</td><td>NS: H508—Improper train make-up</td></tr>
<tr><td colspan="4">Explanation: This was a relatively light (perhaps not that light) but very long train with 78 placarded hazmat cars, 3 of which were damaged. No DPU, no indication of whether a TEMS system was on board and active. Had it been, would it have recognized the improper train make-up from the sequence of cars in the consist?</td></tr>
<tr><td rowspan="2">43</td><td>UP
Houston, TX
11/18/2020

6180.54
(4/6/2022)</td><td>Loads, empties (total): 0, 135 (135)

Power: 1 front, 1 mid-train

Tons: 6,841

Speed: 7 mph

TEMS: Trip Optimizer</td><td>Derailed beginning at position 53

Cars derailed: 11

Damages: $255K, revised upward from $68K</td><td>UP: H503—Buffing or slack action excessive, train handling
H505—Lateral drawbar on curve excessive, train handling</td></tr>
<tr><td colspan="4">Explanation: This looks like a prudently built train of empties. The report narrative adds significant detail which would not be explicated in the coding:<blockquote>ASPLDR-18 , LEAD LOCOMOTIVE UP2591, REPORTED DERAILING CARS FROM THE HEAD END, RIGHT AHEAD OF MID DPU, AROUND EUREKA JCT. CREW REPORTED THEY WERE COMING UP TO A CREW CHANGE LOCATION AND TRIP OPTIMIZER WAS COMING IN FAST, SO ENGINEER TOOK CONTROL AND SET AIR.</blockquote>We are not told if the train was in fenced or synchronous mode, but synchronous would have been expected in the flatlands of Harris County, TX. If the engineer had taken TO off automatic, decreased the throttle and set air, the mid-train DPU should have responded by throttling down and setting air on the remainder of the train. [Is this correct?] The “human factor” codes selected seem to indicate crew error here. What was it? Was the crew change location set as a target in the TO? If so, why was it coming in fast?</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">44</td><td>UP
Meacham, OR
12/14/2020

6180.54
(4/6/2022)</td><td>Loads, empties:
142, 0 (142)

Power: 3 front, 5 DPUs mid-train, 2 DPUs rear

Tons: 19,978

Speed: 15 mph</td><td>Pull-apart at position 64 (“…CONDUCTOR FOUND THAT CAR FMLX51012 TORN APART, PLACING THE TRAIN IN UDE. CAR DID NOT DERAIL.”)

Cars derailed: 0

Damages: $39K</td><td>UP: E29C—Other body defects (Provide detailed description in narrative)</td></tr>
<tr><td colspan="4">Explanation: This gets reported only because damage to the car in question exceeded the reporting threshold. The car “torn apart” was a covered hopper with a 286K gross-weight-on-rail rating, so it was not terribly old. Note 5 DPUs reported mid-train. Do we all agree that mishandling of the 5 DPUs mid-train or the 2 DPUs at the rear could not have ripped out the draft gear or a stub sill, or even compromised the car body? Probably not. So, what detailed description did we get of the car body defects in the narrative, as required? None. What do we know about how the train was being handled (e.g., by TEMS, by engineer; synchronous or fenced)? Nothing.</td></tr>
<tr><td rowspan="2">45</td><td>NS
Roanoke, VA
12/16/2020

6180.54
(4/6/2022)</td><td>Loads, empties (total):
110, 35 (145),

Power: 3 front (see explanation for DPU)

Tons: 14,242

Speed: 6 mph</td><td>Derailed beginning at position 37 (empty) when DPU failed to apply dynamic brake

Cars derailed: 8

Damages: $563K, revised from $176K

52 hazmat cars in consist undamaged, no release or evacuation</td><td>NS: H517—Dynamic brake, insufficient</td></tr>
<tr><td colspan="4">Explanation: The report fails to show a DPU in the proper field over two years after the event, so if we went looking for accidents with DPUs in the consist we would miss this one. However, the narrative is more helpful than usual for this railroad:
<blockquote>WHILE TRAVELING WESTBOUND ON TRAIN 18MV414 ENCOUNTERED AN UNDESIRED EMERGENCY BRAKE APPLICATION. UPON INSPECTION IT WAS DISCOVERED THE TRAIN HAD A TOTAL OF 9 CARS DERAILED…THIS WAS DUE TO THE TTGX 986451 EXPERIENCING HIGH BUFF FORCES WHICH RESULTED IN VERTICAL LIFT OF A END TRUCK, WHICH WAS DUE TO DISTRIBUTED POWER UNIT NS 4123 NOT PRODUCING REACTIVE EFFORT WHILE IN DYNAMIC BRAKE.</blockquote>According to press reports the accident was in downtown Roanoke. There is video of the clean-up at https://roanoke.com/news/local/watch-now-9-norfolk-southern-train-cars-derail-in-downtown-roanoke/article_2c2ff9f8-3fa3-11eb-a912-fb3a729fe182.html

Comment: Of course, we don’t know (i) whether the DPU was under manual or automatic (TEMS) control, (ii) whether it was in comm when dynamic was called for, (iii) if it was in comm, was the failure with the LOCOTROL software or setup or (iv) was it a failure of the dynamic brake on the DPU (which would seem to call for an equipment code). What apparently was not at issue here was crew performance, but the “H” code in this context could easily be construed to indicate a crew failure. This is another example of why “data driven” decision making can’t use raw data for the hardest cases.</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
46	UP Dixon, IL 12/24/2020 6180.54 (3/26/2022)	Loads, empties (total): 96, 105 (201) Power: 5 front Tons: 16,228 Speed: 41 mph	Derailed beginning at position 139 (empty) Cars derailed: 39 (12 loads, 27 empties) Damages: $2.5m Of 14 hazmat cars in the train, one derailed and released some product (sulfuric acid)	UP: H519—Dynamic brake, too rapid adjustment
	Explanation: The UP report was revised after publication of initial versions of this paper. The original UP report showed 5 locomotives on the head end, 4 manual units mid-train, and 1 DPU mid-train (an unlikely combination, to say the least). The revised report shows 5 locomotives on the head end, with no DPUs. The writer would be remiss if he didn't pose this question: Who dispatches a 201-car, 16,228-ton mixed manifest train without DPUs and then blames the accident on the crew's train handling?			
47	UP Spofford, TX 1/1/2021 6180.54 (4/6/2022)	Loads, empties (total): 86, 68 (154) Power: 4 front Tons: 12,735 Speed: 7 mph	Derailed beginning at position 28 (empty) Cars derailed: 4 Damages: $14K	UP: H506 – Lateral drawbar force on curve excessive, train make-up
	Explanation: Minor derailment, explained as follows in the narrative: MEWLF-01, WHILE PULLING INTO YARD AT KCRP AT 7MPH, DERAILED 4 EMPTY CARS. TRAIN WAS PULLING 79KLBS IN THROTTLE 4. THE CARS WERE LINES 25-28 FROM THE HEADEND OF TRAIN, WITH 9600 TONS BEHIND THE CARS, THE CARS WEIGHTS WERE ONLY 241 TONS AND 743 FEET LONG COMBINED, WHICH CAUSED THE STRING LINE DERAILMENT ACCOUNT TRAIN MAKE-UP.			

	Event / Sources	Train consist / speed	Consequences	Cause(s)
48	UP Durkee, OR 1/4/2021 6180.54 (4/6/2022)	Loads, empties (total): 63, 36 (99) Power: 4 front Tons: 9,216 Speed: 19 mph	Derailed beginning at position 53 (empty) Cars derailed: 22 (all empty) Damages: $662K	UP: H503 – Buffing or slack action excessive, train handling

Explanation: To the railroad's credit, explanation is offered in the narrative:

> MHKNPX-04 TRAVELING EAST, 11 LB. BRAKE PIPE APPLICATION, RUNNING ON DESCENDING GRADE. THE TRAIN BEGAN TO SLOW AS THE GRADE REDUCED FROM 2.2% DOWN TO 1.6%. THEY BEGAN TO REDUCE DYNAMIC BRAKING EFFORT. AS TRAIN CONTIUNED TO SLOW, THE ENGINEER RELEASED THE AUTOMATIC BRAKE, THEN BEGAN TO SLOWLY INCREASE THE DYNAMIC BRAKING EFFORT, EVENTUALLY WORKING UP TO 100%. AS THE AIR FLOW REDUCED DOWN TO 21 CFM, THE ENGINEER MADE AN INITIAL BRAKE PIPE REDUCTION, AND APPROXIMATELY 1,600 FEET LATER WENT INTO UDE. THE REDUCTION IN DYNAMIC BRAKING ALLOWED TRAIN TO STRETCH OUT WITH BRAKES SET. WHEN AUTOMATIC BRAKE WAS RELEASED, THE LOADS ON REAR OF THE TRAIN CAUSED A RUN-IN OF THE SLACK, RESULTING IN 22 CARS DERAILING.

Comment: The writer suspects we would need more information to sort this out, particularly as to the time course. This was evidently a blended braking effort with the objective of having the train in buff at the bottom of the grade. When the dynamic brakes failed to reduce the speed sufficiently, a second train brake application was attempted. Why the situation subsequently unfolded as it did is unclear to this writer. What caused the UDE? How should this have been handled? Is it fair to lay the failure of the braking strategy on the operator, when the railroad built the train as it did and specified the MAS down the grade?

ECP brakes would have provided the engineer with the confidence to make the descent with the train brakes being continuously charged.

	Event / Sources	Train consist / speed	Consequences	Cause(s)
	Note for the reader: The following items are new for v3.0.			
49	BNSF Ludlow, CA 3/3/2021 6180.54	Loads, empties (total): 72, 28 (100) Power: 3 front, 2 DPUs rear Tons: 10,528 Speed: 52 mph	Derailed beginning at position 29 (load) Cars derailed: 46 (21 loads, 25 empties) Damages: $4.1m, 28K gallons of ethanol released (no evac.)	BNSF: H504— Buffing or slack action excessive, train makeup
	Explanation: The railroad narrative attributes the derailment to "buffering or slack action," without saying which. Did BNSF conduct a TOES analysis of this very expensive accident? Did the railroad modify its train make-up rules for this territory?			
50	NS Front Royal, VA 3/4/2021 6180.54 (4/4/2022)	Loads, empties (total): 110, 8 (118) Power: 2 front, 2 DPUs or manual helpers rear (see explanation) Tons: 8,461 (narrative says 12,928) Length: 8,147 feet Speed: 18 mph	Derailed beginning position 31 (lines 29-43 derailed) Cars derailed: 15 (loads) Damages: $1.2m The 6180.54 indicates no casualties from this event, but ***a worker evidently died during the wreck clearance operations.*** https://starshazmat.com/2021/03/08/worker-killed-during-derailment-clean-up-in-front-royal-va/	NS: H503— Buffing or slack action excessive, train handling
	Explanation: This consist has helper locomotives at the rear, according to the coding, but the narrative indicates "4 UNITS (2x2DP)". What was the failure in train handling? Were the DPUs in comm, were they fenced, were air brakes in use, etc.? Here again we have the report indicating 2 head end locomotives were derailed, which is pretty clearly not the case. Comment: It should be emphasized that each of these derailment events requires specialized wreck clearance and remediation operations that are themselves inherently hazardous.			
51	NS Martinsville, VA 3/11/2021 6180.54 (4/4/2022)	Loads, empties (total): 121, 10 (131) Power: 3 front Tons: 13,129 Speed: 7 mph	Derailed at position 5 (empty) on 1.3% ascending grade and 6 degree curve "ACCOUNT EMPTY/LOAD MAKE UP." Cars derailed: 5 Damages: $196K	NS: H504— Buffing or slack action excessive, train makeup
	Explanation: Placement of empty cars up front in a heavy train in grade territory with no DPUs likely created stringline.			

