Reducing Hazards Associated with Visual and Automation-Aided Track Inspections: Supplementary Information

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14. ABSTRACT

This supplementary document accompanies the previously published Federal Railroad Administration (FRA) report titled Reducing Hazards Associated with Visual and Automation-Aided Track Inspections, Report No. DOT/FRA/ORD-21/18. The main report documents a study in which a team of Volpe human factors researchers applied a hazard analysis method called Systems-Theoretic Process Analysis (STPA) to examine three possible track inspection sociotechnical systems. This study led to the development of several recommendations that railroads can use to improve the safety and effectiveness of their track inspection processes, particularly regarding the integration of humans and automation.

15. SUBJECT TERMS
Track research, track inspection, inspection, automated inspection, automation-aided inspection, railroad, track safety, safety, human factors, passenger rail, systems-theoretic process analysis, STPA, STAMP, systems-theoretic accident model and process, track geometry measurement system, TGMS, aTGMS

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1. Introduction

This document provides supplementary information to accompany the previously published Federal Railroad Administration (FRA) report titled <u>Reducing Hazards Associated with Visual and Automation-Aided Track Inspections</u>, hereto referred to as the "main report." The main report documents a study in which a team of Volpe human factors researchers applied a hazard analysis method called Systems-Theoretic Process Analysis (STPA) to examine three possible track inspection sociotechnical systems. This study led to the development of several recommendations that railroads can use to improve the safety and effectiveness of their track inspection processes, particularly regarding the integration of humans and automation.

The information presented in this document may be useful for researchers interested in gaining a more detailed understanding of how the Volpe team identified the factors discussed in their report, or looking to learn about applying STPA to rail systems.[1] This information was not essential to the primary audience; therefore, this supplementary document was created. The current document includes more information about the interim steps of the STPA analysis that led to the recommendations in the main report, and the outputs of each stage of the research team's analysis are provided in the appendices. Readers of the current document will want to refer to the main report frequently when reading this, since the current document is not intended to stand alone.

1.1 Framework for Considering Supplementary Information

The Volpe research team revised this data iteratively through the course of its analysis; however, note that the tables in the appendices of this document were created as tools for the team to understand the track inspection process and develop recommendations. They contain hypothetical statements about situations that *could* be hazardous if they occurred, and speculation about how factors could combine to lead to unsafe behavior. None of these statements should be interpreted as facts or as condemnation of any railroad or railroad employee.

Furthermore, despite the best efforts of the research team, these tables may contain inaccuracies or oversimplifications that reflect the team's evolving understanding of the track inspection process. Upon encountering such flaws, readers should recall that the purpose of this document is to share methodological information and insight on the interim stages of the team's STPA analysis – rather than to present a complete and accurate documentation of the track inspection process.

1.2 Organization of this Document

This supplemental document is organized into four sections briefly describing the outputs of the STPA analysis:

- <u>Section 2</u>: Hazards and Safety Control Structures

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[1] However, those looking for information about how to conduct STPA will want to consult a source dedicated to that purpose (e.g., Leveson & Thomas, 2018).

- Section 3: Undesirable Control Actions (UCAs)
- Section 4: Causal Scenarios
- Section 5: Safety Constraints

Following these sections, the team's data analysis tables are included in a series of appendices:

- Appendix A. UCAs for Visual Inspection Sociotechnical System
- Appendix B. Scenarios for Visual Inspection Sociotechnical System
- Appendix C. UCAs for TGMS & Visual Inspection Sociotechnical System
- Appendix D. Scenarios for TGMS & Visual Inspection Sociotechnical System
- Appendix E. UCAs for aTGMS & Visual Inspection Sociotechnical System
- Appendix F. Scenarios for aTGMS & Visual Inspection Sociotechnical System
- Appendix G. Sociotechnical System Safety Constraints

2. Hazards and Safety Control Structures

This section describes the role of hazards and safety control structures (SCS) models in the STPA analysis.

2.1 Hazards

In STPA, accidents are defined as "undesired or unplanned events that result in a loss." Accidents or losses are not always the result of failure events; rather, they may stem from unsafe interactions among components, external disturbance, or behavior of individual components that is not failure, but which lead to a hazardous system state (Leveson, 2012). System-level accidents chosen for STPA typically include loss of life or injury, but they may also include financial losses, equipment and infrastructure damage, or other damages that stakeholders wish to prevent.

To prevent accidents, the behavior of the sociotechnical system must be constrained to avoid hazards. A hazard is defined in this case as "a system state or set of conditions that, together with a particular set of worst-case environment conditions, will lead to an accident (loss)" (Leveson, 2012). Therefore, to proceed with an STPA hazard analysis it is also necessary to define a set of high-level hazards that stakeholders are interested in preventing.

The hazards identified for this study are described in Section 3.3.2 of the main report.

2.2 Safety Control Structure Models

The SCS models are diagrams that depict control and feedback relationships between people and technologies involved in track inspection. They identify the major components in the track defect detection process and show the functional relationships between components that are required for that sociotechnical system to function safely.

A safety control structure model contains actors (e.g., people, organizations, technology, and/or other systems) arranged in a hierarchical order with the actor(s) having greater authority and control at the top of the diagram, and the actors and non-acting components that they impose control over displayed below them. It also shows the actions that flow down the hierarchy, i.e., the actions the actor may take to enforce constraints on the behavior of the actors and non-acting components below them. Likewise, it also shows feedback that flows up the hierarchy from actors with less authority and control up to the actor above. The SCS may also depict information exchanges and interactions that are neither control nor feedback, such as coordination between actors of similar authority and physical interactions between non-acting components.

The three SCS models developed for the study are shown and described in detail in Section 5 of the main report.

3. Undesirable Control Actions

An undesirable[2] control action, or UCA, is a statement that describes context in which a particular control action could lead to a hazard. STPA methodology does not suggest that an accident will occur if the UCA is performed. Rather, it means that if the action occurs (or does not occur) in a particular context, it could lead to one of the associated hazards, and that hazard has the potential to lead to an accident. Additionally, UCAs also do not mean that the person or group responsible for the action, referred to as the actor, made an error. The action could be considered normal behavior considering certain systemic factors. Nonetheless, these actions are labeled UCAs because they *could* lead to hazards in the stated context.

In an STPA analysis, a UCA table shows how undesirable events can occur when the system fails to enforce intended safety constraints. UCAs are written as statements with the following five components: actor, action, type, context, and hazards (Leveson & Thomas, 2018). These are explained below.

1. **Actor:** The person, machine, or other entity responsible for performing the action. This element is taken from the SCS model.

2. **Action:** The specific action being performed (or not performed). This element is taken from the SCS model.

3. **Type:** One of the four UCA types defined by Leveson (2012), reproduced below.

   - **Not providing causes hazard:** A control action required for safety is not provided or not followed.

   - **Providing causes hazard:** An unsafe control action *is* provided, including actions that are performed in an unsafe context, performed incorrectly, or performed at the wrong intensity.

   - **Wrong timing or order:** A potentially safe control action is provided too early or too late; that is, at the wrong time or in the wrong sequence.

   - **Wrong duration:** A control action required for safety is stopped too soon or applied too long.

4. **Context:** The most important piece of each UCA statement. It identifies the conditions under which an action, or lack thereof, could lead to a hazard. This element is often preceded by words like "when" or "while."

5. **Hazard:** The possible outcomes associated with an unsafe control action. In a worst-case scenario, the hazard could lead to an accident. This element is taken from the set of hazards identified in the first step of the STPA analysis. (Hazards identified for the current study are discussed in Section 3.3.2 of the main report.) Hazards are typically included in brackets at the end of the UCA statement.

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[2] The Volpe team uses the term "*undesirable* control action" where the standard terminology used in STPA research is "*unsafe* control action." This is to avoid the possibility of railroad industry readers, who may not be familiar with standard STPA methodology, feeling concern about a report issued by FRA, the regulator, seeming to label certain actions as "unsafe."

The actor, action, and type are all specified by the position in the UCA table. Context and hazards are then added to turn a normal action into an *unsafe* control action. Without context which makes the action unsafe, the statement "Controller 1 provides action A" is simply a control action. Context is needed to explain why that action could be unsafe or undesirable.

The inclusion of relevant hazards is similarly essential to clarify what undesirable outcomes could occur. Using the hazards identified earlier in the STPA process also provides traceability in the analysis; each UCA links to potential hazards which link back to their associated accidents.

UCAs for the three sociotechnical systems included in the analysis are in the following appendices:

- Appendix A. UCAs for Visual Inspection Sociotechnical System
- Appendix C. UCAs for TGMS & Visual Inspection Sociotechnical System
- Appendix E. UCAs for aTGMS & Visual Inspection Sociotechnical System

When reviewing the UCA tables provided in the appendices, the reader should remember that UCAs are *not* based on the frequency of actual safety events. The STPA hazard analysis makes no assumptions about the likelihood of an unsafe control action. In fact, many UCAs can be successfully prevented through sociotechnical system constraints and will rarely, if ever, occur. However, the inclusion of such UCAs in the table denotes that it *could be* unsafe if such an action did occur, and thus it is important to consider how to prevent this action in the design and operation of the sociotechnical system.

UCA tables are a tool to facilitate the next step in the STPA process, which is to identify causal scenarios. The UCAs, in isolation, do not provide sufficient information to develop effective safety recommendations. Rather, UCA tables enabled the team to create scenarios that help identify why UCS may occur through a combination of multiple systemic factors. From those scenarios, the team generated safety recommendations and mitigations for the identified causal factors.

3.1   Examples of Unsafe Control Actions
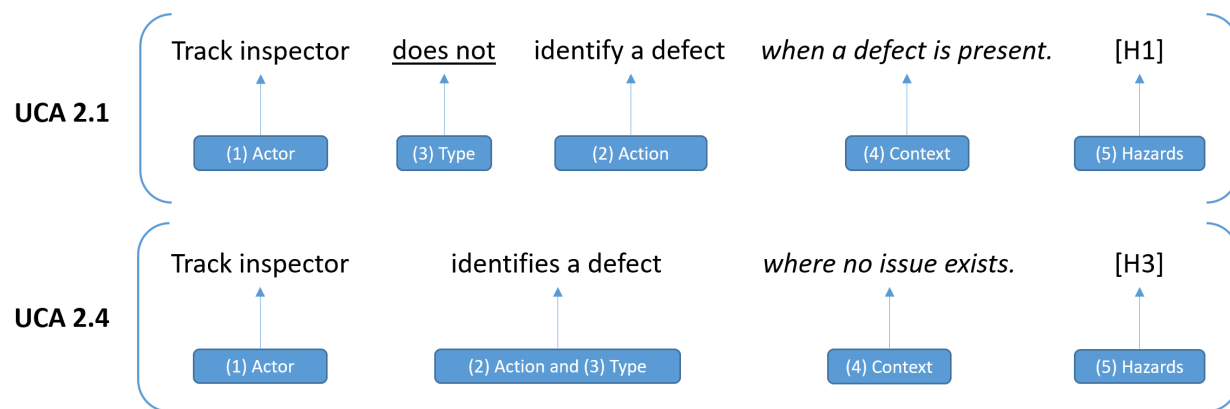
Figure 1: Parts of a UCA, using examples from the Visual Inspection Sociotechnical System

The two UCAs highlighted in Figure 1 illustrate two opposite actions that could lead to different hazards. In UCA 2.1, the track inspector does not identify a defect that is present – which could expose operational crews and equipment to danger. In UCA 2.4, the track inspector *falsely* identifies a defect where there is not an issue. This does not pose a safety risk; however, it may lead to wasted time and resources if maintenance crews are sent to an area where there is no actual defect to repair.

The context "when a defect is present" or "where no issue exists" provides critical information that explains why *identifying* or *not identifying* a defect would be unsafe or undesirable.

At this stage of the analysis, one does not consider *why* an unsafe control action would be performed; only *what* could happen if it occurred. The next stage of the analysis identifies reasons why such an action could occur.

For example, UCA 2.1, "Track inspector does not identify a defect when a defect is present" could occur for a variety of reasons. Below are several potential factors that could contribute to this UCA, especially if they occurred in combination:

- Limited time available to perform a thorough inspection
- Limited training on how to recognize defects of that type
- Limited experience on the territory
- Poor weather or visibility conditions
- Fatigue

Examining why unsafe control actions like this one might be performed will allow us to make recommendations to help prevent them. For example, one recommendation could be to provide mentoring for new inspectors so that experienced inspectors can share their strategies for detecting defects – something that multiple inspectors indicated would be valuable if more widely implemented. This could help address limited training and experience. Another recommendation could be to evaluate territory sizes and staffing practices to make sure that inspectors have adequate time to spend on their inspections.

4. Causal Scenarios and Safety Constraints

Causal scenarios and safety constraints are both outputs of an STPA analysis that can be used to develop recommendations.

- Causal scenarios are more specific and identify how and why unsafe or undesirable control actions may occur. They can be used to detailed recommendations for how to proactively address potential risks.

- Safety constraints are more general, and state *what* must happen to avoid undesirable control actions, but not *how*. They can be used as an intermediate step to develop recommendations, or as general guidance where more specific understanding of causal factors is not available.

This section describes the causal scenarios and safety constraints that the Volpe team developed.

4.1 Causal Scenarios

Causal scenarios help identify how and why unsafe or undesirable control actions may occur and can be used to generate recommendations for how to proactively address potential risks.

A causal scenario is made up of one or more contributing factors, though it is rare that UCAs occur as a result any single factor. Typically, multiple interacting factors combine to lead to UCAs. In isolation, causal factors may, at times, seem innocuous; however, when combined with other causal factors they may interact to lead to undesirable events. For this analysis, causal scenarios were compiled in the form of bulleted factors; these are in the following appendices:

- Appendix B. Scenarios for Visual Inspection Sociotechnical System

- Appendix D. Scenarios for TGMS & Visual Inspection Sociotechnical System

- Appendix E. UCAs for aTGMS & Visual Inspection Sociotechnical System

By reviewing these appendices, one can see that the team has identified a wide range of factors that may contribute to each UCA. However, since it is important to understand that causal factors rarely occur in isolation, Section 4.3 provides specific examples of how multiple factors can combine to lead to UCAs.

Note that for certain actors in the SCS (railroad upper management, labor unions, FRA, and technology manufacturers), the team did not conduct in-depth interviews because it was beyond the scope of this study.[3] Therefore, the team had more limited information on these actors and did not perform the same level of analysis.

- For railroad upper management, the team developed UCAs (as previously described), and safety constraints, which will be described in the following section.

- For labor unions, FRA, and technology manufacturers, the team did not conduct in-depth analysis of the actions they perform (e.g., negotiating collective bargaining agreements, creating and enforcing regulations, etc.). Therefore, this document does not include UCAs, causal scenarios, or safety constraints specific to these actions. However, as

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[3] See Section 3.1 in the main report for more information about the Volpe team's data collection.

important parts of the sociotechnical system, these actors do influence the track inspection process. The team included factors related to these actors in causal scenarios where relevant to the system (i.e., where they shape another actors' behavior in some way).

4.2   Causal Scenario Examples

This section presents example causal scenarios to illustrate how factors can be combined for sample UCAs related to three actors: TGMS sensors, the TGMS operator, and track inspectors.

4.2.1   TGMS Sensor Scenario Examples

Below the team considers how causal factors could combine to lead to the UCA: **"TGMS sensors collect incorrect data."**[4]

The first scenario illustrated how a calibration issue could go unnoticed through a combination of inexperience and trust in technology:

> **Scenario 1:** The TGMS sensors collect incorrect data because they are incorrectly calibrated. The calibration is not so far off that it is immediately obvious; however, it is off enough to critically change the measurements of certain exceptions. The TGMS operator is relatively new to the job and was taught that the technology is extremely reliable. Given the operator's limited experience and trust in the technology, the operator does not pick up on the calibration issue and ignores anything that appears unusual.

An alternate scenario could result from a combination of the TGMS system design, inexperience, and training:

> **Scenario 2:** The TGMS sensors collect incorrect data because the TGMS is stuck behind slow-moving traffic and this system is not designed to collect data at low speeds. The TGMS operator is relatively new to the job and did not realize that TGMS needed to be traveling a certain speed to collect data, which was covered only briefly in training. The operator also does not have enough experience to recognize that there is an issue with the data. Therefore, the operator continues to accept the data collected at low speed.

In both examples, each factor in isolation would not have been sufficient to lead to a UCA. For example, if the TGMS operator were experienced, they may have been more likely to identify the calibration and speed issues. Conversely, if the TGMS were properly calibrated, or designed to collect data even at low speeds, the relative inexperience of the TGMS operator may not have led to a UCA.

4.2.2   TGMS Operator Scenario Examples

One of the benefits of an STPA analysis is that it considers causal factors related to both technology and humans. In the previous examples, TGMS collects incorrect data; however, even if the TGMS data is correct, the actions of the TGMS operator can lead to issues going undetected – such as if the operator dismisses the exception.

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[4] This is UCA 1.2 in Appendix D. Scenarios for TGMS & Visual Inspection Sociotechnical System.

Therefore, consider some example scenarios for the UCA **"TGMS operator dismisses exceptions when they are NOT false alarms."**[5]

Perhaps the TGMS operator is relatively inexperienced with the system and dismisses the exception unintentionally under time pressure:

>**Scenario 1:** The TGMS operator accidentally dismisses an exception that is not a false alarm. The operator was feeling time pressure to catch up quickly on reviewing the scrolling data after coming back from the restroom. In the operator's rush to review the data quickly, the operator mistakenly dismisses a real exception (e.g., accidently clicks the incorrect row or hits an incorrect button). The operator is very familiar with this track but has mostly used the Track Structure Assessment Vehicle (TSAVe) in the past, and thus lacked experience with the TGMS interface.

Alternatively, the operator may be very experienced with TGMS, but less experienced with that exact stretch of track:

>**Scenario 2:** The TGMS operator dismisses an exception when it is not a false alarm. The TGMS operator notices two exceptions come up in close proximity while passing over a frog, where false readings of wide gage are common. The operator incorrectly believes both of those exceptions are false alarms, when in fact there is an actual wide gage issue just past the frog. Because the operator is not familiar enough with the location, the operator did not recognize where false readings normally end and dismissed the actual wide gage defect as well.

The team can also construct scenarios for a TGMS operator who is very familiar with both TGMS and the territory where entirely different types of factors come into play, such as in the following example.

>**Scenario 3:** The TGMS operator dismisses an exception when it is not a false alarm. The operator correctly remembers that wide gage readings are typical at this milepost due to a frog at this location. This time there is also a legitimate exception right next to it. However, the operator's attention is occupied with a call to Dispatch about something else. The operator ends up accidently deleting the legitimate exception as well as the false alarm because of both prior expectations and divided attention.

For these TGMS operator scenarios, as with the TGMS sensor scenarios, it is combinations of factors, rather than isolated issues, that lead to UCAs.

4.2.3 Inspector Scenario Examples

Finally, the team considers some scenarios for the track inspector. The two scenarios presented below showcase different causal factors influencing a track inspector for the UCA **"Track inspector does not identify a defect when a defect exists."**[6]

In the first example, the inspector is faced with a challenging situation – a severe weather event. Fatigue and limited experience then further complicate the situation.

>**Scenario 1:** The track inspector does not identify a defect when a defect exists because the tracks are covered in ice. The track inspector is newly qualified and has never

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[5] This is UCA 5.1 in Appendix D. Scenarios for TGMS & Visual Inspection Sociotechnical System.

[6] This is UCA 9.1 in Appendix D. Scenarios for TGMS & Visual Inspection Sociotechnical System.

conducted an inspection in snow conditions. The inspector does not recognize that the small section where the snow and ice has cracked means that there is a broken tie underneath. The inspector is also tired, having worked overtime for the past 2 days to help with the special inspections needed.

In the second example, the inspector is put in a difficult situation and did not end up with sufficient time to go at the pace needed to find all defects.

> **Scenario 2:** The track inspector does not identify a defect when a defect exists because of insufficient track time. Halfway through inspecting the dispatcher calls to take track back early, despite having granted ample time initially. Because the inspector stopped to make several, small repairs during the inspection, the inspector is now rushed to complete the remainder of the inspection to fulfill regulatory requirements. As a result, the inspector misses a defect.

Like the scenarios for TGMS sensors and operators, these scenarios for the track inspector show how combinations of factors in various circumstances can lead to undesirable control actions. The complexity of these scenarios suggests that there is no "easy fix" or single recommendation that will stop a UCA. Rather, mitigating these undesirable events will require railroads to take a multi-pronged approach to addressing causal factors.

4.3   Safety Constraints

Safety constraints are "acceptable ways the system or organization can achieve the mission goals" (Leveson, 2012). They indicate the type of control that must be exerted to prevent hazardous states. Safety constraints are created by reframing UCA statements to summarize "what must (not) happen in order for hazards to be avoided?"

The Volpe team provided examples of safety constraints for railroad upper management, rather than detailed causal scenarios. These safety constraints provide structured guidance on maintaining system safety related to defect detection and operational safety hazards,[7] while recognizing that the team had limited information about what factors drive decisions at this level of the sociotechnical system. These safety constraints can be found in Appendix G. Example Sociotechnical System Safety Constraints.

4.4   Safety Constraint Example

Safety constraints can be written to address UCAs by reframing the UCA, as shown in Table 1. These constraints provide general information about *what* needs to be done to prevent hazards, but do not specify a solution, or *how* to prevent hazards. System experts may then decide on appropriate requirements to meet these constraints.

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[7] Though not the focus of this study, it is worth mentioning that those interested in high-level guidance on mitigating undesirable control actions associated with incidents during inspection or undue economic burden ("H2" and "H3") can also use the identified UCAs associated with these hazards to create safety constraints.

Table 1. Example UCA and its associated safety constraint

UCA	Safety Constraint
Upper management defines inspection territory that is a non-optimal size (too large or small) and/or complexity for one inspector to cover in the required timeframe. [H1; H3]	Upper management should define inspection territory that is of optimal size and complexity for one inspector to cover in the required timeframe.

5. Conclusion

The current document provides only supplementary information to the main report, [Understanding Hazards Associated with Automation-Aided Track Inspection: A Systems-Theoretic Analysis](), and should not be used as a standalone document.

This document provides basic information about the track inspection systems examined in this analysis, but does not describe the full data collection process followed by the Volpe research team, nor does it attempt to provide recommendations. Readers interested in learning more about automation-aided track inspection, including the Volpe team's methodology and recommendations, should see the main report.

6. References

Leveson, N.G. (2012). Engineering a Safer World: Systems Thinking Applied to Safety. Cambridge, MA: The MIT Press.

Leveson, N.G. & Thomas, J.P. (2018). STPA Handbook.

Appendix A.
UCAs for Visual Inspection Sociotechnical System

These are the UCAs developed for the Visual Inspection Sociotechnical System described in Section 4.1 of the main report.

