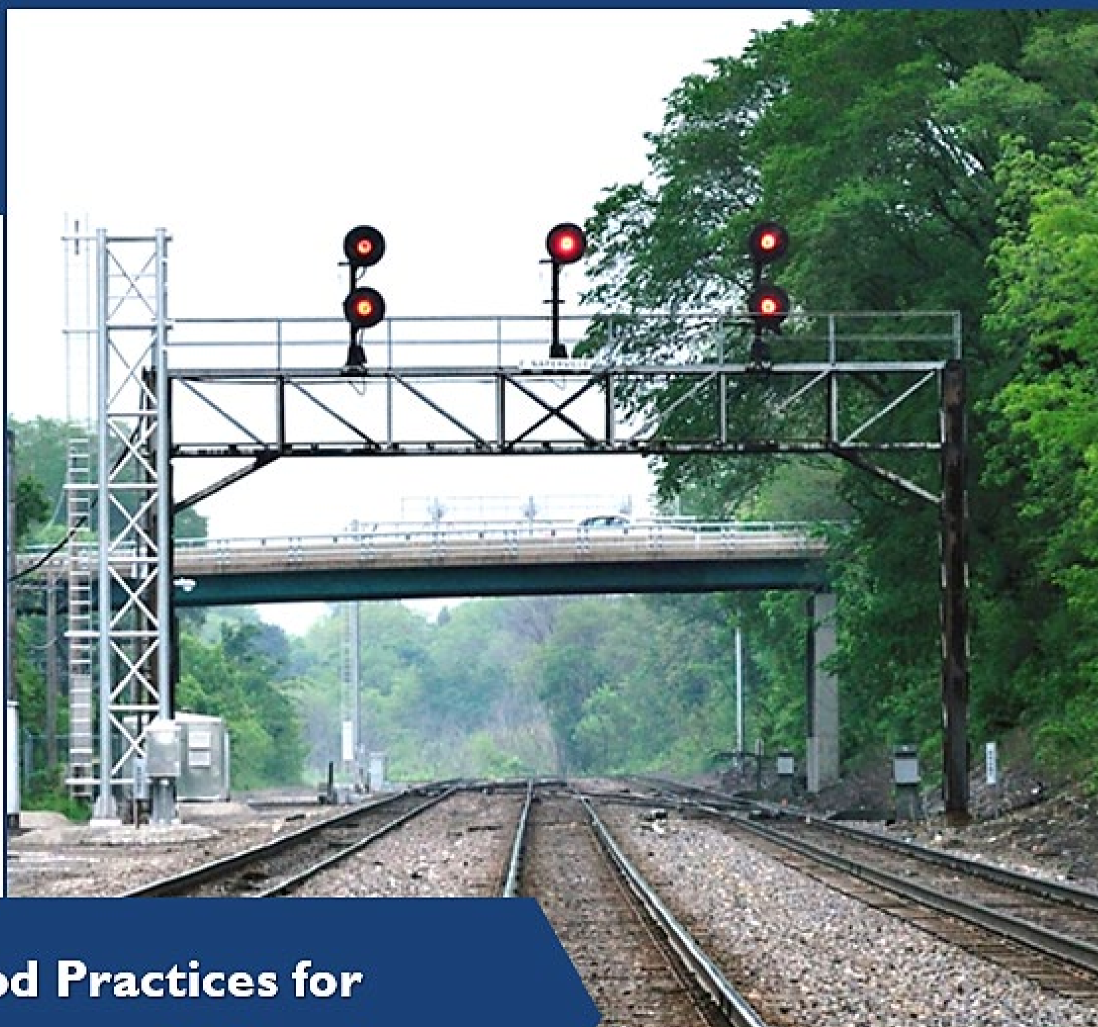
# Preventing Stop Signal Overruns



## Good Practices for Passenger Railroads

U.S. Department of Transportation
Federal Railroad Administration

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We would also like to acknowledge the international experts who reviewed these good practices[1] and provided valuable feedback.

[1] Disclaimer: This document is not legally binding and will not be relied upon by the Federal Railroad Administration as a separate basis for affirmative enforcement action or other administrative penalty. Compliance with understanding the lessons learned in this document (as distinct from existing statutes and regulations) is voluntary only, and noncompliance will not affect rights and obligations under existing statutes and regulations.

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# Purpose

Passing a stop signal without proper authority, also known as a stop signal overrun (SSO), can have serious consequences for safety, such as collisions, derailments, and injury to employees working on or near the track.

The Federal Railroad Administration (FRA) has identified factors that contribute to trains passing stop signals, and possible measures to mitigate the risk of SSOs. This document shares these findings so that railroads may better understand and address causes of SSOs. This publication is a resource for railroad management professionals, including those responsible for operations, infrastructure, and equipment; this also includes content targeted toward a variety of audiences.

# Scope

The practices and findings in this document is based on a pair of empirical studies sponsored by FRA to identify factors that contribute to trains passing stop signals in passenger rail operations.[2] The first study in this series ("An Investigation of Passing Stop Signals at a Passenger Railroad")[3] focused on factors contributing to SSOs in the terminal station at a single railroad. The second study ("Why Do Passenger Trains Pass Stop Signals: A Systems View")[4] examines factors across the entire railroad system for multiple passenger railroads.

The good practices consolidated in these lessons learned are the result of an extensive review of SSO data collected by multiple passenger railroads, a literature review of related published research into SSOs, and several site visits to passenger railroads who allowed us to interview employees at all levels of the organization and conduct head end rides and observations in the dispatch center. These good practices have also been reviewed by international experts on SSOs.

This document is intended to be used by passenger railroads concerned with SSOs, and the good practices we recommend can improve safety in both new and existing systems. The good practices are broadly applicable and informed by railroad data, employee firsthand accounts, as well as by research about the limits of human cognition. Individual railroads should evaluate this material and determine what is most suitable for them to put into practice given existing conditions and operational context.

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[2] This document coincides with the Federal Railroad Administration's "Stop Signal Overruns (SSO) & Near Miss: An Investigation Template for Passenger Railroads."

[3] Federal Railroad Administration. 2015. An Investigation of Passing Stop Signals at a Passenger Railroad. Technical Report No. DOT/FRA/ORD-15/25. Washington, DC: United States Department of Transportation

[4] Federal Railroad Administration. 2019. Why do Passenger Trains Pass Stop Signals? A Systems View. Technical Report No. DOT/FRA/ORD-19/19. Washington, DC: United States Department of Transportation

# How to Use the Lessons Learned

The "Background" section provides context for the recommended practices. Read "What Causes Stop Signal Overruns?" for an overall understanding of the factors that contribute to SSOs, followed by "Learning from Stop Signal Overruns" for suggestions related to effective and actionable data collection and analysis.

The "Good Practices to Prevent SSOs" section is organized around five topic areas shown below. Each subsection describes factors that contribute to SSOs, followed by actionable recommendations or "good practices."

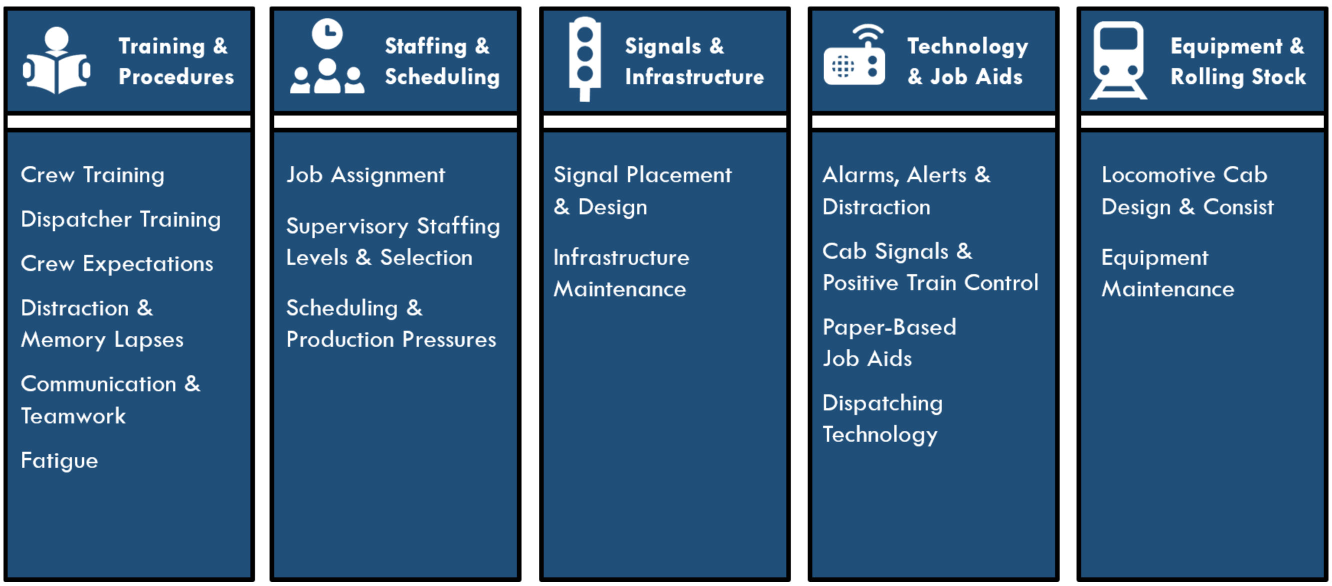



**Figure 1. Visual representation of the sections and subsections covered in this document**

For additional evidence supporting these recommendations, or to obtain more information about this research, please refer to the full FRA report (see footnote #4).

# Background

# What Causes Stop Signal Overruns?

When we asked railroad employees why SSOs occur at their railroad, the most common response was that SSOs happen because of "inattention" or "distraction." Most often these explanations put the responsibility squarely on the train crews, stating that if the engineer is qualified on the territory, he or she should be able to avoid SSOs. These commonly held beliefs are oversimplifications and fail to consider the inherent limitations of human cognition. Our research points to multiple, interconnected factors that contribute to SSOs.

In this section, we will share several myths about why SSOs occur followed by the contributing factors that our research uncovered.

## Common Misconceptions

**What are some of the common misconceptions or 'myths' about why stop signal overruns occur? What are the facts that counter these myths?**

**MYTH**: Train crews that are qualified on the territories they operate should be expected to retain knowledge of the location and characteristics of the signals on those territories for a full year, regardless of how often they operate on that territory.

**FACT**: Train crews cannot be expected to retain a memory of the material covered if they go for long periods without operating on the territory for which they were qualified. A fundamental characteristic of long term memory is that it degrades over time. Additionally, the railroad environment is dynamic, with infrastructure and environmental conditions that change over time. As operating conditions evolve, and the frequency of trips operating on a particular track segment declines, a crew's knowledge may become outdated or inapplicable. Currently, there is no research that specifically addresses the relationship between an engineer's knowledge of track characteristics and the time since last operation over a given track segment. However, broad research regarding training and long-term memory indicates that rehearsal plays an important role in knowledge retention.

**MYTH**: Train crews should not rely on past experience to predict signal states. They should operate on the information provided by signal progression and be prepared to stop.