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">52</td><td>BNSF (on UP)
Caliente, CA
3/16/2021

6180.54</td><td>Loads, empties (total): 38, 43 (81)

Power: 4 front

Tons: 5,846

Speed: 8 mph</td><td>Derailed beginning position 10 (empty)

Cars derailed: 4

Damages: $802K</td><td>BNSF and UP: H506—Lateral drawbar force on curve excessive, train makeup</td></tr>
<tr><td colspan="4">Explanation: The BNSF narrative adds nothing, but the UP narrative states that the train "WAS ON ASCENDING GRADE, WHEN THEY DERAILED 4 EMPTY AUTORACKS…DUE TO A BROKEN DRAWBAR[,] CARS DERAILED TO THE INSIDE OF CURVE (STRINGLINE".</td></tr>
<tr><td rowspan="2">53</td><td>UP
Cheyenne, WY
3/28/2021

6180.54
(4/4/2022)</td><td>Loads, empties (total) 114, 56 (170)

Power: 3 front, 1 manual helper or DPU rear (see explanation)

Tons: 15,932
Length: 11,685 feet

Speed: 6 mph</td><td>Derailed beginning at position 55 (empty) entering yard

Cars derailed: 4 (empties)

Damages: $134K</td><td>UP: H503—Buffing or slack action excessive, train handling; and H514—Failure to allow brakes to release before proceeding</td></tr>
<tr><td colspan="4">Explanation: This is coded as a manual helper on the rear, but from the narrative we would assume a single engineer was in control of the entire consist. Apparently, the road crew was yarding the train, and from the cause codes selected, this looks straightforward ("crew error," to some). However, the railroad favors us with a narrative of near-record detail:
<blockquote>MPCNP-25 WAS COMING WEST TO EAST VIA THE NEW WAY INTO CHEYENNE YARD. THE ENGINEER STOPPED TO HAVE THE NEW SWITCH LINED AFTER LEAVING CPW511. CREW MOVED APPROXIMATELY 2500 FEET INTO THE NORTH LEAD AND WENT INTO EMERGENCY. AT THE TIME OF DERAILMENT, THE TRAIN SPEED RECORDED WAS 6 MPH AND IN DYNAMIC 4-5. MPCNP-25 DERAILED FOUR CARS IN CHEYENE YARD, MP 509.52 ON THE LARAMIE SUBDIVISION. DERAILED CARS WERE 52, 53, 54 AND 55 OF TRAIN CONSIST. ENGINEER WAS MODULATING DYNAMIC BRAKES TO ENSURE SPEED COMPLIANCE. FIRST CAR DERAILED WAS UNABLE TO NAVIGATE TURNOUT, BUT MECHANICAL MEASUREMENTS WERE WITHIN STANDARD. FROG AT POINT OF DERAILMENT WAS WORN, BUT WITHIN ENGINEERING TOLERANCE. TRAIN CONSIST HAD LOADS ON THE REAR, BUT MET WITH TRAIN MAKEUP REQUIREMENTS. ENGINEER OPERATION OF TRAIN WAS COMPLIANT WITH RULE APPLICATION AND NO EXCEPTION TAKEN [emphasis supplied]. IT IS INCONCLUSIVE AS TO WHY THE FIRST CAR FAILED TO NAVIGATE THE TURNOUT. UPON IN-DEPTH ANALYSIS OF THE EVENT, IT HAS BEEN DETERMINED THAT SEVERAL FACTORS, INVOLING MULTIPLE DISCIPLINES CONTRIBUTED TO THIS EVENT [emphasis supplied]. THE TRAIN WEIGHT WAS 16.794 TONS WITH A LENGTH OF 11,685. TOPOGRAPHICAL GRADIENT, THE DEVIATION FROM TANGENT TRACK, GRAVITATIONAL DISBURSEMENT AND FORCE EXHIBITED (LOADS TO EMPTIES), CUSHIONED DRAW BARS AND "SLACK" GENERATED FROM DESCENDING GRADE, THE RETARDING FORCE CREATED TO CONTROL SPEED; ALL COMBINED TO CREATE A LATERAL FORCE AT THE WEAKEST POINT WITHIN THE CONSIST.</blockquote>
Comment: When aggregated with other data, this report would be misleading. The cause codes selected do not appear to match the narrative.</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">54</td><td>CSX
Fairhope, PA
4/1/2021

6180.54
(4/4/2022)</td><td>Loads, empties (total): 69, 8 (77)

Power: 3 front, 1 DPU mid-train

Tons: 12,061

Speed: 12 mph</td><td>Derailed beginning at position 28 (empty)

Cars derailed: 3

Damages: $94K</td><td>CSX: H508—Improper train makeup</td></tr>
<tr><td colspan="4">Explanation: The narrative is concise: “Q13731 DERAILED EMPTY FLAT CARS.”</td></tr>
<tr><td rowspan="2">55</td><td>NS
Knoxville, TN
4/9/2021

6180.54
(3/26/2022)</td><td>Loads, empties (total): 135, 54 (189)

Power: 5 front (see explanation from narrative)

Tons: 18,681

Speed: 7 mph</td><td>Derailed beginning at position 18 (empty) entering terminal on main tracks

Cars derailed: 5

Damages: $151K</td><td>NS: H518—Dynamic brake, excessive</td></tr>
<tr><td colspan="4">Explanation: The narrative adds something, contradicting the coding on locomotive units:
<blockquote>126 WAS CROSSING OVER AT WEST SEVIER TRAVELED FROM MAIN ONE TO MAIN TWO APPROXIMATELY 2,129 FEET INTO THE YARD WHEN THE UNDESIRED EMERGENCY OCCURRED. PRIOR TO THE EMERGENCY, THE ENGINEER WAS OPERATING ASYNCHRONOUSLY WITH THE LEAD ENGINE NS 8005 IN DYYNAMIC BRAKE NUMBER 5 LOADING UP TO 73 KLBS AND THE DP UNIT NS 9945 IN THROTTLE NOTCH 1 THROUGH THE CROSSOVER.</blockquote>
Comment: Again, if one searched for DPU-involved accidents using the proper fields, this event would not appear. We don’t know why the engineer handled this very long and heavy train this way.</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">56</td><td>UP
Union, OR
4/15/2021

6180.54
(4/3/2022)</td><td>Loads, empties (total): 88, 72 (160)

Power: 3 front, 3 DPUs mid-train, 1 DPU rear

Tons: 13,171

Speed: 19 mph

TEMS: TO, in control</td><td>Derailed beginning at position 46 (empty)

Cars derailed: 5, by the coded entries, 4 by the narrative

Damages: $3.4m</td><td>UP: H508—Improper train make-up</td></tr>
<tr><td colspan="4">Explanation: This train was laden with DPUs, and they were in grade territory. The narrative suggests more than placement of cars may have been involved:

MPDNP-13 WAS DESCENDING DOWN A 1 PERCENT GRADE WHEN THE TRAIN SEES AN INCREASE IN AIR FLOW (0 CFM UPTO 20 CFM) AROUND MP 314.24. THE TRAIN WAS BEING CONTROLLED BY EMS/TRIP OPTIMIZER AT THIS TIME. AT THIS TIME, THE HEAD END WAS IN DYNAMIC BRAKING THROTTLE 5 AND THE MID AND REAR DPS WERE IN THROTTLE 5, PUSHING AS THE REAR PART OF THE TRAIN WAS STILL ASCENDING UP A 1.5 PERCENT GRADE. THE ENGINEER TOOK OVER CONTROL OF THE TRAIN AROUND MP 314.3 DUE TO THE ROUGH TRAIN HANDLING BEING FELT ON THE HEAD END. THE TRAIN CONTINUES FOR ANOTHER 1 MILE AND 3,289 FEET BEFORE IT FINALLY GOES INTO UDE. AFTER TAKING OVER CONTROL OF THE TRAIN, THE ENGINEER REDUCED DYNAMIC BRAKING EFFORT FROM THROTTLE 6 DOWN TO THROTTLE 2 AT THE TIME OF THE UDE. THE CONDUCTOR STARTED TO WALK THE TRAIN AND FOUND 2 CARS DERAILED. THREE ARMN CARS WERE NOT INVOLVED IN THE ORIGINAL INCIDENT BUT WERE ON THE SAME TRAIN & WHEN PULLING REMAINING PORTION OF TRAIN BACK TO CLEAR RAIL ROLLED, THESE THREE CARS HAD A MINOR DERAIL AND WERE INSPECTED & RELEASED.

Comment: Most of the damage was to the track structure, presumably from pushing derailed cars that had not separated. Why was TO being used here, when one would have expected use of air brakes (minimum set) once the train had crested the grade?</td></tr>
<tr><td rowspan="2">57</td><td>NS
Greensboro, NC
4/16/2021

6180.54
(4/3/2022)</td><td>Loads, empties (total): 72, 17 (89)

Power: 3 front

Tons: 9,648

Speed: 6 mph</td><td>Derailed on North Lead, beginning at position 65 (empty)

Cars derailed: 8, plus 1 locomotive (see explanation)

Damages: $130K</td><td>NS: H504—Buffing or slack action excessive, train makeup</td></tr>
<tr><td colspan="4">Explanation: The NS narrative and box 34-35 entries says 1 engine and 8 cars derailed, but the first car/unit derailed was at position 65 and all 3 locomotives were up front?</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
58	UP Fort Worth, TX 4/21/2021 6180.54 (4/3/2022)	Loads, empties (total): 15, 6 (21) (see explanation) Power: 3 front, 1 DPU mid-train, 1 DPU rear Tons: 20,097 Speed: 5 mph	Derailed beginning at position 20 (empty) entering yard (initially reported as position 17) Cars derailed: 5 (empties) Damages: $188K	UP: H518—Dynamic brake, excessive
	Explanation: The probable cause declared may be correct, but the car data in the UP report clearly is not, given the power allocation and the tonnage. See the narrative: MDNFW-21 WAS ARRIVING AT THE EAST END OF DAVIDSON YARD, LINED INTO TRACK 104, THE ENGINEER HAD THE DPU FENCED WITH THE HEAD END IN DYNAMIC 8 AND THE MID AND REAR DPU PUSHING IN THROTTLE 3. AFTER THE PICKUP AT ROANOKE, THERE WERE 15 LOADS ON THE HEAD END AND 6 EMPTY CARS BEHIND THOSE. 5 RAILCARS DERAILED. Comment: We presume the pickup was at Roanoke, TX, which is close by. The cars were evidently added to the front of a long, heavy train. It appears the cars that derailed were in the block of empties. The earnest analyst who went looking for long trains in the data based on the number of cars would overlook this entry.			
59	NS Oregon, OH 4/23/2021 6180.54 (3/26/2022)	Loads, empties (total): 112, 69 (181) Power: 3 front Tons: 16,233 Speed: 8 mph	Derailed at position 56 Cars derailed: 8 (loads) Damages: $38K	NS: E41C—Side bearing clearance excessive *Updated from* M505—Cause under active investigation
	Explanation: This is a long and heavy train to be operated without DPUs. The narrative says no exception was taken to train handling. The record for this accident was updated at some point after 8/18/2021, inserting the equipment-related cause code.			

	Event / Sources	Train consist / speed	Consequences	Cause(s)
60	NS Mapleton, PA 5/13/2021 6180.54 (4/4/2022)	Loads, empties (total): 184, 14 (198) Power: 4 front Tons: 21,225 Speed: 45 mph	Derailed at position 50 (load) Cars derailed: 2 Damages: $16K, plus train delays on a line with density of 76 mgt	NS: H503—Buffing or slack action excessive, train handling
	Explanation: The narrative stated as follows: NS TRAIN 36AC113 MOVING EAST MADE A RUNNING RELEASE ON THE TRAIN WHILE IN DYNAMIC AND FAILED TO ALLOW A FULL RELEASE BEFORE EXITING DYNAMIC BRAKING AND APPLYING POWER, DERAILING 2 CARS. Comment: This may be a legitimate cause code, but how was it derived? Did the railroad perform an analysis with TOES or a similar, validated model? This was a very heavy train on a line with significant curvature. The fact that the engineer was employing the air brakes suggests issues managing the speed of the train (along a river route). Why was no distributed power provided to help manage in-train forces? ECP brakes would have reduced uniformly along the entire length of the train.			