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Track Inspector **1: Inspect track.**	**UCA 1.1:** Track inspector does not inspect track when inspection is needed (to meet frequency regulations and because issues could have arisen). [H1; H3] **UCA 1.2:** Track inspector does not conduct field verification of issue when instructed to do so and a safety issue is present. [H1]	**UCA 1.3:** Track inspector inspects track using a method (i.e., on foot/hi-rail) that is not effective or efficient for the territory. [H1; H3] **UCA 1.4:** Track inspector inspects or verifies track at the incorrect location. [H1; H3] **UCA 1.8:** Track inspector inspects track without proper safety measures. [H2]	**UCA 1.5:** Track inspector inspects track when another section of that inspector's territory is in more serious need of inspection. [H1] **UCA 1.9:** Track inspector starts inspecting track before proper safety measures are in place for own protection. [H2] **UCA 1.10:** Track inspector inspects track too soon, before inspection is due. [H3]	**UCA 1.6:** Track inspector inspects track too quickly to detect issues. [H1] **UCA 1.7:** Track inspector stops inspection too soon (before necessary inspection is complete according to regulations or before a section with specific concerns has been inspected). [H1] **UCA 1.11:** Track inspector spends too long inspecting (delays service). [H3]
Track Inspector **2: Identify defect** *(class-limiting FRA defect).*	**UCA 2.1:** Track inspector does not identify a defect when a defect exists. [H1]	**UCA 2.2:** Track inspector identifies a defect as less severe than it is. [H1] **UCA 2.3:** Track inspector identifies a defect as more severe than it is; identifies a defect when it is actually a maintenance condition. [H3] **UCA 2.4:** Track inspector identifies a defect where no issue exists. [H3]	**UCA 2.5:** Track inspector identifies a defect too soon when it is not yet serious enough to impact safety. [H3] **UCA 2.6:** Track inspector identifies a defect too late, when severe enough that track speed must be restricted or track removed from service. [H3]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Track Inspector **3: Identify maintenance condition *(railroad maintenance threshold)*.**	**UCA 3.1:** Track inspector does not identify a maintenance condition when a maintenance condition exists and should be monitored for progression toward a safety defect. [H1; H3]	**UCA 3.2:** Track inspector identifies a maintenance condition where a maintenance condition does not exist. [H3] **UCA 3.3:** Track inspector identifies a maintenance condition as more severe than it is. [H3]	**UCA 3.4:** Track inspector identifies a maintenance condition too soon, before it is actually a maintenance condition. [H3] **UCA 3.5:** Track inspector identifies a maintenance condition too late to incorporate into maintenance planning. [H3]	N/A
Track Inspector **4: Repair maintenance condition/defect.**	**UCA 4.1:** Track inspector does not repair a defect, when they do not restrict or remove the track from service. [H1] **UCA 4.4:** Track inspector does not repair a defect when they have the ability (time, tools, skill) to do so, thus requiring track speed to be restricted or the track removed from service. [H3]	**UCA 4.2:** Track inspector repairs defect/maintenance condition when it affects ability to complete inspection or resulting in service delays [H1; H3]. **UCA 4.3:** Track inspector repairs a maintenance condition or defect incorrectly. [H1; H3] **UCA 4.5:** Track inspector repairs a maintenance condition/defect without safety measures in place. [H2] **UCA 4.6:** Track inspector repairs a maintenance condition when it would be more efficient to wait until later. [H3]	**UCA 4.7:** Track inspector repairs a condition too early, before repair is needed or practical. [H3]	N/A
Track Inspector	**UCA 5.1:** Track inspector does not restrict track speed when a safety issue is present and not	**UCA 5.2:** Track inspector restricts track speed when severe issues are present and track	**UCA 5.4:** Track inspector waits too long to restrict track speed, allowing trains to operate	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
5: Restrict track speed.	otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]	should be removed from service. [H1] **UCA 5.3:** Track inspector restricts track speed incorrectly (e.g., either too strict or not strict enough or wrong location). [H1; H3] **UCA 5.5:** Track inspector restricts track speed when track is not actually a risk to safety (i.e., when there is no issue above threshold for that track class) [H3] **UCA 5.6:** Track inspector restricts track speed when track could have been immediately repaired by the inspector. [H3]	over track with a safety issue in the meantime. [H1]	
Track Inspector **6: Remove track from service.**	**UCA 6.1:** Track inspector does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]	**UCA 6.3:** Track inspector removes track from service incorrectly, e.g., when there is no issue present or at wrong location. [H3] **UCA 6.4:** Track inspector removes track from service when track could have been repaired or restricted. [H3]	**UCA 6.2:** Track inspector removed track from service too late, allowing trains to operate over track with a safety issue in the meantime. [H1]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Track Inspector **7: Log defect.**	**UCA 7.1:** Track inspector does not log a defect when it a defect is present. [H1]	**UCA 7.2:** Track inspector logs a defect incorrectly–with incorrect or incomplete information that limits ability to investigate or repair. [H1]	N/A	**UCA 7.3:** Track inspector spends too long logging defects when doing so during an inspection, causing them not to finish inspection, or need to rush inspection; or causing delays to service. [H1; H3]
Track Inspector **8: Log maintenance condition.**	**UCA 8.1:** Track inspector does not log a maintenance condition when it is detected and needs monitored for progression towards a safety defect. [H1] **UCA 8.4:** Track inspector does not log a maintenance condition when it is detected and would impact longer-term maintenance planning activities. [H3]	**UCA 8.2:** Track inspector logs a maintenance condition incorrectly–with incorrect or incomplete information that limits ability to investigate or repair. [H1; H3]	N/A	**UCA 8.3:** Track inspector spends too long logging maintenance conditions when doing so during an inspection, causing them not to finish inspection, or to need to rush inspection; or causing delays to service. [H1; H3]
Engineering Department **9: Train/employ inspectors.**	**UCA 9.1:** Engineering Department does not train/employ enough inspectors. [H1]	**UCA 9.2:** Engineering Department provides inspectors with unclear, incorrect, or incomplete training. [H1; H2] **UCA 9.6:** Engineering Department trains many more inspectors than the territory requires. [H3]	**UCA 9.3:** Engineering Department trains inspectors too early resulting in loss of knowledge before working in the field. [H1; H2] **UCA 9.4:** Engineering Department (re-) trains inspectors too late, resulting in loss of knowledge in between training. [H1; H2]	**UCA 9.5:** Engineering Department trains inspectors too quickly on practical inspection skills. [H1] **UCA 9.7:** Engineering Department trains inspectors too quickly without enough training on safety. [H2] **UCA 9.8:** Engineering Department spends more time on training than is necessary. [H3]

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Engineering Department **10: Assign territory.**	N/A	**UCA 10.1:** Engineering Department assigns territory to someone with low likelihood of finding issues. [H1]	N/A	N/A
Engineering Department **11: Assign non-routine inspections** *(to track inspectors).*	**UCA 11.1:** Engineering Department does not assign non-routine inspection when there is reason to suspect a defect. [H1]	**UCA 11.2:** Engineering Department assigns a non-routine inspection to an inspector to fill in for someone on territory that the inspector is not trained on/familiar with. [H1] **UCA 11.3:** Engineering Department assigns a non-routine inspection at certain location when another location is in more serious need of inspection. [H1] **UCA 11.4:** Engineering Department assigns inspection at incorrect or unclear location. [H1; H3] **UCA 11.5:** Engineering Department assigns a non-routine inspection by method (on foot/hi-rail) less effective or efficient for the territory. [H1; H3] **UCA 11.6:** Engineering Department assigns special weather inspection when	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		conditions are not safe (e.g., blizzard). [H2] **UCA 11.7:** Engineering Department assigns inspection to verify a safety issue when a safety issue is not present. [H3]		
Engineering Department **12: Coordinate with Dispatch.**	**UCA 12.1:** Engineering Department does not coordinate with Dispatch when needed or at incorrect location to help get track and time or plan outages for inspectors. [H1; H3]	**N/A**	**UCA 12.2:** Engineering Department coordinates with Dispatch too late. [H3]	N/A
Engineering Department **13: Restrict track speed.**	**UCA 13.1:** Engineering Department does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]	**UCA 13.2:** Engineering Department restricts track speed when severe safety issues are present that require track to be removed from service. [H1] **UCA 13.3:** Engineering Department restricts track speed incorrectly (e.g., either too strict or not strict enough or at wrong location). [H1; H3] **UCA 13.5:** Engineering Department restricts track speed when track is not actually a risk to safety. [H3] **UCA 13.6:** Engineering	**UCA 13.4:** Engineering Department waits too long to restrict track speed, allowing trains to operate at track speed over track with a safety issue. [H1; H3] **UCA 13.7:** Engineering Department restricts track speed too early before issue is at/above threshold. [H3]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		Department restricts track speed when track could have been immediately repaired. [H3]		
Engineering Department **14: Remove track from service.**	**UCA 14.1:** Engineering Department does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]	**UCA 14.2:** Engineering Department removes track from service at incorrect location. [H1] **UCA 14.4:** Engineering Department removes track from service when there is no issue present that requires the track to be removed from service. [H3]	**UCA 14.3:** Engineering Department waits too long to remove track from service, allowing trains to operate over track with a safety issue in the meantime. [H1] **UCA 14.5:** Engineering Department removes track from service too early before issue is present that requires track to be removed from service. [H3]	N/A
Dispatcher **15: Grant track and time *(to inspector)*.**	**UCA 15.1:** Dispatcher does not grant track and time when inspection is needed. [H1; H3] **UCA 15.4:** Dispatcher does not provide track and time as soon as possible when inspection is needed. [H3]	**UCA 15.5:** Dispatcher grants track and time when it's not safe to be on the track. [H2] **UCA 15.6:** Dispatcher grants track and time when it would have an excessive impact on scheduling. [H3]	**UCA 15.2:** Dispatcher grants track and time to inspector too late, allowing trains to operate over track when there is a safety issue. [H1] **UCA 15.7:** Dispatcher grants track and time before track inspector is available to inspect. [H3]	**UCA 15.3:** Dispatcher does not grant enough track and time to inspector to complete inspection. [H1]
Upper Management **16: Define territory.**	N/A	**UCA 16.1:** Upper management defines inspection territory that is a non-optimal size (too large or small) and/or complexity for one inspector to cover in	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		the required timeframe. [H1; H3]		
Upper Management **17: Set performance goals** *(incentive to keep trains on schedule).*	N/A	**UCA 17.1:** Upper management sets performance goals that limit track time for inspectors to complete inspection and make repairs. [H1] **UCA 17.2:** Upper management sets performance goals related to particular track conditions which directs attention more on some safety concerns than others. [H1] **UCA 17.3:** Upper management has set too many performance goals so that the number of safety concerns that inspectors must detect exceeds attention limits. [H1]	N/A	N/A
Upper Management **18: Provide resources.**	**UCA 18.1:** Upper management does not provide enough resources when they are needed to efficiently and effectively carry on inspection activities. [H1]	N/A	N/A	

Appendix B.
Scenarios for Visual Inspection Sociotechnical System

These are the scenario factors developed for the Visual Inspection Sociotechnical System described in Section 4.1 of the main report.

ID	UCA Statement	Scenario Factors

1.1	**Track inspector does not inspect track when inspection is needed (to meet frequency regulations and because issues could have arisen). [H1; H3]**	Weather
		
		- Because its's unsafe to inspect (e.g., tornado warning, blizzard)
		- Because it's impractical to inspect (e.g., changing daylight conditions – e.g., sun going down early in winter – not enough light during inspection hours)
		  o Severe weather elsewhere changes the inspectors schedule so he/she goes to inspect where the severe weather happened instead of the track he/she would normally inspect on that day.
		
		Mental Model/Experience
		
		- Inspector does not know that inspection is due.
		  o Record keeping is unclear so inspector doesn't know when inspection is due.
		  o Inspector knows when inspection is due but lost track of the current date.
		- Inspector incorrectly thought track was already inspected.
		  o Not the regular inspector, filling in for an inspector who was sick/on leave, did not check inspection logs to see which track had already been inspected.
		- Inspector knows inspection is due but thinks somewhere else is in more serious need of inspection and does not realize importance of meeting frequency requirements.
		
		Production Pressures
		
		- Dispatcher does not give inspector track time.
		- Dispatcher took away track time halfway through inspection causing track inspector to have to delay inspection on section of track.
		- Unexpected track event (derailment/signal problems/etc.)
		
		Crew Assignment/Scheduling
		
		- Track inspector calls in sick to work; replacement not available OR replacement does not know inspection due at location.
		- Inspector couldn't go out without protection and no one was available at the time needed.
		- Inspector had planned to get it done right before it was due but then was out with illness or emergency. No one else was available that was qualified to inspect that track.
		
		Workload/Distraction
		
		- Inspector got behind on inspections this period and couldn't catch back up.

ID	UCA Statement	Scenario Factors
		o Didn't pace/manage workload effectively - Inspector intended to inspect track but got distracted by other workload/got called away to verify a more pressing issue/had to stop inspection because of weather. Supervisory Practices - Supervisor tells inspector to inspect elsewhere. - Other crew called in suspected issues elsewhere (e.g., called in to say they saw a potential defect elsewhere). - Supervisor asks inspector to check somewhere else instead. o Supervisor incorrectly thinks different inspector or will inspect territory. Lack of Proper Tools/Equipment - Tools needed are not present (e.g., forgot; broke while out and no replacement handy; could not carry). - Hi-rail vehicle is not available when needed.

1.2	**Track inspector does not conduct field verification of issue when instructed to do so and a safety issue is present. [H1]**	Incorrect Mental Model
		
		- Reads location of issue incorrectly, cannot find issue
		- Understands severity but incorrectly thinks issue is not worth verifying based on type of issue
		    o Because of training/experience/production pressures/supervisory practices (inspector believes he/she would not report issue even if verified)
		
		Knowledge/Experience
		
		- Does not know how to verify (training issue)
		
		Lack of Proper Tools
		
		- Tools needed are not present (e.g., forgot; broke while out and no replacement handy; could not carry)
		- Issue not visible without being under load
		
		Weather/Environmental Conditions
		
		- Because it's unsafe (e.g., tornado warning, blizzard)
		- Because it's impractical
		    o Changing daylight conditions (e.g., sun going down early in winter – not enough light)
		
		Production Pressures
		
		- Dispatcher did not give track inspector sufficient track time.
		
		Distraction/Workload
		
		- Inspector got behind on inspections this period and couldn't catch back up.

ID	UCA Statement	Scenario Factors
		o Didn't pace/manage workload effectively o Territory too large - Forgets to because of workload/interrupted by Dispatch/personal reasons (fatigue, etc.) Crew Assignment/Scheduling - Inspector couldn't go out without protection and no one was available at the time needed. - Inspector had planned to get it done right before it was due but then was out with illness or emergency. No one else was available that was qualified to inspect that track.

1.3	**Track inspector inspects track using a method that is not effective or efficient for the territory (foot/hi-rail). [H1; H3]**	Production Pressure
		
		- Dispatcher cannot give ample track time to do walking inspection so inspector inspects via hi-rail even though walking is most effective.
		- Engineering Department needs to move a piece of equipment and as a time saving measure asks inspector to move it while inspecting.
		
		Weather
		
		- Weather conditions cause inspector to need to take hi-rail (rain/snow/thunderstorm) even though walking is most effective.
		- Weather conditions cause inspector to walk (flooding, etc.) even though hi-rail is more efficient.
		
		Physical Environment
		
		- Inspector knows he/she will need to make a repair along the way and therefore needs to bring tools, so has to use hi-rail vehicle even though walking is most effective.
		- Track inspector has an injury/physical impairment that makes walking long distances difficult so needs to use hi-rail even though walking is most effective.
		- Inspector knows that going on foot would be better for finding certain types of defects, but the territory is large and it's not possible to get through it all without using a hi-rail vehicle.
		- Inspector has been tasked with bringing along someone that's learning how to inspect and so had to change the way the inspector would prefer to inspect:
		   o Has to go on foot instead of hi-rail (as preferred) so can show the trainee certain things up close.
		   o Has to take hi-rail instead of going on foot (as preferred) because there isn't enough time to go on foot with a trainee slowing things down
		
		Individual Factors
		
		- Inspector prefers walking inspections to hi-rail so walks the territory even though hi-rail is more efficient.
		
		Technology Problems

ID	UCA Statement	Scenario Factors
		- Hi-rail truck is broken so inspector goes on foot instead even though it's not ideal

1.4	**Track inspector inspects track at the incorrect location. [H1; H3]**	Knowledge/Experience
		
		- Reads location wrong
		   ○ Instructions provide vague or unclear location (e.g., near the station platform around milepost xyz).
		   ○ New or fill-in employee is confused by instructions and goes to wrong location for regular inspection
		
		Distraction/Workload
		
		- Inspector forgets where to go, was distracted by other work when being told about the issue, didn't write it down.
		
		Incorrect Mental Model
		
		- Thinks inspection is needed at incorrect location
		   ○ Did not check inspection logs to see where inspection is due
		   ○ Is a new/different (fill-in) inspector so this is not his normal territory
		   ○ Prior experience leads to an expectation that this is a worsening of an issue the inspector has noticed before at a different location. This expectation shapes what the inspector hears when told or what the inspector remembers when out there.
		
		Incorrect Information
		
		- Inspector given incorrect location to inspect.
		   ○ Incorrect information given by a supervisor/other inspector/etc.
		
		Communication
		
		- Inspector was told the correct location but hears it wrong (e.g., static on the radio; radio crowding).

1.5	**Track inspector inspects track when another section of that inspector's territory is in more serious need of inspection. [H1]**	Production Pressures - Dispatcher does not give inspector track time in section that is in more serious need of inspection. Weather - Bad weather (e.g., flood) makes it impossible to conduct inspection activities in section in more serious need of inspection. Supervisory Practices - Supervisor tells inspector to inspect elsewhere.

ID	UCA Statement	Scenario Factors
		o Other crew called in suspected issues elsewhere (e.g., bridge & building inspectors called in to say they saw a potential defect elsewhere). - Supervisor thinks a different inspector will inspect territory so asks inspector to check somewhere else. Knowledge/Experience - Inspector deliberately chooses to inspect elsewhere. o Because thinks other location is in more serious need (thinks other location is due for inspection, has more potential defects, etc.) Distraction/Scheduling - Inspector intends to inspect both locations but runs out of track time. - Inspector intends to inspect both locations but gets distracted by defects/repairs elsewhere. Tools/Equipment/Technology - Inspector needed a high-rail to inspect the track in serious need and the hi-rail wasn't available.
1.6	**Track inspector inspects track too quickly to detect issues. [H1]**	Production Pressures - Dispatcher can only give inspector certain amount of track time which causes inspector to inspect too quickly. - Dispatcher granted enough time initially but then took the track back. - Dispatcher granted enough time but took too long to do it and inspector was not available during part of the time granted. Knowledge/Experience/Training - Training insufficient. Inspector does not inspect thoroughly or inspector not taught time management, spends too long in certain places leaving not enough time elsewhere. Territory/Physical Characteristics - Territory is too large/complex to cover so inspects quickly in order to complete entire inspection in one day. Workload/Supervisory Practices/Performance Goals - Supervisor tells inspector that inspector needs to do regular inspection plus verify other suspected defect but needs to inspect quickly in order to do both. - Inspector is incentivized to inspect quickly in order to do multiple inspections (performance incentive over safety).

ID	UCA Statement	Scenario Factors

		o Because inspector is trying to avoid overtime, which he/she does not get paid for
		
		Weather
		
		- Shortened the time available to inspect
		  o Impending weather causes inspector to rush inspection in order to not get caught in rain/snow/etc.
		  o Light too low/sun going down (less daylight in winter)
		
		Distraction/Personal
		
		- Inspector has personal issues to attend to and wants to leave work as soon as possible so inspects too quickly.
		- Inspector was out and now behind on inspection, tries to get caught up quickly.

1.7	**Track inspector stops inspection too soon (before necessary inspection is complete according to regulations or before a section with specific concerns has been inspected). [H1]**	Production Pressures - Dispatcher takes away track and time without verifying inspection is complete or making a plan to find additional time to complete inspection. Equipment - Hi-rail vehicle breaks down mid-way through inspection and inspector cannot complete inspection by foot. - Tool needed for inspection breaks. - Inspector wastes time trying to input inspection log data into Toughbook and does not have time to finish inspection. Incorrect Mental Model - Inspector incorrectly thinks inspection is complete. - Inspector incorrectly thinks there is no more track time remaining. Distraction/Workload - Inspector chooses to make a repair which causes him to run out of track time for remaining inspection. Weather - Impending weather causes inspector to stop. inspection mid-way through in order to not get caught in rain/snow/etc. Supervisory Practices - Supervisor asks inspector to stop inspection in order to verify more pressing issue elsewhere. Emergency Interruption

ID	UCA Statement	Scenario Factors

		- Inspector had a personal emergency and needed to leave immediately (e.g., own health or health of a family member).
		
		Remaining Distance
		
		    - Inspector is very close to being done and feels that the inspection is "pretty close" to complete *(especially combined with low expectations for a problem, below).*
		
		Low Expectations for a Problem on Remaining Section of Track
		
		    - Last time the inspector inspected that part of the track, it was in very good condition; and so far the inspector has not been seeing much change in the track. Leads inspector to believe it's going to continue being fine for that last little bit of the track.
		
		Time Pressure
		
		    - Inspector is very close to the deadline and doesn't expect that there's going to be anything wrong on the last stretch of track. Decides it's better to just get it done on time and avoid getting in trouble because the risk of a problem feels low in this case *(especially if combined with above factor of low expectations).*

2.1	**Track inspector does not identify a defect when a defect exists. [H1]**	Training/Experience
		
		    - Track inspector does not have knowledge/experience to detect defect.
		    - Track inspector used tool incorrectly.
		    - Track inspector used incorrect tool.
		
		Equipment
		
		    - Track inspector does not have proper tools to detect defect (e.g., walking inspection and could not carry tools, forgot, broke while out and no replacement, railroad does not supply).
		    - Tool is used correctly but not functioning correctly (e.g., miscalibrated, starting to break).
		    - Defect can only be detected under load.
		
		Weather
		
		    - Weather conditions make it difficult for inspector to identify/measure issue in order to detect that it is a defect (e.g., snow is covering tracks, low light).
		
		Production Pressures
		
		    - Dispatcher did not give track inspector track time or gave too little of it.

ID	UCA Statement	Scenario Factors

		- Time pressure/constraints caused track inspector to rush or not complete inspection.
		   o Spent too long repairing defects, then had to rush through remaining inspection.
		   o Size/complexity of territory.
		   o Inefficient inspection method (walking vs. hi-rail).
		- Time pressures cause inspector to only look for certain defects (that are most visible/obvious).
		
		Inadequate Mental Model
		
		- Incorrect/insufficient/ information previously communicated misleads or shapes expectations (e.g., inspection logs from supervisor/other inspector.
		
		Distraction/ Workload
		
		- Inspector is distracted by personal issues or workload (by own thoughts, by someone calling/interrupting, etc.).
		- Inspector is tired e.g., because has been working lots of overtime.
		
		Incorrect/Insufficient Sensory Cues Caused by Sensor Limitations
		
		- Inspector has sensory limitations that require correction to be at 100% (i.e., glasses, hearing aid).
		- May not be possible to detect defect with human senses.

2.2	**Track inspector identifies a defect as less severe than it is. [H1]**	**Training/Experience** - Track inspector does not have knowledge/experience to detect defect. - Track inspector used tool incorrectly. - Track inspector used incorrect tool. **Equipment** - Track inspector does not have proper tools to detect defect (e.g., walking inspection and could not carry tools, forgot, broke while out and no replacement, railroad does not supply). - Tool is used correctly but not functioning correctly (e.g., miscalibrated, starting to break). - Defect can only be detected under load. **Weather** - Weather conditions make it difficult for inspector to identify/measure issue in order to detect severity (e.g., snow is covering tracks, low light). **Production Pressures** - Inspector does not want to identify defect because will cause track to be removed/restricted and does not want dispatcher/supervisor to get angry; waits to let the next inspector report it.

ID	UCA Statement	Scenario Factors
		Inadequate Mental Model - Incorrect/insufficient/ information previously communicated misleads or shapes expectations (e.g., inspection logs from supervisor/other inspector. **Distraction/Workload** - Inspector is distracted by personal issues or workload (by own thoughts, by someone calling/interrupting, etc.). - Inspector is tired, e.g., because has been working lots of overtime. **Because of Incorrect/Insufficient Sensory Cues Caused by Sensor Limitations** - Inspector has sensory limitations that require correction to be at 100% (i.e., glasses, hearing aid). - May not be possible to detect defect with human senses.

3.1	**Track inspector does not identify a maintenance condition when a maintenance condition exists and should be monitored for progression toward a safety defect. [H1; H3]**	**Training/Experience**
		
		- Track inspector does not have knowledge/experience to detect maintenance condition.
		- Inspector may be so focused on detecting FRA-level defects that they do not look for maintenance conditions.
		- Inadequate training
		    o Inadequate OJT using measurement tools and identifying defects
		        ▪ Tool is functioning correctly, but is used incorrectly.
		    o Inadequate/incorrect knowledge of maintenance thresholds
		
		Equipment
		
		- Track inspector does not have proper tools to detect maintenance condition (e.g., walking inspection and could not carry tools, tools broken, forgot to bring, etc.).
		    o Tool is used correctly, but it's not functioning correctly (e.g., starting to break; miscalibrated).
		- Railroad does not supply adequate tool to measure that condition's threshold.
		- Maintenance condition can only be detected under load.
		
		Production Pressures
		
		- Time pressures cause inspector to only look for FRA level defects (because thinks looking for FRA defects and maintenance conditions will take too long).
		- Time pressures cause inspector to only look for obvious/visible conditions.
		
		Weather
		
		- Weather conditions make it difficult for inspector to identify/measure issue in order to detect that it is a maintenance condition (e.g., snow is covering tracks).

ID	UCA Statement	Scenario Factors
		Because of Incorrect/Insufficient Sensory Cues Caused by Sensor Limitations - Inspector has sensory limitations that require correction to be at 100% (i.e., glasses, hearing aid). - May not be possible to detect maintenance condition threshold with human senses (may be able to be measured but too subtle to the human senses to notice that something needs checked).

4.1	**Track inspector does not repair a defect, when they do not restrict or remove the track from service. [H1]**	Distraction/Workload
		
		- Track inspector intends to repair/restrict/remove but gets distracted by workload/other defect/radio communication.
		- Inspector thought he/she could do the repair, but then discovered he/she could not then inspector forgot.
		   o Didn't have everything needed (i.e., parts, tools, someone to assist)
		   o Didn't have the skill level needed for that problem
		
		Teamwork/Communication/Incorrect Process Model
		
		- Track inspector incorrectly believes someone else will repair/restrict/remove.
		- Believes maintenance gang will come while track still belongs to inspector and repair it, so no trains will operate over
		- Believes supervisor/other track inspector will call Dispatch to restrict/remove
		- Track inspector cannot repair defect (lack of tools/skills/time), but is unable to reach dispatcher by radio/phone communication to remove/restrict track.
		