**FACT**: Operating on expectations is another fundamental characteristic of human cognition. People more readily perceive and act on information that they expect, and they are more likely to make errors in situations where expectations are violated. Developing expectations is a component of the "skill acquisition process." Consequently, asking people to ignore past experiences is unlikely to be successful. Offering periodic training where locomotive engineers are exposed to unexpected conditions can mitigate this problem. Similarly, dispatchers can change a train's routing periodically so that engineers receive greater variation in their routing and signal progressions.

**MYTH**: SSOs occur because train crews are not paying sufficient attention or are distracted. Therefore, an effective way to reduce SSOs is to initiate communication campaigns that highlight the dangers of SSOs and urge train crews to 'focus' more.

**FACT**: While inattention and distraction may play a role in SSOs, understanding and mitigating the sources of the inattention or distraction is critical in addressing SSOs. Campaigns that urge individuals to focus their attention on signals have been an ineffective mitigation strategy since attentional processes are only partly under conscious control. Distraction is often a result of competing work demands or factors outside of an individual's control.

## Contributing Factors to Stop Signal Overruns

### What are the underlying factors that contribute to stop signal overruns?

Most often, SSOs are not the result of a single cause, but result from the confluence of multiple interacting factors. R*egulatory, organizational, individual* and *physical* factors can exert a negative or positive effect on SSOs.


**Figure 2. Factors that can combine and interact in different ways to exert a negative or positive effect on SSOs**

## What Causes SSOs?

Since this document is intended to be a consolidated list of good practices for railroads, we do not include a discussion of the regulatory issues that contribute to SSOs.

The organization of these good practices are according to the contributing factors of the staff or departments at the railroads for whom this is particularly relevant and consolidated within the following framework.

Section 1: Training & Procedures

Section 2: Staffing & Scheduling

Section 3: Signals & Infrastructure

Section 4: Technology & Job Aids

Section 5: Equipment & Rolling Stock

For a better understanding of how multiple factors can combine to create the circumstances for a SSO, consider one engineer's firsthand account of a SSO below. This excerpt was taken from an interview we conducted with engineers who had experienced SSOs at one passenger railroad. In this engineer's experience, the authors can infer from these statements (underlined and numbered within the excerpt) that at least seven factors contributed to the SSO.

This was one example, of many, where multiple factors interacted in different ways to create the circumstances for an engineer to experience a SSO.

**What Causes SSOs?**

## Engineer Stop Signal Overrun, Firsthand Account*

I was on my day off and got called in for overtime. I've been on the list and worked the emergency room, so I'm qualified on those lines and have worked that route many times before.

This time I had 10 M3s, which is older equipment. This was the last run of my day, around 5pm during rush hour. The train was on track 7, which is very tight for 10 cars. There are other tracks that can hold 10 car trains easily, so this train should not have been on this track [1].

Also, the engineer that brought the train in didn't pull the train in far enough [2].

So, the signal was behind me[3] as I started the run. I had to open my window and stick my head down to see what the signal was before I left.

Its 5 minutes before departure and the one trainmen wasn't around and conductor was in the end. I look out the window and see a terminal proceed and the switch is lined for me.

Now, the trainman reports having a problem with the doors [4].

Being a mechanical foremen, I got out of the seat and helped her [5]. Now we're running late.

The railroad makes a big deal that you need to cross the signal at a certain time. If you're due out at 45, they'll call you at 46 [6].

I get two to go and didn't look out the window again [7] to see if the signal had been turned. At this time, the conductor was supposed to be in the head end with me – she was walking towards me [2].

Somehow for whatever reason the signal was red now and not terminal proceed [1]. Because we were late/I had gotten out of my seat/out of my comfort zone, I lost track.

*abridged excerpt

**Contributing Factors**

1. Dispatcher Train Management
2. Teamwork
3. Signal Placement
4. Equipment Maintenance
5. Distraction
6. Production Pressures
7. Expectations

# Learning from Stop Signal Overruns

Since SSOs are most often a result of multiple interacting factors, and multiple mitigation measures are needed to address them. Examining past SSOs and the response to them can help reduce frequency of SSOs and mitigate or, in some cases, eliminate the risk factors that cause them.

Our research discovered an opportunity to improve the investigatory approach most railroads use, which focuses heavily on discipline. After SSOs occur, the staff conducted investigations to uncover the factors that contributed to the incident. These investigations vary among railroads but generally include interviews with the train crew and dispatcher, as well as infrastructure and equipment checks to rule out mechanical malfunctions.

Our findings identified several shortcomings with the current SSO investigation and data collection processes:

- The investigation process is primarily designed to **comply with FRA regulations** and meet discipline and record-keeping requirements.
    - FRA's Notice of Proposed Rulemaking (NPRM) for (49 Code of Federal Regulations [CFR] Part 240) explicitly states that the engineer is responsible when passing a stop signal. The traditional SSO investigation is conducted as a quasi-legal process. Facts are collected. A hearing is conducted and unless mitigating circumstances are identified, discipline is administered. This investigation process impairs information sharing and learning why the event occurred due to employee concerns about discipline.
    - SSO events can generate valuable system-wide data, and provide learning opportunities to improve safety. It is important to more fully investigate the circumstances surrounding the SSO to better understand the broader set of organizational, individual, physical and technology factors that contributed to the SSO. This will allow the railroad to take action to reduce SSO in the future.
- **SSO investigations focus primarily on the train crew** in understanding why the train passed a stop signal, and as a result most often assign responsibility squarely on train crew behavior, rather than understanding the complete set of factors that contributed to the event. Very rarely are the railroads' policies and practices examined as part of the investigation.
    - Without more in-depth analysis underlying contributing factors, such as inadequate training or job assignment and scheduling practices, may not be discovered during the investigation process.

- Employees who conduct the investigations generally receive **minimal training in how to interview** employees or how to collect information and document their findings.
  - The narrative reports we reviewed varied widely in the information and level of detail they provided.
  - We could not determine how much variability was due to the reluctance of the employee to share information and how much was due to the skill of the interviewer to solicit information and document that information.
- **Inaccurate or incomplete data entry** is common.
  - Numerical information like milepost locations or signal names sometimes contain transpositions or typographic errors.
  - Different investigators document the same type of information in multiple ways.
  - Narratives may be abbreviated when converted from paper to digital form.
- **Information from multiple sources** is not easily integrated and accessed.
  - Reports may be stored in separate databases, if they are digitized at all.
  - At railroads we visited, archived investigations were not often consulted when new SSOs occurred.

These observations suggest that decision makers have an opportunity to use individual cases of SSOs and their resulting investigations to obtain a comprehensive and trend-based understanding of the systemic causes of SSOs. If this opportunity is missed, a railroad may have an incomplete or incorrect picture about the current state of safety.

**A better way to handle SSO investigations include:**

- ✓ **Collecting data that supports identification of contributing factors**
- ✓ **Collaborating across organizational boundaries**
- ✓ **Looking for trends over time**

## Collect Data to Identify Contributing Factors

One of the best ways to mitigate future SSOs is to collect data on past SSOs and analyze the data thoroughly. This will enable railroads to understand the contributing factors specific to their environment.

Railroads may benefit from using an industry-wide, common, and comprehensive investigation form to standardize data collection across incidents. This allows trends within and across railroads to emerge, and allows for "apples to apples" comparisons of data.

To improve data collection and analysis, consider the following:

- **Provide investigators with training in how to interview employees**. This can improve the quality of the information they collect. Learning how to frame questions and how to probe for additional information is a skill that can improve with training.
- **Assign at least two people to conduct interviews**. One person should interview the employee while the second person records the information [1].
- **Use digital tools such as speech recognition and computer based data entry**. Digital records make it easier to share information from an investigation with other employees. These tools can also reduce the potential for data entry errors by flagging unusual or unexpected inputs and typographical errors.
- **Include the full narrative in the stored documentation**. Providing the complete narratives from interviews in digital form provides a more complete picture for railroad analysts to evaluate.
- **Use standardization to reduce potential for errors and facilitate comparisons**. Provide a uniform set of terms for common fields that investigators and interviewers use. Providing a standardized form, preferably in digital form can streamline the process.
- **Introduce error checking to correct errors that take place during data collection.** Assign an employee to complete the data validation and verification process by checking for consistency.
- **Use the number of stop signals displayed as the denominator to estimate the SSO rate**. Currently, the US railroad industry uses train miles as the denominator when calculating the SSO rate. However, passenger railroads often space their signals closer together compared to freight railroads which do not require the same number of signals per track mile. Using train miles as a denominator can overestimate the risk for passenger railroads and underestimate the risk for freight railroads.

## Collaborate Across Organizational Boundaries & Look for Trends over Time

In US passenger railroads, managers within each functional department investigate their own employees' role in the event. Since the investigation process tends to focus on rule compliance, once railroad managers decide whether to proceed with discipline, the event investigation concludes.

Once the individual investigations are completed the separate sources of data may not be integrated to create a holistic picture of how the event unfolded and how systemic factors contributed to the event. Assigning the responsibility for aggregating this data to a single entity, such as the safety department, can facilitate this process.

## Learning from SSOs

There is value in aggregating data from multiple instances of SSOs and scrutinizing that information on a regular basis to discern any system-wide trends. Monitoring how contributing factors change over time, for example, can also help railroads determine whether particular mitigation efforts are effective. As the railroad implements actions to address one or more contributing factors, the railroad can monitor how their occurrence changes. As the railroads learn about how different constellations of contributing factors occur together or under particular circumstances, they can refine how they track these contributing factors.

At a broader level, there is an opportunity for railroads to learn from each other by sharing their data. To do this effectively it is important to standardize both their terminology and data to facilitate communication between railroads and FRA. Standardizing the collection of incident data will facilitate the use of actionable information to effect change.

# Good Practices to Prevent Stop Signal Overruns

# Good Practices to Prevent SSOs

SSOs are almost never the result of a single factor, so they cannot be addressed through individual or one-time fixes. Recall the firsthand account of a SSO in the section Learning from Stop Signal Overruns. Railroads are well defended systems with multiple barriers in place to prevent or mitigate SSOs. To prevent SSOs at your railroad, it is important to approach the problem holistically.

The good practices described in the following sections are divided by topic so that managers can learn how specific factors contribute to SSOs. (See Figure 1.) Using these lessons learned, each railroad can assess how these factors could contribute either individually or in combination with other factors to produce an SSO. The authors recommend sharing this across your railroad with those responsible for each area, and coordinating to identify improvements to the system.

Ideally, multiple stakeholders, including department heads, managers, and train and engine (T&E) employees can review the good practices and together select the mitigations to evaluate or implement.

# 1. Training & Procedures

Ensuring train crew and dispatchers are given adequate training and demonstrate proper procedures for safe and efficient operation is perhaps one of the most cost-effective ways to reduce SSOs. This section describes deficiencies in training for the train crews and dispatchers, as well as specific team and individual factors which contribute to SSOs. Training departments may wish to implement the recommendations in this section on a trial basis before codifying them in company policy or training procedures.