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">61</td><td>UP
Sibley, IA
5/16/2021

6180.54
(4/4/2022)</td><td>Loads, empties (total): 116, 43 (159)

Power: 2 front, 1 DPU mid-train

Tons: 16,545

Speed: 46 mph</td><td>Derailed due to run-in coming off of 1% grade starting at position 97 (empty)

Cars derailed: 15 loads, 32 empties (47)

Damages: $3.4m; release of product from 9 out of 27 hazmat cars in the consist (12 derailed or damaged). A significant fire ensued, which was allowed to burn out over several days. Train operations over the line resumed 5/20, according to local news reports. A local news report also referred to precautionary evacuation of "homes and businesses," but the 6180.54 shows no evacuations. See https://www.siouxlandproud.com/news/local-news/developing-train-derailment-near-sibley-iowa/ for video and report of 2.5 mile evacuation zone.</td><td>UP: H504—Buffing or slack action excessive, train make-up</td></tr>
<tr><td colspan="4">Explanation: This was a heavy manifest train operating at significant speed over undulating territory without use of air brakes. The railroad provided significant detail in the narrative:

MSSNP-15 WAS DESCENDING A GRADE THAT WAS GREATER THAN 1% AND THE ENGINEER HAD CONTROLLED THE TRAIN WITH DYNAMIC BRAKES FOR MORE THAN A MILE. WHEN THE HEAD END OF THE TRAIN HAD REACHED THE BASE OF THEGRADE WHERE IT WAS LEVEL FOR ABOUT A QUARTER OF A MILE, BEFORE ASCENDING A SIMILAR GRADE, THE ENGINEER WENT FROM SET UP TO IDLE. IN PTB WE WERE ABLE TO SEE AFTER THE FACT THAT THERE WAS A GREAT DEAL OF BUFF FORCE IN APPROXIMATELY THE 40 CARS RIGHT BEHIND THE CAR THAT WAS DETERMINED TO HAVE DERAILED FIRST. THE ENGINEER DIDN'T VIOLATE ANY TRAIN HANDLING RULES BUT COULD HAVE HAD THE MID TRAIN DISTRIBUTIVE POWER FENCE-UP AND APPLIED ADDITIONAL POWER FROM THAT LOCOMOTIVE TO CONTROL RUN IN AND RUNOUT. THIS IS POTENTIALLY AN ISSUE WITH THE COMBINATION OF TRAIN MAKEUP WITH MULTIPLE CUSHIONED DRAWBAR CARS INTERACTING WITH THE FORCE THAT IS BEING CAUSED. MEANING, THE REASON THIS WOULDN'T HAVE BEEN A TRAIN HANDLING RULE VIOLATION, THE COMBINATION OF THE DRAWBARS AND THE TRAIN HANDLING RESULTEDI N A CAR WITH A CUSHIONED DRAWBAR TO BE FORCED OUT OF THE TRAIN AT THE BOTTOM OF A GRADE (AND IN A SLIGHT CURVE). WITHOUT THE TRAIN BEING BUILT WITH MULTIPLE CUSHIONED DRAWBARS, AS A MID DPU TRAIN, THIS TRAIN HANDLING WOULD NOT HAVE BEEN A CONCERN FOR DERAILMENT. CAR#: TILX 111451 HYDROCHLORIC ACID - 146,775 LBS. CAR#: PROX 12159 HYDROCHLORIC ACID, 95,000 LBS. CAR#: TCIX 161064 POTASSIUM HYDROXIDE, 191,750 LBS. CAR#: TILX 112421 HYDROCHLORIC ACID, 48575 LBS. CAR#: FHRX 135941 MOLTEN SULFUR

Comment: UP has announced that it is working on a new train handling model and planning platform called "Precision Train Builder," evidently the "PTB" referred to in the narrative. According to Jeff Stagl in Progressive Railroading (March 2021), PTB "will simulate trains and their operations over hundreds of miles of track compressed into minutes to more accurately identify where to place cars within a train, how much power is needed, and where to place locomotives for the most efficient and safe operation."</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">62</td><td>NS
Danville, KY
5/24/2021

6180.54
(4/4/2022)</td><td>Loads, empties (total): 46, 38 (84)

Power: 1 (shoving)

Tons: 6,567

Speed: 2 mph</td><td>Derailed beginning at position 17 (load)

Cars derailed: 13

Damages: $54K</td><td>NS: H506—Lateral drawbar on curve excessive, train make-up</td></tr>
<tr><td colspan="4">Explanation: The narrative indicates that a road assignment was shoving out of a yard track. Selected for the cause code.</td></tr>
<tr><td rowspan="2">63</td><td>NS
Tunnelhill PA
6/7/2021

6180.54
(3/26/2022)</td><td>Loads, empties (total): 77, 0 (77)

Power: 3 front

Tons: 0 [<u>sic</u>—see explanation]

Speed: 12 mph</td><td>Derailed at position 7

Cars derailed: 5

Damages: $416K</td><td>NS: H506—Lateral drawbar force on curve excessive, train make-up

Updated from M505—Cause under active investigation</td></tr>
<tr><td colspan="4">Explanation: From the information given on the car first involved, TTAX553214, this would appear to be an intermodal train, but 14 cars are said to be carrying hazmat (none damaged or derailed). TTAX cars can each have 5 articulated platforms. See http://www.spookshow.net/freight/nsk53spine.html. The spine cars are light, but even unloaded they would not add up to "O" trailing tons. Why would FRA edit routines permit this error? The 6180.54 for this event was retrieved on 9/20/2021, but the accident was still said to be under active investigation. By 3/26/2022 the cause had been determined, but the error regarding trailing tonnage had not been corrected.

This derailment was near the front of the train, on territory where NS had previously stringlined empty cars. Is there any chance that one or more platforms of the first car derailing were empty? (NOTE: FRA instructions call for platforms to be counted as individual cars (FRA Guide at 124), and the narrative is to include a reference to articulated cars. However, narratives rarely contain such a reference, and there is none here.)</td></tr>
<tr><td rowspan="2">64</td><td>CSX
Bessemer, AL
6/22/2021

6180.54
(4/4/2022)</td><td>Loads, empties (total): 64, 84 (148)

Power: 4 front

Tons: 8,432

Speed: 8 mph</td><td>Derailed cars 42 through 46

Cars derailed: 5 (empties)

Damages: $37K</td><td>CSX: M405—Interaction of lateral/ vertical forces (includes harmonic rockoff)</td></tr>
<tr><td colspan="4">Explanation: This appears to be a flatcar empty, with placement of loads not provided. The track is identified as FRA Class I with 1.00 gross tonnage, but CWR. The location plots on a wye by Interstates 20 and 59. Train placement an issue?</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
65	NS Norris, SC 6/23/2021 6180.54 (4/4/2022)	Loads, empties (total): 55, 15 (70) Power: 2 front Tons: 36 [*sic*—see explanation] Speed: 26 mph TEMS: Leader	Derailed at position 59 (empty) Cars derailed: 13 Damages: $1.2m	NS: E40C—Side bearing clearance insufficient
	Explanation: Here is another patent error from NS, showing 36 trailing tons for a substantial train. The narrative: 265P323 WAS OPERATING IN LEADER AUTO ACTIVE AT 26 MPH, LOADING 29 KLBS, IN NOTCH 6 WHEN THE REAR 13 CARS DERAILED. NS reports that the 13 cars were empty. Local news photos (https://www.greenvilleonline.com/picture-gallery/news/2021/06/23/photos-pickens-county-13-car-train-derailment-norris/5328512001/) show derailed well car platforms loaded with containers (which may themselves have been empty, but clearly would be cargo).			

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">66</td><td>UP
Ames, IA
6/24/2021

6180.54
(3/29/2022)</td><td>Loads, empties (total): 126, 112 (238)

Power: 3 front, 1 mid-train DPU, 1 rear manual (see explanation)

Tons: 20,331

Speed: 30 mph</td><td>Derailed at position 176 due to equipment defect at position 79 (see explanation/comment), while executing a crossover

Cars derailed: 27

Damages: $2m

Railroad reported 19 hazmat cars in consist, with 2 derailing, no release, no evacuation. Local media referred to release of LPG and evacuation of 12-15 residences (https://www.wowt.com/2021/06/25/petroleum-gas-leaks-after-train-derailment-ames/)</td><td>UP: E47C—Defective snubbing</td></tr>
<tr><td colspan="4">Explanation: There was a coding error on the locomotives, we assume. This long, heavy train probably had a mid-train DPU and another at the end. But the railroad had fixed an error showing the mid-train as manual and left the rear end locomotive as manual in an updated report.

Perhaps there was no necessity for an evacuation, but the debris field was sufficient for concern (local media), and local authorities believed there was a “minor leak.” https://www.kcci.com/article/authorities-investigate-train-derailment-in-downtown-ames/36831863

That doesn’t explain how a “car causing” at position 79 could result in car 176 being first off, though the narrative indicates “considerable track damage” to the two main tracks. The car said to be at fault (but not first off?) was identified as CNW 178176, which is an old bottom-dump covered hopper with a UP-predecessor car number), running empty. So, this was a car suspension defect, but no in-train forces were involved? Was a TEMS system in control at the time? Did FRA investigate?

In the initial report, the engineer and conductor are both shown exceeding their hours of service at the time of the derailment. Were there other problems with this train that resulted in significant delays? Why were the hours of service revised in the later filing to show an even 11 hours for both crew members?</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
67	NS Royalton (initially York Haven), PA 6/28/2021 6180.54 (3/29/2022)	Loads, empties (total): 104, 26 (131) Power: 3 front (see explanation) or 1X1DPU Tons: 13,610, up from 8,480 (see explanation) Speed: 41 mph	Derailed 27th through 59th cars Cars derailed: 33 Damages: $2.8m Of 38 hazmat cars, 18 were damaged/derailed; no release, but narrative stated "NRC notification for potential release of benzene, butane, crude oil" Local news indicated that 12 state or local agencies responded. https://www.ydr.com/story/news/2021/06/29/norfolk-southern-train-derailment-investigation-cleanup-underway-newberry-township-york-county-pa/7794373002/	NS: H501—Improper train make-up at initial terminal *Updated from* M505—Cause under active investigation
	Explanation: Was this train under TEMS control? Did the railroad model the accident using TOES? If there was crude oil in the train, why was the special study block not completed? 80 FR 23069 (April 24, 2015). Quality control issues seem endemic. The initial report said there were 3 head-end locomotives and no DPUs. The most recent record has one unit up front, which derailed (it clearly didn't), and one mid-train DPU. To make things even more strange, the trailing tonnage was increased from 8,480 in the earlier record to 13,610 in the more recent record. If the railroad actually dispatched a 13,610 trailing ton train with only 2 locomotives, one would have to say that was beyond thrifty.			
68	BNSF Marcelene, MO 7/8/2021 6180.54 (3/29/2022)	Loads, empties (total): 108, 28 (136) Power: 3 front, 2 DPUs rear Tons: 14,223 Speed: 53 mph	Derailed beginning at car 100 (load) Cars derailed: 35 Damages: $3.4m Double track main line was blocked by the derailment, based on local press photo	BNSF: H504—Buffing or slack action excessive, train make-up
	Explanation: This was a big derailment on a 85.62 mgt main line. Were the DPUs in communication? Were they synchronous or fenced? Was a TEMS system operating the controls?			

	Event / Sources	Train consist / speed	Consequences	Cause(s)
69	UP Brewster, MN 7/10/2021 6180.54 (3/29/2022)	Loads, empties (total): 108, 43 (151) Power: 3 front Tons: 15,095 Speed: 28 mph	Derailed beginning at position 20 (empty) Cars derailed: 16 Damages: $870K 4 of the 36 hazmat cars in the train were damaged, but no release according to the report. Local news quoted a UP spokesperson as saying that a "minor amount" of isooctane, a flammable liquid, was spilled and remediation was underway. https://www.dglobe.com/news/7109386-Cleanup-continues-after-16-car-train-derailment-near-Brewster	UP: H503—Buffing or slack action excessive, train handling H504—Buffing or train handling excessive, train make-up

Explanation: The UP narrative follows—

MSSNP-09 WAS TRAVELING NORTH BOUND AT 33 MPH, COMING UP TO A RED SIGNAL AT SX171, TRAIN GAINS SPEED TO 37 MPH. ENGINEER WAS IN THROTTLE 8, AND ATTEMPTED TO SLOW TRAIN SPEED BY COMING OFF OF THE THROTTLE AND SETTING AIR. ENGINEER GOES HEAVY IN DYNAMICS WITH 12 PSI OF AIR SET, CREATING EXCESSIVE BUFF AND DRAFT FORCES, RESULTING IN DERAILING 16 RAILCARS. NO IMPROPER TRAIN MAKEUP, HOWEVER A BLOCK OF 11 EMPTIES BETWEEN LOADS, CONTRIBUTED TO THE DERAILMENT.

Comment: The railroad's characterization seems reasonable, but consider that this engineer had been given a long and heavy mixed manifest train with only 3 locomotives at the front (no DPUs).

The method of operation is coded as not signaled, but the train is approaching an absolute signal when it derailed and must have passed an approach signal. This appears to be an automatic block signal system with track warrant control. This was not PTC territory, according to the report. Active PTC would have provided continuous warning that the train needed to slow for the home signal. The accident is likely PTC-preventable, but UP has elected to build out PTC only on those lines where required.