		Knowledge/Experience
		
		- Track inspector does not realize that the defect requires track to be removed/restricted if not repaired.
		- Inspector thought he/she had repaired it but the repair was not complete/correct.

4.2	**Track inspector repairs defect/maintenance condition when it affects ability to complete inspection or resulting in service delays. [H1; H3]**	Knowledge/Experience - Track inspector knows the repair will affect ability to complete inspection but thinks the repair is more important than completing inspection. - Track inspector does not have the knowledge/experience to know that doing the repair will affect ability to complete inspection. - Repair takes longer than expected, which affects ability to complete inspection. - Track inspector is new/inexperienced. - Repair is more difficult because of unanticipated circumstances/missing tools/weather. Pressures from Supervisor/Dispatcher - Pressure to repair defects since maintenance gang is unavailable/too busy and/or supervisor/dispatcher pressure inspector to not remove/restrict track.

ID	UCA Statement	Scenario Factors
		Other:
		- Inspector thought he/she had enough time to repair and still finish inspection but then circumstances changed.
		o Dispatch needed to take track back.
		o Incoming weather made it unsafe for inspector to be on the track during allotted time.

4.3	**Track inspector repairs a maintenance condition or defect incorrectly. [H1; H3]**	Knowledge/Experience
		
		- Inadequate training for making repairs
		- Little experience making repair
		- Inspector thinks he/she had repaired it but the repair wasn't complete/correct.
		- Repair more difficult than expected
		- Repair is more difficult because of unanticipated circumstances or adjacent defects/weather.
		
		Production Pressures
		
		- Time pressures causes inspector to rush and make a mistake.
		    o Dispatcher pressuring inspector to work quickly because Dispatch needs to take track back so inspector takes shortcuts and repairs incorrectly.
		    o Pressure from supervisor to not leave issues unaddressed, even though inspector was in a hurry.
		
		Tools/Equipment
		
		- Inspector does not have adequate tools/people to make the repair.
		- Whoever last used the hi-rail vehicle used up the materials inspector needed and did not replace.
		- Inspector attempted repair without assistance but it required more than one person.

5.1	**Track inspector does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]**	Distraction/Workload
		
		- Track inspector intends to restrict but gets distracted by workload/other defect/radio communication.
		
		Teamwork/Communication/Incorrect Process Model
		
		- Track inspector incorrectly believes someone else will restrict or remove track from service.
		    o Someone (e.g., track supervisor or another inspector/foreman) was there and then left. Inspector thought they called on their way out.
		    o Inspector called supervisor and thought supervisor was going to take it from there and call Dispatch.
		- Track inspector is unable to reach dispatcher by radio/phone communication to restrict track.
		
		Knowledge/Experience
		
		- Track inspector does not realize that the defect requires track to be restricted if not otherwise addressed.

ID	UCA Statement	Scenario Factors
		- Was not feeling confident in his/her assessment so was stalling on calling it in - Inspector is filling in, waits for the regular inspector. Production Pressures - Track inspector does not want to bother/anger the dispatcher by restricting track, especially if the issue present does not seem severe and/or is borderline.

5.2	**Track inspector restricts track speed when severe issues are present and track should be removed from service. [H1]**	Knowledge/Experience
		
		- Track inspector incorrectly thinks that restricting track is adequate for the issues present (training/experience).
		- Track inspector does not know that severe issues are present.
		    o Misdiagnosed issues as less severe than they really are
		    o Lack of proper tools to measure
		    o Used proper tools, but incorrectly
		
		Production Pressures
		
		- Track inspector correctly diagnosis issues but restricts, rather than removes, track because of pressure from dispatcher and/or supervisor to keep trains moving.
		
		Supervisory Practices
		
		- Supervisor disagrees with inspectors assertion that track needs removed from service and so inspector defers to supervisor's opinion and restricts instead.
		
		Distraction/ Workload
		
		- Inspector called Dispatch intending to remove track from service, but then was momentarily distracted/confused and ended up just asking to restrict track speed.
		
		Communication
		
		- Track inspector correctly stated to remove track from service but dispatcher misunderstood and restricted track speed instead.
		    o Because of radio issues (e.g., static, poor signal)
		    o Because of expectations (e.g., restricting speed is more common)

5.3	**Track inspector restricts track speed incorrectly (e.g., either too strict or not strict enough or wrong location). [H1; H3]**	Knowledge/Experience/Mental Model - Inspector incorrectly thinks defect is more or less severe than it is. - Track inspector does not know correct restriction, lacks accessible reference info. - Track inspector has incorrect knowledge about track class (which determines speed restrictions). o New on territory/not qualified on territory/or hasn't inspected that territory in a long time Production Pressures

ID	UCA Statement	Scenario Factors

		- Makes restriction less restrictive so as not to slow trains/traffic too much due to pressures from dispatcher/supervisor
		
		Communication
		
		- Inspector intended to say the correct track speed/location but misspoke, saying the incorrect degree of restriction (not strict enough) or incorrect location for the restriction.
		- Inspector said the correct (more strict) track speed and at the correct location but Dispatch heard the incorrect restriction information (not strict enough) or heard the incorrect location (e.g., due to static).
		- Inspector does not or cannot call supervisor for guidance.
		    o Doesn't want supervisor to think he/she can't handle it
		    o Bad relationship with supervisor
		    o Can't reach supervisor – supervisor tied up or communications not working properly.
		
		Distraction/Workload
		
		- Inspector is distracted (by own thoughts, by someone calling/interrupting, etc.) and says the wrong information.

5.4	**Track inspector waits too long to restrict track speed, allowing trains to operate over track with a safety issue. [H1]**	Workload/Distraction
		
		- Track inspector busy attending to other work/distracted by phone call etc. and forgets to call dispatcher until too much time has passed and trains have operated over track with safety issue.
		
		Incorrect Mental Model
		
		- Track inspector thinks he/she has the track long enough so can wait to call to restrict, but in fact does not have track long enough or track gets taken back.
		- Inspector believes someone else is dealing with it
		- The inspector thinks the issue will be fixed before track is active again, but realize later that they should still tell Dispatch to restrict it.
		- They've told the engineering department and they think the engineering department will tell Dispatch.
		- They are waiting for a second opinion from their supervisor or another inspector before restricting.
		
		Communication
		
		- Track inspector unable to reach dispatcher in time.
		    o Dispatcher busy with other work/not at desk
		    o Issues with radio/phone
		
		Production Pressures:

ID	UCA Statement	Scenario Factors
		- Inspector isn't comfortable restricting track (because of concern that Dispatch will give inspector a hard time then or in the future) so inspector delays taking action. - Inspector wants to allow a train to pass prior to restricting because Dispatch will be unhappy if that train is delayed (e.g., rush hour).

6.1	**Track inspector does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]**	Distraction/Workload
		
		- Track inspector intends to remove track from service but gets distracted by workload/other defect/radio communication.
		
		Teamwork/Communication/Incorrect Process Model
		
		- Track inspector incorrectly believes someone else will remove track from service.
		   o Believes supervisor/other track inspector will call Dispatch to remove track from service
		- Track inspector is unable to reach dispatcher by radio/phone communication to remove track from service.
		
		Knowledge/Experience
		
		- Track inspector does not realize that the defect requires track to be removed from service.
		   o Thinks the defect is less severe (or doesn't know it is there) and so no action is needed
		   o Thinks someone else will take an alternate action (repair or restrict speed)
		- Inspector wasn't feeling confident in his/her assessment so decided not to remove track from service.
		
		Production Pressures
		
		- Inspector wants to allow a train to pass prior to removing track from service because Dispatch will be unhappy if that train is delayed or rerouted.

6.2	**Track inspector removes track from service too late, allowing trains to operate over track with a safety issue in the meantime. [H1]**	Workload/Distraction - Track inspector busy attending to other work/distracted by phone call, etc., and forgets to call dispatcher until too much time has passed and trains have operated over track with safety issue. Communication/Teamwork - Inspector cannot reach dispatcher in time (dispatcher busy/issues with radio). - Inspector thinks someone else will coordinate with Dispatch, e.g., supervisor or maintenance gang. Incorrect Mental Model - Track inspector thinks he/she has the track long enough/no other trains will operate on the track for a long time so can wait to call to remove track from service. - Inspector is unsure of severity and waiting on a supervisor or second inspector's opinion before removing track from service.

ID	UCA Statement	Scenario Factors

		Communication
		
		    - Track inspector unable to reach dispatcher in time.
		        o Dispatcher busy with other work/not at desk
		        o Issues with radio/phone

7.1	**Track inspector does not log a defect when a defect is present. [H1]**	Technology
		
		    - Track inspector intends to/tries to log a defect but does not.
		        o The technology (e.g., Toughbook) is difficult to use and defect does not get logged.
		        o The technology requires you to hit save (does not automatically save when you close out of a record/report), and the inspector does not.
		
		Distraction/Workload
		
		    - Inspector forgets.
		        o Intends to log a defect but is too busy during the inspection (e.g., because dispatcher could only give a short window of track time) so decides to wait and log at the end of inspection but forgets.
		        o Something or someone interrupts inspector and inspector forgets (e.g., someone calls with an emergency).
		
		Knowledge/Experience
		
		    - Inspector does not know there is a defect to log (see UCA 9.1).
		
		Communication/Teamwork
		
		    - Inspector calls supervisor or maintenance gang to tell them about defect and arrange for a repair but does not log the defect because thinks it will be resolved.

7.2	**Track inspector logs a defect incorrectly–with incorrect or incomplete information that limits ability to investigate or repair. [H1]**	Technology
		
		    - Track inspector intends to/tries to log a defect correctly but the technology (e.g., Toughbook) is difficult to use and defect does not get logged correctly/completely.
		
		Operator error
		
		    - Track inspector logs defect incorrectly by mistake.
		        o Because of a typo/bad handwriting
		        o Because he/she waited to log it (until later in the shift or when the shift was done) and some of the information was misremembered.
		    - Track inspector logs defect incompletely by mistake.
		        o Because he/she forgot to fill in certain information.
		            ▪ Because was in hurry and got distracted
		            ▪ Because doesn't have a protocol for double checking before submitting log
		            ▪ Because inspector has logged this issue before (e.g., may have logged it as a maintenance condition several times before it became a defect) and so is used to filling

ID	UCA Statement	Scenario Factors
		it in and got a little sloppy (especially if trying to move quickly) Knowledge/Experience/Training - Track inspector logs defect correctly but has incorrect/incomplete information, e.g., incorrect GPS location or defect type, because of inexperience/training.

7.3	**Track inspector spends too long logging defects when doing so during an inspection, causing them not to finish inspection, or need to rush inspection; or causing delays to service. [H1; H3]**	Technology
		
		 - Track inspector wastes time trying to log defect correctly because of the technology (e.g., Toughbook).
		      o Technology freezes, have to re-start logging multiple times.
		      o Technology interface difficult to figure out correct way to input.
		 - Lack of technology, e.g., inspector needs to handwrite everything which can be time-consuming.
		
		 Knowledge/Experience
		
		 - Inspector is new/inexperienced and does not know shorthand/tips/tricks for logging quickly.
		      o E.g., maybe experienced inspectors will jot down quick notes during inspection and then when returning to field office complete the inspection log, to ensure adequate time to complete inspection – because this inspector is new, does not know to do this, writes out complete descriptions of defects while on the track.
		      o Inspector includes too much information, more than is needed/useful, which takes longer.
		 - Inspector didn't get sufficient training on the computer system being used.

8.1	**Track inspector does not log a maintenance condition when it is detected and needs monitored for progression towards a safety defect. [H1]**	Supervisory Practices
		
		 - Supervisor prefers/pressures inspector not to log these types of issues.
		      o Because it makes the defect logs too long/cumbersome to read and prioritize.
		      o Because supervisor doesn't want inspector to log more things than can be addressed.
		
		 Inspector Chooses to Ignore Protocol/Training
		
		 - Inspector doesn't think it's important because it's only barely over the threshold of a maintenance condition.
		      o Inspector chooses to not report the geometry condition since it's not safety-critical (not a defect). (Particularly likely if inspector is concerned that supervisor will be unhappy with inspector for reporting more than can be fixed/kept track of.)
		 - Inspector knows it won't be repaired anytime soon anyway.
		 - Inspector knows that once it gets reported, he/she will have to write it up at every inspection for quite a while (before it's finally repaired) so inspector doesn't like to report conditions that seem very mild.

ID	UCA Statement	Scenario Factors
		- Inspector feels that he/she can simply keep an eye on it and monitor it on their own without having to do the work of logging it each time (especially when issue is barely over threshold and logging is time consuming and inspector may have plenty to write up each time anyhow and not want to keep adding more). Knowledge/Experience - Inspector does not realize that it is helpful for the engineering department to know of the maintenance condition so it can be monitored. Workload/Distraction - Inspector intends to log the maintenance condition but because it is low priority waits until end of shift and gets distracted and forgets. Technology - Inspector intends to log the maintenance condition but technology is being difficult and so inspector does not want to waste any more time and thinks since it is only a maintenance condition he/she does not need to waste time trying to input.

8.2	**Track inspector logs a maintenance condition incorrectly–with incorrect or incomplete information that limits ability to investigate or repair. [H1; H3]**	Technology
		
		- Track inspector intends to/tries to log a maintenance condition correctly but the technology (e.g., Toughbook) is difficult to use and defect does not get logged correctly/completely.
		
		Operator Error
		
		- Track inspector logs maintenance condition incorrectly by mistake.
		   o Because of a typo/bad handwriting
		   o Because he/she waited to log it (until later in the shift or when the shift was done) and some of the information was misremembered.
		- Track inspector logs maintenance condition incompletely by mistake.
		   o Because he/she forgot to fill in certain information.
		     ▪ Because was in hurry and got distracted
		     ▪ Because doesn't have a protocol for double checking before submitting log
		     ▪ Because inspector has logged this maintenance condition before several times and is so used to filling it in that he/she got a little sloppy (especially if trying to move quickly).
		   o Track inspector logs maintenance condition incompletely on purpose.
		     ▪ Inspector has logged it in detail many times before and assumes that if someone is ready to fix/look at it, they can pull up the info in the other records (may be especially likely if inspector is in a hurry and inspector thinks its unlikely someone will be ready to address it yet).

ID	UCA Statement	Scenario Factors
		Knowledge/Experience - Track inspector logs maintenance condition correctly but has incorrect/incomplete information, e.g., incorrect GPS location or condition type, because of inexperience/training.

8.3	**Track inspector spends too long logging maintenance conditions when doing so during an inspection, causing them not to finish inspection, or to need to rush inspection; or causing delays to service. [H1; H3]**	Technology
		
		- Track inspector wastes time trying to log maintenance condition correctly because of the technology (e.g., Toughbook).
		    o Technology freezes, have to re-start logging multiple times.
		    o Technology interface difficult to figure out correct way to input.
		- Lack of technology, e.g., inspector needs to handwrite everything, which can be time-consuming.
		    o Technology that is user-friendly can be easy to input condition information (e.g., pre-populated fields, uploading pictures, carryover conditions from previous inspection logs that have not been repaired so do not need to re-enter).
		
		Knowledge/Experience
		
		- Inspector is new/inexperienced and does not know shorthand/tips/tricks for logging quickly.
		    o E.g., maybe experienced inspectors will jot down quick notes during inspection and then when returning to field office complete the inspection log, to ensure adequate time to complete inspection – because this inspector is new, does not know to do this, writes out complete descriptions of defects while on the track.
		    o Inspector includes too much information, more than is needed/useful, which takes longer.
		- Inspector didn't get sufficient training on the computer system being used.

9.1	**Engineering Department does not train/employ enough inspectors. [H1]**	Training Resources
		
		- Lack of applicants
		    o Poor financial incentives to become track inspector.
		    o Poor working conditions for track inspectors (physically demanding, difficult schedule)
		    o Too many constraints on who can bid for track inspector job.
		- Not enough foremen hired to grow the ranks sufficiently.
		- Enough foremen are hired (or as many as possible) but too many foremen leaving (for jobs at other railroads or for other careers) railroad.
		- Not enough foremen are decided to be ready/qualified/able to take on inspection duties.
		- Engineering Department does not have enough resources (money, training instructors) to train enough inspectors.
		
		Collective Bargaining Agreement
		
		- Railroad loses inspectors to other territories shorty after getting them trained on it. Results in constant need for new training.
		
		Applicants Cannot Pass Track Inspector (MOW) Exam

ID	UCA Statement	Scenario Factors
		- Training not up to par/exam too difficult Supervisory Practices - Engineering Department has incorrect beliefs about how many inspectors they need.

9.2	**Engineering Department provides inspectors with unclear, incorrect, or incomplete training. [H1; H2]**	Limitations in Trainer Knowledge/Skill/Abilities
		
		- Trainers are not up-to-date on proper training / inspection methods.
		- Trainers lack experience/not qualified (e.g., have never worked as inspectors themselves).
		
		Training Does Not Include Enough Hands-On Experience to Properly Train Inspectors Regarding OTJ Inspection Methods
		
		- Inadequate resources
		   o Trainers are not significantly more experienced than trainees.
		   o Not enough trainers available because people don't want to do it/lack of incentive to become a trainer.
		   o Not enough time to spend on OJT because it's costly to double up and railroad wants new inspectors to go work their own territories.
		- Railroad relies on informal mentorship.
		   o Incorrect beliefs about how long OJT should be
		   o Railroad thinks current OJT is adequate/informal mentorship is sufficient.
		
		Incomplete Curriculum Does Not Cover Everything Inspector Needs
		- Because some things are expected to be intuitive so they don't make it into training.
		   o E.g., not enough training on software where they log in defect records.
		- Because certain topics, though important, are awkward to cover explicitly because to do so formally admits the existence of problems in the system.
		   o E.g., how to handle it in the event someone tries to pressure the inspector into not logging something/not taking the level of action that's needed (e.g., a two class drop)/not giving you access to the track.
		
		Training Materials Contain Inaccuracies
		
		- Typographical errors
		- Outdated information (e.g., railroad now uses stricter maintenance standards than when materials were developed)
		- Lack of resources to update training materials.

9.3	**Engineering Department trains inspectors too early resulting in loss of knowledge before working in the field. [H1; H2]**	Engineering Department has Incorrect Beliefs - About how many inspectors they will need - Incorrectly believe many inspectors will retire/bid on different jobs. - About how long inspectors can retain knowledge without using it Training - Training offered very infrequently, so inspectors may have to take training early to ensure they can take it before it's needed.

ID	UCA Statement	Scenario Factors
		Scheduling Practices - Inspectors trained and qualified on territory but may not work it regularly; then have forgotten knowledge before being asked to fill in or being assigned to that territory.
9.4	**Engineering Department (re-) trains inspectors too late, resulting in loss of knowledge in between training. [H1; H2]**	Incorrect Beliefs/Priorities - Engineering Department has incorrect beliefs about how long inspectors can retain knowledge without using it. - Engineering Department doesn't see refresher training as very important and believes inspectors don't really need it. It's viewed as mostly a formality. Resources - Engineering Department lacks adequate resources to do requalification training.

9.5	**Engineering Department trains inspectors too quickly on practical inspection skills. [H1]**	Resources
		
		- Engineering Department does not have resources to properly train inspectors.
		- Training is not long enough to adequately train.
		- Training does not include enough hands on experience to properly train inspectors with regard to on the job inspection methods.
		- Because they don't have enough funding to train longer.
		  - o Because the number of people they have to train is so high (given job bidding and frequency of people changing jobs) that they can't afford to do longer training for all those people.
		
		Incorrect Beliefs
		
		- Engineering Department incorrectly believes that training is long enough to adequately train inspectors.
		  - o Because they believe they covered everything.
		  - o Because they believe that that classroom training isn't that important and most of important learning happens OTJ anyhow.

10.1	**Engineering Department assigns territory to someone with low likelihood of finding issues. [H1]**	Lack of Resources
		
		- Do not have enough inspectors who are trained on/familiar with territory.
		- Inspector trained on that territory is not present/available.
		
		Knowledge/Beliefs/Mental Models
		
		- Engineering Department believes that inspector is trained/familiar enough with territory when he/she is not.
		  - o Believes just because inspector received training they are suitable, but training does not produce adequately trained/experienced inspector.
		  - o Receives incorrect feedback from inspector supervisor or trainer that inspector is qualified/completed training (e.g., completed classroom training but are doing OJT with mentor but get sent to do a real inspection).

ID	UCA Statement	Scenario Factors

		o Inspector personnel files do not contain information about which territory they are familiar, or information is unclear.
		- Engineering Department is unaware that this inspector's skill/knowledge of inspection is not up to par (regardless of the territory).
		- Engineering Department feels that this is an emergency and they need someone out there ASAP and this is the inspector that can be there the fastest.
		
		Job Assignment
		
		    - It's out of the hands of the Engineering Department. Someone that's not a strong inspector bid onto a challenging territory.
		    - Scheduling policies preclude more qualified inspectors from working (because of amount of hours they have already worked).

11.1	**Engineering Department does not assign non-routine inspection when there is reason to suspect a defect. [H1]**	Production Pressures
		
		- Engineering Department does not want to take track and time and disrupt train service.
		
		Communication and Mental Models
		
		- Engineering Department does not know non-routine inspection is needed.
		    o Because they did not receive information about suspected track defects from other inspectors, or received the information too late.
		- Engineering Department unable to reach inspector in time.
		    o Phone/radio not working.
		    o Inspector too busy to pick up phone/radio
		- Engineering Department receives incorrect information about track condition.
		    o Other inspectors (e.g., B&B, C&S) did not recognize a track issue that should have merited special inspection.
		- Engineering Department receives correct information about defect but interprets it incorrectly.
		    o Interprets it to believe it does not need to be inspected.
		    o Interprets it to believe it will be inspected by other means (e.g., maintenance department).
		
		Inadequate Resources
		
		 - Lacking inspector availability
		    o Inspector on that territory is already busy or behind for that period.
		    o Territories very large and/or complex
		    o No other inspectors available (short-staffed)
		- Maintenance crews already have too much on their plate and supervisor doesn't want to add to the list and risk having known defects go unaddressed.

ID	UCA Statement	Scenario Factors

		Staffing/Scheduling
		
		- Engineering Department does not have an available inspector to assign non-routine inspection to.
		- Inspector on that territory is already swamped, possibly behind for that period.
		- Not enough available inspectors qualified on the territory.
		- Not enough available inspectors with experience to look for specific defect.
		- No other inspectors available
		    o Understaffed
		    o Too much on inspectors' plates; territories very large and/or complex
		- Maintenance crews already have too much on their plate and supervisor doesn't want to add to the list and risk having known defects go unaddressed.
		
		Workload
		
		- Engineering Department gets busy/distracted by other issue to contact inspector in time
		    o Engineering Department meant to assign the non-routine inspection but then got busy/distracted and forgot
		    o Supervisors are understaffed/oversee too large of a territory

11.2	**Engineering Department assigns a non-routine (substitute) inspection to an inspector to fill in for someone on territory that the inspector is not trained on/familiar with. [H1]**	Engineering Department Does Not Have Adequate Resources
		
		- Do not have enough inspectors who are trained on/familiar with territory.
		- Inspector that IS trained on that territory is not present/available (e.g., because of schedule / hours already worked).
		
		Incorrect Information/Beliefs
		
		- Engineering Department incorrectly believes that inspector is trained/familiar with territory.
		    o Believes just because inspector received training they are suitable.
		    o Receives incorrect feedback from inspector supervisor or trainer that inspector is qualified/completed training (e.g., they completed classroom training but are doing OJT with mentor but get sent to do a real inspection).
		    o Inspector personnel files do not contain information about which territory they are familiar, or information is unclear.
		- Engineering Department feels that this is an emergency and they need someone out there ASAP and this is the inspector that can be there the fastest.

11.3	**Engineering Department assigns a non-routine inspection at certain location when other location is**	Physical Environment - The other location's environmental conditions are not conducive to inspection (e.g., track is flooded). Supervisory Practices

ID	UCA Statement	Scenario Factors

	in more serious need of inspection. [H1]	- Engineering Department prioritizes a potential safety issue over meeting regulations.
		   o The track getting the non-routine inspection is a situation where there is the potential or strong likelihood for something very serious and that was given precedent over being a little late on getting the mandated inspection done.
		- Engineering Department is trying to make good use of maintenance crew time.
		   o The maintenance crew is already working right near the area of the non-routine inspection and could quickly address any issue uncovered.
		   o Engineering Department is trying to make good use of limited crew time so they don't spend all their time traveling around.
		- Engineering Department thinks it's unlikely that an FRA inspector will show up at the other track that's due soon before they can get to it.
		