Note that while the cognitive factors that underlie team and individual performance may be most easily improved through changes to training or procedures, it is critical to understand that individual and team factors that underlie SSOs, such as erroneous expectations, distraction and memory lapses, communication breakdowns, and fatigue cannot be eliminated through training alone. The most effective approaches to mitigating SSOs will consider the role that signal infrastructure, job aids, equipment and scheduling play in creating these cognitive conditions, in addition to supporting individuals and teams through training and procedures. Therefore, this section contains several good practices related to signals, infrastructure, job aids, and scheduling, and includes cross-references to other relevant sections.

**GAUGE YOUR RAILROAD**

Does your railroad…

- ❑ Provide crews with track charts and job aids that may be out of date?
- ❑ Lack realistic and up-to-date simulator based training?
- ❑ Lack sufficient refresher training?
- ❑ Rely on train crews to re-qualify on territory on days off?

## Crew Training

Locomotive engineers and conductors receive initial and recurrent training, but training program limitations can and do contribute to SSOs. For example, when training resources are strained, railroads may be unable to provide proper staffing, up-to-date training materials (e.g., track charts) and/or scenario based (simulator) training.

Simulator-based training is an excellent way to expose train crews to a variety of situations that they may never encounter during on-the-job (OJT) or classroom-based training, and through which it may be impossible to adequately train for with only classroom training. Our findings suggest that use of training simulators is limited, and where simulators are available the simulator software may not have been kept up to date with the changes to a railroad's physical characteristics.

**Learning from SSOs**


*Cab Technology Integration Lab (CTIL) simulator located at the Volpe National Transportation Systems Center*

**Figure 3. CTIL simulator**

Some railroads expressed a shortage of qualified training staff and mentors for OJT. We heard from train crews that trainers sometimes had little experience in the field, rendering them less effective at meeting training goals and objectives.

Locomotive engineers face a unique challenge: current FRA regulations for qualifying on a territory may not be sufficient to maintain knowledge of territory characteristics, and requirements for maintaining those qualifications may not be sufficient to operate safely.

Engineers are considered qualified on a territory for up to 1 year from the last time they operated on that territory. However, knowledge of territory characteristics may deteriorate more rapidly than that, and there can be significant changes in signals, switches and rules in effect over that period of time. A result of this decline in knowledge may occur due to forgetting over time and changes that take place on the territory since the engineer last operated over the territory.

Another concern is that a locomotive engineer can maintain his or her qualifications on a line by merely riding in the head end with an engineer on that line. However, to maintain technical skill, it may be necessary to operate a train on that line. Finally, some railroads require locomotive engineers to requalify on a territory on their personal time which can serve as a disincentive.

For conductors, our findings suggest that conductor training does not provide sufficient instruction and experience on signal progression or on conducting complex tasks like shoving moves, which depend on rapid recognition of signals, estimation of distances, and communication and coordination with locomotive engineers. Conductors and locomotive engineers across several railroads indicated that conductors could benefit from more training and experience on signal progression and conducting shoving movements.

## Good Practices

- Keep training materials, including track charts, multi-media training materials, and simulator modules up to date
- Improve the process of **selecting, training and evaluating** the performance of the individuals assigned to mentor students during OJT, for example by providing mentorship training

## Learning from SSOs

- Provide **systematic on-the-job training** to build the perceptual, sensory motor, and communication skills required to perform challenging tasks such as shoving moves. Use objective performance criteria to establish mastery of those skills.
- Allow and encourage train crews to take additional **refresher train rides** on company time when they feel a need beyond the annual requalification criteria.
- **Re-evaluate the 1-year requalification criteria** for maintaining currency on a territory characteristics. Objective performance-based criteria should be used to evaluate whether a year is a reasonable length of time to expect locomotive engineers and conductors to be able to recall the characteristics of portions of track that they have not had opportunity to ride over.
- **Strengthen training for conductors** with respect to reading signals and understanding signal progression. This can be reinforced through simulator scenario-based training. Conduct **performance-based testing** to establish mastery of these concepts.
- Provide more **extensive training on conducting shoving moves**, paying attention to communication and coordination requirements between conductors and locomotive engineers. Conduct performance-based testing to establish mastery of shoving operations.
- Provide periodic recurrent **simulator based training** to accelerate and preserve train crew experience and knowledge of all branches of territories they will be expected to operate over.
- **Combat engineer's reliance on incorrect expectations** through simulator training. Simulators can be used to provide train crews with broader experiences of alternative routing and different signal aspects when reaching particular interlockings. The simulator can thus provide virtual experiences to help combat incorrect expectations.
- Provide **scenario-based training** to address particular challenges that come up with respect to SSOs. 'Scenario-based' approaches refer to explicitly designing simulated situations (i.e., scenarios) that the train crews are expected to respond to. These scenarios are intended to expose the train crews to complex situations they are likely to confront in actual events and provide them the opportunity to practice how they would respond. The scenarios can be set up in a high-fidelity train simulator and/or through 'role-play' situations where, for example train crews might practice performing a job brief, or communicating with dispatchers or yard masters.
- Ensure that simulator modules are kept up to date.

Learning from SSOs

# Dispatcher Training

The routes that the dispatchers set can increase or decrease the probability that an engineer will overrun a stop signal. Experienced dispatchers say it can take several years to learn effective routing and communication strategies that minimize disruptions and keep trains moving when delays and breakdowns occur.

The routes dispatchers set are important because they impact the number and location of stop signals that an engineer will encounter. Effective dispatching includes productive communication with train crews when necessary and giving clear routes whenever possible.

Conversely, less optimal train routing can result in awkward routes, more "stop and go" particularly within the terminal, and dropped signals—which all contribute to SSOs. Formalized training of dispatchers could result in more efficient routing and communication, and fewer SSOs.

**Dispatcher Training and Inexperience**

As the dispatching workforce shifts from dispatchers being hired from other railroads to dispatchers being hired off the street, and with many experienced dispatchers at or near retirement age, railroads have begun to see the importance of standardized dispatcher training.

In contrast to train crews that undergo both formal classroom and field-based training, dispatcher training at railroads we visited was apprentice-based and lacked a formal curriculum. In this model, a newly-hired dispatcher would "post" with an experienced dispatcher and observe how he or she works. As a result, dispatcher training can be inconsistent. The quality of the training depends largely on the teaching abilities and preferences of the experienced dispatcher. Similarly, because training was at the discretion of the dispatcher 'trainer' some apprentice dispatchers could "graduate" to full dispatcher status before they were fully ready, since they were not required to meet any objective performance criteria as part of training.

Dispatchers may also benefit from more training 'on the ground' in the territory they manage. When dispatchers are not familiar with the territory characteristics they are routing engineers through, they may unknowingly assign trains difficult routes (e.g., to platforms that are too tight given the length of the train, on routes that cross many tracks, or routes with signals around curves and/or signals that are very close together). These factors all contribute to SSOs.

> *"I don't think dispatchers know the complexity of some of the routes they give."*
>
> *-Engineer's account*

**Dispatcher Communication**

Dispatcher communication with train crews can both negatively and positively impact SSOs. Understanding when communication with the train crew is important, in contrast to when communication serves as a distraction, is an important part of good train dispatching. From focus groups with train crews and dispatchers we heard several instances where good communications helped to facilitate better train operations.

## Good Practices

- **Dispatcher training should be formalized**, with trainers receiving formal guidance on teaching expert strategies. Duration of dispatcher training should be determined by objective performance criteria such that trainees only graduate to "full dispatcher" after displaying competence. The goal is to create a consistent approach to conducting dispatching operations
- **Dispatcher trainers should be well qualified**. Railroads should determine what qualifications are required in order to become a dispatcher trainer. For example, consider the following: How many years of experience as a dispatcher should one have prior to being eligible for promotion to dispatcher trainer?
- Dispatcher training should emphasize:
  - ✓ Efficient and safe train **routing**
  - ✓ Effective **communication** strategies
  - ✓ **Workload management** strategies
  - ✓ Strategies for **rapidly identifying and responding to SSOs**
- Dispatcher training should **include field observations** to make dispatchers aware of the complexity of the territory they work over.
- **Emphasizing efficient and safe train routing**, rather than emphasizing on-time departure and arrival rates, could help to minimize potential for SSOs.
- **Emphasis should not be on strictly adhering to time-table**. This may cause dispatchers to prematurely route a train out of the platform only to then sit at a stop signal all the while blocking other tracks.

## Erroneous Expectations

Train crews form expectations regarding the next signal aspect based on the prior signal, their knowledge of signal progression, and their past experience on a given route [2] [3] [4].

> *"He was coming down the front ladder. Typically, you go straight but the dispatcher crossed him over. He was looking at a signal up ahead instead of the signal right in front of him, because they're so close together. We don't ever really use that short crossover. It was kind of a set up."*
>
> *- Engineer's account*

Expectations generated based on knowledge and experience can reduce the likelihood of a SSO. For example, knowledge of signal progression allows train crews to operate more efficiently.

Expectations can negatively impact operation when those expectations are disconfirmed. For example, where the order of signal progression is violated or a signal is dropped in front of the train. When a signal drops in front of the train, the signal changes to stop when the train is in close proximity to the signal leaving insufficient time for the engineer to avoid passing the stop signal. SSOs also occur when expectations based on prior experience on a route are violated, for example when engineer's expectations of how they will be routed or what the signal aspect is likely to be based on repeated prior experience.

Generating and operating on expectations based on prior experience is a fundamental aspect of human cognition that cannot be changed through counseling or admonition. A better strategy is to provide countermeasures to foster more accurate expectations with respect to routing and signal aspects.

## Good Practices

- Strengthen and reinforce **training on signal progression**, particularly for conductors
- Combat the engineer's reliance on incorrect expectations through **simulator training**. Simulators can be used to provide train crews with broader experiences of alternative routing and different signal aspects when reaching particular interlockings. The simulator can thus provide virtual experiences to foster the desired behavior.
- **Improve dispatcher training and procedures to minimize dropping signals** in front of the train when there is no time to avoid overrunning the signal without first informing the train crew unless it is an emergency.

- **Instead of giving train crews the same route every day, 'mix it up'** when possible to provide opportunity to experience more of the territory, and counter strong expectancies regarding likely routing and expected signal aspects.
- Have **dispatchers contact train crews before or during train runs** of any route deviations that are foreseen to counter incorrect expectations [3].
- In addition to training, **implement infrastructure and technology mitigations** to address erroneous expectations:
  - In-cab displays (see Section 5)
  - Link signal progression (see Section 3)
  - Improve track maintenance (see Section 3)

## Distraction & Memory Lapses

There appears to be a common belief across railroads that lack attention on the part of the individual(s) in the cab was the primary cause of SSOs. The railroads we worked with indicated that SSOs can be reduced by urging individuals to consciously focus more attention on signals.

Locomotive engineers and conductors themselves mentioned paying closer attention to reduce SSOs. Based on this belief, a common mitigation strategy to reduce SSOs involved the railroads conducting campaigns designed to alert train crews to the dangers of SSOs and urge them to 'keep the focus' on monitoring signals. However, urging individuals to 'pay closer attention' is an ineffective strategy for preventing SSOs, given the long periods for which engineers must pay attention. Humans have difficulty sustaining attention for prolonged periods of time. This mitigation strategy also ignores the multiple competing work-related demands for their attention during normal operations.