	Event / Sources	Train consist / speed	Consequences	Cause(s)
70	CSX Elizabethtown, KY 7/20/2021 (4/20/2022) 6180.54	Loads, empties (total): 70, 26 (96) Power: 4 front Tons: 9,205 Speed: 23 mph	Derailed descending hill at position 13 (empty) Cars derailed: 8 Damages: $575K	CSX: H504—Buffing or slack action excessive, train make-up

Explanation: Local news showed a substantial pile up in a populated area, but the 4 cars carrying hazmat did not release. The CSX narrative is helpful:

> TRAIN DEPARTED NASHVILLE CAME ACROSS MAINLINE SUB WHEN COMING DOWN TUNNEL HILL AT MP 000034 TRAIN WENT INTO EMERGENCY-AFTER COMING TO A STOP CO-WALKED TRAIN AND FOUND 8 CARS PILED UP AND DERAILED LINES 13-20. AFTER INVESTIGATING WAS FOUND THAT THE DERAILMENT OCCURRED AT 000036.AND CAR TRAVEL APPROXIMATELY 2 MILES PRIOR TO GOING INTO EMERGENCY. WHEEL LIFTED INTO THE INSIDE COMING DOWN TUNNEL HILL AROUND CURVE DUE TO IMPROPER TRAIN MAKE-UP AT INITIAL TERMINAL. THE TRAIN HAD 15 INTERMODAL CARS ON THE H/E-THE 13 CAR FEC 70052 WAS THE PRINCIPAL CAR AND WAS EMPTY WHILE COMING DOWNHILL THE TRAILING TONS OF 8321 BUNCHED THE TRAIN UP AND CAUSED THE WHEEL SET TO LIFT OFF TRACK. TRAIN WAS OPERATING IN TO AND PTC AT 23 MPH-AUTHORIZED SPEED WAS 25 MPH. AT PD TRAIN WAS IN A LEFT HAND CURVE AT-THE CURVE WAS A 6 DEGREE 18 MIN CURVE. THE CROSS LEVEL AT PD WAS 1 ? INCH AND THE GAUGE WAS 56 ? THIS WAS GOING DOWNHILL AT A 1.3% GRADE. AT PD THE WHEEL MARK WAS SHORT 16 INCHES-WHEEL ACTION WAS A LIFT CARS DERAILED TO THE INSIDE.

Comment: The reference to TO is to Trip Optimizer. It is not clear why TO would be used coming over a significant grade, given that air brakes would seem to be indicated to reduce run-in. The reference to PTC is interesting, because the method of operation coding does not call out PTC, as required.

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>71</td><td>NS
Harrodsburg, KY
7/22/2021

6180.54
(4/4/2022)</td><td>Loads, empties (total): 94, 94 (188)

Power: 3 front

Tons: 5,808 [sic; see explanation]

Speed: 2 mph</td><td>Derailed beginning at position 110 (empty)

Cars derailed: 8

Damages: $257K

Local news showed a video of the low-speed derailment directly in town (appears to be stringline), which damaged a building. https://www.wtvq.com/new-video-neighbor-react-to-train-derailment-in-downtown-harrodsburg/</td><td>NS: H505—Lateral drawbar force on curve excessive, train handling</td></tr>
<tr><td></td><td colspan="4">Explanation: Either the car counts or the trailing tonnage value submitted by the railroad would appear to be erroneous. Assuming this is not a data entry error, the train is too long to be handled without a mid-train DPU. The narrative suggests additional concern:
NS TRAIN 167TA21 WHILE OPERATING AND ENROUTE TO DANVILLE, KY EXPERIENCED AN EMERGENCY BRAKE APPLICATION AT MP 353.0 W RESULTING IN A DERAILMENT OF CARS 110 THROUGH 117. NO HAZMAT CARS DERAILED OR RELEASED. CAUSE CODE TO BE ENTERED AFTER CONFIRMATIOON. ADDITIONAL INFORMATION PENDING INVESTIGATION. TENTATIVE CAUSE CODE ASSIGNED.

Comment: This record was last retrieved on 4/4/2022, and no change to the cause code or narrative had been made. Was the train being handled by a TEMS system? What did the TOES model say about in-train forces? What train-handling nuance produces a derailment at position 110 at 2 mph?</td></tr>
<tr><td>72</td><td>UP
Burns, WY
7/28/2021

6180.54
(4/20/2022)</td><td>Loads, empties (total): 121, 0 (121)

Power: 3 front, 2 DPUs rear

Tons: 17,303

Speed: 15 mph</td><td>Derailed moving on siding

Cars derailed: 16

Damages: $868K</td><td>UP: T199—Other track geometry defects (Provide detailed description in narrative)</td></tr>
<tr><td></td><td colspan="4">Explanation: This appears to be a loaded coal unit train. It would not have been included here except that the railroad failed to provide the required description of the track geometry defect in the narrative. The available codes for track geometry defects are pretty inclusive. What was going on here? Why is there apparently no check in the reporting system to note the error (record last retrieved 4/20/2022)?</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>73</td><td>NS
Rensselaer, MO
8/2/2021

6180.54
(4/20/2022)</td><td>Loads, empties (total): 119, 5 (124)

Power: 4 front

Tons: 12,895
Length: 10,747 feet

Speed: 44 mph</td><td>Derailed 6th through 30th head cars and the 76th through 98th cars (80th car first involved, empty, bearing an NS car mark)

Cars derailed: 48

Damages: $4.2m

A number of the cars--at least a dozen--were auto racks loaded with new vehicles. Local press reported a company spokesperson as saying that the cars were a total loss (not included in the railroad damage total).</td><td>NS: H518—Dynamic brake, excessive</td></tr>
<tr><td></td><td colspan="4">Explanation: This was a heavy train with all locomotives up front. The facts may indicate that a brake application caused compressive forces in the train, with one of the few empty cars off first, resulting in an emergency application of the brakes and secondary derailment at the front of the train. Was a TEMS system operating the train? Was a TOES analysis run? If in control, what prompted the engineer to go so deep into the dynamic brakes?</td></tr>
<tr><td>74</td><td>UP
Kingsville, MO
8/9/2021

6180.54
(4/20/2022)</td><td>Loads, empties (total): 0, 107 (107)

Power: 1 front, I DPU mid-train, 1 DPU rear

Tons: 13,797 (see explanation)

Speed: 36 mph</td><td>Derailed at position 89 (empty) when rail rolled

Cars derailed: 21, plus rear DPU

Damages: $1.9m</td><td>UP: H506—Lateral drawbar force on curve excessive, train make-up</td></tr>
<tr><td></td><td colspan="4">Explanation: It's difficult to reconcile the trailing tons with the consist of 107 empties. If they were empties, what purpose was the rear DPU serving? Is that the meaning of the cause code? How often will compressive forces on empty cars result in a rail rolling? Here is the narrative:
<blockquote>TRAIN MASNP-08 WENT INTO EMERGENCY AT MP 235.4. UPON INSPECTION, 21 CARS HAD DERAILED ALONG WITH THE MID-DPU DUE TO THE LATERAL FORCES FROM THE MID-DPU AND REAR-DPU ON UNDULATING TERRITORY THAT SHOVED THE 6TH CAR LATERAL FORCES OUT ON COER816525 FROM THE MID-DPU, CAUSING THE RAIL TO ROLL UNDER THE TBOX638239 AND DERAILING THE 21 CARS AND LOCOMOTIVE UP8993.</blockquote>
Comment: Were the DPUs in synchronous mode or fenced? Was a TEMS controlling the train? How did they pack 13,797 trailing tons into 107 empties?</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>75</td><td>NS
Ossian, IN
8/16/2021

6180.54
(3/29/2022)</td><td>Loads, empties (total): 0, 185 (185)

Power: 5 front

Tons: 6,778
Length: 11,026

Speed: 56 mph</td><td>Derailed toward back of train. Resulting UDE derailed from 118th car

Cars derailed: 3

Damages: $55K</td><td>NS: E4TC—Truck hunting

Updated from M505—Cause under active investigation</td></tr>
<tr><td></td><td colspan="4">Explanation: This record had been flagged as an M505. The subsequent cause code seems plausible, given the speed. However, note the length of the train and absence of DPUs. Here is the narrative:
NS TRAIN 61CL014 WAS TRAVELING WEST WITH LOCOMOTIVES; NS 8168, NS 4299, NS 9606, NS 7703, NS 4475 AND 0 X 185 X 6778 X 11026 FEET WHEN TRAIN EXPERIENCED AN UDE AND FOUND 3 CARS DERAILED; THE 118TH CAR, NW 189639(A-END), 184TH CAR, NW 189393(BOTH ENDSS), AND 185TH CAR, NW 190298(A END).
Apparently empty gondolas derailing, evidently a unit train.</td></tr>
<tr><td>76</td><td>NS
New Orleans, LA
8/22/2021

6180.54
(3/29/2022)</td><td>Loads, empties (total): 97, 31 (128)

Power: 1 front, 1 manual helper rear

Tons: 13,346

Speed: 9 mph</td><td>Derailed beginning at position 2 (empty) departing Oliver Yard

Cars derailed: 2

Damages: $45K</td><td>NS: H505—Lateral drawbar force on curve excessive, train handling</td></tr>
<tr><td></td><td colspan="4">Explanation: We assume from the narrative that both cars derailing were empty autoracks, which typically have long-travel draft gear. The engineer may have made a mistake here. But it is just as likely that train make-up was a factor, given the tonnage behind the empties. There is some possible confusion here, since the report shows a helper at the rear but one engineer for the consist, with no separate report for the helper crew. Was it a DPU? Is the train handling error imputed to the helper crew? Headend crew?</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
77	UP Mount Shasta, CA 8/27/2021 6180.54 (3/29/2022)	Loads, empties (total): 56, 45 (101) Power: 3 front Tons: 9,262 Speed: 8 mph	Derailed beginning at position 38 (empty) in mountain grade territory Cars derailed: 20 (all empty) Damages: $933K	UP: H506—Lateral drawbar force on curve excessive, train make-up

Explanation: The location is on the Cantara Loop, a known challenging piece of railroad that was the site of the disastrous spill of 1991, which polluted the Sacramento River for 41 miles downstream, killing fish and trees along the banks (and resulting in addition of metam sodium to the hazmat table). The railroad provided significant detail in its narrative for this most recent derailment:

> MDPRVB-26 TRAIN BUILD, 3X0 WITH 33 LOADS ON THE HEAD, 16 LOADS ON THE REAR, WITH 43 OF THE 50+ CARS BETWEEN LOAD BLOCKS BEING EMPTY. 75 TOTAL CUSHIONED DRAWBARS, 33 OF WHICH WERE EMPTY AUTOS, TRAIN WAS BUILT WITHIN THE CURRENT GUIDELINES OF OUR TAIN HANDLING REQUIREMENTS. WHILE ON DESCENDING (HEAVY MOUNTAIN) GRADE WITH FIRST SERVICE APPLICATION EXPERIENCED A 2PSI DECREASE IN AIR ON THE REAR OF THE TRAIN AS INDICATED BY EOT DEVICE WHILE TRAVERSING A SMALL SECTION OF LESS STEEP GRADE IN HEAVILY CURVED 20MPH AREA. THIS FORCED THE TRAIN TO SLOW DOWN TO A POINT WHERE IT WAS NECESSARY FOR THE ENGINEER TO RELEASE THE AUTOMATIC BRAKES. ENGINEER RELEASES BRAKES AND FOR THE NEXT MINUTE AND SEVEN SECONDS, SLOWLY INCREASES THE DYNAMIC BRAKING EFFORT WITH THE REAR END REGISTERING A RELEASE OF THE BRAKES AT 32 SECONDS FROM THE TIME OF RELEASE AND 30% DYNAMICS AT THAT TIME. AT SOME POINT AFTER THE RELEASE, DUE TO BUFF/LATERAL FORCES THE REAR AXLE OF THE TTGX157390 LIFTED OFF THE RAIL AND CAME DOWN OUTSIDE THE GAUGE OF THE RAIL ON A CURVE AT MP328.11. THIS IN TURN CAUSED THE TRAIN TO GO INTO EMERGENCY. THE EMERGENCY NEAR THE REAR OF THE TRAIN CAUSED THAT SECTION TO SLOW DOWN FIRST AND AS THE WEIGHT TOWARDS THE HEAD END OF THE TRAIN CONTINUED WITH MORE MOMENTUM THE REST OF THE CARS INVOLVED IN THE INCIDENT WERE STRINGLINED TO THE INSIDE OF THE 2 CURVES INVOLVED DERAILMENT. ALL PARTIES THAT REVIEWED THE EVENT RECORDER AND ALL AVAILABLE DOCUMENTATION AGREE THAT TRAIN MAKE-UP LIKELY SI

Comment: This derailment was fortunate in that, among the 7 hazmat cars in the train, the 3 that derailed were apparently residue cars that did not release product. Did UP alter its train make-up rules for this subdivision? Would have adding a DPU mid-train have provided the tractive effort needed to keep the train moving without releasing the air brakes (which were helping to keep the train stretched)?