		Knowledge/Communications
		
		- Engineering Department has lost track of when that inspection is due so just sends inspector out to deal with that non-routine issue without thinking about the fact inspector has a track in serious need.
		- Engineering Department doesn't know/realize that there's another area is greater need of inspection. (E.g., inspector is somewhat new and doesn't feel comfortable telling his/her boss that he/she can't go do the non-routine inspection.)
		
		Missing or Wrong Feedback/Information
		
		- Engineering Department receives incorrect information about conditions at the two locations.
		   o From inspector/supervisor e.g., after special weather event
		- Engineering Department receives correct feedback/information but interprets it incorrectly/ignores it.
		- Engineering Department does not receive feedback/information before assigning inspection (delayed/never received).
		
		Traffic/Production Pressure
		
		- Traffic influences where Engineering Department sends inspection.
		   o Because traffic in the non-routine area is higher so they are concerned that the potential issues there are more likely to get worse quickly and/or would result in greater likelihood of having a derailment.
		   o Because traffic in the area that is in more serious need of inspection (to meet FRA regulations) is so backed up that they don't think they'll be able to get in so targeting the non-routine area rather than waiting around and wasting time where they don't think they can get track and time.

11.4	**Engineering Department assigns**	Missing or Wrong Feedback/Information

ID	UCA Statement	Scenario Factors

	inspection at incorrect or unclear location. [H1; H3]	- Engineering Department receives incorrect information about: track condition at particular location (e.g., that track is degraded) OR receives incorrect location information – e.g., wrong GPS location.
		    o Inspector handwriting is illegible.
		    o Inspector incorrectly enters data into Toughbook because its interface is difficult.
		- Engineering Department receives correct feedback/information but interprets it incorrectly/ignores it.
		- Engineering Department does not receive feedback/information before assigning inspection (delayed/never received).
		- Missing or wrong feedback/information about where inspection is necessary according to FRA regulations.
		
		Communication Errors
		
		- Engineering Department accidently said the wrong thing – meant to say the correct location information but then misspoke.
		- Engineering Department said the location in a way that could have different interpretations.
		    o Because inspector did not repeat back his/her own understanding for confirmation, this miscommunication went undetected.
		
		Skill/Experience
		
		- Engineering Department employee does not have enough experience.
		    o Not enough field-experience to know best way to explain it to inspector.
		    o Not enough supervisory experience to know best way to assign non-routine inspections clearly.

11.5	**Engineering Department assigns a non-routine inspection by method (on foot/hi-rail) less effective or efficient for the territory. [H1; H3]**	Production Pressures - Engineering Department needs to move a piece of equipment and as a time saving measure asks inspector to move it while inspecting. - Dispatcher unable to give adequate time for most effective inspection method (e.g., dispatcher cannot give enough time for a walking inspection but can give enough time for a hi-rail inspection). - It's not possible to do via the preferred method right now and the railroad wants to have a record of having followed up on the non-routine situation (even if the inspection might not be very effective). Knowledge/Experience - Engineering Department does not know effective/efficient methods for each territory. o Engineering Department employees have never worked as track inspectors/have not worked as track inspectors for a long time.

ID	UCA Statement	Scenario Factors
		Weather - Impending weather forces engineering department to assign non-routine inspection a certain method (i.e., impending thunderstorms so need inspection to be quick/covered so assign hi-rail).

12.1	**Engineering Department does not coordinate with Dispatch when needed or at incorrect location to help get track and time or plan outages for inspectors. [H1; H3]**	Teamwork/Communication
		
		- Engineering Department does not know that they need to help coordinate with Dispatch.
		- Inspector does not inform supervisor that they need help obtaining track and time.
		   o Bad relationship with supervisor
		   o Can't reach supervisor by phone.
		   o Inspector doesn't want to look like he/she can't handle it; wants to try to deal with it on his/her own.
		- Engineering Department accidently said the wrong thing – meant to say the correct location information but then misspoke.
		- Engineering Department said the location in a way that could have different interpretations.
		   o Because inspector did not repeat back his/her own understanding for confirmation, this miscommunication went undetected.
		
		Supervisory Practices
		
		- Engineering Department does not think it is their job to help coordinate with Dispatch.
		- Has a bad rapport with dispatcher and does not want to coordinate with them; possibly due to past disagreements on prioritizing schedule vs. inspection.
		- Thinks the inspector should handle coordination with Dispatch (maybe it isn't explicitly part of supervisor's job, or supervisor is not taught to do it).
		
		Workload
		- Engineering Department intends to but gets busy/distracted by other issue to coordinate with Dispatch.
		   o Supervisors are understaffed/oversee too large of a territory.
		   o It's a particularly busy time for supervisor and/or something has happened that impacts traffic flow/Dispatch (e.g., weather slowing down traffic, derailment elsewhere in system that same dispatcher deals with).
		
		Communication
		
		- Engineering Department unable to reach Dispatch.
		   o Phone/radio not working.
		   o Dispatcher too busy to pick up phone/radio.

13.1	**Engineering Department does not restrict track speed when a safety issue is present and not**	Communication/Teamwork - Engineering Department incorrectly believes someone else will, or already did, restrict track (e.g., track inspector).

ID	UCA Statement	Scenario Factors

	otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]	- Engineering Department incorrectly believes maintenance crew was going to fix it immediately; therefore, track does not need to be restricted.
		- Engineering Department thinks no more trains will operate on track before maintenance gang has a chance to repair it, so does not bother calling dispatcher to restrict speed.
		- Engineering Department is unable to reach dispatcher by radio/phone to restrict track.
		- Engineering Department receives information from track inspector about safety issue but does not realize that track needs to be restricted and/or does not realize it is their job to call Dispatch to restrict track in this case.
		    ○ Engineering Department doesn't think it's their job because the inspector usually takes care of this.
		    ○ Inspector did not clarify that they expected the engineering department to restrict track if needed.
		
		Distraction/Workload
		
		- Engineering Department intends to restrict but gets distracted by workload/other communication
		
		Production Pressures
		
		- Engineering Department does not want to bother/anger the dispatcher by restricting track speed if the issue does not seem severe and/or is borderline.

13.2	**Engineering Department restricts track speed when severe safety issues are present that require track to be removed from service. [H1]**	Knowledge/Experience
		
		- Engineering Department does not realize that severe safety issues require track to be removed from service.
		    ○ Incorrect knowledge about the defect's severity
		    ○ Incorrect knowledge about track class at that location
		    ○ Incorrect knowledge about what needs to be done/regulation.
		
		Production Pressures
		
		- Engineering Department supervisor knows track should be removed from service but knows Dispatch and/or supervisor's own manager will get angry if track is removed from service/traffic disrupted so restricts track instead.
		
		Supervisory Practices
		
		- Supervisor disagrees with inspectors assertion that safety issue is a defect that requires track to be removed from service, thinks it is less severe, so restricts instead.
		
		Distraction
		
		- Engineering Department called Dispatch intending to remove track from service, but then was momentarily distracted/confused or too busy and ended up just asking to restrict track speed.

ID	UCA Statement	Scenario Factors

		Communication
		
		- Engineering Department correctly stated to remove track from service but dispatcher misunderstood and restricted track speed instead.
		    o Because of radio issues (e.g., static, poor signal)
		    o Because of expectations (e.g., restricting speed is more common)

13.3	**Engineering Department restricts track speed incorrectly (e.g., either too strict or not strict enough or at wrong location). [H1; H3]**	Knowledge/Experience - Engineering Department does not know correct restriction and lacks readily accessible reference information. - Engineering Department has incorrect knowledge about track class (which determines speed restrictions). - Engineering Department employee is new in the position/has little experience, or has not been trained as an inspector, or hasn't worked as an inspector in a long time. Supervisory Practices - Supervisor disagrees with inspectors assertion of how track should be restricted and overrides inspector (but inspector was correct). Communication/Error - Engineering Department receives incorrect information from inspector – e.g., static on the radio, misspeak, inspector has incorrect information. - Engineering Department receives correct information from inspector but information is incorrect when it is transmitted to dispatcher – e.g., static on the radio, misspeak. - Engineering Department received the correct information from inspector and said the correct (more strict) track speed and at the correct location, but Dispatch heard the incorrect restriction information (not strict enough) or heard the incorrect location. Distraction/Workload - Engineering Department called Dispatch with the correct track restriction information and location in mind, but then was momentarily distracted/confused and ended up saying the wrong information.
13.4	**Engineering Department waits too long to restrict track speed, allowing trains to operate at track speed over track with a safety issue. [H1; H3]**	Communication/Teamwork - Engineering Department cannot reach dispatcher in time because dispatcher is busy or because of issues with radio/phone. Workload/Distraction - Engineering Department busy dealing with other issues, put off calling dispatcher because of more pressing issues. o Engineering Department is understaffed.

ID	UCA Statement	Scenario Factors

		Incorrect Mental Model
		
		- Engineering Department employee does not realize urgent nature of calling the dispatcher, thinks it can wait until other work is complete.
		    o Because engineering department is inexperienced or has no experience working as track inspector to understand implications of defect.
		    o Because engineering department employee was not well trained on this.
		    o Because engineering department employee hasn't worked as an inspector in a long time and knows other priorities as a supervisor are urgent.
		- Engineering Department employee is unsure of the severity of the defect and waiting to restrict track speed until they can get a second opinion.
		    o Because they don't have confidence in the first assessment.
		    o Because no actual measurements were taken so they do not have actual numbers to compare with requirements until someone can verify.
		
		Engineering Department Believes Someone Else Is Dealing with It and Realizes Too Late
		
		- The issue has been assigned to a maintenance crew to fix right away, and so Engineering Department doesn't think it needs to be reported to Dispatch as well; they think it will be fixed before track is active again.
		- They assume inspector will tell Dispatch, so they don't have to.
		    o Inspector and Engineering Department miscommunicate about who is going to call.
		
		Production Pressures
		
		- Engineering Department waits to restrict to let more trains pass through the track quickly (e.g., during rush hour).

14.1	**Engineering Department does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]**	Knowledge/Experience
		
		- Engineering Department does not realize that severe safety issues require track to be removed from service.
		    o Incorrect knowledge about the defect's severity
		    o Incorrect knowledge about track class at that location
		    o Incorrect knowledge about what needs to be done/regulation.
		
		Communication
		
		- Engineering Department thinks someone else will remove track (inspector or maintenance gang).
		- Engineering Department thinks no more trains will operate on track before maintenance gang has a chance to repair it, so does not bother removing track from service.
		- Engineering Department is unable to reach dispatcher by radio/phone to remove track from service.

ID	UCA Statement	Scenario Factors
		Production Pressures - Engineering Department knows track needs to be removed but does not because of production knows Dispatch will get angry if track is removed from service. Supervisory Practices - Supervisor disagrees with inspectors assertion that safety issue is a defect that requires track to be removed – thinks it is less severe. Distraction/Workload - Engineering Department intends to remove track from service, but gets distracted by workload/other issue/radio communication.
14.2	**Engineering Department removes track at incorrect location. [H1]**	Communication/Error - Engineering Department receives incorrect information from inspector – e.g., static on the radio, misspeak, inspector has incorrect information. - Engineering Department receives correct information but information is incorrect when it is transmitted to dispatcher – e.g., static on the radio, misspeak. - Engineering Department receives correct information from inspector but then Dispatch heard the incorrect location for where track should be removed. o Because Dispatch did not repeat it back again, it went unnoticed. Expectations - Engineering Department recalls information about other defects and thinks/expects that is the location where track should be removed. Distraction/Workload - Engineering Department called Dispatch with the correct location information for where to remove track from service in mind, but then was momentarily distracted/confused and ended up saying the wrong information.

14.3	**Engineering Department waits too long to remove track from service, allowing trains to operate over track with a safety issue in the meantime. [H1]**	Knowledge/Experience
		
		- It takes a while for Engineering Department to realize that track needed to be removed from service.
		    o Insufficient knowledge about defect's severity
		    o Insufficient knowledge about track class at that location
		
		Communication/Teamwork
		
		- Engineering Department cannot reach dispatcher in time (dispatcher busy/issues with radio).

ID	UCA Statement	Scenario Factors

		- Engineering Department thinks someone else will remove track from service, e.g., track inspector or maintenance gang.
		
		Workload/Distraction
		
		- Engineering Department busy dealing with other issues, put off calling dispatcher because of more pressing issues.
		   o Engineering Department is understaffed.
		
		Incorrect Mental Model
		
		- Engineering Department employee does not realize urgent nature of calling the dispatcher, thinks it can wait until other work is complete.
		   o Because engineering department is inexperienced or has no experience working as track inspector to understand implications of defect.
		
		Production Pressures
		
		- Engineering Department waits to remove track to let more trains pass through the track quickly/until not so busy.
		   o E.g., it is rush hour, so they wait until rush hour is over to remove track.

15.1	**Dispatcher does not grant track and time when inspection is needed. [H1; H3]**	Production Pressures/Workload
		
		- Dispatcher is tired of inspector going out and finding issues on the track which will potentially cause track restrictions or removals.
		- Dispatchers incorrectly believe on-time performance is more important than inspection/safety.
		   o Because performance goals and/or training prioritize on-time performance over safety (incorrect feedback).
		- Evaluation of dispatcher performance focus more on on-time performance than safety.
		
		Relationship to Inspectors
		
		- Dispatcher hopes inspector will give up on waiting and try another day when someone else is working Dispatch for that track.
		   o Because dispatcher believes inspector is likely to hold up traffic based on past experiences with him/her inspecting slowly and/or judging defects very strictly so that speeds often need to be reduced or track taken out of service more often than with other inspectors.
		   o Because the dispatcher knows that he/she will have a hard time getting track back from that inspector if needed.
		   o Because that dispatcher does not like to work with inspectors at all.
		   o Because the dispatcher believes that it is not that hard for inspectors to just come again another day since they are out inspecting all the time anyhow.

ID	UCA Statement	Scenario Factors

		Supervisory Practices
		
		- Dispatcher is less prone to listen to inspector when they request track time but supervisor did not step in to call Dispatch and request track and time.
		    o The dispatcher may have a poor relationship with this inspector due to past experience (e.g., inspector taking too long, restricting "too much").
		    o The dispatcher may be reluctant to grant track and time to the inspector if they are new to the territory or inexperienced.
		
		Scheduling/Workload/Non-routine Inspections
		
		- Dispatchers are less likely to give track and time to non-routine inspections because they have no bandwidth to figure out alternate routes/scheduling.
		    o If Dispatch center is understaffed it could be easier to refuse track time than to think of alternate ways to move traffic.
		- Dispatcher feels overwhelmed due to other factors (e.g., previous derailment or other issues, weather, etc.).
		
		Dispatcher experience/training
		
		- Dispatcher lacks experience.
		- Not taught strategies in training to accommodate non-routine inspections.
		
		Physical Characteristics of the Track
		
		- Weather conditions were unsafe (e.g., thunder/lightning) for inspector to do walking inspection (territory is walking inspection only) so dispatcher thinks it's better to keep trains moving over the tracks

15.2	**Dispatcher grants track and time to inspector too late, allowing trains to operate over track when there is a safety issue. [H1]**	**Production Pressures**
		
		- Dispatcher is tired of inspector going out and finding issues on the track which will potentially cause track restrictions or removals so waits to grant track and time out after all trains have passed.
		- Dispatchers incorrectly believe on-time performance is more important than inspection/safety.
		    o Because performance goals and/or training prioritize on-time performance over safety.
		
		Supervisory Practices
		
		- Dispatcher waited until supervisor stepped in to grant track and time.
		    o Dispatcher may have a poor relationship with this inspector due to past experience (e.g., inspector taking too long, restricting "too much")
		    o Dispatcher may be reluctant to grant track and time to the inspector if they are new to the territory or inexperienced

ID	UCA Statement	Scenario Factors
		Dispatcher Experience/Training - Dispatcher lacks experience/training to consider best practices for granting track and time. - Does not realize that inspector can use hi-rail for inspection which can go up to 30 mph.

15.3	**Dispatcher does not grant enough track and time to inspector to complete inspection. [H1]**	Production Pressures
		
		- Dispatchers incorrectly believe on-time performance is more important than inspection/safety.
		    - o Because performance goals and/or training prioritize on-time performance over safety.
		- Territory is busy but dispatcher tries to give track when available even if it means smaller timeframes in which inspector cannot complete inspection.
		
		Incorrect Mental Models about Inspection
		
		- Dispatcher assumes that inspector has time/availability to pick up inspection again another time.
		- Dispatcher does not know how long inspection will take (e.g., due to inexperience).
		- Dispatcher does not realize inspection practices will make inspection take longer.
		    - o Inspector stopped to repair something and/or took more time than initially asked for.
		    - o Inspector had to stop to do more measurements than anticipated.
		    - o Inspector did a walking inspection instead of using hi-rail even though time was limited.
		
		Communication
		
		- Dispatcher thought inspector was inspecting via hi-rail (therefore inspection would be quicker) rather than by foot.
		- Inspector did not give an estimate of time needed; or estimated too little.
		- Inspector did not update dispatcher when inspection took longer than planned.

Appendix C.
UCAs for TGMS & Visual Inspection Sociotechnical System

These are the UCAs developed for the TGMS & Visual Inspection Sociotechnical System described in Section 4.2 of the main report.

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
TGMS Sensors **1: Collect data (e.g., take measurements, images etc. of all track, not just defects).**	**UCA 1.1:** TGMS sensors do not collect data while in operation. [H1; H3]	**UCA 1.2** TGMS sensors collect incorrect data. [H1; H3]	N/A	N/A
TGMS Computer **2: Identify defect (class-limiting safety defect).**	**UCA 2.1:** TGMS computer does not identify a defect when a defect exists. [H1]	**UCA 2.2:** TGMS computer identifies a defect where a defect does not actually exist. [H3] **UCA 2.3:** TGMS computer identifies a defect when it is really a maintenance condition. [H3]	N/A	N/A
TGMS Computer **3: Identify maintenance condition (railroad maintenance threshold).**	**UCA 3.1:** TGMS computer does not identify a maintenance condition when a maintenance condition is present and should be monitored for progression toward a safety defect. [H1] **UCA 3.2:** TGMS computer does not identify a maintenance condition when a maintenance condition is present that could be fixed as part of capital	**UCA 3.3:** TGMS computer identifies a maintenance condition where a maintenance condition does not actually exist. [H3] **UCA 3.4:** TGMS computer identifies a maintenance condition as a defect (more severe than it is). [H3]	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
	planning/strategic process. [H3]			
TGMS Operator(s) **4: Set parameters (track class, which determines thresholds, location, e.g., track 1 or 2).**	**UCA 4.1:** TGMS operator does not set track class/ maintenance thresholds prior to inspection run. [H1; H3] **UCA 4.2:** TGMS operator does not change track class when switching onto a different stretch of track that has a different track class. [H1]	**UCA 4.3:** TGMS operator sets track class/ maintenance thresholds incorrectly. [H1; H3]	**UCA 4.4:** TGMS operator sets track class too soon/too late after switching tracks. [H1; H3]	N/A
TGMS Operator(s) **5: Dismiss exceptions (e.g., wide gage at frog).**	**UCA 5.2:** TGMS operator does not dismiss exceptions when they are false alarms. [H3]	**UCA 5.1:** TGMS operator dismisses exceptions when they are NOT false alarms. [H1]	N/A	N/A
TGMS Operator(s) **6: Remove track.**	**UCA 6.1:** TGMS operator does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]	**UCA 6.3:** TGMS operators remove track from service incorrectly, e.g., when there is no issue present or at the wrong location. [H3] **UCA 6.4:** TGMS operator removes track from service when track could have been repaired or restricted. [H3]	**UCA 6.2:** TGMS operator removes track from service too late, allowing trains to operate over track with a safety issue in the meantime. [H1] **UCA 6.5:** TGMS operator removes track from service too early, before issue requires track to be removed from service. [H3]	N/A
TGMS Operator(s) **7: Restrict track speed.**	**UCA 7.1:** TGMS operator does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by	**UCA 7.2:** TGMS operator restricts track speed when severe issues are present and track should be removed from service. [H1] **UCA 7.3:** TGMS operator restricts	**UCA 7.4:** TGMS operator restricts track too late, allowing trains to operate over track with a safety issue in the meantime. [H1]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
	removing it from service). [H1]	track speed incorrectly (not strict enough or too strict). [H1; H3] **UCA 7.5:** TGMS operator restricts track speed when track is not actually a risk to safety (i.e. when there is no issue above maintenance threshold for that track class). [H3] **UCA 7.6:** TGMS operator restricts track speed when track could have been immediately repaired. [H3]		
Track Inspector **8: Inspect track.**	**UCA 8.1:** Track inspector does not inspect track when inspection is needed (to meet frequency regulations and because issues could have arisen). [H1; H3] **UCA 8.2:** Track inspector does not conduct field verification of issue when instructed to do so and a safety issue is present. [H1]	**UCA 8.3:** Track inspector inspects track using a method (i.e., on foot/hi-rail) that is less effective or efficient for the territory. [H1; H3] **UCA 8.4:** Track inspector inspects or verifies track at incorrect location. [H1; H3] **UCA 8.8:** Track inspector inspects track without proper safety measures. [H2]	**UCA 8.5:** Track inspector inspects track when another section of that inspector's territory is in more serious need of inspection. [H1] **UCA 8.9:** Track inspector starts inspecting track before proper safety measures are in place for own protection. [H2] **UCA 8.10:** Track inspector inspects track too soon, before inspection is due. [H3]	**UCA 8.6:** Track inspector inspects track too quickly to detect issues. [H1] **UCA 8.7:** Track inspector stops inspection too soon (before necessary inspection is complete according to regulations or before a section with specific concerns has been inspected). [H1] **UCA 8.11:** Track inspector spends too long inspecting (delays service). [H3]