## Good Practices

- **Institute a 'sterile cab' policy during high workload conditions** (e.g., as the train enters a terminal). 'Sterile cab' is a term that borrows from a similar term used in the airline industry called 'sterile cockpit.' It specifies that only immediately task-relevant communication is allowed between individuals in the cab. The objective is to eliminate what engineers indicated was a major source of external distraction.
- **Communicate and practice effective strategies for attention management and task prioritization**. Provide training to practice attention allocation and management skills. For example, create training scenarios in which locomotive engineers are able to prioritize focusing on upcoming signals over other work-related tasks (e.g., responding to a radio communication). The skill that can be developed with appropriate practice.

- **Assign a second person**, such as the conductor, to concurrently perform the task to mitigate against locomotive engineer memory lapses. An example is to require the conductor to personally confirm a clear signal before giving the engineer 'two to go'[5] indicating that it is OK to start the train to guard against memory lapses during station stops. A 2014 study by Phillips and Sagberg provides support for the efficacy of this strategy [3]. In a survey of SSOs and near misses they report 21 cases where the locomotive engineer missed the signal, but the conductor caught it, and only 2 cases where they both missed the signal. Provide opportunities to practice these strategies in recurrent training.
- Explicitly **teach effective behavior strategies** that have been developed by experienced engineers for guarding against mental lapses. Behavior strategies communicated to us by train crews included train-related interactions, physical and verbal actions, and use of physical objects as aids to memory. For example, one experienced engineer communicated his strategy of removing his hat and placing it on the throttle while stopped at a platform where the signal was behind the cab. This provided him with a physical reminder that the signal was behind him. These behavior strategies seem effective for many train crews but may not be effective for all [5].
- In addition to training, **implement technology and scheduling mitigations** to address distractions, memory lapses, and attention management:
  - Safety critical alerts only (see Section 4)
  - Sufficient turn-time (see Section 2)

[5] The term 'two to go' is used by railroads to refer to the practice of having a conductor give the engineer two buzzes to indicate ready for departure.

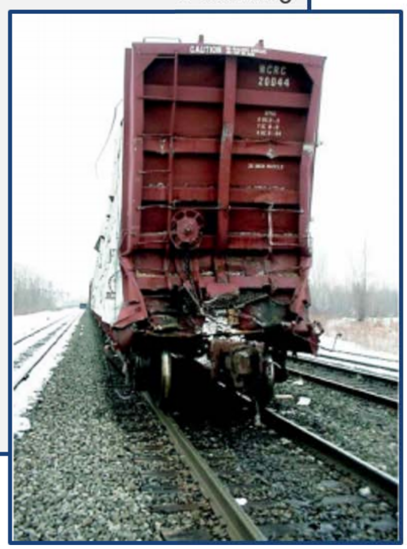
Learning from SSOs

## Case in Point: 2001 Amtrak Train Collision with CSXT Freight Train | Syracuse, NY

Eastbound Amtrak train 286 with 100 passengers and 4 crewmembers, struck the rear of eastbound CSX Transportation (CSXT) freight train Q620 on the CSXT railroad near Syracuse, NY. The National Transportation Safety Board (NTSB) determined that the probable cause of the February 5, 2001, collision of Amtrak train 286 with the rear of CSXT freight train Q620 was the Amtrak engineer's inattention to the operation of his train, which led to his failure to recognize and comply with the speed limit imposed by the governing wayside signal.

The NTSB report notes that according to signal computer memory log, Signal 6E displayed a "solid" red light over solid yellow light, or restricting. The engineer stated that he believed it displayed a solid red over a flashing yellow, indicating a medium approach.

Two of the main factors identified in the post-accident analysis appear to be **operating on expectations** and **distractions**. The engineer stated that he had never received a restricting signal at 6E, most of the time it would show [medium] clear and "40% of the time" it would show medium approach. The engineer also recalled that immediately prior to the collision, he was distracted due to retrieving track bulletins from his bag.



Learning from SSOs

# Communication & Teamwork

Railroad operations involve interaction among multiple individuals requiring effective communication and teamwork. While the locomotive engineer operates the train, the actions of others, such as the dispatchers, also impact the likelihood of an SSO both positively and negatively.

Communication is regarded as positive when it provides the engineer with critical information. For example, effective communication between an engineer and a conductor includes the conductor alerting the engineer to upcoming speed restrictions, reminding the engineer to check signals, and in certain cases helping the engineer identify signals. Effective communication between an engineer and the dispatcher includes the dispatcher informing the engineer of safety-critical information, for example, when a signal is being dropped, or informing the engineer when the train is being re-routed unexpectedly as a courtesy.

Communication was regarded negatively when it served to distract the engineer, primarily in times of high workload (e.g., in the terminal). Examples of this include conductors in the head end engaged in non-work-related discussions and dispatchers calling at inopportune times for non-safety-critical purposes.

In the good practices below, we provide a table showing effective radio communication between engineers and dispatchers, but note that non-safety critical information should not be communicated during times of high workload.

# Good Practices

- Provide **Crew Resource Management (CRM)** training to train crews (locomotive engineers and conductors). CRM training is meant to educate crews regarding the roles and responsibilities of each member and how team members will communicate with each other. This should be helpful in getting locomotive engineers to speak up as needed (e.g., to institute a "sterile cab") as well as provide guidance for constructive communication among team members.
- Use '**scenario-based' training approaches** to develop more effective team communication and coordination skills both between conductors and engineers and between the train crew and others (e.g., dispatchers and yardmasters).
- Provide **explicit training for communication between dispatchers and train crews**, such as in Figure 3 below, which shows the type of communication that should be initiated by the engineer and by the dispatcher.

Learning from SSOs

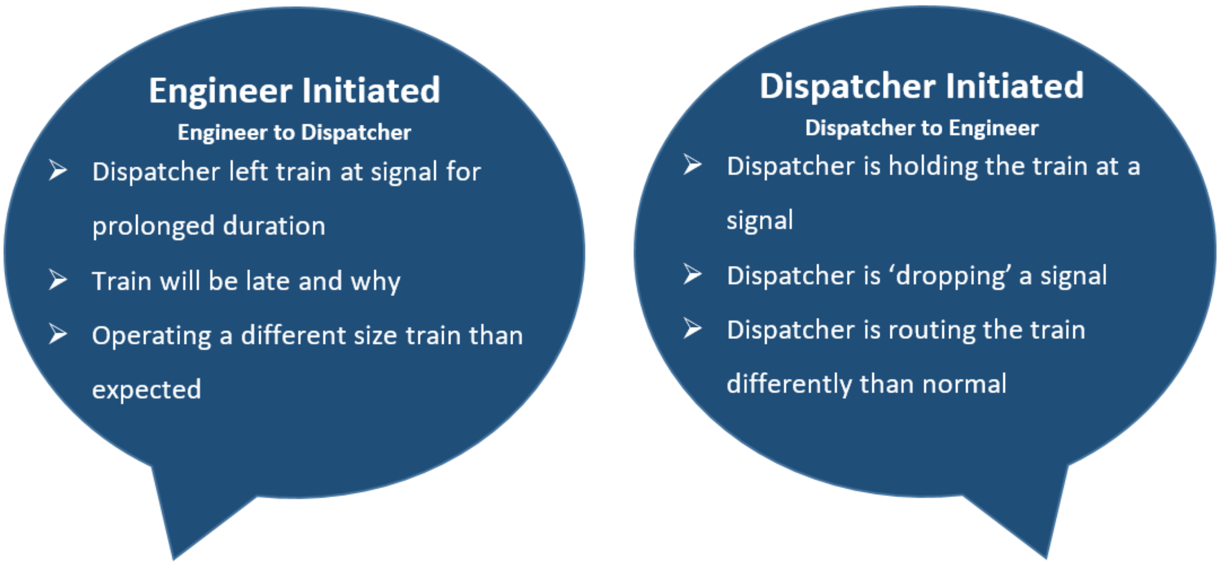



**Figure 4. Examples of recommended engineer/dispatcher communication**

## Fatigue

Fatigue is also a contributor to SSOs. Fatigue impacts susceptibility to distraction as well as impacts judgment and decision-making. Fatigue is a particular problem for individuals working the extra-board and those whose regular schedule has large variability in start times.

There is evidence that the role of fatigue on SSOs may be underreported. Train crews who experience an SSO are reluctant to bring up fatigue as a contributing factor. They raised the concern that they would be held legally liable for accepting the assignment when they were fatigued. At the same time, they mentioned that train crew members can be penalized for refusing too many assignments, placing them in a 'double-bind' situation.

## Good Practices

- Encourage train personnel to **talk about their fatigue**, what causes it, and ways to mitigate it, both with each other and with management. This is consistent with guidelines from Great Britain's Rail Safety and Standards Board that highlight the need for an open culture to foster early identification of fatigue problems before they become a safety critical issue [6].
- In addition to training, implement **scheduling mitigations** to address fatigue
    - Examine scheduling practices (see Section 2)

Learning from SSOs

## Recommended Practices and Procedures

Included in the good practices above are recommended procedures to consider implementing as part of your railroad policies. Below we consolidate these procedures.

**Train Crews should:**

- Implement a "sterile cab" policy during periods of high workload (e.g., when the train enters a terminal). This specifies that only immediately task-relevant communication is allowed. The objective is to eliminate distractions.
- Assign a second crew member, for example a conductor, to independently perform signal sighting tasks to mitigate against locomotive engineer memory lapses. For example, require the conductor to personally confirm a clear signal before giving the engineer "two to go."

**Dispatchers should:**

- Communicate to train crews when there are foreseen route deviations to counter incorrect expectations.
- Avoid giving train crews the same routes every day to counter expectations.
- Emphasize safety and efficiency, along with on-time departure and arrival.

**Dispatchers and Train Crews should:**

- Follow clear communication protocol to facilitate better movement, while also reducing engineer distraction.

# 2. Staffing & Scheduling

Railroad policies and practices can exert a negative or positive effect on SSOs. Tight schedules and production pressures, for example, may cause train crews to prioritize on-time arrivals and departures at the cost of safety checks and related activities [7].

The emphasis on schedule adherence may cause dispatchers, particularly inexperienced ones, to send trains out right away to avoid late departures, even though this may mean reducing system throughput and increasing the number of stop signals. Inexperienced dispatchers tend to send trains out on-time because of schedule pressure only to have them stop at the next signal, creating stop and go traffic and more congestion. Expert dispatchers noted that sometimes it is best to keep a train at the platform, even if it means a late departure, to ensure clearer routes (fewer stop signals) and ultimately keep more trains on schedules.

Crew assignment and scheduling creates circumstances that can exacerbate the potential for safety-related incidents. New, inexperienced employees are often given extra list jobs that challenge them due to the size of the territory they are expected to learn and the irregular shifts they may be expected to work.

## Job Assignment

Job assignments at many railroads are governed by collective bargaining agreements. Typically, new schedules for passenger railroads are posted twice per year (spring and fall) and employees are given the opportunity to select which job they want based on seniority, provided they are qualified for that assignment. As a result of this seniority-based job assignment system, more experienced engineers and conductors often select the more regular assignments while less experienced crews are left to choose from variable schedules and extra list assignments.