This type of accident is among those illustrative of the point that train length, while potentially salient with respect to air brake issues, is hardly the only consideration with respect to management of in-train forces.

From the data available, ECP brakes may have prevented or mitigated this accident.

	Event / Sources	Train consist / speed	Consequences	Cause(s)
78	UP Houston, TX 8/30/2021 6180.54 (3/29/2022)	Loads, empties (total): 56, 108 (164) Power: 7 front Tons: 10,746 Speed: 7 mph	Derailed beginning at position 86 (empty) "…COMING OFF THE HOUSTON SUB." Cars derailed: 8 Damages: $333K	UP: H503—Buffing or slack action excessive, train handling and H607—Failure to comply with restrictive speed or its equivalent not in connection with a block or interlocking signal *Revised from* H008—Improper operation of train line connections (bottling the air)
	Explanation: The initial cause code suggested run-in by cars unresponsive to a train air brake application, with the suggestion of bottled air. Now it's train handling. But why do we have 7 units under power at the front? The accident report says 164 cars contained hazmat (or residue), but none of the 164 were damaged or derailed. Still, of the 164 cars in the train 8 were derailed, with over $330,000 worth of *equipment* damage. The first involved car was a covered hopper, so perhaps there were fewer than 164 hazmat cars in the train? Comment: The road crew moving this train was at 11 hours and 28 minutes at the time of the derailment, according to the report. Had this train experienced other problems as it was assembled?			

	Event / Sources	Train consist / speed	Consequences	Cause(s)
79	CSX crossing NS diamond Birmingham, AL 9/22/2021 6180.54s (3/29/2022)	Loads, empties (total): 0, 209 (209) Power: 4 front Tons: 660 [sic: see explanation] Speed: 14 mph	Derailed beginning at position 102 at NS diamond and continued on NS track (?) Cars derailed: 20 (NS narrative says 22) Damages: $140K	CSX and NS: H519—Dynamic brake, too rapid adjustment
	Explanation: This was a long, light string of empties, but not 660 tons as reported. The consist would likely be over 4,500 tons based on the tare weight of the gondolas. The “employee” responsible for the use of dynamic brakes may have had a difficult job given the length of the train and absence of DPUs.			

	Event / Sources	Train consist / speed	Consequences	Cause(s)
80	UP Gold Run, CA 9/24/2021 6180.54 (3/29/2022)	Loads, empties (total): 128, 8 (136) Power: 3 front, 3 DPUs mid-train, 2 DPUs rear Tons: 14,252 Speed: 14 mph	Derailed beginning at position 46 on ascending grade Cars derailed: 10 Damages: $87K	UP: E79L—Other locomotive defects (requires description in narrative)

Explanation: The UP narrative, revised from the initial submission, apparently after examination of the event recorder data for the DPUs:

> MRVNP-23 ON THE ROSEVILLE SUB, WENT INTO UDE AT MILEPOST 152.219 TRAVELING AT 14 MPH. ENGINEER USING EMS AT THE TIME OF THE UDE, WITH NO AIR BRAKES SETUP IN THE TRAIN. UPON INSPECTION, IT WAS DISCOVERED 10 CARS DERAILED, 8 LOADED AUTO-RACKS AND 2 LOADED LUMBER CARS. THIS TRAIN IS TRAVELING ON 2% ASCENDING GRADE. BIT 3 CARS AHEAD OF MID DPU 10 CARS STRING LINED ON 9% CURVE. THE MRVNP-28 WAS OPERATING WITH A HEAD CONSIST & MID CONSIST & REAR CONSIST. ENERGY MANAGEMENT WAS OPERATIVE AND BEING USED AT THE TIME OF THE INCIDENT. THE LEAD CONSIST SHOWS NO SIGNS OF LOCOMOTIVE ISSUES NOR DOES THE REAR CONSIST. HOWEVER, LEADING UP TO THE DERAILMENT THE UP6751 STARTS TO HAVE SPORADIC LOADING ISSUES DROPPING THE KLBS OF EFFORT FROM A STEADY STATE OF 90 KLBS DROPPING TO 55 KLBS, THEN INCREASING BACK TO 90 KLBS AND THEN DROPPING LOAD AGAIN TO 60 KLBS. THE DOWNLOAD SHOWS THIS CONTINUES ON FOR 2MINUTES AND 51 SECONDS AND AS THE MID DPU STABILIZES BACK TO A STEADY TRACTIVE EFFORT OF 90 KLBS, THEY EXPERIENCE A UDE. THE CREW WALKED THE TRAIN AND FOUND THAT THE TRAIN WAS BROKE IN TWO 3 CARS BEHIND THE MID DPU. THE REAR PORTION OF THE TRAIN WAS NAVIGATING A 9% CURVE AND 4 INCH ELEVATION AT THE TIME OF THE UDE, CAUSING A STRING LINE EFFECT TO THE CARS THAT DERAILED.

The railroad is laying this on one of the mid-train DPUs (3). So, was the irregular loading limited to one unit? Was it caused by a fault in the individual locomotive, the LOCOTROL system, or perhaps even the TEMS (EMS)? Were there intermittent comm problems? Were all three mid-train DPUs experiencing the same surges? What is the remedy?

Comment: This is one of the most challenging pieces of railroad in the country. Plenty of power was provided for this train, and one would not expect to set air brakes if the ascent is continuous. Still, relying on "EMS" in grade territory seems unusual, unless we now trust it more than engineer judgment. One will not save much fuel while ascending the Sierra Nevada toward Donner Pass.

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>81</td><td>UP
Smithville, TX
9/26/2021

6180.54
(3/30/2022)</td><td>Loads, empties (total): 112, 40 (152)

Power: 3 front, 2 DPUs rear

Tons: 20,362

Speed: 12 mph</td><td>Derailed beginning at position 79 (empty)

Cars derailed: 6

Damages: $182K

One tank car released a small quantity of hydrochloric acid</td><td>UP: M405—Interaction of lateral/ vertical forces (includes harmonic rock off)

Revised from T199—Other track geometry defects (requires explanation in narrative)</td></tr>
<tr><td></td><td colspan="4">Explanation: The original UP narrative didn’t tell us what the “other” defects were, stating only as follows:
THE MWTSA-24 WAS TRAVELING SOUTHBOUND OFF THE WACO SUB, ONTO THE LOCKHART SUB WHEN THEY DERAILED 7 CARS DUE TO GEOMETRY ISSUES IN THE CURVE THAT INVOLVED ADDITIONAL ISSUES WITH A LONG MANIFEST TRAIN [emphasis supplied].
The revised narrative removed the reference to “additional issues”:
THE MWTSA-24 WAS TRAVELING SOUTHBOUND OFF THE WACO SUB, ONTO THE LOCKHART SUB WHEN THEY DERAILED 6 CARS DUE TO GEOMETRY ISSUES IN THE CURVE. CAR# GATX 61104 HYDROCHLORIC ACID - 10 TO 20 GALLONS.

Comment: The narratives neither explain the problem with the curve nor with the train. No contributory cause code is provided for train make-up or train operation. When the statisticians work the issue of train energy management, they will dismiss this case as “other” and thus of lesser or no interest.</td></tr>
<tr><td>82</td><td>UP
on KCT/UP
Kansas City, MO
9/28/2021

6180.54
(3/30/2022)</td><td>Loads, empties (total): 104, 3 (107)

Power: 3 front

Tons: 13,913

Speed: 9 mph</td><td>Derailed at position 108 (empty)

Cars derailed: 1

Damages: $75K</td><td>UP/KCT: H501—Improper train make-up at initial terminal</td></tr>
<tr><td></td><td colspan="4">Explanation: This is a bit of a puzzle, but since locomotives are counted in the position sequence, perhaps one or two heavy, loaded cars were placed behind the empty covered hopper that derailed. Most of the damage was to the track, as a derailed wheelset was dragged for 20 miles, according to the narrative. An interesting sidelight here is the absence of a conductor on the train (according to the report). If there had been a conductor on the train, inspecting the train to the rear from time to time, would sparks from the derailed wheel have been evident (dark, clear conditions at 2:02 a.m.)?</td></tr>
</table>

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<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>83</td><td>UP
Addis, LA
10/4/2021

6180.54
(3/30/2022)</td><td>Loads, empties (total): 76, 116 (192)

Power: 1 front

Tons: 3,200 [sic: see explanation]

Speed: 6 mph</td><td>Derailed at position 21 (loaded tank car)

Cars derailed: 10 (2 loads, 8 empties)

Damages: $678K (most to track)

Of 50 hazmat cars in the train, 2 were damaged (no releases)</td><td>UP: T108—Track alignment irregular (other than buckled/sun-kink)</td></tr>
<tr><td></td><td colspan="4">Explanation: The cause may be validly reported (we do not know). However, the rest of the report has issues. We are given 3,200 as the trailing tons, which the tare weight would have exceeded if the car count is even close. This 192-car train is being handled by a single locomotive (according to the report), which must have strained to move this train a considerable distance before the UDE, given that over $500K in track damage is reported.</td></tr>
<tr><td>84</td><td>CSX
Savannah, GA
10/11/2021

6108.54
(3/30/2022)</td><td>Loads, empties (total): 108, 80 (188)

Power: 1 front, 1 DPU mid-train

Tons: 16,812

Speed: 12 mph</td><td>Derailed at position 51 (empty), side swiped train on adjacent track (Golden Isles Terminal RR train being handle by CSXT crew)

Cars derailed: 8, plus some damage to side-swiped cars

Damages: $300K</td><td>CSX: H993—Human Factor, track</td></tr>
<tr><td></td><td colspan="4">Explanation: Here, again, the cause may be legitimate. The Gold Isles narrative is the best of the two initial narratives:
<blockquote>CSX TRAVELING NORTHBOUND ON #2 MAIN TRACK WHILE GIMY WAS TRAVELING SOUTHBOUND ON #1 MAIN TRACK. GACX-55796 ON CSX DERAILED AT LIBERTY STREET LEAD STRIKING GIMY ON EAST SIDE OF TRAIN AFTER TRAVELING A MILE. CSX DERAILED 8 CARS. CSX CREW RESPONSIBLE FOR HFI. GIMY HAD 3 CARS/CONTAINERS DAMAGED.</blockquote>CSX updated its narrative, adding a useful explanation:
<blockquote>Q49211 RECEIVED DRAGGING EQUIPMENT FROM DEFECT DETECTOR. INSPECTION FROM THE GROUND REVEALED 8 CARSDERAILED AND SIDE SWIPED GOLDEN ISLE TERMINAL Z10011 DUE TO NEW CROSS TIES BEING INSTALLED THAT WERE NOT PROPERLY SURFACED AND CREATED A WARP IN THE CURVE. THIS CAUSED THE PRINCIPLE CAR TO UNLOAD AND DERAIL. GIMY REPORTS $50,000.00 DAMAGES.</blockquote></td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">85</td><td>UP on Kansas City Terminal Ry.
Kansas City, MO
10/19/2021

6180.54
(3/30/2022)</td><td>Loads, empties (total): 120, 49 (169)

Power: 1 front, 1 DPU mid-train, 1 DPU rear

Tons: 15,805

Speed: 10 mph</td><td>Derailed at position 24 (loaded autorack)

Cars derailed: 1

Damages: UP reported $159.00 in equipment damage and $94,605 in damage to its track. KCT reported $17,500 in damage to its signals (said to be track by UP). Total: $112K</td><td>UP/KCT: T199—Other track geometry defects (provide detailed description in narrative)</td></tr>
<tr><td colspan="4">Explanation: Here we have another unexplained track cause. KCT contends in its narrative that track geometry was within FRA standards.