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Track Inspector **9: Identify defect (class-limiting FRA defect).**	**UCA 9.1:** Track inspector does not identify a defect when a defect exists. [H1]	**UCA 9.2:** Track inspector identifies a defect as less severe than it is. [H1] **UCA 9.3:** Track inspector identifies a defect as more severe than it is; identifies a defect when it is actually a maintenance condition. [H3] **UCA 9.4:** Track inspector identifies a defect where no issue exists. [H3]	**UCA 9.5:** Track inspector identifies defect too soon, before it is actually a defect. [H3] **UCA 9.6:** Track inspector identifies a defect too late, when severe enough that track speed must be restricted or track removed from service. [H3]	N/A
Track Inspector **10: Identify maintenance condition (railroad maintenance threshold).**	**UCA 10.1:** Track inspector does not identify a maintenance condition when a maintenance condition exists and should be monitored for progression toward a safety defect. [H1; H3]	**UCA 10.2:** Track inspector identifies a maintenance condition where a maintenance condition does not exist. [H3] **UCA 10.3:** Track inspector identifies a maintenance condition as more severe than it is. [H3]	**UCA 10.4:** Track inspector identifies a maintenance condition too soon, before it is actually a maintenance condition. [H3] **UCA 10.5:** Track inspector identifies a maintenance condition too late to incorporate into maintenance planning. [H3]	N/A
Track Inspector **11: Repair maintenance condition/ defect.**	**UCA 11.1:** Track inspector does not repair a defect, when they do not restrict or remove the track from service. [H1] **UCA 11.4:** Track inspector does not repair defect when they have the ability (time, tools, skill) to do so, thus requiring track speed to be restricted or the	**UCA 11.2:** Track inspector repairs defect/maintenance condition when it affects ability to complete inspection or resulting in service delays. [H1; H3] **UCA 11.3:** Track inspector repairs a maintenance condition/defect incorrectly. [H1; H3]	**UCA 11.7:** Track inspector repairs a maintenance condition too early, before repair is needed or practical. [H3]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
	track removed from service. [H3]	**UCA 11.5:** Track inspector repairs a maintenance condition/defect without safety measures in place. [H2] **UCA 11.6:** Track inspector repairs a maintenance condition when it would be more efficient to wait until later. [H3]		
Track Inspector **12: Restrict track speed.**	**UCA 12.1:** Track inspector does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]	**UCA 12.2:** Track inspector restricts track speed when severe issues are present and track should be removed from service. [H1] **UCA 12.3:** Track inspector restricts track speed incorrectly (e.g., either too strict or not strict enough or wrong location). [H1; H3] **UCA 12.5:** Track inspector restricts track speed when track is not actually a risk to safety (i.e., when there is no issue above maintenance threshold for that track class). [H3] **UCA 12.6:** Track inspector restricts track speed when track could have been immediately repaired by the inspector. [H3]	**UCA 12.4:** Track inspector waits too long to restrict track speed, allowing trains to operate over track with a safety issue in the meantime. [H1]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Track Inspector **13: Remove track from service.**	**UCA 13.1:** Track inspector does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]	**UCA 13.3:** Track inspector removes track from service incorrectly, e.g., when there is no issue present or at the wrong location. [H3] **UCA 13.4:** Track inspector removes track from service when track could have been repaired or restricted. [H3]	**UCA 13.2:** Track inspector removes track from service too late, allowing trains to operate over track with a safety issue in the meantime. [H1]	N/A
Track Inspector **14: Log defect.**	**UCA 14.1:** Track inspector does not log a defect when a defect is present. [H1; H3]	**UCA 14.2:** Track inspector logs a defect incorrectly– with incorrect or incomplete information that limits ability to investigate or repair. [H1; H3]	N/A	**UCA 14.3:** Track inspector spends too long logging defects when doing so during an inspection, causing them not to finish inspection, or need to rush inspection; or causing delays to service. [H1; H3]
Track Inspector **15: Log maintenance condition.**	**UCA 15.1:** Track inspector does not log a maintenance condition when it is detected and needs monitored for progression towards a safety defect. [H1] **UCA 15.4:** Track inspector does not log a maintenance condition when it is detected and would impact longer-term maintenance planning activities. [H3]	**UCA 15.2:** Track inspector logs a maintenance condition incorrectly, with incorrect or incomplete information that limits the ability to investigate or repair. [H1; H3]	N/A	**UCA 15.3:** Track inspector spends too long logging maintenance conditions when doing so during an inspection, causing them not to finish inspection, or to need to rush inspection; or causing delays to service. [H1; H3]
Engineering Department	**UCA 16.1:** Engineering Department does not assign TGMS inspection when there is reason to	**UCA 16.2:** Engineering Department assigns TGMS inspection at certain location when another	**UCA 16.7:** Engineering Department assigns TGMS inspection too often, when not necessary according	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
16: Assign inspections (to TGMS operators).	suspect territory geometry has degraded. [H1] **UCA 16.4:** Engineering Department does not assign TGMS inspection when necessary, according to FRA regulations. [H3]	location is in more serious need of inspection. [H1] **UCA 16.3:** Engineering Department assigns TGMS inspection at incorrect or unclear location. [H1; H3] **UCA 16.5:** Engineering Department assigns TGMS inspection when conditions are not safe (e.g., blizzard). [H2] **UCA 16.6:** Engineering Department assigns TGMS inspection to verify an issue or verify repair when the issue/repair is not present. [H3]	to FRA regulations, railroad determined maintenance thresholds, or track data. [H3]	
Engineering Department **17: Train /employ inspectors.**	**UCA 17.1:** Engineering Department does not train/employ enough inspectors. [H1] **UCA 17.2:** Engineering Department does not train inspectors with regard to track inspection technology. [H1, H3]	**UCA 17.3:** Engineering Department provides inspectors with unclear, incorrect, or incomplete training. [H1; H2] **UCA 17.7:** Engineering Department trains/employs many more inspectors than the territory requires. [H3]	**UCA 17.4:** Engineering Department trains inspectors too early resulting in loss of knowledge before working in the field. [H1; H2] **UCA 17.5:** Engineering Department (re-) trains inspectors too late, resulting in loss of knowledge in between training. [H1; H2]	**UCA 17.6:** Engineering Department trains inspectors too quickly on practical inspection skills. [H1] **UCA 17.8:** Engineering Department trains inspectors too quickly without enough training on safety. [H2] **UCA 17.9:** Engineering Department spends more time on training than is necessary. [H3]
Engineering Department	N/A	**UCA 18.1:** Engineering Department assigns	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
18: Assign territory.		territory to someone with low likelihood of finding issues. [H1]		
Engineering Department **19: Assign non-routine inspections (to track inspectors).**	**UCA 19.1:** Engineering Department does not assign non-routine inspection when there is reason to suspect a defect. [H1]	**UCA 19.2:** Engineering Department assigns a non-routine inspection to an inspector to fill in for someone on territory that inspector is not trained on/familiar with. [H1] **UCA 19.3:** Engineering Department assigns a non-routine inspection at certain location when other location is in more serious need of inspection. [H1] **UCA 19.4:** Engineering Department assigns non-routine inspection at incorrect or unclear location. [H1; H3] **UCA 19.5:** Engineering Department assigns a non-routine inspection by method (on foot/hi-rail/TGMS) less effective or efficient for the territory. [H1; H3] **UCA 19.6:** Engineering Department assigns special weather inspection when conditions are not safe (e.g., in	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		blizzard). [H2] **UCA 19.7:** Engineering Department assigns non-routine inspection to verify a safety issue when a safety issue is not present. [H3]		
Engineering Department **20: Coordinate with Dispatch.**	**UCA 20.1:** Engineering Department does not coordinate with Dispatch when needed to help get track and time or plan outages for inspectors or TGMS. [H1; H3] **UCA 20.2:** Engineering Department does not coordinate with Dispatch to schedule outages for planned TGMS inspections. [H3]	**UCA 20.3:** Engineering Department coordinates with Dispatch for track and time at incorrect location. [H3]	**UCA 20.4:** Engineering Department coordinates with Dispatch too soon (getting track and time before inspector needs it). [H3] **UCA 20.5:** Engineering Department coordinates with Dispatch too late. [H3]	N/A
Engineering Department **21: Restrict track speed.**	**UCA 21.1:** Engineering Department does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1] **UCA 21.2:** Engineering Department does not restrict track speed when TGMS finds a safety issue that requires speed restriction. [H1]	**UCA 21.3:** Engineering Department restricts track speed when severe safety issues are present that require track to be removed from service. [H1] **UCA 21.4:** Engineering Department restricts track speed incorrectly (e.g., either too strict or not strict enough or at wrong location). [H1; H3] **UCA 21.6:** Engineering Department restricts	**UCA 21.5:** Engineering Department waits too long to restrict track speed, allowing trains to operate at track speed over track with a safety issue. [H1; H3] **UCA 21.8:** Engineering Department restricts track speed too early before issue is at/above maintenance threshold. [H3]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		track speed when track is not actually a risk to safety. [H3] **UCA 21.7:** Engineering Department restricts track speed when track could have been immediately repaired. [H3]		
Engineering Department **22: Remove track from service.**	**UCA 22.1:** Engineering Department does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]	**UCA 22.2:** Engineering Department removes track from service at incorrect location. [H1] **UCA 22.4:** Engineering Department removes track from service when there is no issue present that requires the track to be removed from service. [H3]	**UCA 22.3:** Engineering Department waits too long to remove track from service, allowing trains to operate over track with a safety issue in the meantime. [H1] **UCA 22.5:** Engineering Department removes track from service too early before issue is present that requires track to be removed from service. [H3]	N/A
Dispatcher **23: Grant track and time (to TGMS operator).**	**UCA 23.1:** Dispatcher does not grant track and time when TGMS inspection is needed. [H1] **UCA 23.3:** Dispatcher does not grant track and time as soon as possible when TGMS inspection is needed and TGMS is ready and waiting. [H3]	**UCA 23.2:** Dispatcher grants track and time to TGMS when scheduling causes TGMS to go too slow to collect data. [H1] **UCA 23.4:** Dispatcher grants track and time to TGMS when track conditions are not safe for TGMS to be on the track. [H2]	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		UCA 23.5: Dispatcher grants track and time to TGMS when it would have an excessive impact on scheduling. [H3]		
Dispatcher **24: Grant track and time (to inspector).**	**UCA 24.1:** Dispatcher does not grant track and time to inspector when visual inspection is needed. [H1] **UCA 24.4:** Dispatcher does not grant track and time to inspector as soon as possible when visual inspection is needed. [H3]	**UCA 24.5:** Dispatcher grants track and time to inspector when it's not safe to be on the track. [H2] **UCA 24.6:** Dispatcher grants track and time to inspector when it would have an excessive impact on scheduling. [H3]	**UCA 24.2:** Dispatcher grants track and time to inspector too late, allowing trains to operate over track when there is a safety issue. [H1] **UCA 24.7:** Dispatcher grants track and time to inspector before track inspector is available to inspect. [H3]	**UCA 24.3:** Dispatcher does not grant enough track and time to inspector and safety issue is not found. [H1]
Upper Management **25: Define territory.**	N/A	**UCA 25.1:** Upper management defines inspection territory that is a non-optimal size (too large or small) and/or complexity for one inspector to cover in the required timeframe. [H1; H3]	N/A	N/A
Upper Management **26: Set performance goals (incentive to keep trains on schedule).**	N/A	**UCA 26.1:** Upper management sets performance goals that limit track time for inspectors to complete inspection and make repairs. [H1] **UCA 26.2:** Upper management sets performance goals related to particular track conditions which directs attention more on some safety	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		concerns than others. [H1] **UCA 26.3:** Upper management sets performance goals such that the number of safety concerns that inspectors must detect exceeds attention limits. [H1]		
Upper Management **27: Provide resources.**	**UCA 27.1:** Upper management does not provide adequate resources when they are needed to carry on inspection activities efficiently and effectively. [H1]	N/A	N/A	N/A

Appendix D.
Scenarios for TGMS & Visual Inspection Sociotechnical System

These are the scenario factors developed for the TGMS and Visual Inspection Sociotechnical System described in Section 4.2 of the main report.

ID	UCA Statement	Scenario Factors
1.1	**TGMS sensors do not collect data while in operation. [H1, H3]**	Sensor Failure - Physical component of TGMS sensor broken during operation and stops collecting data. Inadequate Sensor Response - Something interferes with sensor data collection (e.g., environmental conditions like sun, water, snow, etc.)

1.2	**TGMS sensors collect incorrect data. [H1, H3]**	Inadequate Sensor Response
		
		- Something interfering with sensor data collection (e.g., environmental conditions like sun, water, snow etc.) causes sensors to interpret data incorrectly
		- Speed is too low to collect accurate data.
		- TGMS improperly/not calibrated
		   o TGMS was not calibrated properly during maintenance.
		   o TGMS maintenance schedule does not exist or is not adequate to ensure accurate calibration.
		
		TGMS Operator Has Incorrect Mental Model; Does Not Realize Data Is Incorrect
		
		- Operator does not know that there are limitations to operating speed at which TGMS is still effective (lack of training/experience).
		- TGMS operator does not know enough to tell from outputs that TGMS is not calibrated (possibly because of training/experience).

2.1	**TGMS computer does not identify a defect when a defect exists. [H1]**	Supervisory Practices - Engineering Department chooses to use TGMS only to meet minimum frequency regulations only, so TGMS did not have opportunity to detect the defect. Incorrect Sensor Inputs Sent to TGMS Computer - Sensor does not provide computer with ANY measurements (speed too low, sensor component failure, etc.). - Sensor provides incorrect measurements (GPS or calibration issue, inaccuracies due to environmental factors like glare, etc.). Correct Sensor Input Is Not Received by TGMS Computer - Sensor data not received by TGMS computer due to transmission issues (e.g., not set up to properly receive signal, poor signal in tunnels, etc.). TGMS Computer Has Incorrect Process Model

ID	UCA Statement	Scenario Factors
		- TGMS computer programmed with incorrect inputs (maintenance thresholds). - Wrong parameters (track class, location); perhaps railroad provided data that is outdated and did not update or TGMS on different track than intended. - TGMS computer programmed with incorrect algorithm; does not apply maintenance thresholds appropriately and gives wrong output.
3.1	**TGMS computer does not identify a maintenance condition when a maintenance condition is present and should be monitored for progression toward a safety defect. [H1]**	Supervisory Practices - Engineering Department chooses to use TGMS only to meet minimum frequency regulations only, so TGMS did not have opportunity to detect the maintenance condition. Incorrect Sensor Inputs Sent to TGMS Computer - Sensor does not provide computer with ANY measurements (speed too low; sensor component failure; etc.) - Sensor provides incorrect measurements (GPS or calibration issue, inaccuracies due to environmental factors like glare, etc.). Correct Sensor Input Is Not Received by TGMS Computer - Sensor data not received by TGMS computer due to transmission issues (e.g., not set up to properly receive signal, poor signal in tunnels, etc.). TGMS Computer Has Incorrect Process Model - TGMS computer programmed with incorrect inputs (maintenance thresholds) for railroad maintenance standards. - Wrong parameters (track class, location); perhaps railroad provided data that is outdated and did not update or TGMS on different track than intended. - TGMS computer programmed with incorrect algorithm; does not apply maintenance thresholds appropriately and gives wrong output.

4.1	**TGMS operator does not set track class/ maintenance thresholds prior to inspection run. [H1; H3]**	Knowledge/Experience/Training
		
		- TGMS operator does not have enough experience to know that he/she must set or check accuracy of track class maintenance thresholds.
		    o New/inexperienced TGMS operator because regular operator is sick/on vacation/retired.
		- TGMS operator thinks he/she set or verified track class maintenance thresholds but in reality did not.
		    o TGMS interface does not clearly show when maintenance thresholds are set.
		
		Production Pressures
		
		- TGMS operator intends to set track class/maintenance thresholds but forgets.
		    o TGMS operator is running late and dispatcher is pressuring TGMS to go out immediately so as not to delay trains, because of the rush TGMS operator forgets to set track maintenance thresholds.

ID	UCA Statement	Scenario Factors
		o Engineer operating TGMS leaves before operator is ready with that information entered due to insufficient communication. Employee Scheduling - TGMS operator is tired because he/she has been working overtime to conduct TGMS inspections across territories.

4.2	**TGMS operator does not change track class when switching onto a different stretch of track that has a different track class. [H1]**	Knowledge/Experience/Training
		
		- TGMS operator does not have enough experience to know that he/she must change track class/ maintenance thresholds when switching onto a different set of track.
		- TGMS operator does not realize train switched tracks.
		   o Was distracted by other task
		   o Does not know territory well enough to know changeover occurred
		
		Production Pressures
		
		- TGMS operator intends to set track class/maintenance thresholds but forgets.
		   o TGMS operator is running late and dispatcher is pressuring TGMS to go quickly so as not to delay trains, because of the rush TGMS operator forgets to change track maintenance thresholds.
		
		Employee Scheduling
		
		- TGMS operator is tired because he/she has been working overtime to conduct TGMS inspections across territories.
		
		Technology/Interface design
		
		- TGMS operator thinks he/she changed track class maintenance thresholds when switching tracks but in reality did not.
		   o TGMS interface does not clearly show when thresholds are set.
		   o Interface does not show what the maintenance thresholds are set to; operator thinks he/she changed maintenance thresholds but they reverted to old maintenance thresholds.
		- Operator does know how to switch track class correctly, but still made a mistake in doing it that went unnoticed.
		   o Typo (re-entered the same information by mistake)
		
		Workload/Distraction
		
		- Mind wandering, or preoccupied by other tasks (e.g., communicating with dispatcher or supervisors)
		- Doesn't notice TGMS moved onto new track
		- Operator started to switch it but then was interrupted/distracted part way through and didn't finish.

ID	UCA Statement	Scenario Factors

4.3	**TGMS operator sets track class/ maintenance thresholds incorrectly. [H1; H3]**	Knowledge/Experience/Training
		
		- TGMS operator does not have enough experience to know correct track class maintenance thresholds.
		- TGMS operator training did not cover how to set track class maintenance thresholds.
		
		Technology/Interface Design
		
		- Operator does know how to set track class correctly, but still made a mistake in doing it that went unnoticed.
		  - o Typo (re-entered the same information by mistake) – execution error
		- TGMS operator thinks he/she set track class maintenance thresholds correctly but in reality did not.
		  - o TGMS interface does not clearly display which maintenance thresholds are set so operator cannot tell when maintenance thresholds are incorrect.
		
		Workload/Distraction
		
		- Mind wandering, or preoccupied by other tasks (e.g., communicating with dispatcher or supervisors)
		- Operator started to set track class/maintenance thresholds but then was interrupted/distracted part way through and didn't finish.
		- TGMS operator thinks they are inspecting different track and puts track class for that track into computer.
		
		Production Pressures
		
		- TGMS operator is tired, long shifts, etc.
		  - o May be working long shifts to make up for operator shortage.

4.4	**TGMS operator sets track class too soon or too late after switching tracks. [H1; H3]**	Knowledge/Experience/Training - Operator doesn't know how to switch track class in TGMS system; took them a while to figure it out and system was already running. - Operator not clear on the exact place where new parameters should be applied so may enter changes too early or too late. Communication Protocol/ Error - Operator started to switch it but then was interrupted/distracted part way through and was late in getting it done. - Operator wasn't told about a change that would need to be entered (e.g., slight variation in route through terminal). Workload/Distraction - Mind wandering, or preoccupied by other tasks (e.g., communicating with dispatcher or supervisors) - Doesn't notice TGMS moved onto new track - o Because was operator was busy attending to other work (e.g., conferring with another operator about a possible exception).

ID	UCA Statement	Scenario Factors
		Technology - TGMS interface confusing/does not show track class. - Operator thinks they entered it but because they receive no feedback from interface cannot be sure and are unable to tell if they make a mistake while entering.

5.1	**TGMS operator dismisses exceptions when they are NOT false alarms. [H1]**	Knowledge/Experience
		
		- Inadequate training
		   o TGMS operator does not know when exceptions are not false alarms.
		   o Not enough familiarity with territory
		      ▪ Remembering false alarm situation on another track (e.g., frog)
		- Misleading expectations: exception is close to a false alarm.
		   o Operator correctly remembers that there's something at that location that triggers false alarms; but there is also a legitimate exception right next to it. Operator ends up deleting both records because of the correct expectation there is a false alarm in that location.
		- Missing relevant information (e.g., TGMS operator was not made aware of past inspection logs or special weather events that have occurred that would make this exception more likely to NOT be a false alarm).
		
		Expectations
		
		- Operator expects to see a lot of false alarms based on previous experience so he/she may be more likely to attribute exceptions to being FAs.
		
		Operator Error
		
		- Operator made a mistake in using the system.
		   o Dismissed the wrong row/exception record
		      ▪ Hit the wrong key/clicked the wrong place on screen
		   o Was trying to do something else and accidently selected the option to dismiss the exception
		
		Distraction
		
		- TGMS operator got distracted and missed critical information to realize the exception was not a false alarm.
		
		Inadequate Mental Model
		
		- Operator is incorrect about exactly where the train is.
		
		Supervisory Practices/Production Pressures
		
		- TGMS operator dismisses exceptions that are less severe because of pressure to not report issues that cannot be fixed immediately.

ID	UCA Statement	Scenario Factors

6.1	**TGMS operator does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]**	Knowledge/Experience/Training
		
		- TGMS operator does not realize that multiple issues are present that, combined, pose risk to safety and should result in track being removed from service.
		  o TGMS computer does not flag these issues and TGMS operator does not see it because individually, they are fine/do not pose a risk.
		  o TGMS operator thinks this type of issue is the inspector's responsibility.
		- TGMS operator does not realize which track class he/she is on so does not realize that safety issue is an FRA defect and track much be removed from service.
		- TGMS operator does not know regulation well enough to know that track needs to be removed from service.
		
		Communication/Teamwork
		
		- TGMS operator thinks someone else (supervisor/maintenance gang) will remove track from service.
		- TGMS operator incorrectly thinks the defect is being addressed (repaired) by maintenance gang.
		- TGMS operator thinks no more trains will operate on track before maintenance gang has a chance to repair so does not bother calling dispatcher to remove track form service.
		
		Operator Unaware of Issue/TGMS Interface
		
		- Operator does not see/notice the defect onscreen.
		  o Because operator is doing something else while it's on screen (e.g., in bathroom; discussing another issue with coworker).
		  o Because the design of the interface does not clearly highlight defects.
		  o Because there are too many false alarms (things flagged as exceptions that are not truly there) that it gets overlooked.
		Distraction/Workload
		
		- TGMS operator gets distracted by something else (communication with supervisor, another defect on TGMS log screen, etc.) and forgets to call dispatcher to remove track from service.
		
		Production Pressure
		
		- TGMS operator thinks dispatcher will get upset (i.e., not give him track time in the future) if he removes track at the current time so waits to do it later.

6.2	**TGMS operator removes track from service too late, allowing trains to operate over track with a safety issue in the meantime. [H1]**	Knowledge/experience/training - Operator doesn't know/remember the proper protocol to remove track from service; took him/her a while to remember what needed done, and be sure it was appropriate to do that. - Operator is waiting for a second opinion or verification from an inspector to remove track from service.

ID	UCA Statement	Scenario Factors

		Production Pressure
		
		- TGMS operator thinks dispatcher will get upset (i.e., not give him track time in the future) if he removes track from service at the current time so waits to do it later.
		
		Communication/Teamwork
		
		- TGMS operator not able to reach dispatcher quickly (dispatcher pre-occupied/radio or phone busy).
		- TGMS operator waited because they thought someone else would remove track from service (e.g., supervisor onboard TGMS vehicle or inspector sent to verify).
		
		Distraction/Workload
		
		- TGMS operator busy/distracted (doing other work/calling maintenance or supervisor/talking to someone else. onboard TGMS vehicle) to call dispatcher immediately
		- Operator was attending to something else (e.g., bathroom, conversation with a coworker) and did not see the issue come up on the screen.
		
		TGMS Interface
		
		- Operator does not see/notice the defect onscreen.
		  - o Because the design of the interface does not clearly highlight defects.
		  - o Because there are too many false alarms (things flagged as exceptions that are not truly there) that it gets overlooked.
		
		Incorrect Mental Model
		
		- TGMS thinks no other trains are scheduled for the track and therefore thinks he/she can wait to remove track from service since it won't be in use.
		- Know trains are scheduled but think it's OK to let them pass.

7.1	**TGMS operator does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]**	Knowledge/Experience/Training
		
		- TGMS operator does not realize that multiple issues are present that, combined, pose risk to safety.
		  - o TGMS computer does not flag these issues and TGMS operator does not see it because individually, they are fine/do not pose a risk.
		  - o TGMS operator thinks this type of issue is the inspector's responsibility.
		- TGMS operator does not realize which track class he/she is on so does not realize that safety issue is an FRA defect and track much be restricted.
		- TGMS operator does not know regulation well enough to know that track needs to be restricted.
		
		Operator Unaware of Issue/TGMS Interface
		
		- Operator does not see/notice the defect onscreen.

ID	UCA Statement	Scenario Factors
		o Because operator is doing something else while it's on screen (e.g., in bathroom; discussing another issue with coworker). o Because the design of the interface does not clearly highlight defects. o Because there are too many false alarms (things flagged as exceptions that are not truly there) that it gets overlooked. Teamwork/Communication - TGMS operator incorrectly believes that maintenance gang will address/repair issue and therefore track does not need to be restricted. - TGMS operator thinks someone else will call dispatcher to restrict track (supervisor/maintenance gang). - TGMS operator thinks no more trains will operate on track before maintenance gang has a chance to repair so does not bother calling dispatcher to restrict speed. Production Pressure - TGMS operator thinks dispatcher will get upset (i.e., not give him track time in the future) if he restricts track at the current time so waits to do it later.
7.2	**TGMS operator restricts track speed when severe issues are present and track should be removed from service. [H1]**	Knowledge/Experience/Training - TGMS operator does not know that defect requires track to be removed from service (thinks restricting it is enough). - TGMS operator thinks the defect is less severe due to misreading the interface. - TGMS operator thinks defect is less severe due to a problem with the data. Production Pressure - TGMS operator thinks dispatcher will get upset (i.e., not give him track time in the future) if he removes track so he restricts instead. - Supervisor has told TGMS operator not to remove track because he/she knows the issue cannot be repaired soon but also cannot have track out of service for that long, so tells operator to restrict instead. Distraction/Workload - Operator called Dispatch intending to remove track from service but then was momentarily distracted or too busy and ended up just asking to restrict track speed. Communication - Engineering Department correctly stated to remove track from service but dispatcher misunderstood and restricted track speed instead. o Because of radio issues (e.g., static, poor signal) o Because of expectations (e.g., restricting speed is more common)

ID	UCA Statement	Scenario Factors

7.3	**TGMS operator restricts track speed incorrectly (not strict enough or too strict). [H1; H3]**	Knowledge/Experience
		
		- TGMS operator does not know what the proper speed restriction should be given the defect.
		    ○ Defect requires verification but they incorrectly diagnose/measure the defect (e.g., do not have proper tools to measure).
		    ○ Has incorrect knowledge about the track class
		    ○ TGMS operator was newly hired or is unfamiliar with the territory.
		
		Production Pressures
		
		- Operator isn't comfortable restricting track speed that much (because of concern that Dispatch will give operator a hard time then or in the future).
		
		Communication
		
		- Operator intended to say the correct (more strict) track speed but misspoke and said the wrong thing.
		- Operator said the correct (more strict) track speed but Dispatch heard the wrong thing.
		- Does not/cannot call supervisor to ask for guidance on how to restrict
		
		Distraction/Workload
		
		- TGMS Operator intended the correct restriction but when they called Dispatch they were momentarily distracted/confused and ended up asking for the wrong speed.