An unintended consequence of this seniority-based assignment process is that less experienced conductors and engineers, because of their lower seniority, may end up with the more cognitively-challenging jobs, resulting in an increased risk of an SSO. Jobs with less regular schedules (i.e., schedules that include non-routine start and stop times, particularly when they include both daytime and nighttime shifts) make engineers more susceptible to fatigue. Fatigue, by reducing attentional resources, contributes to SSOs, particularly when coupled with inexperience.

### GAUGE YOUR RAILROAD

Does your railroad…

- ❑ Reward on-time performance at the expense of safety?
- ❑ Have less-experienced employees working jobs with greater schedule and route variability?
- ❑ Have insufficient supervisory oversight of employees? (Including inadequate ratio of road foremen to engineers?)
- ❑ Have short turn times for crews?
- ❑ Have high train density in the terminal, resulting in “stop and go” traffic?
- ❑ Have unrealistic schedules and a focus on on-time performance above all?

Learning from SSOs

Extra list assignments are especially challenging. The unpredictable nature of when someone on the extra board will be called to work, and the possibility that they can be called back to work as soon as the minimum legal hours of rest are satisfied, increases the risk of fatigue, and possibly SSOs.

An additional cognitive challenge of extra list jobs is that they have more route variability. Engineers on the extra list are less likely to work the same route each day. They have less opportunity to develop the route knowledge than engineers who work a regular route. Working a regular route allows engineers to develop and act on expectations of signal location, type and aspect. Experience-based expectations are important for rapid and accurate identification and response to stop signals. Train crews on the extra-board are less likely to have developed experience-based expectations and therefore may be more vulnerable to SSOs. Conversely, engineers on the extra board are less likely to make errors based on expectations.

At the same time, employees with greater experience are likely to operate regular routes that cover only a portion of the territory on which they are qualified to operate. These individuals may be at greater risk of forgetting the physical characteristics on the portions of territory over which they no longer operate. They may become unfamiliar with those portions of territory that have changed since the last time they operated over them.

# Good Practices

- Understand that **less experienced engineers** are often assigned jobs with more schedule and route variability, which may contribute to SSOs.
- Provide **additional support** for individuals who are operating on a portion of territory that they have not traversed in the recent past. Support includes job aids such as accurate track charts, and the opportunity to be accompanied by an experienced locomotive engineer or road foreman on a familiarization run on the territory prior to taking on the assignment.
- **Design job assignments** to cover only as much territory for which the train crew can remain qualified by operating over at regular intervals. Railroads should determine the appropriate intervals by evaluating the employees' ability to maintain route knowledge, i.e., complex territories may require shorter intervals for train crews to operate over to remain qualified than less complex territories.
- Provide additional support in the form of **job aids** and **training** to the employees assigned to these jobs to reduce their potential to make mistakes on the job, if adjustments to the job selection process cannot be accomplished.

## Supervisory Staffing Levels & Selection

An important part of system safety includes supervisory oversight and supervisory practices. Some of these practices are Federally-mandated whereas some practices are railroad specific, so the supervisors' assigned tasks may vary by railroad. Many employees reported too few supervisors were assigned to conduct these necessary oversight tasks and safety checks; some employees reported concerns about supervisor qualifications. Railroads varied in the ratio of supervisors to employees from 1 road foreman managing 10 engineers to one road foreman managing 80 engineers.

The most notable example of insufficient supervisor-to-employee ratios occurred with road foreman. The road foremen we spoke with reported difficulty completing the required operational efficiency testing and check rides required, while supervisors in the dispatch center reported insufficient staffing which resulted in dispatchers being unable to fulfill certain qualification requirements in a timely manner.

Employees also expressed concern that it is difficult to attract talented staff for management level positions because managers must often take significant pay cuts. At two of the railroads we visited, some engineers expressed dissatisfaction with the qualifications of the trainers and road foremen, who in some cases had very little experience operating as locomotive engineers. Supervisors themselves reported little training for important supervisory practices, such as investigating why SSOs occur. As a result, they are often expected to "learn as they go" and use their experience in the field as a guide when conducting stop signal investigations. This is problematic when they have very little experience in the field.

## Good Practices

- **Determine acceptable supervisory staffing levels** based on required tasks and the size of the train crew population with the understanding that complying with minimum requirements specified in regulations does not necessarily make the system safe. For example, supervisors who are responsible for overseeing both training for engineers and testing of engineer qualifications will need more staff than supervisors who only oversee testing of engineer qualifications, since they perform additional duties.
- Consider the following qualifications for promotions to supervisory roles:
  - How many years of experience should a locomotive engineer have prior to being eligible for promotion to road foreman, or engineer trainer?
  - How many years of experience should a conductor have prior to being eligible for promotion to train master or conductor trainer?
- Develop **supervisor communication and training skills**.
- The pay structure most railroads have in place may limit the pool of applicants. When increases in pay are not possible, railroads might **consider providing additional incentives** to attract talented employees.

## Scheduling & Production Pressures

On-time performance is an important aspect of passenger railroad operations. Keeping trains on schedule, however, is becoming more difficult in part due to longer and more frequent trains operating on physical infrastructure that was not built to support them.

The increase in train density reduces the amount of slack in the system and causes train crews to experience shorter turn times as a result of tight schedules that cannot support the train density. The lack of spare capacity means that the whole system is more brittle and has difficulty adjusting to unexpected conditions. Operating with insufficient slack in the system creates pressure to take short cuts to address the production pressures.

**Train density as a result of increased service demands**

As revenue service continues to increase and track capacity remains fixed, train density is at an all-time high as longer and more trains are operated in the same amount of space. In the terminal during peak periods when nearly all platforms and tracks are occupied, trains are constantly moved in and out of the system with little slack. As a result, engineers are subject to more "stop and go" traffic and see more stop signals in the terminal because there are fewer opportunities for dispatchers to give clear routes, especially as they seek to maintain on-time performance. When train crews encounter more stop signals there are more opportunities for stop signal overruns. Passenger terminals were typically the area with the highest number of SSOs.

Learning from SSOs

*"I think quick turns are a problem. I get an 8-minute turn in the terminal. Next thing you know, you're getting tooted to go. Don't have your papers out, haven't done a job safety briefing."*

*- Engineer's account*

**Impact of short turn times resulting from too-tight schedules**

When trains run according to schedule, the railroads we visited operated with approximately 15–20 minutes between trains for train crews to complete the necessary personal and safety-related tasks. For some railroads, this turn time duration may be too short to complete all the required tasks without taking shortcuts. Trains may arrive late at their destination, giving crews even less time to perform their post-arrival and pre-departure tasks. Engineers we spoke with said when this happens they may skip some turn-time activities, use time on their current trip to prepare for their next trip, or shift pre-departure activities they would normally be expected to perform prior to leaving the station to during their trip. These actions all have important safety implications.

**Production requirement incentives and implications for safety**

Railroads (understandably) provide incentives for meeting schedule requirements. Dispatch centers, for example, keep tally of how many on-time trains they have and road foreman keep track of how often engineers are late. Production requirement incentives may result in unsafe practices that can contribute to SSOs. A manager-level employee at one railroad told us he often employed "out of the box" methods to keep trains moving, admitting they sometimes have implications for safety. We heard multiple instances from engineers of locomotives being put into service despite maintenance needs in order to keep trains moving. While it is not clear how widespread these varying practices are among all railroads, it is evident that employees feel pressure to meet production requirements at the expense of safety.

## Good Practices

- Increased **train density contributes to SSOs** because it increases the frequency of stop signals. Consider adjusting schedules so that fewer trains are in the terminal at any one time.
- **Adjust train schedules or provide additional staff** to enable sufficient time for crews to perform post arrival and pre-departure tasks. One way to do this would be to test the following process:
  1. Identify all the activities (safety and personal) that train crews need to perform and determine the time range needed for each activity.

Learning from SSOs

- Consider employees who are required to dead head into the terminal, particularly those dead-heading on empty equipment, who state that they often have short turn times because empty trains are given low priority to get into the terminal when tracks are congested. These jobs may require extra turn-time built into their schedules.

2. Compare the total time needed to perform all these activities with the turn-time available for the train crews.
3. Make adjustments in either the procedures train crews need to follow and/or the amount of time available between trains.
4. Provide additional staff to support the post-arrival and/or pre-departure activities.
5. Build slack in the schedule based on historical data on late trains.

- **Modify work flow requirements** to offload tasks and reduce non-essential activities where possible. Solicit feedback from train crews, dispatchers and other front-line employees to understand their perspectives.
- **Facilitate information flow with technology**: Use electronic delivery of bulletins and other materials rather than depending on hard-copy/paper materials located in the railroad office. To avoid distractions in the cab, it will be important to create crew and train schedules that provide adequate time for crews to check bulletins prior to departure.
- Teach **dispatching practices that maximize the continued movement of trains** across the entire system which minimize the need for trains to stop. This may result in a trade-off between on-time departures and arrivals and overall system throughput.
- Identify ways to **reduce the demands across the system** to enable employees to operate safely and recover from mistakes without compromising safety.
- Identify how **incentives for on-time performance** impact system, human, and organizational behavior. Financial incentives for on-time performance can contribute to gaming the system and adversely impact system safety performance.
- **Provide incentives for safety** like those for on-time performance for all railroad employees, including management levels.

# 3. Signals & Infrastructure

Complex signal environments can contribute to SSOs. In the terminal, inconsistent or ambiguous signal placement and platforms that are too short for today's increasingly longer trains can be problematic.

On the mainline, signals around curves, weather conditions, and deferred or insufficient maintenance can make it difficult or even impossible for engineers to correctly locate and identify the signal aspect.

This section offers good practices for mitigating signal and infrastructure issues, including signal placement, design and infrastructure maintenance.

> **GAUGE YOUR RAILROAD**
>
> Does your railroad have…
>
> - ☐ Signals obstructed by objects or curves?
> - ☐ Closely spaced signals?
> - ☐ Inconsistently placed signals?
> - ☐ Signals behind the cab at station platforms?
> - ☐ Fallen, dark or dirty signals?
> - ☐ Leaves, snow or ice obstructing signals?

## Signal Placement & Design

**Signal placement** is a major contributor to SSOs. Signals placed around curves in the terminal and on the mainline are difficult to see. At high speeds on the mainline, it can be difficult for an engineer to slow or stop the train if an unexpected signal aspect is around a "blind" curve.

In the terminal, signals placed behind retaining walls, near catenaries and other obstacles are difficult for a train crew to see. Weather conditions like fog or sun glare will affect a crew's ability to locate and identify signals.

Inconsistent signal placement in the terminals and at station platforms can create "traps" for engineers. Signals are sometimes placed too close to the end of the platform for longer trains, which causes the signal to be behind the cab, and out of the engineer's line of sight. In other cases, signals at platforms are located too far out from the platform and out of the engineer's line of sight.

Similarly, signals placed too closely together in the terminal create ambiguity as to which track they govern. These inconsistencies create a complex environment where engineers must memorize the exact locations of signals and the tracks they govern. Optimizing signal placement can be a more effective way of mitigating overruns.