UP, it must be said, may protest too much:<blockquote>SOUTHBOUND TRAIN MNPEW-18 DERAILED THE GTW504114 WHILE TRANSFERRING FROM THE KC TERMINAL SUB MAIN TRACK 4, ONTO TRACK 233 TO THE KC METRO COFFEYVILLE SUB MAIN TRACK ONE. THE ENGINEER MADE A 10LB SETOUT PRIOR TO ENTERING THE TURNOUT, THEN RELEASED AND RE-APPLIED A MINIMUM AS HE ENTERED THE TURNOUT.THE ENGINEER WAS IN DB 6 ON THE HEADEND WITH THE FENCE UP, PUSHING IN T1 ON THE MID AND REAR CONSISTS. THE ENGINEER MAINTAINS THIS THROTTLE SETTING THROUGH THE POINT OF THE DERAILMENT. THE MID AND REAR CONSISTS ARE FALLING OFF A 0.79 PERCENT GRADE THAT SADDLES BEFORE FLATTENING OUT FOR THE CURVE.THE SINGLE LEAD ENGINE WAS PRODUCING 80KLBS OF DYNAMIC BRAKING EFFORT. AS A RESULT [emphasis supplied], THE 24TH CAR DERAILED ON KCT PROPERTY AND CONTINUED SOUTH ON THE UP MAINTAINED TRACK, CAUSING ADDITIONAL DAMAGES. CAUSE WAS DETERMINED TO BE TRACK GEOMETRY. KCT MAINTAINS TRACK.</blockquote>UP is one of the owners of KCT.

Note the equipment damage figure.</td></tr>
<tr><td rowspan="2">86</td><td>NS
Roanoke, VA
11/05/2021

6180.54
(3/30/2022)</td><td>Loads, empties (total): 109, 60 (169)

Power: 0 front, 2 rear (shoving in yard?)

Tons: 15,908
Length: 11,866 feet

Speed: 9 mph</td><td>Derailed beginning at position 85 (empty), at cross-over

Cars derailed: 3 (empties)

Damages: $51K</td><td>NS: H505—Lateral drawbar force on curve excessive, train handling</td></tr>
<tr><td colspan="4">Explanation: This is a big, long train, arguably with marginal power, apparently being shoved to a position where it can move forward on its route. We don’t know how the cause was determined. The crew is reported to have consisted of an engineer and a conductor, both at precisely 12 hours of service (12:01 would be a violation). From press accounts and photographs, the derailment was in downtown Roanoke, at approximately the same spot as item 45, above.</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
87	NS Knoxville, TN 11/8/2021 6180.54 (3/30/2022)	Loads, empties (total): 138, 58 (196) Power: 3 front, 2 manual rear [sic: see explanation] Tons: 11,040 Speed: 6 mph	Derailed beginning at position 46 (empty) traversing a crossover from main to yard lead for planned stop Cars derailed: 6, plus another damaged Damages: $149K	NS: H518—Dynamic brake, excessive
	Explanation: This train is reported to have one engineer and one conductor, so it is very possible the two units coded as helpers were DPUs. We assume no TEMS was active approaching the yard, but we are not told whether the engineer was using the dynamic brakes in a fenced or synchronous mode, or for that matter whether the DPUs (if that's what they were) were in communication with the head end. Though the length of the train is not given, it would have been well in excess of 10,000 feet long.			
88	NS Paxtang, PA 11/8/2021 6180.54 (3/30/2022)	Loads, empties (total): 20, 50 (70) Power: 3 front Tons: 5,421 Length: 12,895 feet Speed: 1 mph ["recorded" value given by the railroad]	Derailed beginning at position 24 (loaded) on a yard track in Rutherford Yard (intermodal facility) Cars derailed: 6 (2 empty, 4 loads) Damages: $36K	NS: H503—Buffing or slack action excessive, train handling
	Explanation: The railroad's narrative repeats the tonnage entered in block 29 and adds the train length. The first car to derail was apparently an intermodal car of greater than 200 feet in length, suggesting multiple platforms (3 in this case). From the train length, it should be clear that the number of cars given is incorrect, since FRA's instructions are clear that platforms of multi-platform cars are to be counted as separate cars AND the narrative is required to explain that there were articulated cars in the consist (which is seldom if ever done). One can only marvel at the ability of the engineer to derail 6 cars 20+ positions behind the locomotives at 1 mph ("R" for recorded).			

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>89</td><td>UP
Coffeyville, KS
11/9/2021

6180.54
(4/21/2022)</td><td>Loads, empties (total): 54, 87 (141)

Power: 6 front

Tons: 9,099

Speed: 2 mph</td><td>Derailed beginning at position 66 (empty)

Cars derailed: 8 (empties)

Damages: $103K</td><td>UP: H505—Lateral drawbar force on curve excessive, train handling</td></tr>
<tr><td></td><td colspan="4">Explanation: Depending on how the data run is sequenced, this could go down as a main track derailment, since the railroad so indicated in two separate fields (form boxes 20, 21), as well as the information that this was signal territory. However, the narrative explains:
<blockquote>TRAIN MSANP-07, LEAD LOCOMOTIVE UP8856, HAD EIGHT EMPTY FLAT CARS DERAIL ON THEIR SIDES IN THE COFFEYVILLE YARD IN COFFEYVILLE, KS. THE TRAIN WAS MAKING A SETOUT INTO TRACK INTO TRACK 3 BEHINE 90 CARS. AS THE TRAIN WAS COMING TO A STOP, THE TRAIN WENT INTO UDE. DURING INSPECTION THE CREW FOUND EIGHT CARS ON THEIR SIDE.</blockquote>
A resort to car information indicates that the first derailing (FMLX001153) was perhaps a covered hopper, not a flatcar, but no need to dwell on that.

Comment: Some of apparent anomalies may be capable of explanation, given the fact that a 141-car train might occupy the main as well as a yard track. The point to be taken here is that heavy, long trains tax the personnel and facilities at terminals, not just over the road. The number of powered axles used to move this consist is also worthy of note.</td></tr>
<tr><td>90</td><td>NS
Sankertown, PA
11/12/2021

6180.54
(4/21/2022)</td><td>Loads, empties (total): 154, 43 (197)

Power: 1 front, 2 manual rear [see explanation]

Tons: 12,404

Speed: 11 mph</td><td>Derailed beginning at position 177 (empty)

Cars derailed: 4 (empties)

Damages: $211K</td><td>NS: H507—Lateral drawbar force on curve excessive, car geometry (short car/long car combination)</td></tr>
<tr><td></td><td colspan="4">Explanation: The narrative states that the train experienced a broken knuckle while crossing over from one main track to another. The first car off was a 92-foot flat (long car). Use of H507 indicates incorrect train placement, unless of course the main problem was too much horsepower shoving from the rear. The 2 rear locomotives are shown as manual, but may be DPUs given the absence of additional crew members in box 40.

Comment: It’s seldom one thing. The other factor in this case might have been lack of coordination between the engineer of an underpowered train and a helper crew (not accounted for in the crew count) or some problem handling rear DPUs (not properly coded in the report). We’ll likely never know.</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
91	CSX Atlanta, GA 11/16/2021 6180.54 (3/20/2022)	Loads, empties (total): 100, 36 (136) Power: 6 front Tons: 13,140 Speed: 5 mph	Derailed beginning at position 10 (empty) Cars derailed: 10 (2 loaded, 8 empty) Damages: $76K	CSX: H524—Excessive horsepower
	Explanation: The report narrative says it like this: M78416 DEPARTING HOWELL YARD IN A NORTH DIRECTION DERAILED AT HUFF ROAD AS A RESULT OF TRAIN HANDLING. Huff Road is apparently timetable south and directionally south of Howell Yard. The GPS location given is north of the yard. Comment: This was a heavy train with empty cars up front that could be easily stringlined with the 6 locomotives up front and no DPUs to bring up the rear.			
92	NS Jennings, MO 11/24/2021 6180.54 (3/30/2022)	Loads, empties (total): 104, 15 (119) Power: 3 front Tons: 1,506 [sic: see explanation] Speed: 6 mph	Derailed beginning at position 22 Cars derailed: 11 Damages: $19K	NS: H520—Dynamic brake, excessive axles
	Explanation: This derailment apparently occurred on what may have been a “through” track on the perimeter of the NS yard (tangent at the GPS location given in the report). The back of the train would have been on a descending grade coming down into the yard (0.8% according to the narrative). The writer’s understanding of the cause code would be that an excessive number of locomotive axles were cut in for dynamic braking. The first car to derail was an auto rack, loaded, but 2 of the 11 cars derailing were empty. This railroad seems to have difficulty reporting trailing tonnage (box 29) with any fidelity. Comment: Was there a minimum set on the air brakes? Was the train under the control of the engineer or TEMS?			

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>93</td><td>UP
Bloomington, CA
11/27/2021

6180.54
(3/30/2022)</td><td>Loads, empties (total): 90, 57 (147)

Power: 2 front, 1 manual mid-train (see explanation)

Tons: 13,113

Speed: 10 mph</td><td>Derailed departing UP yard beginning at position 111 (empty)

Cars derailed: 4

Damages: $288K</td><td>UP: H525—Independent brake, improper use</td></tr>
<tr><td></td><td colspan="4">Explanation: The railroad narrative appears to indicate that FRA's contractor asked about this one:
TRAIN MWCML-27 DERAILED FOUR CARS AS THEY WERE DEPARTING AROUND THE BALLOON TRACK DUE TO IMPROPER USE OF INDEPENDENT BRAKE. PER RAILROAD, DATA IN #34 IS CORRECT.
If there was a manual helper in the train under power, then the crew count (1 engineer, 0 conductors) would appear to be off. The derailment is not a particularly serious one, but this movement is coded as a freight train (not yard movement), and it's a heavy one. Placing a helper locomotive mid-train would seem unconventional. Was the helper behind the cars derailing? Was the mis-use of the independent (locomotive) brake at the front or mid-train?</td></tr>
<tr><td>94</td><td>UP
Hammett, ID
12/5/2021

6180.54
(3/30/2022)</td><td>Loads, empties (total): 135, 70 (205)

Power: 3 front, 2 DPUs mid-train, 2 DPUs rear

Tons: 19,396

Speed: 30 mph</td><td>Derailed following "a big run in" initiated at position 86 (UP007706)

Cars derailed: 28

Damages: $2.45m

The railroad's notice to customers on 12/6 predicted 36-72 hour delays for traffic over the line.</td><td>UP: E06L—Brake valve malfunction (locomotive) and H504—Buffing or slack action excessive, train make-up</td></tr>
<tr><td></td><td colspan="4">Explanation: This was a big, heavy train with DPUs placed center and rear. The initiating locomotive appears to have been UP7706, placed mid-train, and we are told this was a brake valve malfunction, evidently made worse by the mix of cars behind it. This is rugged territory, with the derailment site near the town and between Interstate 84 and the Snake River. None of the 9 hazmat cars in the train were damaged.

Comment: Why did the locomotive valve "malfunction"? Was there excessive air flow in the train line? Did variations in the train line pressure set it off? This is the kind of accident that deserves closer attention to verify the circumstances and tease out solutions.</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">95</td><td>CSX
Ansonia, OH
12/22/201

6180.54
(3/30/2022)</td><td>Loads, empties (total): 74, 80 (154)

Power: 2 front

Tons: 5,779

Speed: 3 mph</td><td>Derailed beginning at position 63 (empty) during pull of 83 cars from interchange point with short line railroad

Cars derailed: 9 (empties)

Damages: $34K</td><td>CSX: H505—Lateral drawbar force on curve excessive, train handling</td></tr>
<tr><td colspan="4">Explanation: Here is the narrative—
Q63122 REAR END PICKUP OF 83 CARS OFF THE CORMAN MAIN. AFTER MAKING THE JOINT PULLED AHEAD AROUND 15 CARS TO HANG EOT. UPON STOPPING, TRAIN WENT TO EMERGENCY. UPON INSPECTION TOWARDS THE HEAD END, FOUND LINES 63 THROUGH 71 (EMPTY AUTO RACKS) DERAILED ON THE GROUND ON THE CORMAN LEAD. 8 CARS ON ITS SIDE AND 9TH CAR LEANING ON THE CORMAN LEAD WHERE TRACK CURVES.
It is not clear why CSXT is listed as responsible for track maintenance and why the short line (a Corman affiliate, apparently) did not file its own report.