7.4	**TGMS operator restricts track too late, allowing trains to operate over track with a safety issue. [H1]**	Knowledge/Experience/Training: - They don't know the regulations well enough; takes them a while to be sure what to do and act on it. Production Pressure - TGMS operator thinks dispatcher will get upset (i.e., not give him track time in the future) if he restricts track at the current time so waits to do it later. - Operator is waiting for trains to pass to prevent delays (e.g., during rush hour). Communication/Teamwork - TGMS operator not able to reach dispatcher (dispatcher pre-occupied/radio or phone busy). - TGMS operator waited because they thought someone else would restrict track (e.g., supervisor onboard TGMS vehicle or inspector sent to verify). Distraction - TGMS operator too busy/distracted (doing other work/calling maintenance or supervisor/talking to someone else onboard TGMS vehicle) to call dispatcher immediately.

ID	UCA Statement	Scenario Factors

		- Operator does not see/notice the defect because doing something else while it's on screen (e.g., in bathroom; discussing another issue with coworker).
		
		 TGMS Interface
		
		 - Multiple issues below maintenance threshold but TGMS operator does not realize it until he/she goes through the log later on (since these are not flagged on computer) so calls dispatcher to restrict later on/too late.
		 - Operator does not see/notice the defect onscreen.
		   o Because the design of the interface does not clearly highlight defects.
		   o Because there are too many false alarms (things flagged as exceptions that are not truly there) that it gets overlooked.
		
		 Incorrect Mental Model
		
		 - TGMS thinks no other trains are scheduled for the track and therefore thinks he/she can wait to restrict track since it won't be in use.

8.1	**Track inspector does not inspect track when inspection is needed (to meet frequency regulations and/or because issues could have arisen). [H1, H3]**	Weather
		
		 - Because its's unsafe to inspect (e.g., tornado warning, blizzard).
		 - Because it's impractical to inspect (e.g., changing daylight conditions – e.g., sun going down early in winter – not enough light during inspection hours).
		   o Severe weather elsewhere changes the inspectors schedule so he/she goes to inspect where the severe weather happened instead of the track he/she would normally inspect on that day.
		
		 Mental Model/Experience
		
		 - Inspector does not know that inspection is due.
		   o Record keeping is unclear so inspector doesn't know when inspection is due.
		   o Inspector knows when inspection is due but lost track of the current date.
		 - Inspector incorrectly thought track was already inspected.
		   o Not the regular inspector, filling in for an inspector who was sick/on leave, did not check inspection logs to see which track had already been inspected.
		 - Inspector knows inspection is due but thinks somewhere else is in more serious need of inspection and does not realize importance of meeting frequency requirements.
		
		 Production Pressures
		
		 - Dispatcher does not give inspector track time.
		 - Dispatcher took away track time halfway through inspection causing track inspector to have to delay inspection on section of track.
		 - Unexpected track event (derailment/signal problems/etc.)
		
		 Crew Assignment/Scheduling
		
		 - Track inspector calls in sick to work; replacement not available OR replacement does not know inspection due at location.

ID	UCA Statement	Scenario Factors

		- Inspector couldn't go out without protection and no one was available at the time needed.
		- Inspector had planned to get it done right before it was due but then was out with illness or emergency. No one else was available that was qualified to inspect that track.
		
		Workload/Distraction
		
		- Inspector got behind on inspections this period and couldn't catch back up.
		   o Didn't pace/manage workload effectively
		- Inspector intended to inspect track but got distracted by other workload/got called away to verify a more pressing issue/had to stop inspection because of weather.
		
		Supervisory Practices
		
		- Supervisor tells inspector to inspect elsewhere.
		- Other crew called in suspected issues elsewhere (e.g., bridge & building inspectors called in to say they saw a potential defect elsewhere).
		- Supervisor asks inspector to check somewhere else instead.
		   o Supervisor incorrectly thinks a different inspector or inspection vehicle will inspect territory.
		
		Lack of Proper Tools/Equipment
		
		- Tools needed are not present (e.g., forgot; broke while out and no replacement handy; could not carry).
		- Hi-rail vehicle is not available when needed.

8.2	**Track inspector does not conduct field verification of issue when instructed to do so and a safety issue is present. [H1]**	Incorrect Mental Model - Reads TGMS output incorrectly and misinterprets severity (not trained to read output/output is confusing) - Reads location of issue incorrectly, cannot find issue - Understands severity but incorrectly thinks issue is not worth verifying based on type of issue o Because of training/experience/production pressures/supervisory practices (inspector believes he/she would not report issue even if verified) Knowledge/Experience - Does not know how to verify (training issue) Lack of proper tools - Tools needed are not present (e.g., forgot; broke while out and no replacement handy; could not carry). - Issue not visible without being under load. Weather/Environmental Conditions - Because it's unsafe (e.g., tornado warning, blizzard). - Because it's impractical.

ID	UCA Statement	Scenario Factors

		o Changing daylight conditions (e.g., sun going down early in winter – not enough light)
		
		Production Pressures
		
		- Dispatcher did not give track inspector sufficient track time.
		
		Distraction/Workload
		
		- Inspector got behind on inspections this period and couldn't catch back up.
		  o Didn't pace/manage workload effectively
		  o Territory too large
		- Forgets to because of workload/interrupted by Dispatch/personal reasons (fatigue, etc.)
		
		Crew Assignment/Scheduling
		
		- Inspector couldn't go out without protection and no one was available at the time needed.
		- Inspector had planned to get it done right before it was due but then was out with illness or emergency. No one else was available that was qualified to inspect that track.

8.3	**Track inspector inspects track using a method (i.e., on foot/hi-rail) that is less effective or efficient for the territory. [H1; H3]**	Production Pressure
		
		- Dispatcher cannot give ample track time to do walking inspection so inspector inspects via hi-rail even though walking is most effective.
		- Engineering Department needs to move a piece of equipment and as a time saving measure asks inspector to move it while inspecting.
		
		Weather
		
		- Weather conditions cause inspector to need to take hi-rail (rain/snow/thunderstorm) even though walking is most effective.
		
		Physical Environment
		
		- Inspector knows he/she will need to make a repair along the way and therefore needs to bring tools, so has to use hi-rail vehicle even though walking is most effective.
		- Track inspector has an injury/physical impairment that makes walking long distances difficult so needs to use hi-rail even though walking is most effective.
		- Inspector knows that going on-foot would be better for finding certain types of defects, but the territory is large and it's not possible to get through it all without using a hi-rail vehicle.
		- Inspector has been tasked with bringing along someone that's learning how to inspect and so had to change the way the inspector would prefer to inspect.
		  o Has to go on foot instead of hi-rail (as preferred) so can show the trainee certain things up close.
		  o Has to take hi-rail instead of going on foot (as preferred) because there isn't enough time to go on foot with a trainee slowing things down

ID	UCA Statement	Scenario Factors
		Individual Factors - Inspector prefers walking inspections to hi-rail so walks the territory even though hi-rail is more efficient. Technology Problems - Hi-rail truck is broken so inspector goes on foot instead even though it's not ideal.

8.4	**Track inspector inspects or verifies track at incorrect location. [H1; H3]**	Knowledge/Experience
		
		- Reads location wrong
		  o Confusing data output/not trained how to read output; instructions provide vague or unclear location (e.g., near the station platform around milepost xyz).
		  o New or fill-in employee is confused by instructions and goes to wrong location for regular inspection.
		
		Distraction/Workload
		
		- Inspector forgets where to go, was distracted by other work when being told about the issue, didn't write it down.
		
		Incorrect Mental Model
		
		- Thinks inspection is needed at incorrect location
		  o Did not check inspection logs to see where inspection is due
		  o Is a new/different (fill-in) inspector so this is not his normal territory
		  o Prior experience leads to an expectation that this is a worsening of an issue the inspector has noticed before at a different location. This expectation shapes what the inspector hears when told or what the inspector remembers when out there.
		
		Incorrect Information
		
		- Inspector given incorrect location to inspect.
		  o Because TGMS GPS coordinates were incorrect/TGMS not correctly calibrated.
		  o Incorrect information given by a supervisor/other inspector/etc.
		
		Communication
		
		- Inspector was told the correct location but hears it wrong (e.g., static on the radio; radio crowding).

8.5	**Track inspector inspects track when another section of that inspector's territory is in more serious need of inspection. [H1]**	Production Pressures - Dispatcher does not give inspector track time in section that is in more serious need of inspection. Weather - Bad weather (e.g., flood) makes it impossible to conduct inspection activities in section in more serious need of inspection.

ID	UCA Statement	Scenario Factors

		Supervisory Practices
		
		- Supervisor tells inspector to inspect elsewhere.
		    o Other crew called in suspected issues elsewhere (e.g., bridge & building inspectors called in to say they saw a potential defect elsewhere).
		- Supervisor thinks a different inspector or inspection vehicle will inspect territory so asks inspector to check somewhere else.
		
		Knowledge/Experience
		
		- Inspector deliberately chooses to inspect elsewhere.
		    o Because thinks other location is in more serious need (thinks other location is due for inspection, has more potential defects, etc.).
		
		Distraction/Scheduling
		
		- Inspector intends to inspect both locations but runs out of track time.
		- Inspector intends to inspect both locations but gets distracted by defects/repairs elsewhere.
		
		Tools/Equipment/Technology
		
		- Inspector needed a high-rail to inspect the track in serious need and the hi-rail wasn't available.

8.6	**Track inspector inspects track too quickly to detect issues. [H1]**	Production Pressures - Dispatcher can only give inspector certain amount of track time which causes inspector to inspect too quickly. - Dispatcher granted enough time initially but then took the track back. - Dispatcher granted enough time but took too long to do it and inspector was not available during part of the time granted. Knowledge/Experience/Training - Training insufficient. Inspector does not inspect thoroughly or inspector not taught time management, spends too long in certain places leaving not enough time elsewhere. Territory/Physical Characteristics - Territory is too large/complex to cover so inspects quickly in order to complete entire inspection in one day. Workload/supervisory practices/performance goals - Supervisor tells inspector that inspector needs to do regular inspection plus verify other suspected defect but needs to inspect quickly in order to do both. - Inspector is incentivized to inspect quickly in order to do multiple inspections (performance incentive over safety). o Because inspector is trying to avoid overtime, which he/she does not get paid for.

ID	UCA Statement	Scenario Factors

		Weather
		
		- Shortened the time available to inspect
		  o Impending weather causes inspector to rush inspection in order to not get caught in rain/snow/etc.
		  o Light too low/sun going down (less daylight in winter)
		
		Distraction/Personal
		
		- Inspector has personal issues to attend to and wants to leave work as soon as possible so inspects too quickly.
		- Inspector was out and now behind on inspection, tries to get caught up quickly.
		
		Technology-Related
		
		- Inspection technology recently ran over this track and didn't find any issues related to the issue so inspector is a bit more lax in looking for those issues, may look for those things less closely and/or skip some measurements, assuming that technology already measured it and would have found any issues.

8.7	**Track inspector stops inspection too soon (before necessary inspection is complete according to regulations or before a section with specific concerns has been inspected). [H1]**	Production Pressures - Dispatcher takes away track and time without verifying inspection is complete or making a plan to find additional time to complete inspection. Equipment - Hi-rail vehicle breaks down mid-way through inspection and inspector cannot complete inspection by foot. - Tool needed for inspection breaks. - Inspector wastes time trying to input inspection log data into Toughbook and does not have time to finish inspection. Incorrect Mental Model - Inspector incorrectly thinks inspection is complete. - Inspector incorrectly thinks there is no more track time remaining. Distraction/Workload - Inspector chooses to make a repair which causes him to run out of track time for remaining inspection Weather - Impending weather causes inspector to stop inspection mid-way through in order to not get caught in rain/snow/etc. Supervisory Practices - Supervisor asks inspector to stop inspection in order to verify more pressing issue elsewhere.

ID	UCA Statement	Scenario Factors
		Emergency Interruption - Inspector had a personal emergency and needed to leave immediately (e.g., own health or health of a family member). Remaining Distance - Inspector is very close to being done and feels that the inspection is "pretty close" to complete. *(Especially combined with low expectations for a problem, below.)* Low Expectations for a Problem on Remaining Section of Track - Last time the inspector inspected that part of the track, it was in very good condition; and so far the inspector has not been seeing much change in the track. Leads inspector to believe it's going to continue being fine for that last little bit of the track. - Automated inspection technologies have recently traveled over this track and the inspector knows that the technology didn't find anything of concern. Time Pressure - Inspector is very close to the deadline and doesn't expect that there's going to be anything wrong on the last stretch of track. Decides it's better to just get it done on time and avoid getting in trouble because the risk of a problem feels low in this case. *(Especially if combined with above factor of low expectations.)*
9.1	**Track inspector does not identify a defect when a defect exists. [H1]**	Training/Experience - Track inspector does not have knowledge/experience to detect defect. - Track inspector used tool incorrectly. - Track inspector used incorrect tool. Equipment - Track inspector does not have proper tools to detect defect (e.g., walking inspection and could not carry tools, forgot, broke while out and no replacement, railroad does not supply). - Tool is used correctly but not functioning correctly (e.g., miscalibrated, starting to break). - Defect can only be detected under load. Weather - Weather conditions make it difficult for inspector to identify/measure issue in order to detect that it is a defect (e.g., snow is covering tracks, low light). Production Pressures - Dispatcher did not give track inspector track time or gave too little of it. - Time pressure/constraints caused track inspector to rush or not complete inspection.

ID	UCA Statement	Scenario Factors

		o Spent too long repairing defects then had to rush through remaining inspection
		    o Size/complexity of territory
		    o Inefficient inspection method (walking vs. hi-rail)
		- Time pressures cause inspector to only look for certain defects (that are most visible/obvious).
		
		Inadequate Mental Model
		
		- Incorrect/insufficient/ information previously communicated misleads or shapes expectations (e.g., inspection logs from supervisor/other inspector.
		
		Distraction/ Workload
		
		- Inspector is distracted by personal issues or workload (by own thoughts, by someone calling/interrupting, etc.).
		- Inspector is tired e.g., because has been working lots of overtime
		
		Incorrect/Insufficient Sensory Cues Caused by Sensor Limitations
		
		- Inspector has sensory limitations that require correction to be at 100% (i.e., glasses, hearing aid).
		- May not be possible to detect defect with human senses.

9.2	**Track inspector identifies a defect as less severe than it is. [H1]**	Training/Experience - Track inspector does not have knowledge/experience to detect defect. - Track inspector used tool incorrectly. - Track inspector used incorrect tool . Equipment - Track inspector does not have proper tools to detect defect (e.g., walking inspection and could not carry tools, forgot, broke while out and no replacement, railroad does not supply). - Tool is used correctly but not functioning correctly (e.g., miscalibrated, starting to break). - Defect can only be detected under load. Weather - Weather conditions make it difficult for inspector to identify/measure issue in order to detect severity (e.g., snow is covering tracks, low light). Production Pressures - Inspector does not want to identify defect because will cause track to be removed/restricted and does not want dispatcher/supervisor to get angry; waits to let the next inspector or TGMS report it. Inadequate Mental Model - Incorrect/insufficient/ information previously communicated misleads or shapes expectations (e.g., inspection logs from supervisor/other inspector.

ID	UCA Statement	Scenario Factors
		Distraction/Workload
		- Inspector is distracted by personal issues or workload (by own thoughts, by someone calling/interrupting, etc.).
		- Inspector is tired, e.g., because has been working lots of overtime.
		Because of Incorrect/Insufficient Sensory Cues Caused by Sensor Limitations
		- Inspector has sensory limitations that require correction to be at 100% (i.e., glasses, hearing aid).
		- May not be possible to detect defect with human senses.
10.1	Track inspector does not identify a maintenance condition when a maintenance condition exists and should be monitored for progression towards a safety defect. [H1; H3]	Training/Experience
		- Track inspector does not have knowledge/experience to detect maintenance condition.
		- Inspector may be so focused on detecting FRA level defects that they do not look for maintenance conditions.
		- Inadequate training
		o Inadequate OJT using measurement tools and identifying defects.
		▪ Tool is functioning correctly, but is used incorrectly.
		o Inadequate/incorrect knowledge of maintenance thresholds
		Equipment
		- Track inspector does not have proper tools to detect maintenance condition (e.g., walking inspection and could not carry tools, tools broken, forgot to bring, etc.).
		o Tool is used correctly, but it's not functioning correctly (e.g., starting to break; miscalibrated).
		- Railroad does not supply adequate tool to measure that condition's maintenance threshold.
		- Maintenance condition can only be detected under load.
		Production Pressures
		- Time pressures cause inspector to only look for FRA level defects (because thinks looking for FRA defects and maintenance conditions will take too long).
		- Time pressures cause inspector to only look for obvious/visible conditions.
		Weather
		- Weather conditions make it difficult for inspector to identify/measure issue in order to detect that it is a maintenance condition (e.g., snow is covering tracks).
		Because of Incorrect/Insufficient Sensory Cues Caused by Sensor Limitations
		- Inspector has sensory limitations that require correction to be at 100% (i.e., glasses, hearing aid).
		- May not be possible to detect maintenance condition threshold with human senses (may be able to be measured but too subtle to the human senses to notice that something needs checked).

ID	UCA Statement	Scenario Factors

11.1	**Track inspector does not repair a defect, when they do not restrict or remove the track from service. [H1]**	Distraction/Workload
		
		- Track inspector intends to repair/restrict/remove but gets distracted by workload/other defect/radio communication.
		- Inspector thought he/she could do the repair, but then discovered he/she could not then inspector forgot.
		   o Didn't have everything needed (i.e., parts, tools, someone to assist)
		   o Didn't have the skill level needed for that problem
		
		Teamwork/Communication/Incorrect Process Model
		
		- Track inspector incorrectly believes someone else will repair/restrict/remove.
		- Believes maintenance gang will come while track still belongs to inspector and repair it, so no trains will operate over.
		- Believes supervisor/other track inspector will call Dispatch to restrict/remove.
		- Track inspector cannot repair defect (lack of tools/skills/time) but is unable to reach dispatcher by radio/phone communication to remove/restrict track.
		
		Knowledge/Experience
		
		- Track inspector does not realize that the defect requires track to be removed/restricted if not repaired
		- Inspector thought he/she had repaired it but the repair was not complete/correct

11.2	**Track inspector repairs defect/maintenance condition when it affects ability to complete inspection or resulting in service delays. [H1; H3]**	Knowledge/Experience
		
		- Track inspector knows the repair will affect ability to complete inspection but thinks the repair is more important than completing inspection.
		- Track inspector does not have the knowledge/experience to know that doing the repair will affect ability to complete inspection.
		- Repair takes longer than expected, which affects ability to complete inspection.
		- Track inspector is new/inexperienced.
		- Repair is more difficult because of unanticipated circumstances/missing tools/weather.
		
		Pressures from Supervisor/Dispatcher
		
		- Pressure to repair defects since maintenance gang is unavailable/too busy and/or supervisor/dispatcher pressure inspector to not remove/restrict track.
		
		Other
		
		- Inspector thought he/she had enough time to repair and still finish inspection but then circumstances changed.
		   o Dispatch needed to take track back.
		   o Incoming weather made it unsafe for inspector to be on the track during allotted time

ID	UCA Statement	Scenario Factors

11.3	**Track inspector repairs a maintenance condition or defect incorrectly. [H1; H3]**	Knowledge/Experience
		
		- Inadequate training for making repairs
		- Little experience making repair
		- Inspector thinks he/she had repaired it but the repair wasn't complete/correct.
		- Repair more difficult than expected
		- Repair is more difficult because of unanticipated circumstances or adjacent defects/weather.
		
		Production Pressures
		
		- Time pressures cause inspector to rush and make a mistake.
		  - Dispatcher pressuring inspector to work quickly because Dispatch needs to take track back so inspector takes shortcuts and repairs incorrectly.
		  - Pressure from supervisor to not leave issues unaddressed, even though inspector was in a hurry.
		
		Tools/Equipment
		
		- Inspector does not have adequate tools/people to make the repair.
		- Whoever last used the hi-rail vehicle used up the materials inspector needed and did not replace.
		- Inspector attempted repair without assistance but it required more than one person.

12.1	**Track inspector does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]**	Distraction/Workload
		
		- Track inspector intends to restrict but gets distracted by workload/other defect/radio communication.
		
		Teamwork/Communication/Incorrect Process Model
		
		- Track inspector incorrectly believes someone else will restrict or remove track from service.
		  - Someone (e.g., track supervisor or another inspector/foreman) was there and then left.
		  - Inspector thought they called on their way out.
		  - Inspector called supervisor and thought supervisor was going to take it from there and call Dispatch.
		- Track inspector is unable to reach dispatcher by radio/phone communication to restrict track.
		
		Knowledge/Experience
		
		- Track inspector does not realize that the defect requires track to be restricted if not otherwise addressed.
		- Was not feeling confident in his/her assessment so was stalling on calling it in.
		- Inspector is filling in, waits for the regular inspector.
		
		Production Pressures
		
		- Track inspector does not want to bother/anger the dispatcher by restricting track, especially if the issue present does not seem severe and/or is borderline.

ID	UCA Statement	Scenario Factors

12.2	**Track inspector restricts track speed when severe issues are present and track should be removed from service. [H1]**	Knowledge/Experience
		
		- Track inspector incorrectly thinks that restricting track is adequate for the issues present (training/experience).
		- Track inspector does not know that severe issues are present.
		    o Misdiagnosed issues as less severe than they really are.
		    o Lack of proper tools to measure.
		    o Used proper tools, but incorrectly
		
		Production Pressures
		
		- Track inspector correctly diagnosis issues but restricts, rather than removes, track because of pressure from dispatcher and/or supervisor to keep trains moving.
		
		Supervisory Practices
		
		- Supervisor disagrees with inspectors assertion that track needs removed from service and so inspector defers to supervisor's opinion and restricts instead.
		
		Distraction/ Workload
		
		- Inspector called Dispatch intending to remove track from service, but then was momentarily distracted/confused and ended up just asking to restrict track speed.
		
		Communication
		
		- Track inspector correctly stated to remove track from service but dispatcher misunderstood and restricted track speed instead.
		    o Because of radio issues (e.g., static, poor signal)
		    o Because of expectations (e.g., restricting speed is more common)

12.3	**Track inspector restricts track speed incorrectly (e.g., either too strict or not strict enough, or wrong location). [H1; H3]**	Knowledge/Experience/Mental Model - Inspector incorrectly thinks defect is more or less severe than it is. - Track inspector does not know correct restriction, lacks accessible reference info. - Track inspector has incorrect knowledge about track class (which determines speed restrictions). o New on territory/not qualified on territory/or hasn't inspected that territory in a long time Production Pressures - Makes restriction less restrictive so as not to slow trains/traffic too much due to pressures from dispatcher/supervisor Communication - Inspector intended to say the correct track speed/location but misspoke, saying the incorrect degree of restriction (not strict enough) or incorrect location for the restriction.

ID	UCA Statement	Scenario Factors

		- Inspector said the correct (more strict) track speed and at the correct location but Dispatch heard the incorrect restriction information (not strict enough) or heard the incorrect location (e.g., due to static).
		- Inspector does not or cannot call supervisor for guidance.
		    o Doesn't want supervisor to think he/she can't handle it
		    o Bad relationship with supervisor
		    o Can't reach supervisor – supervisor tied up or communications not working properly.
		
		Distraction/ Workload
		
		- Inspector is distracted (by own thoughts, by someone calling/interrupting, etc.) and says the wrong information.

12.4	**Track inspector waits too long to restrict track speed, allowing trains to operate over track with a safety issue. [H1]**	Workload/Distraction
		
		- Track inspector busy attending to other work/distracted by phone call etc. and forgets to call dispatcher until too much time has passed and trains have operated over track with safety issue.
		
		Incorrect Mental Model
		
		- Track inspector thinks he/she has the track long enough so can wait to call to restrict, but in fact does not have track long enough or track gets taken back.
		- Inspector believes someone else is dealing with it.
		- The inspector thinks the issue will be fixed before track is active again, but realize later that they should still tell Dispatch to restrict it.
		- They've told the engineering department and they think the engineering department will tell Dispatch.
		- They are waiting for a second opinion from their supervisor or another inspector before restricting.
		
		Communication
		
		- Track inspector unable to reach dispatcher in time.
		    o Dispatcher busy with other work/not at desk
		    o Issues with radio/phone
		
		Production Pressures
		
		- Inspector isn't comfortable restricting track (because of concern that Dispatch will give inspector a hard time then or in the future) so inspector delays taking action.
		- Inspector wants to allow a train to pass prior to restricting because Dispatch will be unhappy if that train is delayed (e.g., rush hour).

13.1	**Track inspector does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through**	Distraction/Workload - Track inspector intends to remove track from service but gets distracted by workload/other defect/radio communication. Teamwork/Communication/Incorrect Process Model - Track inspector incorrectly believes someone else will remove track from service.

ID	UCA Statement	Scenario Factors

	restricting track speed). [H1]	o Believes supervisor/other track inspector will call Dispatch to remove track from service
		- Track inspector is unable to reach dispatcher by radio/phone communication to remove track from service.
		