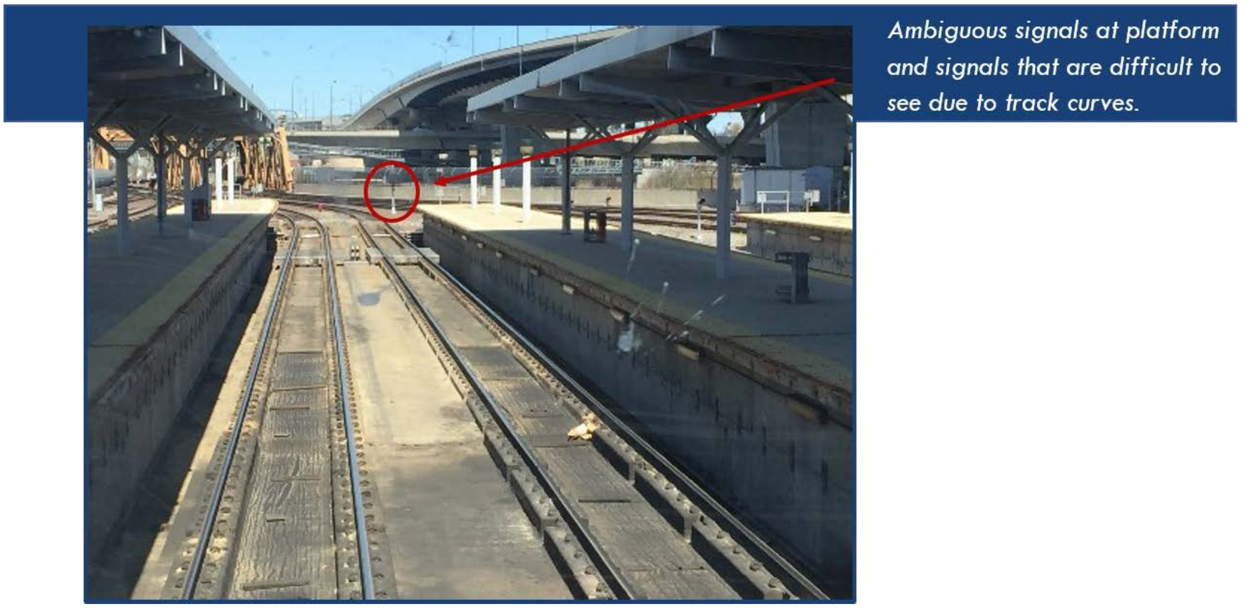



**Figure 5. Ambiguous signals at platform and signals that are difficult to see due to track curves**


**Figure 6. Catenaries may make it difficult to identify signals on signal bridges**

As shown in Figure 5, **signal design** may also contribute to SSOs, especially in conjunction with other factors. Dwarf signals, in particular, may be difficult to locate as a result of cab design (e.g., operating with the long hood forward) and weather (e.g., fog, sun glare, snow accumulation). Factors that make signal detection difficult (i.e., signals around curves and behind walls, signals that are inconsistently placed, and signals behind the train at platforms) are often exacerbated for dwarf signals. Finally dwarf signals may also be more liable to be "looked through" to the following signal when other signals on the route are high mast because engineers are expecting similar high mast signals and dwarf signals may be outside the engineer's center of gaze, as shown in Figure 6.

Figure 7 shows weather conditions such as snow, glare and fog that create conditions that make signal sighting even more difficult for properly placed high-mast signals. Improving signal design so they may be more visible will help reduce SSOs resulting from weather conditions. The authors provide several good practices below to make signals more visible.


**Figure 7. Signals that are difficult to see due to fog and other weather conditions**

## Good Practices

- When designing or re-designing terminals, create a **signal sighting committee** to determine optimal signal placement given track and train characteristics. A committee should include all stakeholders, like in Figure 8,below.


**Figure 8. Stakeholders should provide insight when designing and re-designing terminals**

- Provide guidance for signal designers and signal sighting committees that specifies a **standard adequate time** for an engineer to see and respond to a signal, and the level of signal obstruction that is tolerated. For example, Australia's standard setting body recommends designers place signals on the wayside to provide engineers with a minimum of 6 seconds to read and respond to the signal.
- Place **signals at train platforms in consistent locations**, within sight distance in front of the longest train that that the platform can accommodate. Position signals in front of the train. A signal located behind the cab is not visible to the engineer and may be missed.
- When changing crews, the departing train crew should **verify that the signal is visible in front of the train for the next crew** to depart the platform. If the signal is behind the engineer's position in the cab, the departing crew should communicate to the new crew that the signal position is located behind the engineer.
- Place **clearly visible signs at every station platform** showing where to stop the train for different train lengths. This will minimize the situation, described above, where the train has not been pulled up far enough resulting in the signal being behind the engineer at the other end of the train. Establish a schedule to clean and maintain these signs.


*Example of the train stop sign instructing the crew where to stop the train according to car length.*

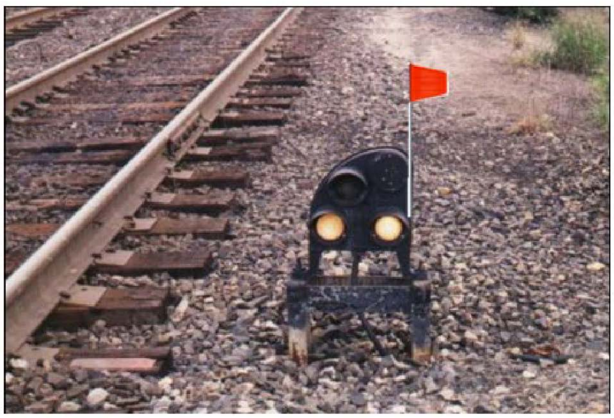
- When possible, **extend the length of the platform** to accommodate the longest train lengths expected. Where this is not possible, recognize that when the signal is located behind the engineer it can contribute to a SSO and consider procedural mitigations.
- For signals that may be difficult to see in time to stop, such as signals imbedded in walls or located around curves, or for closely spaced signals, consider the following:
  - Using 'repeater' signals to **indicate upcoming signals**. Where repeater signals may not be feasible, for example due to cost, borrow from roadway engineering practices and use signage as a cue to indicate upcoming signals.


*Example of the sign instructing the crew to a signal ahead*

- Electronically coupling closely-placed signals so that the initial signal and problematic signal are always both red, or are always more favorable than red. This is something experienced dispatchers typically do on their own via train routing practices, but it is a good practice to automate it.

➲ **Consider replacing signal bulbs with LED bulbs** to make them easier to see. Before implementing LEDs, **measure the luminance values** of the LEDs and non-LEDs to determine whether they will be too bright or attract attention to the wrong signal.

➲ Place **retroreflective signal markers** on dwarf signals and **retroreflective signal borders** on the signal mast and bridge to make them more visible to train crews and maintenance workers (see Figure 9, below).



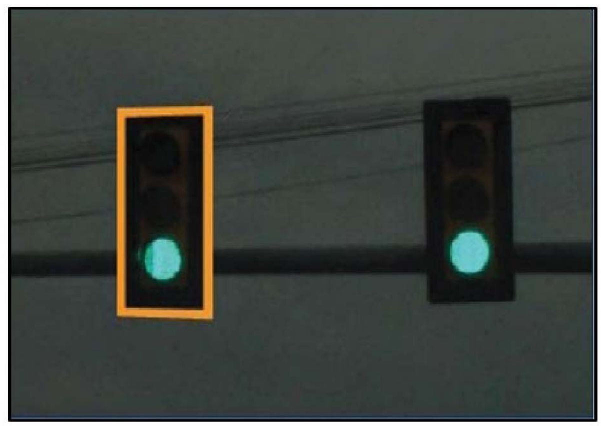


**Figure 9. (Left) retroreflective signal markers and (right) retroreflective signal borders**

➲ When making changes to the signal system, perform a hazard analysis and risk assessment to identify new risks from any proposed changes and evaluate whether changes in the proposed signal system are needed.

## Infrastructure Maintenance

**Infrastructure maintenance** is an important aspect of safe railroad operations. When infrastructure, including signals and tracks, are not properly maintained the human operator is often forced to adapt to imperfect conditions, which can result in distractions and/or unsafe situations. Train crews have reported that the most common maintenance issues are fallen signals, dark signals, and dirty signals.

These fallen, dark, or dirty signals can prevent engineers from clearly seeing the signal and/or signal aspect. In current practice, the burden is on the engineer to remember the location of every signal, even when signals are not visible.

*"My stop signal overrun was because a signal had fallen over… I looked out the window and saw a signal on the ground. It was dark, no lights. Evidently a train had come in and knocked the signal down. I should've known where the signal was but I wasn't looking for a signal on the ground."*

*- Engineer's account*

## Good Practices

- **Identify conditions that cause signals to come out of position** and find ways to prevent or minimize these conditions from occurring.
- Notify the dispatcher and signal department that a signal has fallen or gone dark. **Dispatchers should immediately communicate to train crews** when a signal is down, malfunctioning, or where a bulb burnt out.
- Place a **visual warning in the terminal to indicate when dwarf signals have fallen** or been knocked over so train crews can see where signals should be. Given the complex nature of many terminals and the difficulty of detecting the absence of a signal, providing information of where signals should be can alert train crews to a missing signal.
- Some signal locations may require more frequent maintenance than others. **Modify the maintenance schedule** to reflect this need. For example, signals need to be cleaned more often in terminals where diesel locomotives operate compared to electrically powered trains. Signals may need to be maintained more frequently in locations where heavy equipment traverses frequently, as these can knock dwarf signals out of place.

## Case in Point: The 1999 Ladbroke Grove Accident | London, UK

An outbound turbo diesel train ran past a signal and proceeded onto the mainline where it collided nearly head on with a high-speed train traveling inbound at a combined speed of 130 mph.

The accident killed 31 people and injured hundreds more.

An investigation into the crash found that the **signal's design and physical location** contributed to the event.

Due to limited space on the ground, signals at this location were in gantries over the tracks. The curvature of the tracks was such that it was difficult to ascertain which signal was for which track.

What's more, the standard signals had recently been replaced with non-standard "reverse L" signals, they had been implemented prior to formal approval by a signal sighting committee.

Another important factor was insufficient **training;** training did not adequately cover details of signals with repeated SSOs, among other curriculum inadequacies. There was no standardized testing for engineers, and no pass/fail criteria.

# 4. Technology & Job Aids

In today's complex work environments, both engineers and dispatchers must attend to multiple sources of information as well as respond to a range of alarms and alerts that compete for their attention.

Engineers rely on in-cab technologies (e.g., cab signals and train protection systems, like Positive Train Control [PTC]) as well as paper-based job aids (e.g., track charts and bulletin orders), in combination with radio communications to understand the territory they are operating on and the state of upcoming signals.

Cab signal malfunctions and mode transitions (when trains pass from territory that uses cab signals to territory that does not) can make it difficult to determine the correct signal indication. Outdated or inaccurate track charts also make it difficult for engineers (particularly less experienced engineers) to locate signals, while poorly organized bulletin orders make it difficult to access necessary information. These all contribute to SSOs.

Dispatchers also deal with complexity in their work, planning routes while responding to alarms and alerts and monitoring the location of trains. Current dispatching software can contribute to errors and inefficiencies, and make it difficult to recognize when SSOs occur.