Comment: This will go down as a “human factor accident,” but one wonders how well the railroad’s most skillful road foreman would have done. The first car derailing was an empty autorack, which is both a rather long car and likely equipped with end of car cushioning. It may have had some heavy loads behind it. The less frequent the pick ups at any given interchange, the more cars that will need to be marshalled. One suspects that the short line did not “hold” this many cars voluntarily.</td></tr>
<tr><td rowspan="2">96</td><td>BNSF
Superior, WI
12/25/2021

6180.54
(3/30/2022)</td><td>Loads, empties (total): 180, 0 (180)

Power: 2 front, 1 DPU rear

Tons: 24,048

Speed: 5 mph</td><td>Derailed at position 24 while pulling out of yard track

Cars derailed: 3 (loads)

Damages: $187K</td><td>BNSF: M505—Cause under active investigation by reporting railroad</td></tr>
<tr><td colspan="4">Explanation: This is a minor accident involving what appears to be an underpowered unit train.</td></tr>
<tr><td rowspan="2">97</td><td>BNSF
Baring, MO
12/26/2021

6180.54
(3/30/2022)</td><td>Loads, empties (total): 110, 26 (136)

Power: 3 front, 2 DPUs rear

Tons: 15,678

Speed: 38 mph</td><td>Derailed beginning at position 78 (empty)

Cars derailed: 36

Damages: $3.7m

Of the 20 hazmat cars in the train, only 1 was damaged (no release)</td><td>H504—Buffing or slack action excessive, train make-up</td></tr>
<tr><td colspan="4">Explanation: We are not advised what the problems were with train make-up, whether the railroad’s train make-up rules were observed, or what to watch out for in the future.</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td>98</td><td>NS
Fort Wayne, IN
1/19/2022

6180.54
(5/9/2022)</td><td>Loads, empties (total): 130, 79 (209)

Power: 4 front

Tons: 19,444

Speed: 19 mph</td><td>Derailed at position 92 (empty) when off-center car lost truck at grade crossing

Cars derailed: 1

Damages: $11K</td><td>NS: E24C—Center plate disengaged from truck (car off center)</td></tr>
<tr><td></td><td colspan="4">Explanation: This was a heavy mix-manifest train. Why did the empty tank car in the middle of the train lift off its truck?</td></tr>
<tr><td>99</td><td>UP
North Platte, NE
1/31/2022

6180.54
(5/10/2022)</td><td>Loads, empties (total): 125, 52 (177)

Power: 3 front, 1 DPU mid-train

Tons: 11,518

Speed: 5 mph</td><td>Derailed coming into receiving track

Cars derailed: 6, plus 1 DPU

Damages: $406K</td><td>UP: H521—Dynamic brake, other improper use</td></tr>
<tr><td></td><td colspan="4">Explanation: The UP narrative:
MPRNP-29, WHILE COMING INTO RECEIVING TRACK 5, ENGINEER REPORTED SLOWING DOWN BECAUSE A VEHICLE WASCOMING AT HIM AND HE COULD SEE A BLUE LIGHT ON THE RAIL. AS HE SLOWED DOWN, HE FELT THE TRAIN COME TO A STOP. THE VEHICLE PICKED UP THE BLUE LIGHT AND DROVE OFF. WHEN HE TRIED TO GO AGAIN, HE COULD NOT MOVE AND CALLED FOR ASSISTANCE. UPON CONDUCTOR INSPECTION, FOUND 3 RAILCARS AHEAD OF THE MID-DPU, THE MID-DPU AND 4 CARS BEHIND THE MID-DPU DERAILED.

Comment: This was a low-speed derailment, apparently occasioned by an unexpected portable blue signal (indicating mechanical workers on the track) on the receiving track. Should the engineer have been advised of work on the track when told to enter yard track 225? Did the engineer have the DPU in synchronous mode? If not, why?</td></tr>
<tr><td>100</td><td>NS
Calhoun, TN
2/2/2022

6180.54
(5/9/2022)</td><td>Loads, empties (total): 43,74 (117)

Power: 5 front

Tons: 8,334

Speed: 47 mph</td><td>Derailed beginning at position 56

Cars derailed: 1

Damages: $52,000</td><td>NS: M505—Cause under active investigation</td></tr>
<tr><td></td><td colspan="4">Explanation: Minor derailment that could have been much worse with train moving at 47 mph.</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">101</td><td>UP on KCT
Kansas City, MO
2/2/2022

6180.54
(6/9/2022)</td><td>Loads, empties (total): 120, 39 (159)

Power: 3 front

Tons: 15,154

Speed: 9 mph</td><td>Derailed beginning at position 35 (empty center beam flat, 80 feet)

Cars derailed: 6 empties

Damages: $293K</td><td>UP: H503—Buffing or slack action excessive, train handling</td></tr>
<tr><td colspan="4">Explanation: The Kansas City Terminal report most recently accessed provides a useful narrative:
UP TRAIN MDMNL-01 TRAVELING WEST FROM KCT M4 TO TRACK 80, AS TRAIN CAME AROUND CURVE, ENGINEER WENT FROM THROTTLE POSITION 1 TO DYNAMIC 5 CAUSING SLACK TO RUN IN AND PUSH NOKL738791 OFF TRACK. TOTAL OF 6 CARS DERAILED. NOKL738791, TTZX 863662, AOK 26909, GATX 213959, GATX 221285, AND GATX 223826. UP EQUIPMENT DAMAGE IN AMOUNT OF $234546. KCT MAINTAINS TRACK/SIGNAL/STRUCTURE DAMAGE ESTIMATED AT$58000

Comment: No doubt the cause reported is warranted. We don’t know why the engineer would have made such an abrupt adjustment or why no mid-train DPU was entrained. However, note that most of the tonnage would have been behind the empty cars that derailed. The derailment was captured on video at https://www.youtube.com/watch?v=KaIalUgCyXc</td></tr>
<tr><td rowspan="2">102</td><td>NS
Northfork, WV
2/19/2022

6180.54
(5/9/2022)</td><td>Loads, empties (total): 112, 29 (141)

Power: 3 front [see explanation]

Tons: 12,274

Speed: 14 mph</td><td>Derailed beginning at position 86

Cars derailed: 10

Damages: $31K</td><td>NS: E30C—Knuckle broken or defective</td></tr>
<tr><td colspan="4">Explanation: This would seem like a simple case. But read all of the narrative:
392U218 EXPERIENCED A BROKEN KNUCKLE WITH 35% OLD BREAK RESULTING IN AN EMERGENCY BRAKE APPLICATION WHILE TRAVERSING A 4.5 DEGREE CURVE WITH PUSHER ENGINES ATTACHED. A 13 SECOND BRAKEPIPE PROPAGATION TIME FOR POWER KNOCK DOWN ON PUSHER UNITS RESULTED IN EXCESSIVE LATERAL FORCES IN THE 4.5 DEGREE CURVE ROLLING THE OUTSIDE RAIL IN 2 LOCATIONS AND SUBSEQUENTLY DERAILING LINE 86, LINES 88 THROUGH 91AND LINES 97 THROUGH 101.
There is no indication in box 34 that pusher units (manual helpers? DPUs?) were in use. From the narrative, one would conclude that the broken knuckle was the source of the UDE but the delayed response of the pusher units was the cause of the excessive in-train forces and derailment.

Comment: The low damage figure may be subject to later adjustment, but a local news photograph does show the auto rack cars upright.</td></tr>
</table>

<table>
<tr><th></th><th>Event / Sources</th><th>Train consist / speed</th><th>Consequences</th><th>Cause(s)</th></tr>
<tr><td rowspan="2">103</td><td>UP
Coolidge, AZ
2/21/2022

6180.54
(5/11/2022)</td><td>Loads, empties (total): 121, 24 (145)

Power: 3 front

Tons: 15,734

Speed: 4 mph</td><td>Derailed beginning at position 40 (empty)

Cars derailed: 15

Damages: $914K; of 45 hazmat cars in the train, 4 were damaged and 1 released 200 gallons of a flammable liquid</td><td>UP: H519—Dynamic brake, too rapid adjustment</td></tr>
<tr><td colspan="4">Explanation: It appears this road crew was involved in local switching, and when cars had been added to this heavy mix-manifest train, with no DPUs, a low-speed dynamic brake application was blamed for the derailment. The narrative is wordy, but not helpful:
MTUPX-21 HAD STOPPED TO DROP THE CONDUCTOR OFF AT THE HERITAGE ENVIRONMENT SERVICES INDUSTRY SWITCH.ENGINEER PULLED AHEAD AND STOPPED AGAIN TO MAKE A CUT. ENGINEER CAME OFF WITH 16 CARS, SET 1 OUT AT HERITAGE AND WENT BACK TO THE TRAIN AND GRABBED 6 MORE CARS TO TAKE TO WESTERN EMULSIONS. THEY NOW HAVE A HOLD OF 21 CARS. THEY SET OUT THE 6 REAR CARS AND RETURNED TO THE TRAIN WITH 15 CARS AND MADE A JOINT TO THE TRAIN. AFTER BUILDING THE AIR, THE ENGINEER DEPARTS AND TRAVELED 1,300 FEET AND TRAIN WENT INTO UDE. INSPECTION FOUND 15 CARS DERAILED. CAR#: TILX270028 CYCLOHEXANONE AND APPROXIMATELY 200 GALLONS.

Comment: Over the space of 1,300 feet, this engineer managed to develop sufficient in-train forces and then take sufficient dynamic braking effort to derail 15 cars at 4 mph? Was the crew in any way challenged when assigned to perform multiple local switching moves with a train already quite heavy and long?</td></tr>
<tr><td rowspan="2">104</td><td>NS
New Galilee, PA
2/23/2022

6180.54
(5/9/2022)</td><td>Loads, empties (total): 68, 104 (172)

Power: 3 front

Tons: 11,542

Speed: 7 mph</td><td>Derailed beginning at position 21 (empty)

Cars derailed: 7

Damages: $334K</td><td>NS: H506—Lateral drawbar force on curve excessive, train make-up</td></tr>
<tr><td colspan="4">Explanation: The location given is at I-376 (railroad under).</td></tr>
</table>

	Event / Sources	Train consist / speed	Consequences	Cause(s)
105	UP Glenns Ferry, ID 2/24/2022 6180.54 (5/11/2022)	Loads, empties (total): 142, 0 (142) Power: 2 front, 5 manual mid-train, 2 manual rear Tons: 20,003 Speed: 2 mph	Derailed beginning at position 75 Cars derailed: 3, plus 3 mid-train locomotives Damages: $83K	UP: H307—Shoving movement, man on or at leading end of movement, failure to control; and S014—Computer system design error (vendor)
	Explanation: Let's hope the narrative clarifies this, since there seems to be only one record for this occurrence and it shows a single engineer miraculously operating the lead unit and two controlling locomotives (mid-train and rear): OGNT4-22 CREW WAS PULLING OUT OF OLD MAIN, MOVEMENT ABRUPTLY STOPPED AND CONDUCTOR INSPECTED. FOUND 3 CARS AND 3 LOCOMOTIVES DERAILED. Old Main is coded as a siding. So, the amply powered train was pulling out, not shoving, but the error was with the conductor controlling the shove? And the computer system design error would have been what? Comment: One might guess there was a problem with control of DPUs (not manual helpers), but how that relates to protecting the point is beyond the writer's admittedly limited imagination.			
	Note for readers: Review of the data was attempted ending 5/22/2022, at which time data had been posted to the FRA web site for accidents through the end of February.			

Appendix C – History and Basics of Train Air Brakes

With the development of the steam locomotive in the early 19th century the concurrent need for a method of controlling the speed of a train became most obvious. The crudest method, which was employed almost universally through the 19th century, was to employ brakemen (note the origin of the term still in use) to manually apply the brakes on individual cars on a whistle signal from the locomotive engineer.

Advent of the Train Air Brake System

In 1869, George Westinghouse developed a system using compressed air from the locomotive to apply brake shoes against the wheels of a train to control the speed, or to stop. This "straight air" system required all the air volume and pressure to be supplied through a pipe extending through every car in the train to actuate a piston inside a brake cylinder on each car, and through a linkage (the brake gear) press the shoes against the wheels. When the pressure in the brake pipe was released at the locomotive, the brake shoes were released from the wheels.

This "straight" air brake system, though revolutionary for its time, had several major weaknesses.