		Knowledge/Experience
		
		- Track inspector does not realize that the defect requires track to be removed from service.
		      o Thinks the defect is less severe (or doesn't know it is there) and so no action is needed
		      o Thinks someone else will take an alternate action (repair or restrict speed)
		- Inspector wasn't feeling confident in his/her assessment so decided not to remove track from service (especially if TGMS had recently run over the track and not found the issue).
		
		Production Pressures
		
		- Inspector wants to allow a train to pass prior to removing track from service because Dispatch will be unhappy if that train is delayed or rerouted.

13.2	**Track inspector removes track from service too late, allowing trains to operate over track with a safety issue in the meantime. [H1]**	Workload/Distraction
		
		- Track inspector busy attending to other work/distracted by phone call etc. and forgets to call dispatcher until too much time has passed and trains have operated over track with safety issue.
		
		Communication/Teamwork
		
		- Inspector cannot reach dispatcher in time (dispatcher busy/issues with radio).
		- Inspector thinks someone else will coordinate with Dispatch, e.g., supervisor or maintenance gang.
		
		Incorrect Mental Model
		
		- Track inspector thinks he/she has the track long enough/no other trains will operate on the track for a long time so can wait to call to remove track from service.
		- Inspector is unsure of severity and waiting on a supervisor or second inspector's opinion before removing track from service.
		
		Communication
		
		- Track inspector unable to reach dispatcher in time
		      o Dispatcher busy with other work/not at desk
		      o Issues with radio/phone

14.1	**Track inspector does not log a defect when a defect is present. [H1; H3]**	Technology - Track inspector intends to/tries to log a defect but does not. o The technology (e.g., Toughbook) is difficult to use and defect does not get logged.

ID	UCA Statement	Scenario Factors

		o The technology requires you to hit save (does not automatically save when you close out of a record/report) and the inspector does not.
		- Inspector doubts own assessment of the geometry issue because TGMS just ran over the same track and didn't find the issue.
		
		Distraction/Workload
		
		- Inspector forgets.
		  o Intends to log a defect but is too busy during the inspection (e.g., because dispatcher could only give a short window of track time) so decides to wait and log at the end of inspection but forgets
		  o Something or someone interrupts inspector and inspector forgets (e.g., someone calls with an emergency).
		
		Knowledge/Experience
		
		- Inspector does not know there is a defect to log (see UCA 9.1).
		
		Communication/Teamwork
		
		- Inspector calls supervisor or maintenance gang to tell them about defect and arrange for a repair but does not log the defect because thinks it will be resolved.

14.2	**Track inspector logs a defect incorrectly–with incorrect or incomplete information that limits ability to investigate or repair. [H1; H3]**	Technology
		
		- Track inspector intends to/tries to log a defect correctly but the technology (e.g., Toughbook) is difficult to use and defect does not get logged correctly/completely.
		
		Operator error
		
		- Track inspector logs defect incorrectly by mistake.
		  o Because of a typo/bad handwriting
		  o Because he/she waited to log it (until later in the shift or when the shift was done) and some of the information was misremembered.
		- Track inspector logs defect incompletely by mistake.
		  o Because he/she forgot to fill in certain information.
		    ▪ Because was in hurry and got distracted
		    ▪ Because doesn't have a protocol for double checking before submitting log
		    ▪ Because inspector has logged this issue before (e.g., may have logged it as a maintenance condition several times before it became a defect) and so is used to filling it in and got a little sloppy (especially if trying to move quickly).
		
		Knowledge/Experience/Training
		
		- Track inspector logs defect correctly but has incorrect/incomplete information, e.g., incorrect GPS location or defect type, because of inexperience/training.

ID	UCA Statement	Scenario Factors

14.3	**Track inspector spends too long logging defect when doing so during an inspection, causing them not to finish, or need to rush inspection; or causing delays to service. [H1; H3]**	Technology
		
		- Track inspector wastes time trying to log defect correctly because of the technology (e.g., Toughbook).
		    o Technology freezes, have to re-start logging multiple times.
		    o Technology interface difficult to figure out correct way to input.
		- Lack of technology, e.g., inspector needs to handwrite everything which can be time consuming.
		
		Knowledge/Experience
		
		- Inspector is new/inexperienced and does not know shorthand/tips/tricks for logging quickly.
		    o E.g., maybe experienced inspectors will jot down quick notes during inspection and then when returning to field office complete the inspection log, to ensure adequate time to complete inspection – because this inspector is new, does not know to do this, writes out complete descriptions of defects while on the track.
		    o Inspector includes too much information, more than is needed/useful, which takes longer.
		- Inspector didn't get sufficient training on the computer system being used.

15.1	**Track inspector does not log a maintenance condition when it is detected and needs monitored for progression towards a safety defect. [H1]**	Supervisory Practices
		
		- Supervisor prefers/pressures inspector not to log these types of issues
		    o Because it makes the defect logs too long/cumbersome to read and prioritize
		    o Because supervisor doesn't want inspector to log more things than can be addressed
		
		Inspector Chooses to Ignore Protocol/Training:
		
		- Inspector doesn't think it's important because it's only barely over the threshold of a maintenance condition.
		    o Inspector chooses to not report the geometry condition since it's not safety-critical (not a defect) and TGMS will be coming through soon. Will let TGMS report it. (Particularly likely if inspector is concerned that supervisor will be unhappy with inspector for reporting more than can be fixed/kept track of.)
		- Inspector knows it won't be repaired anytime soon anyway.
		- Inspector knows that once it gets reported, he/she will have to write it up at every inspection for quite a while (before it's finally repaired) so inspector doesn't like to report conditions that seem very mild.
		- Inspector feels that he/she can simply keep an eye on it and monitor it on their own without having to do the work of logging it each time (especially when issue is barely over maintenance threshold and logging is time consuming and inspector may have plenty to write up each time anyhow and not want to keep adding more).
		
		Knowledge/Experience
		
		- Inspector does not realize that it is helpful for the engineering department to know of the maintenance condition so it can be monitored.

ID	UCA Statement	Scenario Factors
		Workload/Distraction - Inspector intends to log the maintenance condition but because it is low priority waits until end of shift and gets distracted and forgets. Technology - Inspector intends to log the maintenance condition but technology is being difficult and so inspector does not want to waste any more time and thinks since it is only a maintenance condition he/she does not need to waste time trying to input. - Inspector intends to log it but the technology requires you to hit save (does not automatically save when you close out of a record/report) and so the inspector does not actually log it. - Overreliance on technology o Inspector chooses not to log it because he/she doubts own assessment of the geometry issue because TGMS just ran over the same track and did not find anything there.

15.2	Track inspector logs a maintenance condition incorrectly, with incorrect or incomplete information that limits ability to investigate or repair. [H1; H3]	Technology
		
		- Track inspector intends to/tries to log a maintenance condition correctly but the technology (e.g., Toughbook) is difficult to use and defect does not get logged correctly/completely
		
		Operator Error
		
		- Track inspector logs maintenance condition incorrectly by mistake.
		  o Because of a typo/bad handwriting
		  o Because he/she waited to log it (until later in the shift or when the shift was done) and some of the information was misremembered.
		- Track inspector logs maintenance condition incompletely by mistake.
		  o Because he/she forgot to fill in certain information.
		    ▪ Because was in hurry and got distracted
		    ▪ Because doesn't have a protocol for double checking before submitting log
		    ▪ Because inspector has logged this maintenance condition before several times and is so used to filling it in that he/she got a little sloppy (especially if trying to move quickly).
		  o Track inspector logs maintenance condition incompletely on purpose.
		    ▪ Inspector has logged it in detail many times before and assumes that if someone is ready to fix/look at it, they can pull up the info in the other records. (May be especially likely if inspector is in a hurry and inspector thinks its unlikely someone will be ready to address it yet.)
		
		Knowledge/Experience
		
		- Track inspector logs maintenance condition correctly but has incorrect/incomplete information, e.g., incorrect GPS location or condition type, because of inexperience/training.

ID	UCA Statement	Scenario Factors

15.3	**Track inspector spends too long logging maintenance conditions when doing so during an inspection, causing them not to finish inspection, or to need to rush inspection; or causing delays to service. [H1; H3]**	Technology
		
		- Track inspector wastes time trying to log maintenance condition correctly because of the technology (e.g., Toughbook).
		   o Technology freezes, have to re-start logging multiple times.
		   o Technology interface difficult to figure out correct way to input.
		- Lack of technology, e.g., inspector needs to handwrite everything which can be time consuming
		   o Technology that is user-friendly can be easy to input condition information (e.g., pre-populated fields, uploading pictures, carryover conditions from previous inspection logs that have not been repaired so do not need to re-enter).
		
		Knowledge/Experience
		
		- Inspector is new/inexperienced and does not know shorthand/tips/tricks for logging quickly.
		   o E.g., maybe experienced inspectors will jot down quick notes during inspection and then when returning to field office complete the inspection log, to ensure adequate time to complete inspection – because this inspector is new, does not know to do this, writes out complete descriptions of defects while on the track.
		   o Inspector includes too much information, more than is needed/useful, which takes longer.
		- Inspector didn't get sufficient training on the computer system being used.

16.1	**Engineering Department does not assign TGMS inspection when there is reason to suspect territory geometry has degraded. [H1]**	Production Pressures
		
		- TGMS will slow regular service; engineering department doesn't try to assign TGMS inspection because they expect that dispatcher won't give track and time.
		
		Missing or Wrong Feedback/Information
		
		- Engineering Department does not receive information/feedback about suspected track geometry defects.
		- Inspector assigned to that territory is not experienced/skilled enough to detect full number/degree of problems so does not accurately convey full extent of degraded track condition.
		- Do not get information/feedback when it is needed (i.e., before decisions about where to send TGMS are made).
		- Engineering Department receives incorrect information about track condition.
		- Inspector felt pressure to not report more issues than there were resources to address.
		- Time pressure limited how much information the inspector could put into the report and still get inspection completed.
		- Because of limitations with method of documentation
		   o Inspector handwriting is illegible.
		   o Inspector incorrectly entered data into Toughbook because Toughbook interface is difficult.

ID	UCA Statement	Scenario Factors
		o Inspector does not enter information into Toughbook because of usability issues with Toughbook (Toughbook crashes, takes too long to enter/re-enter information). - TGMS dataset is difficult to interpret; analyst makes mistake determining whether territory is likely to need another TGMS inspection. - Engineering Department receives correct information about track condition but interprets it incorrectly. - Engineering Department received correct information but ignores it. - Engineering Department is not concerned with degraded track conditions unless they are a defect or exceed the railroad 's maintenance standards. Resources - Limited resources require TGMS be sent to another area with a more immediate need (i.e., where a known condition is worse or where an FRA mandated TGMS condition is due). - Mechanical/physical failure of TGMS Weather - Weather conditions make it impossible to send TGMS.

16.2	**Engineering Department assigns TGMS inspection at certain location when another location is in more serious need of inspection. [H1]**	Missing or Wrong Feedback/Information
		
		- Inspector felt pressure to not report more issues than there were resources to address.
		- Time pressure limited how much information the inspector could put into the report and still get inspection completed.
		- Because of limitations with method of documentation
		  o Inspector handwriting is illegible.
		  o Inspector incorrectly entered data into Toughbook because Toughbook interface is difficult.
		  o Inspector does not enter information into Toughbook because of usability issues with Toughbook (Toughbook crashes, takes too long to enter/re-enter information).
		- Engineering Department did not receive feedback indicating that the other location is in more serious need of TGMS inspection.
		  o Communication was lost (e.g., email not delivered).
		  o Someone in communication chain failed to pass on communication.
		  o Communication was delayed (e.g., someone was out sick or on vacation).
		- TGMS dataset is difficult to interpret; analyst makes mistake determining whether territory is likely to need another TGMS inspection.
		- Because inspector assigned to that territory is not experienced/skilled enough to detect full number/degree of problems so does not accurately convey the full extent of the degraded track condition.
		- Because miscommunication regarding the condition one or both tracks
		
		Other (Regulatory Practices/Weather/Knowledge)
		
		- Engineering Department receives correct information about conditions at locations but do not act on it.

ID	UCA Statement	Scenario Factors
		o Because location where it was done was due for FRA regulated inspection and other location was not. o TGMS cannot operate at location that is in more serious need (e.g., due to weather conditions). - Engineering Department receives correct feedback/information but interprets it incorrectly. o Knowledge/training, Engineering Department reads log incorrectly.

16.3	**Engineering Department assigns TGMS inspection at incorrect or unclear location. [H1; H3]**	Missing or Wrong Feedback/Information about Which Tracks Need Inspection
		
		- Because of limitations with method of documentation
		    o Inspector handwriting is illegible.
		    o Inspector incorrectly entered data into Toughbook because Toughbook interface is difficult.
		    o Inspector does not enter information into Toughbook because of usability issues with Toughbook (Toughbook crashes, takes too long to enter/re-enter information).
		- Engineering Department receives incorrect or miscommunicated information.
		    o About where TGMS inspection is due.
		    o About condition of the track
		
		Communication/Teamwork
		
		- Miscommunication between engineering department and TGMS operator about which track to inspect, or which locations to be sure to cover.
		    o Radio issues (e.g., static, congestion) contribute to misunderstanding.
		    o Lack of shared language/understanding (esp. if TGMS operator is contracted and not a railroad employee)

17.1	**Engineering Department does not train/employ enough inspectors. [H1]**	Training Resources
		
		- Lack of applicants
		    o Poor financial incentives to become track inspector.
		    o Poor working conditions for track inspectors (physically demanding, difficult schedule)
		    o Too many constraints on who can bid for track inspector job.
		- Not enough foremen hired to grow the ranks sufficiently.
		- Enough foremen are hired (or as many as possible) but too many foremen leaving railroad (for jobs at other railroads or for other careers).
		- Not enough foremen are decided to be ready/qualified/able to take on inspection duties.
		- Engineering Department does not have enough resources (money, training instructors) to train enough inspectors.
		
		Collective Bargaining Agreement
		
		- Railroad loses inspectors to other territories shorty after getting them trained on it. Results in constant need for new training.
		Applicants Cannot Pass Track Inspector (MOW) Exam
		
		- Training not up to par/exam too difficult

ID	UCA Statement	Scenario Factors
		Supervisory Practices - Engineering Department has incorrect beliefs about how many inspectors they need.

17.2	**Engineering Department does not train inspectors with regard to track inspection technology. [H1; H3]**	Incorrect Mental Model
		
		- Engineering Department believes inspectors do not need to understand how track inspection technology works and/or read inspection technology output.
		- Inspectors often switch jobs soon after passing exam so engineering department believes that training them on track inspection technology is too costly.
		- Because Engineering Department does not understand how it would be useful.
		   o Because they have not spent enough time in the field since these technologies have been deployed and their output worked with on a regular basis.
		   o Because no one is passing up the information that it would be helpful for inspectors to have a better understanding of how it works.
		
		Resources
		
		- Engineering Department does not have resources to train inspectors with regard to track inspection technology.
		- Inadequate financial resources, missing training instructors who understand track inspection technology.

17.3	**Engineering Department provides inspectors with unclear, incorrect, or incomplete training. [H1; H2]**	Limitations in Trainer Knowledge/Skill/Abilities
		
		- Trainers are not up-to-date on proper training/inspection methods.
		- Trainers lack experience/not qualified (e.g., have never worked as inspectors themselves).
		
		Training Does Not Include Enough Hands-On Experience to Properly Train Inspectors Regarding OTJ Inspection Methods
		
		- Inadequate resources
		   o Trainers are not significantly more experienced than trainees.
		   o Not enough trainers available because people don't want to do it/lack of incentive to become a trainer.
		   o Not enough time to spend on OJT because it's costly to double up and railroad wants new inspectors to go work their own territories.
		- Railroad relies on informal mentorship.
		   o Incorrect beliefs about how long OJT should be.
		   o Railroad thinks current OJT is adequate/informal mentorship is sufficient.
		
		Incomplete Curriculum Does Not Cover Everything Inspector Needs
		
		- Because curriculum has not been updated as the inspection system has evolved.
		   o E.g., does not include things like how to understand the output generated from automated systems nor giving inspectors a general sense of how automated systems work. That info

ID	UCA Statement	Scenario Factors

		wasn't needed when course was developed or when instructor started teaching.
		- Because some things are expected to be intuitive so they don't make it into training.
		   o E.g., not enough training on software where they log in defect records.
		- Because certain topics, though important, are awkward to cover explicitly because to do so formally admits the existence of problems in the system.
		   o E.g., how to handle it in the event someone tries to pressure the inspector into not logging something/not taking the level of action that's needed (e.g., a two class drop)/not giving you access to the track.
		
		Training Materials Contain Inaccuracies
		
		- Typographical errors
		- Outdated information (e.g., railroad now uses stricter maintenance standards than when materials were developed)
		- Lack of resources to update training materials.

17.4	**Engineering Department trains inspectors too early, resulting in loss of knowledge before working in the field. [H1; H2]**	Engineering Department Has Incorrect Beliefs - About how many inspectors they will need. Incorrectly believe many inspectors will retire/bid on different jobs. - About how long inspectors can retain knowledge without using it. Training - Training offered very infrequently, so inspectors may have to take training early to ensure they can take it before it's needed. Scheduling Practices - Inspectors trained and qualified on territory but may not work it regularly; then have forgotten knowledge before being asked to fill in or being assigned to that territory.
17.5	**Engineering Department (re-) trains inspectors too late, resulting in loss of knowledge in between training. [H1; H2]**	Incorrect Beliefs/Priorities - Engineering Department has incorrect beliefs about how long inspectors can retain knowledge without using it. - Engineering Department doesn't see refresher training as very important and believes inspectors don't really need it. It's viewed as mostly a formality. Resources - Engineering Department lacks adequate resources to do requalification training.
17.6	**Engineering Department trains inspectors too quickly on practical inspection skills. [H1]**	Resources - Engineering Department does not have resources to properly train inspectors. - Training is not long enough to adequately train. - Training does not include enough hands-on experience to properly train inspectors with regard to on-the-job inspection methods. - Because they don't have enough funding to train longer.

ID	UCA Statement	Scenario Factors
		o Because the number of people they have to train is so high (given job bidding and frequency of people changing jobs) that they can't afford to do longer training for all those people.
		Incorrect Beliefs
		- Engineering Department incorrectly believes that training is long enough to adequately train inspectors. o Because they believe they covered everything. o Because they believe that that classroom training isn't that important and most of important learning happens OTJ anyhow.
18.1	**Engineering Department assigns territory to someone with low likelihood of finding issues. [H1]**	Lack of Resources - Do not have enough inspectors who are trained on/familiar with territory. - Inspector trained on that territory is not present/available. Knowledge/Beliefs/Mental Models - Engineering Department believes that inspector is trained/familiar enough with territory when he/she is not. o Believes just because inspector received training they are suitable, but training does not produce adequately trained/experienced inspector o Receives incorrect feedback from inspector supervisor or trainer that inspector is qualified/completed training (e.g., completed classroom training but are doing OJT with mentor but get sent to do a real inspection) o Inspector personnel files do not contain information about which territory they are familiar, or information is unclear. - Engineering Department is unaware that this inspector's skill/knowledge of inspection is not up to par (regardless of the territory). - Engineering Department feels that this is an emergency and they need someone out there ASAP and this is the inspector that can be there the fastest. Job Assignment - It's out of the hands of the Engineering Department. Someone that's not a strong inspector bid onto a challenging territory. - Scheduling policies preclude more qualified inspectors from working (because of amount of hours they have already worked).
19.1	**Engineering Department does not assign non-routine inspection when there is reason to suspect a defect. [H1]**	Production Pressures - Engineering Department does not want to take track and time and disrupt train service. Communication and Mental Models - Engineering Department does not know non-routine inspection is needed. o Because they did not receive information about suspected track geometry defects, or received the information too late. - Engineering Department unable to reach inspector in time.

ID	UCA Statement	Scenario Factors
		o Phone/radio not working.
		o Inspector too busy to pick up phone/radio.
		- Engineering Department receives incorrect information about track condition.
		o Other inspectors (e.g., B&B, C&S) did not recognize a track issue that should have merited special inspection.
		o Incorrect TGMS data does not reflect an issue that should have merited special inspection.
		- Engineering Department receives correct information about defect but interprets it incorrectly.
		o Interprets it to believe it does not need to be inspected
		o Interprets it to believe it will be inspected by other means (TGMS/other inspection vehicle/maintenance department)
		Inadequate Resources
		- Lacking inspector availability
		o Inspector on that territory is already busy or behind for that period.
		o Territories very large and/or complex
		o No other inspectors available (short-staffed)
		- Maintenance crews already have too much on their plate and supervisor doesn't want to add to the list and risk having known defects go unaddressed.
		Staffing/Scheduling
		- Engineering Department does not have an available inspector to assign non-routine inspection to.
		- Inspector on that territory is already swamped, possibly behind for that period.
		- Not enough available inspectors qualified on the territory.
		- Not enough available inspectors with experience to look for specific defect.
		- No other inspectors available
		o Understaffed
		o Too much on inspectors' plates; territories very large and/or complex
		- Maintenance crews already have too much on their plate and supervisor doesn't want to add to the list and risk having known defects go unaddressed.
		Workload
		- Engineering Department gets busy/distracted by other issue to contact inspector in time.
		o Engineering Department meant to assign the non-routine inspection but then got busy/distracted and forgot.
		o Supervisors are understaffed/oversee too large of a territory.

ID	UCA Statement	Scenario Factors
19.2	**Engineering Department assigns a non-routine (substitute) inspection to an inspector who is not trained on/familiar with the territory. [H1]**	Engineering Department does not have adequate resources - Do not have enough inspectors who are trained on/familiar with territory. - Inspector who IS trained on that territory is not present/available (e.g., because of schedule / hours already worked). Incorrect information/beliefs - Engineering Department incorrectly believes that inspector is trained/familiar with territory. o Believes just because inspector received training they are suitable o Receives incorrect feedback from inspector supervisor or trainer that inspector is qualified/completed training (e.g., they completed classroom training but are doing OJT with mentor but get sent to do a real inspection) o Inspector personnel files do not contain information about which territory they are familiar, or information is unclear. - Engineering Department feels that this is an emergency and they need someone out there ASAP and this is the inspector that can be there the fastest.
19.3	**Engineering Department assigns a non-routine inspection at certain location when other location is in more serious need of inspection. [H1]**	Physical Environment - The other location's environmental conditions are not conducive to inspection (e.g., track is flooded). Supervisory Practices - Engineering Department prioritizes a potential safety issue over meeting regulations. o The track getting the non-routine inspection is a situation where there is the potential or strong likelihood for something very serious and that was given precedent over being a little late on getting the mandated inspection done. - Engineering Department is trying to make good use of maintenance crew time. o The maintenance crew is already working right near the area of the non-routine inspection and could quickly address any issue uncovered. o Engineering Department is trying to make good use of limited crew time so they don't spend all their time traveling around. - Engineering Department thinks it's unlikely that an FRA inspector will show up at the other track that's due soon before they can get to it. Knowledge/Communications - Engineering Department has lost track of when that inspection is due so just sends inspector out to deal with that non-routine issue without thinking about the fact inspector has a track in serious need. - Engineering Department doesn't know/realize that there's another area is greater need of inspection. (E.g., inspector is somewhat new and doesn't feel comfortable telling his/her boss that he/she can't go do the non-routine inspection.)

ID	UCA Statement	Scenario Factors

		Missing or Wrong Feedback/Information
		
		- Engineering Department receives incorrect information about conditions at the two locations.
		   o From inspector/supervisor, e.g., after special weather event
		- Engineering Department receives correct feedback/information but interprets it incorrectly/ignores it.
		- Engineering Department does not receive feedback/information before assigning inspection (delayed/never received).
		
		Traffic/Production Pressure
		
		- Traffic influences where Engineering Department sends inspection.
		   o Because traffic in the non-routine area is higher so they are concerned that the potential issues there are more likely to get worse quickly and/or would result in greater likelihood of having a derailment.
		   o Because traffic in the area that is in more serious need of inspection (to meet FRA regulations) is so backed up that they don't think they'll be able to get in so targeting the non-routine area rather than waiting around and wasting time where they don't think they can get track and time.

19.4	**Engineering Department assigns non-routine inspection at incorrect or unclear location. [H1; H3]**	Missing or Wrong Feedback/Information
		
		- Engineering Department receives incorrect information about: track condition at particular location (e.g., that track is degraded) OR receives incorrect location information – e.g., wrong GPS location.
		   o Inspector handwriting is illegible.
		   o Inspector incorrectly enters data into Toughbook because Toughbook interface is difficult.
		   o TGMS dataset is difficult to interpret.
		- Engineering Department receives correct feedback/information but interprets it incorrectly/ignores it.
		- Engineering Department does not receive feedback/information before assigning inspection (delayed/never received).
		- Missing or wrong feedback/information about where inspection is necessary according to FRA regulations.
		