This section will examine the role of technology and job aids for train crews and dispatchers, and discuss the ways in which technology contribute to or help prevent SSOs.

GAUGE YOUR RAILROAD

Does your railroad have…

- ❑ Frequent, disruptive alerts in the locomotive cab and dispatch center?
- ❑ Alarms or alerts that cannot be turned off or adjusted?
- ❑ Unreliable cab or wayside signal systems?
- ❑ Transitions between cab-signal and wayside signal territory?
- ❑ Outdated or incomplete track charts?
- ❑ Lengthy bulletin orders?

## Alarms, Alerts, & Distraction

Both train crews and dispatchers regularly encounter alarms and alerts designed to draw their attention. These auditory and visual signals can be helpful in some cases, but during periods of high workload, unnecessary noise and visual clutter can distract both engineers and dispatchers and contribute to the risk of SSOs.

Interviews with engineers indicated that in-cab displays and alerts not associated with cab signals contribute to distraction and SSOs. Engineers told us that some locomotive cab displays present **non-safety-critical** alerts that can be disruptive. When triggered, these alerts may sound continuously despite being acknowledged, which can annoy and distract the engineer. Exposure to frequent non-safety-critical alerts may increase the risk that engineers will miss safety critical alarms.

*"The trouble screen goes off, it's very loud. BEEP. BEEP. BEEP. When vents are out of whack it beeps and blinks red. You can ignore it but it keeps beeping. Sometimes if you acknowledge it, it goes away but can come back. It's very annoying."*

*- Engineer's account*

Dispatchers also mentioned that false indications and nuisance alarms (low priority non-safety-critical alarms) can be a problem. They often have to silence audible alarms that distract them from their radio communications and other job demands.

In addition to being an important source of information, the radio is also a constant source of noise in both the train cab and the dispatch center. Engineers described problems with static on radios that made it difficult to communicate with dispatchers or the conductor, and contributed to distraction.

*"Radio communication between an engineer and a dispatcher can't always be heard by the conductor. Sometimes there's static; sometimes you can make it out but sometimes not."*

*- Conductor's account*

At one railroad, engineers complained that the radio volume was too high and could not be adjusted: several engineers told us they would put stickers over the speaker to muffle the sound. One engineer said he used ear plugs because the high volume of the radio combined with the static was so distracting. Providing the ability to adjust radio volume within a pre-determined set of safe sound levels, and reducing radio static, would reduce distraction and facilitate better communications.

## Good Practices

- Give engineers and dispatchers the ability to control the display of non-safety critical alerts.
- Allow engineers and dispatchers to acknowledge and silence alerts.
- During times of high workload (e.g., in the terminal), show only safety-critical alerts.
- Display non-safety-critical alerts during periods of low or moderate workload.
- Minimize the number of non-safety-related alerts displayed.
- Review in-cab alerts to make sure that non-critical alerts that do not require an immediate response do not occur while the train is operating.
- Review in-cab and dispatcher systems to reduce or eliminate false alarms.

# Cab Signals & Positive Train Control

Cab signals and PTC are designed to help engineers recognize and respond appropriately to signals. While PTC, a train protection system used in the U.S., is a relatively new technology and during the drafting of this document has not yet been implemented across all railroads, cab signals are widely used. Cab signals are generally viewed as helpful by engineers, particularly during periods of inclement weather when it may be difficult to locate or identify a signal. However, cab signals can create complexity when they fail or during mode transitions, when engineers encounter transitions between territory with and without cab signals. SSOs may occur when engineers are relying on cab signals but have difficulty recognizing when cab signal malfunctions or mode transitions occur.

### Cab Signal Malfunctions

When engineers rely on cab signals, cab signal malfunctions can result in SSOs. The authors heard varying accounts of how often cab signal malfunctions occur. According to the communications and signaling department at one railroad, cab signal malfunctions occurred approximately 50 times in 1 year. The engineers that the authors spoke with stated that cab signal malfunctions happen "a couple times per year, per engineer."

*Example cab signal used in passenger operations*


**Figure 10. Example cab signal used in passenger operations**

When cab signals malfunction while enroute, it may not be immediately obvious to the engineer. Typically, a mismatch between cab and wayside signals is the first indication of a cab signal malfunction. However, for the reasons described below, a malfunction may be difficult to detect.

Railroads may have different ways of handling a cab signal malfunction once it has been detected. At some railroads, the conductor is required to ride up front with the engineer if a cab signal malfunction occurs. This is intended to aid in signal detection, but the effectiveness of this policy has not been measured.

**Difficult-to-See Signals**

Engineers rely on cab signals more heavily when wayside signals are difficult to see, such as in bad weather or when encountering signals around curves. If engineers are unable to see the wayside signal, they are less likely to recognize a mismatch that indicates a cab signal malfunction.

**Dark Signals**

At some railroads, engineers may operate according to cab signals when wayside signals are dark.* If cab signals fail in this scenario, the crew will not be able to compare the wayside signal and a SSO could occur. Additionally, if engineers are responsible for reporting dark signals to the dispatcher, they may forget to do so if they are relying on cab signals.

**Cab-Signal Only Territory**

In cab signal only territory, engineers lack the redundancy of wayside signals; therefore, cab signal failures may be difficult to detect.

*By operating rule, engineers are supposed to treat dark signals as a stop signal.

**Figure 11. Scenarios that make cab signal malfunction difficult to detect**

### Mode Transitions

Engineers must stay alert during mode transitions when cab signals or PTC shift from being in use to not being in use. Currently, cab signals and PTC are only active in territory with speeds above 20 mph, thus excluding terminal and yard environments. However, the majority of SSOs in passenger operations occur in and around the terminal, at speeds below 20 mph where cab signals and PTC are not active.

A SSO can occur if an engineer forgets that he or she is operating within territory with no cab signals and expects to hear auditory alerts to know when train speed is downgraded.

Another mode transition occurs when the train moves from wayside and cab signal territory to cab signal only territory. In cab signal only territory engineers must rely on cab signals and do not have the added redundancy of wayside signals. This creates complexity because it is not immediately evident to engineers if cab signals have failed.

As PTC is implemented, it is likely that this new technology could result in changes to the signaling infrastructure, such as the removal of wayside signals and creation of additional cab signal only territory.

**Limited Route-Ahead Information**

Cab signals and PTC systems provide some degree of information about the route and signals ahead. However, the features of these systems vary, and existing systems may vary in the kind of information they display. Engineers may still require paper-based track charts and bulletin orders to understand the route ahead for some systems.

# Good Practices

- **Extend use of cab signals and PTC to both the terminal and yard** to eliminate mode transitions and reduce low speed SSOs. As technologies improve and become more cost effective, there may be significant benefit to using cab signals and PTC in these new areas.
- Clearly **indicate mode transitions and cab signal failures** to the locomotive engineer to reduce the risk of SSOs in sections of track without cab signals or in areas where cab signals have failed.
- Engineers should **operate on the more restrictive indication and call the dispatcher** to notify them of the failure when cab signals conflict with wayside signals.
- **Provide visual route guidance and upcoming signal indications** in the locomotive cab to help engineers anticipate and respond to stop signals. Such systems may provide more comprehensive information than current cab signals. Displaying information like that shown in PTC displays such as Interoperable Electronic Train Management System (I-ETMS®) represent an example of this approach.
- Design cab signals, PTC systems or other job aids to **provide audio and/or visual alerts** as the train approaches a stop signal to direct attention toward the signal.
- **Assess the impact of any changes to the wayside signal system**. With the implementation of PTC and upgrades to signaling systems, railroads may reduce use of wayside signals in some areas. If such changes are made, railroads should carefully track the impact of the change to ensure that cab signal malfunctions or other unintended consequences do not increase the risk of SSOs.
- Create and assess policies for handling cab signal malfunctions to determine the impact on signal detection. For example, some railroads may require a **conductor to ride with the engineer in the cab** to support detecting and responding to signals.
- In addition to technology mitigations, implement **signal and infrastructure mitigations** to address overreliance on cab signal systems, and **equipment maintenance mitigations** to reduce cab signal malfunctions:
    - Placement of wayside signals (see Section 3)
    - Equipment maintenance (see Section 5)

# Track Charts & Bulletin Orders

Railroads expect the train crew to memorize the physical characteristics of the territory that they operate. However, the ability for train crews to stay knowledgeable is compromised by the dynamic nature of the work and environment and the way that information is presented to the engineer. Challenges to accessing up-to-date information on their territory, such as out of date track charts and cumbersome bulletin orders, increase susceptibility to SSOs.

**Track Charts**

Crew members are provided with paper-based track charts that show the layout of the tracks, signals, switches, grade crossings, and other relevant information (see Figure 10). These track charts are particularly useful for crews looking to re-examine the characteristics of territory they have not worked recently, and for crews working in complex environments like yards and terminals.

> *"The charts are all nice and neat and clean, but they don't give you a good idea about where the signals are in the station."*
>
> *- Engineer's account*

However, track charts do not always include the types of information crews need, due to differences between the needs of the signaling department and train crews. The track charts created by the signal departments are often not drawn to a scale, do not show curves in the rail, and may display incorrect information.

Track charts can also become out of date very quickly, and must be updated to keep up with the changing physical characteristics of the territory. At some railroads, they are updated annually, while others may update them as infrequently as every 5 years. Engineers we spoke to felt that the rate at which track charts were updated was insufficient to keep up with changes to the territory.

To compensate for track charts limitations, many engineers modify their charts by hand or draw their own. One engineer showed us a 15-year-old track chart that he had updated by hand to include landmarks, speed limit changes, operating rule transition points, interlocking boundaries and compass location (e.g., north and south). However, engineers entering territory that they do not encounter frequently, who have not had the opportunity to create such supplementary materials, may be especially susceptible to SSOs that result from inaccurate or outdated charts.

In the future, railroads may move to electronic track charts, which may be helpful for maintaining and accessing up-to-date information. If this is done, it is important to preserve the ability for engineers to annotate the charts and ensure that information displayed is relevant to them.

*Cropped track chart that has been modified by an engineer*

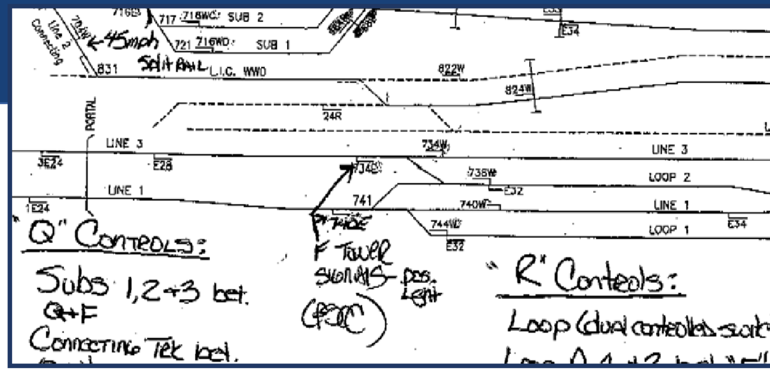



**Figure 12. Actual track chart that has been modified by a locomotive engineer**

### Bulletin Orders

Railroads provide daily bulletin orders documenting changes to the physical environment that are not captured in the track charts, such as information about signals that have been moved. However, due to the infrequency of track chart updates, bulletin orders may become very lengthy, and can be difficult to scan for new information.