First, all the energy (air pressure and volume) required for a brake application came from a single limited source - the air pump (compressor), and the air volume stored in a reservoir, on the locomotive, after the brake application was initiated. The time required for a full brake application was thus increased proportionally with the number of cars in a train.

Secondly, the brakes necessarily applied from the front to the rear of the train, which would usually cause cars at the rear of the train to successively collide with the cars at the front, causing impacts between cars and large buff (compressive) forces in the train.

The major, and fatal, weakness, was the fact that any failure of the brake pipe, including the separation of sections of the train, would render the straight air brake system totally ineffective.

The Automatic Air Brake System

Westinghouse devised the solution to those basic problems with his 1872 invention of the "Automatic Air Brake." The new system used a brake valve (the "Triple Valve") and an air reservoir (pressure tank) on each car in the train. The brake pipe passing through each car was pressurized and the air reservoir on each car was "charged" to the pressure in the brake pipe before the train departed.

While the brake pipe pressure equaled or exceeded the pressure in the air reservoir, the triple valve vented the brake cylinder to the atmosphere and the brake on the car remained in the released condition.

To apply the brake, the engineman released some air from the brake pipe. The decreased brake pipe pressure at each car caused the triple valve to switch from "release" to "apply," air pressure was passed from the car's air reservoir to the brake cylinder, and the brake on the car was applied.

To release the brake, the engineman increased the air pressure in the brake pipe. The triple valve on each car, sensing the pressure increase, vented the brake cylinder to the atmosphere and recharged the air reservoir from the brake pipe.

This revolutionary development essentially solved two of the major problems inherent in the straight air brake. If a train broke in two ("train parted") the brakes on each car in both parts of the train would apply at an "emergency" rate, described as the quickest and heaviest application that could be made. Also, the braking energy, as air volume and pressure, was distributed among the air reservoirs of each car in the train before a brake application, so it was available for use at the point of application on each car when the train brake was applied.

The Westinghouse Automatic Air Brake, and the closed-circuit signal control system developed in 1871 by William Robinson, are among the first, if not the first, application of "Fail Safe Principles" to safety-critical functions in transportation. "Fail Safe" means that the system is designed assume the safe mode if it should fail.

Present Day

The Automatic Air Brake has been greatly improved and refined over the past century and a half, but the basic principle has been retained. The brake equipment on all freight cars and locomotives in general service are compatible with the common standard. Of course, the components of the original system are no longer compatible, and are not permitted.

Appendix D—Description of ECP Brake Systems

ECP (Electronically Controlled Pneumatic) brake systems can improve railroad efficiency, capacity, and safety and can set the stage for continued improvements in train performance. A basic understanding of how conventional air brake systems operate is necessary to understand the advantages of an ECP brake system.

Conventional air brake systems use a pressurized pneumatic brake pipe that runs the length of the train. The brake pipe is charged with compressed air to 90 PSI. The compressed air is used as:

- the medium for communicating brake application and release commands,
- the source of power for brake operation, and,
- the source of auxiliary energy to stop the train in emergencies.

The operator commands a brake application by venting the air pressure in the brake pipe with the locomotive brake valve. The brake control valves mounted on each freight car detect the pressure drop and react by applying air pressure from an air reservoir to a brake cylinder which forces brake shoes against the wheels through a series of levers. Each brake valve controls the brakes on one freight car.

To release the brakes, the operator increases the air pressure in the brake pipe with the locomotive brake valve. The brakes release when the brake pipe is fully pressurized. The brake control logic means that the brakes will apply automatically if the train becomes uncoupled. A break in two separates the brake pipe air hoses between cars and vents all brake pipe pressure applying the brakes.

Brake commands begin at the front of the train and propagate to the rear of the train at the speed of sound. The slow propagation causes uneven braking and a low brake rate until all cars in the train fully respond to the brake command. Slow propagation causes long stopping distances and high run-in forces because freight cars at the rear of the train brake later than freight cars at the front. Uneven brake application and excessive run-in forces cause premature wear on mechanical components and lading damage. If severe enough, uneven brake applications and excessive run-in forces can cause a train to derail.

ECP brakes and conventional air brakes both require a brake control valve and an air reservoir on each freight car and both use compressed air for brake applications. ECP brakes, however, differ in the method used to communicate the brake control commands. Conventional air brake systems communicate the brake command via a change in pressure through the brake pipe. ECP brake systems transmit the brake command through an electrical cable that runs the length of the train. The speed of the electrical command signal is instantaneous, which assures even activation of all brakes on the train. The uniform and instantaneous brake application throughout the train results in significantly shorter stopping distances and elimination of in-train forces.

Benefits of ECP Brakes:

1. **Reduced stopping distances:** ECP brake systems eliminate the brake signal propagation issue by instantaneously applying brakes throughout the train through the electric train

line. Stopping distances are reduced over 60 percent for the longest trains. Simultaneous braking of all cars eliminates significant in-train forces and avoids damage and premature wear of brake system elements and car components. Shorter stopping distances will reduce the consequences of train accidents where the brakes are applied before the accident. ECP brake systems can potentially reduce collision speeds by slowing the train over that achievable with a conventional air brake system.

2. **Graduated brake application and release:** Conventional air brake systems are designed as direct release systems. Direct release is necessary to prevent brakes from dragging on long trains. Once the brakes are applied, they cannot be partially released – they can only be fully released. This characteristic of conventional air brake systems poses significant train handling challenges, can result in dragging brakes, and damages wheels through overheating.

   ECP brake systems operate as a graduated release system which allows the operator to modulate the brake application throughout the stop without fully releasing the brakes (similar to how a driver brakes an automobile). Graduated release allows the operator to accurately and continuously adjust the braking level to suit operating conditions and is especially important when trains operate on steep grades or in mountainous territory. Use of ECP brake systems can prevent accidents resulting from train handling and wheel defects.

3. **Train management controls:** The ECP two-conductor electric train line spans the entire train and provides power to operate all ECP control valves and the end-of-train device. The electric train line includes communications network signals which are superimposed on the power voltage. The communications network allows real-time self-diagnostic functions to be incorporated in the brake system. Brake failures are detected and immediately passed to the train operator. Other failure detection features such as hot bearings or impact detectors to signify a derailed axle are also possible.

4. **Business Benefits:** There are significant business benefits associated with ECP brakes including fuel savings, improved equipment utilization, and more network capacity.

Difficulties in Adoption of the Technology: The most difficult issue is the question of "who pays" and "who benefits." A rail car owner would invest about $750,000 to install ECP brakes on one train-set. The benefits of this investment would be reduced wheel wear, reduced brake shoe consumption, and reduced wear and tear on the rail car. The car owner's investment would be recovered but only over the 20 to 30-year life of the rail car.

The cost of installing ECP brakes and brake controls on the locomotive would be about 20% of the car owner's investment. However, the railroad begins to recover its investment immediately through increased fuel efficiency, reduced train delays, and regulatory relief from mandated tests and inspections.

Transition Towards ECP Brake Systems: Because of compatibility issues, the transition to ECP brakes really requires a captive fleet of cars or cars undergoing major modifications operated in unit trains. The crude oil and ethanol tank car fleet meet this requirement. Freight cars equipped with conventional air brakes are not compatible with ECP brake freight cars. To respond to this challenge, the railroad industry developed three approaches to ECP brake design. The three approaches to ECP brake design are:

- **Stand-alone ECP Brake (ECP only):** can only operate if all the cars and locomotives in a train are ECP equipped. Mixtures of ECP equipped and conventional air brake cars and locomotives are not possible because stand-alone ECP brake systems do not include pneumatic control valves that can respond to pneumatic control signals generated in the brake pipe.

- **Overlay or Dual Mode ECP Brake (conventional air brake and ECP brake):** Overlay ECP-equipped freight cars are equipped with both ECP car control devices (CCDs) and conventional pneumatic control valves. The use of an overlay system allows the freight car to be operated in any train as either an ECP-braked car or as a conventional air brake car. Segregation of ECP and non-ECP-equipped cars into separate trains is not required.

- **Emulation ECP Brake (conventional and ECP brake modes emulated):** Emulation ECP brake systems use a car control device that is capable of operating in either ECP or conventional mode without requiring conventional pneumatic control portions.

ECP BRAKE SYSTEM SUPPLIERS

United States manufacturers of ECP brakes are positioned to provide ECP brake systems for the domestic and international market. Currently, there are two active ECP brake suppliers in the United States:

- New York Air Brake
- Wabtec

Both manufacturers have applied their equipment to test trains operating in the U.S., Canada, and overseas.

Summary of Benefits of ECP Brakes:

Service Brake:

1. Service Brake Stopping distance reduced by up to 60% - helps to avoid accidents.
2. Eliminates significant in-train forces that can cause damage or derailments.
3. Prevents premature wear of brake system elements and car components.
4. Eliminates most dragging brake issues.
5. Prevents damage to wheels from overheating.
6. Prevents accidents due to train handling or emergency brake applications.
7. Provides real time failure monitoring.
8. Communications network can be configured to:
    a. Detect derailed axles
    b. Detect hot bearings
    c. Apply and release hand brakes
9. Graduated apply and release results in:
    a. Improved capacity

   b. Improved speed matching
   c. Decreased fuel usage
   d. Longer wheel life
10. Eliminates the possibility of run-away trains

Emergency Brakes:

1. Results of derailment (size of pileup) reduced
2. Stopping distance reduced by 10% to 15%

Consist integrity:

1. Provides uninterrupted communications from the controlling locomotive to any distributed power locomotives and to the end of the train.
2. May reduce requirements for supplementary data radio installations.
3. Provides an alternative means of currently verifying consist integrity in route and determining the location of the end of the train—supporting eventual "moving block" PTC.

Appendix E: FRA Research

The following is a clipped slide from FRA's 2022 research plan, retrieved on May 2, 2022 from

https://railroads.dot.gov/elibrary/fra-office-research-development-and-technology-current-projects-2022

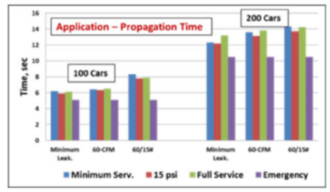
Review of Very Long Train (VLT) Operations

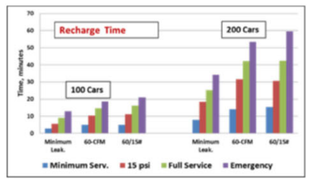
PROJECT DESCRIPTION

There have been notable increases in the length and weight of trains on the North American rail network, with many trains exceeding 200 cars. It was considered prudent to review and understand train performance and accepted practices for VLT (200+ cars) operations. This effort focuses on confirming the safe performance of the air brake system as well as resulting train dynamics for VLTs through a series of tests and simulations.

This is a collaborative effort with industry stakeholders, including the Association of American Railroads (AAR) representing the railroads, air brake system vendors, and labor unions. A Test Review Committee (TRC), with representation from the various parties, guides the technical effort.

In Phase II, rack tests have been completed and an interim report has been reviewed by the TRC. Phase III, the standing train test plan, is currently in development.





	Time from brake release (min) / Number of cars released			
False Gradient (psi) →	0	-2	-3	-4
100 Cars - Minimum Leakage	10.5	7.9	6.5	4.3/50
100 Cars - 60-CFM	20.1	11.5	8.3/49	6.5/63
100 Cars - 60-CFM / 15-psi Gradient	23.8	14.0	10.8/48	7.8/50
200 Cars - Minimum Leakage	29.7	20.7	16.0/60	13.7/105
200 Cars - 60-CFM	64.8	37.5	28.5/143	21.5/151
200 Cars - 60-CFM / 15-psi Gradient	71.5	37.7	28.8/148	21.5/151

RAILROAD IMPACT

- Improved and demonstrated operational safety through better understanding of brake system performance
- Potential to document safety benefits of using technologies, such as distributed power.
- Simulation tools will have been validated under these newer operating regimes, allowing better customization of operating protocols.

PROJECT PARTNERS

- AAR
- Class I railroads (UP, BNSF, NS, CSX, KCS, CN, CP)
- Transportation Technology Center, Inc.
- Wabtec Corp.
- New York Air Brake Corp.
- Sharma & Associates, Inc.
- Rail labor unions

COST & SCHEDULE

- Funding, FY22: $273,500
- Project Duration: September 2020 – September 2022

U.S. Department of Transportation
Federal Railroad Administration

FRA PROJECT MANAGER: Monique Ferguson Stewart • (202) 493-6358 • monique.stewart@dot.gov