Bulletin orders are printed, rather than electronic, and cannot be searched or filtered for relevant information. Additionally, information in bulletin orders was frequently presented in ways that made them more difficult to use. Some bulletin orders use fonts and formatting that slow the reading process and limit the engineer's ability to find information they need to operate the train safely.

## Good Practices

- Provide **accurate, up-to-date track charts** tailored to the needs of train crews, especially for railroad yards and complex terminals.
- **Organize bulletin orders** so that information is easier to locate quickly. Information should be grouped according to the engineer's task requirements.
- **Highlight changes** to bulletin orders so that new information is easily identified and accessed.
- Consider providing the crews with **track charts and other paperwork in an electronic format**. This has several benefits, including:
  - Saving employees time in going up to the office to get bulletins
  - Reducing the amount of paperwork employees need to carry around with them
  - Enabling employees to easily access the most up-to-date versions of paperwork

- Consider the following when creating electronic versions of track charts:
  - Make them **customizable** so that employees can select or de-select the physical characteristics (e.g., signal type, milepost number, electrified track locations, etc.) they want to see depending on their needs
  - Provide an ability for the user to **annotate electronic materials**

# Dispatching Technology

Dispatching systems that require manual input of train routes can contribute to errors, inefficiencies, and SSOs. However, current dispatching systems the authors observed did not provide decision-support to help dispatchers plan better routes.

Furthermore, current dispatching systems at the railroads the authors visited made it more difficult to recognize and respond to SSOs. In some cases, this was due to inadequate notification when SSOs occur, while in others it resulted from lack of trust in the dispatching system due to frequent nuisance alarms or erroneous indications by the dispatching system.

These factors increase the challenge of the dispatcher's role in preventing SSOs, as well as their role in ensuring that SSOs that occur do not lead to a more serious event.

### Dispatcher Planning Support

Current computer-based dispatching systems allow users to view train locations, track occupancy, and manually enter train routes. They are designed to prevent egregious errors, like routing two trains to the same track, and provide certain critical alerts, such as alerts of power failures and stop signal overruns. However, they do not display train length or signal aspect (i.e., dispatchers can only see if the signal is permissive or not), and do not provide any real-time support for planning and adjusting routes.

Railroads may wish to explore the use of more advanced displays, real-time decision-aid systems, and training aids for dispatchers to avoid the pitfalls of inefficient routing discussed in previous sections. Future dispatching systems could provide dispatchers with more information about the state of the tracks and the whole system. Such systems could also help dispatchers plan optimal routes based on historical and current information to minimize overall delays while also minimizing the number of stop signals trains experience.

### Recognizing and Responding to SSOs

It is important for dispatching systems to immediately notify dispatchers that an SSO has occurred because train crews may rely on dispatchers to confirm whether they went through a stop signal. If a crew is uncertain, but does not hear from the dispatcher, they may assume they did not go by the signal and proceed with their route. However, at some railroads these alerts were not sufficiently attention-grabbing—or nuisance alerts and inaccurate information reduced the dispatcher's ability to trust the system and correctly interpret alerts. These factors which might prevent a dispatcher from recognizing an SSO are detailed below.

### Why might a dispatcher not recognize an SSO?

1. **The alert indicating an SSO is not sufficiently attention-grabbing**. One dispatcher told us that the alert for a SSO is not easily noticeable and "doesn't really stand out."
2. **The dispatcher does not trust the information provided by the dispatching system**. Dispatch systems may have high false alarm rates and errors called "phantom track occupancy lights," which incorrectly indicate that track is occupied. If a dispatcher is accustomed to false alarms and erroneous indications, they may be less likely to correctly interpret when a track occupancy alert indicates that an SSO has occurred.
3. **The dispatch system incorrectly registers the SSO as a different issue**. One railroad described an incident in which the dispatch system alarms indicated a "power and code failure." As a result, the train that went through the stop signal kept operating for upwards of 10 minutes.

> *"We have an alarm that is generated when a train overruns a signal, but it doesn't really jump out at dispatcher. It's really small text. Something like an SSO is something we want to grab dispatchers' attention immediately."*
>
> *- Dispatcher's account*

## Good Practices

- Consider procuring and/or developing software that supports more efficient **real-time rerouting of trains** to optimize the ability to maintain the schedule while simultaneously reducing the need to stop trains within the terminal.
- Dispatch systems should clearly and immediately **notify dispatchers when a SSO occurs** so that dispatchers can quickly stop the trains from proceeding.
- **Dispatching systems should be reviewed** to make sure that nuisance, uninformative, and false alarms and erroneous indications such as "phantom occupancy lights" are reduced.

# 5. Equipment & Rolling Stock

Railroads often operate a mix of new and old equipment. Train crews must adapt to the characteristics of the locomotives and consist they are assigned; this can be an impediment to avoiding SSOs.

Locomotive cab type can affect the engineer's ability to see signals depending on the configuration and type of controls and the engineer's seated position. Consist length can also impact visibility; particularly when longer equipment is used where the infrastructure does not support it. Lastly, the condition of equipment has important safety implications, particularly regarding the ability to brake to avoid an SSO.

GAUGE YOUR RAILROAD

Does your railroad have…

- ❑ Locomotive cabs with limited out-the-window visibility?
- ❑ Tracks that are too short for modern consists?
- ❑ Equipment in poor condition?
- ❑ Brakes that do not work well enough in snow and ice?

## Locomotive Cab Design & Consist

Locomotive cab design can contribute to SSOs through differences in the engineer's seating position, placement of displays, control design, and the type of power. These factors can affect the engineer's field of view, and can influence the engineer's ability to see signals depending on their placement.

**Seating Position**

Depending on the design of the workstations, engineers may be seated in different positions (e.g., more upright or more reclined) to see and operate in-cab controls and displays. More reclined seating configurations can reduce out-the-window visibility, as displays may block the window view. This can reduce the visibility of signals, especially dwarf signals which are lower to the ground.

*Examples of control stands in locomotive cabs*

**Figure 13. Example of control stands in locomotive cabs**

### Display Placement

The introduction of technologies like PTC can trigger a need to retrofit additional displays in the cab. In many cases, space in the cab may be limited.

In focus groups, several engineers noted that their out-the-window view was partially blocked by displays, limiting their ability to see signals. Some engineers took to standing up or moving around to compensate for this limited visibility. It is critical for managers to consider the impact of new in-cab displays on the engineer's visibility.

> *"To work around your blind spot, you spend most of the time standing up, looking out of the window."*
>
> *- Engineer's account*

### Spring-Loaded Throttles

Engineers mentioned that the spring-loaded throttles on older electric multiple units (EMUs) acted as a deterrent to SSOs. The spring-loaded throttle resulted in the engineer applying continuous pressure to the throttle. As one employee said, spring-loaded throttles force engineers to "sit up straight and use both hands" while operating the locomotive.

The need to sit up straight *may* make it easier to see out the window to locate signals (i.e., in contrast to the more reclined position in the newer EMUs) and the need to place continuous pressure on the throttle means the engineer must remain at the control stand and cannot move around the cab or do other tasks (e.g., look through paperwork, etc.).

Another advantage of the spring-loaded throttle, according to railroad employees, was that the engineer can stop the train more quickly. With the spring-loaded throttle, the engineer only has to lift her or his hand from the throttle. In contrast, newer EMUs require the engineer to take the extra step of physically putting the train into emergency.

*"I think the spring-loaded throttle saved a lot of SSOs. All you had to do was let go of the power and it would stop the train. Couldn't be moving around the cab, looking at paper, etc., if I lifted my hand the train would go into emergency."*

*- Engineer's account*

### Power Type

SSOs appear to be less common in diesel-electric locomotives. This was partially explained by a lower rate of exposure to stop signals. The railroad operated fewer diesel-electric trains than EMUs. The difference also resulted from the way the trains were operated. Concerns about losing power resulted in dispatchers giving the diesel-electric trains routes that minimized stop signals.

*"Electrics stop much quicker. But with diesels it takes a while"*

*- Engineer's account*

Engineers also said that display interfaces and the design of the controls were more intuitive in the EMUs than the diesel-electric locomotives.

The different locomotive types have different braking characteristics, with diesel-electric locomotives taking longer to bring to a stop than EMUs. Counterintuitively, engineers indicated that they operated the diesel-electric trains with greater vigilance than EMUs because of this longer braking time.

### Consist Length

In addition to the type of locomotive, consist make-up (i.e., length and type of cars) can also contribute to SSOs. Longer trains can contribute to the risk of SSOs at shorter platforms which were not designed to accommodate the lengths of today's trains. When these longer trains are stopped at short platforms, the signal may be located behind the cab and out of the engineer's line of sight. Engineers must remember that the signal is behind the locomotive cab, and that the signal ahead is not (yet) for them.

*"When they switched engineers, the new engineer didn't see the signal because it was behind him, so he inched up to the platform to see the next signal"*

*- Engineer's account*

## Good Practices

- When procuring new power equipment, vendor specifications for new locomotives and EMUs should require that all **wayside signals and in-cab signals be visible from the engineer's position**.
- **Perform an ergonomic analysis on existing cab configurations** to assess the engineer's ability to see the wayside signals and in-cab signals.
- Record or document the locomotive type and consist length during SSO investigations to better understand the role these factors may play in SSO events.

## Equipment Maintenance

Maintenance can play an important role in preventing SSOs. In Section 3, the authors described the importance of keeping signals functioning and unobstructed, and track infrastructure in good shape. Likewise, it is important for trains themselves to be in good working order, because improperly maintained equipment can lead to safety issues such as braking difficulty and distraction.

In Section 4, the authors discussed the issues posed by cab signal malfunctions. Such malfunctions have a significant impact on the engineer's ability to recognize and respond to signals, and therefore are important to address quickly through repairing or replacing the system.

Brake maintenance is another critical area for safety. Some engineers indicated that brake shoes may not be replaced as often as necessary to function optimally in snow and ice. This increases the risk of SSOs in such challenging weather conditions.

Finally, as we mentioned in Section 4, there are risks associated with nuisance alarms. Non-critical equipment malfunctions may increase the risk of SSOs by contributing distracting alerts to the cab environment. For example, one engineer told us that he was distracted by alerts signaling that the air conditioning unit needed maintenance. Ensuring timely maintenance of equipment and applying the good practices for alarms and alerts discussed in Section 4 can reduce the frequency of such distractions.

## Good Practices

- Conduct **locomotive maintenance** at the manufacturer recommended periods.
  - **Monitor and service brakes regularly**, particularly in snow/ice conditions.
  - **Repair or replace malfunctioning cab signals promptly** so that malfunctions do not lead to SSOs (see Section 4).

- **Repair or replace malfunctioning equipment promptly**, even if it is not safety-critical, so that malfunctions or alerts do not become a source of distraction to the train crew.

➲ **Implement alarm and alert design mitigations**, such as allowing engineers to acknowledge and silence alerts, to address nuisance alarms (see Section 4).

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