		-Communication Errors
		
		- Engineering Department accidently said the wrong thing – meant to say the correct location information but then misspoke.
		- Engineering Department said the location in a way that could have different interpretations.
		   o Because inspector did not repeat back his/her own understanding for confirmation, this miscommunication went undetected.
		
		Skill/Experience
		
		- Engineering Department employee does not have enough experience.
		   o Not enough field-experience to know best way to explain it to inspector.
		   o Not enough supervisory experience to know best way to assign non-routine inspections clearly.

ID	UCA Statement	Scenario Factors
19.5	**Engineering Department assigns a non-routine inspection by method (on foot/hi-rail/TGMS) less effective or efficient for the territory. [H1; H3]**	Production Pressures - Engineering Department needs to move a piece of equipment and as a time saving measure asks inspector to move it while inspecting. - Dispatcher unable to give adequate time for most effective inspection method (e.g., dispatcher cannot give enough time for a walking inspection but can give enough time for a TGMS/Hi-rail inspection). - It's not possible to do via the preferred method right now and the railroad wants to have a record of having followed up on the non-routine situation (even if the inspection might not be very effective). Knowledge/Experience - Engineering Department does not know effective/efficient methods for each territory. - Engineering Department employees have never worked as track inspectors/have not worked as track inspectors for a long time. Weather - Impending weather forces engineering department to assign non-routine inspection a certain method (i.e., impending thunderstorms so need inspection to be quick/covered so assign hi-rail or TGMS)

20.1	**Engineering Department does not coordinate with Dispatch when needed or at incorrect location to help get track and time or plan outages for inspectors or TGMS. [H1; H3]**	Teamwork/Communication
		
		- Engineering Department does not know that they need to help coordinate with Dispatch.
		- Inspector does not inform supervisor that they need help obtaining track and time.
		  - Bad relationship with supervisor
		  - Can't reach supervisor by phone.
		  - Inspector doesn't want to look like he/she can't handle it; wants to try to deal with it on his/her own.
		- Engineering Department accidently said the wrong thing – meant to say the correct location information but then misspoke.
		- Engineering Department said the location in a way that could have different interpretations.
		  - Because inspector did not repeat back his/her own understanding for confirmation, this miscommunication went undetected.
		
		Supervisory Practices
		
		- Engineering Department does not think it is their job to help coordinate with Dispatch.
		- Has a bad rapport with dispatcher and does not want to coordinate with them; possibly due to past disagreements on prioritizing schedule vs. inspection.
		- Thinks the inspector should handle coordination with Dispatch (maybe it isn't explicitly part of supervisor's job, or supervisor is not taught to do it).
		
		Workload
		
		- Engineering Department intends to but gets busy/distracted by other issue to coordinate with Dispatch.
		  - Supervisors are understaffed/oversee too large of a territory.

ID	UCA Statement	Scenario Factors

		o It's a particularly busy time for supervisor and/or something has happened that impacts traffic flow/Dispatch (e.g., weather slowing down traffic, derailment elsewhere in system that same dispatcher deals with).
		
		Communication
		
		- Engineering Department unable to reach Dispatch.
		  o Phone/radio not working.
		  o Dispatcher too busy to pick up phone/radio.

21.1	**Engineering Department does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]**	Communication/Teamwork
		
		- Engineering Department incorrectly believes someone else will, or already did, restrict track (e.g., track inspector).
		- Engineering Department incorrectly believes maintenance crew was going to fix it immediately, therefore track does not need to be restricted.
		- Engineering Department thinks no more trains will operate on track before maintenance gang has a chance to repair it, so does not bother calling dispatcher to restrict speed.
		- Engineering Department is unable to reach dispatcher by radio/phone to restrict track.
		- Engineering Department receives information from track inspector about safety issue but does not realize that track needs to be restricted and/or does not realize it is their job to call Dispatch to restrict track in this case.
		  o Engineering Department doesn't think it's their job because the inspector usually takes care of this.
		  o Inspector did not clarify that they expected the engineering department to restrict track if needed.
		
		Distraction/Workload
		
		- Engineering Department intends to restrict but gets distracted by workload/other communication.
		
		Technology
		- Recent TGMS output shows the defect as only a maintenance condition, so engineering department is hesitant to restrict track until they can get another inspector out there to take a look.
		  o Because first inspector that was relatively inexperienced.
		  o Because management has a bias to always trust the technology.
		Production Pressures
		
		- Engineering Department does not want to bother/anger the dispatcher by restricting track speed if the issue does not seem severe and/or is borderline.

21.2	**Engineering Department does not restrict track speed when TGMS finds a safety issue that requires speed restriction. [H1]**	Communication/Teamwork - TGMS operator does not tell engineering department that a defect exists that requires track to be restricted. - Engineering Department incorrectly believes someone else will, or did, restrict track (e.g., TGMS operator). - Engineering Department incorrectly believes maintenance crew was going to fix it immediately, therefore track does not need to be restricted.

ID	UCA Statement	Scenario Factors

		- Engineering Department thinks no more trains will operate on track before maintenance gang has a chance to repair it, so does not bother calling dispatcher to restrict speed.
		- Engineering Department is unable to reach dispatcher by radio/phone to restrict track.
		- Engineering Department waiting for inspector to verify before restricting track speed.
		- Engineering Department receives information from TGMS operator about safety issue but does not realize that track needs to be restricted and/or does not realize it is their job to call Dispatch to restrict track.
		    o Usually, TGMS operator handles track speed restrictions.
		    o Usually, an Engineering Department employee is onboard the TGMS, but currently they are not so they don't know about the issue.
		
		Distraction/Workload
		
		- Engineering Department intends to restrict but gets distracted by workload/other communication.

21.3	**Engineering Department restricts track speed when severe safety issues are present that require track to be removed from service. [H1]**	Knowledge/Experience
		
		- Engineering Department does not realize that severe safety issues require track to be removed from service.
		    o Incorrect knowledge about the defect's severity
		    o Incorrect knowledge about track class at that location
		    o Incorrect knowledge about what needs to be done/regulation.
		
		Production Pressures
		
		- Engineering Department supervisor knows track should be removed from service but knows Dispatch and/or supervisor's own manager will get angry if track is removed from service/traffic disrupted so restricts track instead.
		
		Supervisory Practices
		
		- Supervisor disagrees with inspectors assertion that safety issue is a defect that requires track to be removed from service, thinks it is less severe, so restricts instead.
		
		Distraction
		
		- Engineering Department called Dispatch intending to remove track from service, but then was momentarily distracted/confused or too busy and ended up just asking to restrict track speed.
		
		Communication
		
		- Engineering Department correctly stated to remove track from service but dispatcher misunderstood and restricted track speed instead.
		    o Because of radio issues (e.g., static, poor signal)
		    o Because of expectations (e.g., restricting speed is more common)

ID	UCA Statement	Scenario Factors

21.4	**Engineering Department restricts track speed incorrectly (e.g., either too strict or not strict enough or at wrong location). [H1; H3]**	Knowledge/Experience
		
		- Engineering Department does not know correct restriction and lacks readily accessible reference information.
		- Engineering Department has incorrect knowledge about track class (which determines speed restrictions).
		- Engineering Department employee is new in the position/has little experience, or has not been trained as an inspector; or hasn't worked as an inspector in a long time.
		- Engineering Department is restricting based on information gathered from TGMS.
		    o Reads output incorrectly or as a different defect (therefore restricts incorrectly) or at incorrect location
		    o TGMS output for GPS location of defect, or severity reading, is incorrect.
		
		Supervisory Practices
		
		- Supervisor disagrees with inspectors assertion of how track should be restricted and overrides inspector (but inspector was correct).
		
		Communication/Error
		
		- Engineering Department receives incorrect information from inspector – e.g., static on the radio, misspeak, inspector has incorrect information.
		- Engineering Department receives correct information from inspector/TGMS but information is incorrect when it is transmitted to dispatcher – e.g., static on the radio, misspeak.
		- Engineering Department received the correct information from inspector/TGMS and said the correct (more strict) track speed and at the correct location, but Dispatch heard the incorrect restriction information (not strict enough) or heard the incorrect location.
		- Engineering Department reads TGMS output incorrectly.
		    o No training or experience on reading output, TGMS analyst usually reads and interprets the output but is on vacation/sick.
		
		Distraction/Workload
		
		- Engineering Department called Dispatch with the correct track restriction information and location in mind, but then was momentarily distracted/confused and ended up saying the wrong information.

21.5	**Engineering Department waits too long to restrict track speed, allowing trains to operate at track speed over track with a safety issue [H1; H3]**	Communication/Teamwork - Engineering Department cannot reach dispatcher in time because dispatcher is busy or because of issues with radio/phone. Workload/Distraction - Engineering Department busy dealing with other issues, put off calling dispatcher because of more pressing issues. o Engineering Department is understaffed. Incorrect Mental Model - Engineering Department employee does not realize urgent nature of calling the dispatcher, thinks it can wait until other work is complete.

ID	UCA Statement	Scenario Factors

		o Because engineering department is inexperienced or has no experience working as track inspector to understand implications of defect.
		o Because engineering department employee was not well trained on this.
		o Because engineering department employee hasn't worked as an inspector in a long time and knows other priorities as a supervisor are urgent.
		- Engineering Department employee is unsure of the severity of the defect and waiting to restrict track speed until they can get a second opinion .
		  o Because they don't have confidence in the first assessment.
		  o Because no actual measurements were taken so they do not have actual numbers to compare with requirements until someone can verify.
		
		Engineering Department Believes Someone Else Is Dealing with It and Realizes Too Late
		
		- The issue has been assigned to a maintenance crew to fix right away, and so Engineering Department doesn't think it needs to be reported to Dispatch as well; they think it will be fixed before track is active again.
		- They assume inspector will tell Dispatch, so they don't have to.
		  o Inspector and Engineering Department miscommunicate about who is going to call.
		
		Production Pressures
		
		- Engineering Department waits to restrict to let more trains pass through the track quickly (e.g., during rush hour).

22.1	**Engineering Department does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]**	Knowledge/Experience
		
		- Engineering Department does not realize that severe safety issues require track to be removed from service.
		  o Incorrect knowledge about the defect's severity
		  o Incorrect knowledge about track class at that location
		  o Incorrect knowledge about what needs to be done/regulation.
		
		Communication
		
		- Engineering Department thinks someone else will remove track (inspector or maintenance gang).
		- Engineering Department thinks no more trains will operate on track before maintenance gang has a chance to repair it, so does not bother removing track from service.
		- Engineering Department is unable to reach dispatcher by radio/phone to remove track from service.
		
		Production Pressures
		
		- Engineering Department knows track needs to be removed but does not because of production knows Dispatch will get angry if track is removed from service.

ID	UCA Statement	Scenario Factors
		Supervisory Practices - Supervisor disagrees with inspectors assertion that safety issue is a defect that requires track to be removed, thinks it is less severe. Distraction/Workload - Engineering Department intends to remove track from service, but gets distracted by workload/other issue/radio communication.

22.2	**Engineering Department removes track from service at incorrect location. [H1]**	Communication/Error
		
		- Engineering Department receives incorrect information from inspector – e.g., static on the radio, misspeak, inspector has incorrect information.
		- Engineering Department receives correct information but information is incorrect when it is transmitted to dispatcher – e.g., static on the radio, misspeak.
		- Engineering Department receives correct information from inspector/TGMS but then Dispatch heard the incorrect location for where track should be removed.
		    o Because Dispatch did not repeat it back again, it went unnoticed.
		
		Expectations
		
		- Engineering Department recalls information about other defects and thinks/expects that is the location where track should be removed.
		
		Distraction / Workload
		
		- Engineering Department called Dispatch with the correct location information for where to remove track from service in mind, but then was momentarily distracted/confused and ended up saying the wrong information.
		
		Technology
		
		- Engineering Department is removing track from service at that location based on information gathered from TGMS.
		    o Reads correct location information incorrectly
		        ▪ Because was not given sufficient training
		        ▪ Because not enough experience (usually someone else does this, but that person is unavailable)
		        ▪ Because it is confusing.
		    o Location information provided by TGMS is incorrect.

22.3	**Engineering Department waits too long to remove track from service, allowing trains to operate over track with a safety issue in the meantime. [H1]**	Knowledge/Experience
		
		- It takes a while for Engineering Department to realize that track needed to be removed from service.
		    o Insufficient knowledge about defect's severity
		    o Insufficient knowledge about track class at that location
		    o Insufficient understanding of/experience with TGMS output
		
		Communication/Teamwork
		
		- Engineering Department cannot reach dispatcher in time (dispatcher busy/issues with radio).

ID	UCA Statement	Scenario Factors

		- Engineering Department thinks someone else will remove track from service, e.g., track inspector or maintenance gang.
		
		Workload/Distraction
		
		 - Engineering Department busy dealing with other issues, put off calling dispatcher because of more pressing issues.
		    o Engineering Department is understaffed.
		
		Incorrect Mental Model
		
		 - Engineering Department employee does not realize urgent nature of calling the dispatcher, thinks it can wait until other work is complete.
		    o Because engineering department is inexperienced or has no experience working as track inspector to understand implications of defect.
		
		Production Pressures
		
		 - Engineering Department waits to remove track to let more trains pass through the track quickly/until not so busy.
		    o E.g., it is rush hour, so they wait until rush hour is over to remove track.

23.1	**Dispatcher does not grant track and time when TGMS inspection is needed. [H1]**	Production Pressures
		
		 - Dispatcher is tired of TGMS going out and finding issues on the track which will potentially cause track restrictions or removals.
		 - Dispatchers incorrectly believe on-time performance is more important than TGMS inspections/safety.
		    o Because performance goals and/or training prioritize on-time performance over safety (incorrect feedback).
		    o Because risks identified by TGMS are usually minor and derailments are rare, dispatcher thinks TGMS inspection is not that important.
		 - Evaluation of dispatcher performance focus more on on-time performance than safety.
		 - When dispatcher thinks of cost they may only know about fines for not being on time and not realize the cost of keeping TGMS waiting.
		
		Physical characteristics of the Track
		
		 - Territory has no sidings so it is not possible for TGMS to "get out of the way" into a siding when a train needs to come through? (heard about this for hi-rail).
		 - Territory is single track so sending TGMS out stops all traffic on that route.
		 - Weather conditions were unsafe (thunder/lightning) for inspector to do walking inspection (territory is walking inspection only) so dispatcher thinks it's better to keep trains moving over the tracks.
		
		Supervisory Practices
		
		 - Dispatcher is less prone to listen to TGMS analyst/operator when they request track time but supervisor did not step in to call Dispatch and request track and time.

ID	UCA Statement	Scenario Factors
		o Dispatcher may be less familiar with TGMS operator, but work with track inspectors and supervisors frequently so they have more trust in them. Scheduling/Non-Routine Inspections - Dispatchers are less likely to give track and time to non-routine inspections because they have no bandwidth to figure out alternate routes/scheduling. - If Dispatch center is understaffed it could be easier to refuse track time than to think of alternate ways to move traffic. Dispatcher Experience/Training - Dispatcher lacks experience. - Dispatcher is not taught strategies in training to accommodate inspection technology. - Other issues going on that day that lead the dispatcher to feel overwhelmed just managing traffic and/or determining that it is not possible to fit in (e.g., previous derailment or other issues, weather, etc.).

23.2	**Dispatcher grants track and time to TGMS when scheduling causes TGMS to go too slow to collect data. [H1]**	Production Pressures
		
		- Dispatcher is tired of TGMS going out and finding issues on the track which will potentially cause track restrictions or removals so waits to send TGMS out after all trains have passed.
		- Dispatchers incorrectly believe on-time performance is more important than TGMS inspections/safety.
		   o Because performance goals and/or training prioritize on-time performance over safety (incorrect feedback).
		   o Because risks identified by TGMS are usually minor and derailments are rare, dispatcher thinks TGMS inspection is not that important.
		   o Because performance goals and/or training prioritize on-time performance over safety.
		
		Supervisory practices
		
		- Dispatcher is less prone to listen to TGMS analyst/operator when they request track time but supervisor did not step in to call Dispatch and request track and time.
		   o Dispatcher may be less familiar with TGMS operator, but work with track inspectors and supervisors frequently so they have more trust in them.
		
		Dispatcher Experience/Training
		
		- Dispatcher lacks experience/training to consider best practices for granting track and time to TGMS / inspection technology.
		- Does not realize that TGMS can go at track speed and thinks it will cause too much delay to send it in front of other traffic (when in fact the traffic slows the TGMS).

24.1	**Dispatcher does not grant track and time to inspector when visual**	Production Pressures/Workload - Dispatcher is tired of inspector going out and finding issues on the track which will potentially cause track restrictions or removals.

ID	UCA Statement	Scenario Factors

	inspection is needed. [H1]	- Dispatchers incorrectly believe on-time performance is more important than inspection/safety.
		   ○ Because performance goals and/or training prioritize on-time performance over safety (incorrect feedback).
		   ○ Because risks identified by TGMS are usually minor and derailments are rare, dispatcher thinks TGMS inspection is not that important.
		- Evaluation of dispatcher performance focus more on on-time performance than safety.
		
		Relationship to Inspectors
		
		- Dispatcher hopes inspector will give up on waiting and try another day when someone else is working Dispatch for that track.
		   ○ Because dispatcher believes inspector is likely to hold up traffic based on past experiences with him/her inspecting slowly and/or judging defects very strictly so that speeds often need to be reduced or track taken out of service more often than with other inspectors.
		   ○ Because the dispatcher knows that he/she will have a hard time getting track back from that inspector if needed.
		   ○ Because that dispatcher does not like to work with inspectors at all.
		   ○ Because the dispatcher believes that it is not that hard for inspectors to just come again another day since they are out inspecting all the time anyhow.
		
		Supervisory Practices
		
		- Dispatcher is less prone to listen to inspector when they request track time but supervisor did not step in to call Dispatch and request track and time.
		   ○ The dispatcher may have a poor relationship with this inspector due to past experience (e.g., inspector taking too long, restricting "too much").
		   ○ The dispatcher may be reluctant to grant track and time to the inspector if they are new to the territory or inexperienced.
		
		Scheduling/Workload/Non-Routine Inspections
		
		- Dispatchers are less likely to give track and time to non-routine inspections because they have no bandwidth to figure out alternate routes/scheduling.
		   ○ If Dispatch center is understaffed it could be easier to refuse track time than to think of alternate ways to move traffic.
		- Dispatcher feels overwhelmed due to other factors (e.g., previous derailment or other issues, weather, etc.).
		
		Dispatcher Experience/Training
		
		- Dispatcher lacks experience.
		- Not taught strategies in training to accommodate non-routine inspections.
		
		Physical Characteristics

ID	UCA Statement	Scenario Factors
		- Weather conditions were unsafe (e.g., thunder/lightning) for inspector to do walking inspection (territory is walking inspection only) so dispatcher thinks it's better to keep trains moving over the tracks.

24.2	**Dispatcher grants track and time to inspector too late, allowing trains to operate over track when there is a safety issue. [H1]**	Production Pressures
		
		- Dispatcher is tired of inspector going out and finding issues on the track which will potentially cause track restrictions or removals so waits to grant track and time out after all trains have passed.
		- Dispatchers incorrectly believe on-time performance is more important than inspection/safety.
		    o Because performance goals and/or training prioritize on-time performance over safety.
		    o Because risks identified by TGMS are usually minor and derailments are rare, dispatcher thinks TGMS inspection is not that important.
		
		Supervisory Practices
		
		- Dispatcher waited until supervisor stepped in to grant track and time.
		    o The dispatcher may have a poor relationship with this inspector due to past experience (e.g., inspector taking too long, restricting "too much").
		    o The dispatcher may be reluctant to grant track and time to the inspector if they are new to the territory or inexperienced.
		
		Dispatcher Experience/Training
		
		- Dispatcher lacks experience/training to consider best practices for granting track and time.
		- Does not realize that inspector can use hi-rail for inspection which can go up to 30 mph.

24.3	**Dispatcher does not grant enough track and time to inspector to complete inspection. [H1]**	Production Pressures
		
		- Dispatchers incorrectly believe on-time performance is more important than inspection/safety.
		    o Because performance goals and/or training prioritize on-time performance over safety.
		    o Because risks identified by TGMS are usually minor and derailments are rare, dispatcher thinks TGMS inspection is not that important.
		- Territory is busy but dispatcher tries to give track when available even if it means smaller timeframes in which inspector cannot complete inspection.
		
		Incorrect Mental Models about Inspection
		
		- Dispatcher assumes that inspector has time/availability to pick up inspection again another time.
		- Dispatcher does not know how long inspection will take (e.g., due to inexperience).
		- Dispatcher does not realize inspection practices will make inspection take longer.
		    o Inspector stopped to repair something and/or took more time than initially asked for.

ID	UCA Statement	Scenario Factors
		o Inspector had to stop to do more measurements than anticipated. o Inspector did a walking inspection instead of using hi-rail even though time was limited. Communication - Dispatcher thought inspector was inspecting via hi-rail (therefore inspection would be quicker) rather than by foot. - Inspector did not give an estimate of time needed; or estimated too little. - Inspector did not update dispatcher when inspection took longer than planned.

Appendix E.
UCAs for aTGMS & Visual Inspection Sociotechnical System

These are the UCAs developed for the aTGMS & Visual Inspection Sociotechnical System described in Section 4.3 of the main report.

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
aTGMS l **Locomotive-Mounted Sensors** **1: Collect data (e.g., take measurements, images etc. of all track, not just defects).**	**UCA 1.1:** aTGMS sensors do not collect data while in operation. [H1; H3]	**UCA 1.2:** aTGMS sensor collects incorrect data. [H1; H3]	N/A	N/A
aTGMS Locomotive-Mounted Computer **2: Identify defect (class-limiting safety defect).**	**UCA 2.1:** aTGMS computer does not identify a defect when a defect exists. [H1]	**UCA 2.3:** aTGMS computer identifies a defect where a defect does not actually exist [H3]. **UCA 2.4:** aTGMS computer identifies a defect when it is really a maintenance condition [H3]. **UCA 2.2:** aTGMS computer identifies a defect at an incorrect location [H1; H3].	N/A	N/A
aTGMS Locomotive-Mounted Computer **3: Identify maintenance condition (railroad maintenance threshold).**	**UCA 3.1:** aTGMS computer does not identify a maintenance condition when a maintenance condition is present and should be monitored for progression toward a safety defect. [H1] **UCA 3.2:** aTGMS computer does not	**UCA 3.3:** aTGMS computer identifies a maintenance condition where a maintenance condition does not actually exist. [H3] **UCA 3.4:** aTGMS computer identifies a maintenance condition as a defect	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
	identify a maintenance condition when a maintenance condition is present that could be fixed as part of capital planning/ strategic process. [H3]	(more severe than it is). [H3] **UCA 3.5:** aTGMS computer identifies a maintenance condition at an incorrect location. [H3]		
Central Server **4: Filter data.**	**UCA 4.3:** aTGMS central server does not filter out anomalies in the data (e.g., false alarms). [H3]	**UCA 4.1:** aTGMS central server filters out exceptions that were not false alarms. [H1] **UCA 4.2:** aTGMS central server filters data correctly but presents it in a way that is confusing to the end-user. [H1, H3] **UCA 4.4:** aTGMS central server does not filter out exceptions that are false alarms. [H3]	N/A	N/A
aTGMS Analyst **5: Dismiss exceptions** *(e.g., wide gage at frog).*	**UCA 5.2:** aTGMS analyst does not dismiss exceptions when they are false alarms. [H3]	**UCA 5.1:** aTGMS analyst dismisses exceptions when they are NOT false alarms. [H1]	N/A	N/A
aTGMS Analyst **6: Provide exception data (to Eng. Dept.).**	**UCA 6.1:** aTGMS analyst does not provide exception data to Engineering Department. [H1]	**UCA 6.2:** aTGMS analyst provides the incorrect exception data to Engineering Department. [H1; H3] **UCA 6.3:** aTGMS analyst provides exception data in a way that is not easily used by field	**UCA 6.4:** aTGMS analyst provides exception data too late, data is not accessible to inspectors/supervisors/maintenance, allowing trains to operate over track with a safety issue	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		personnel as-is. [H1; H3]	in the meantime. [H1]	
Track Inspector **7: Inspect track.**	**UCA 7.1:** Track inspector does not inspect track when inspection is needed (to meet frequency regulations and because issues could have arisen). [H1; H3] **UCA 7.2:** Track inspector does not conduct field verification of issue when instructed to do so and a safety issue is present. [H1]	**UCA 7.3:** Track inspector inspects track using a method (i.e., on foot/hi-rail) that is less effective or efficient for the territory. [H1; H3] **UCA 7.4:** Track inspector inspects or verifies track at incorrect location. [H1; H3] **UCA 7.8:** Track inspector inspects track without proper safety measures. [H2]	**UCA 7.5:** Track inspector inspects track when another section of that inspector's territory is in more serious need of inspection. [H1] **UCA 7.9:** Track inspector starts inspecting track before proper safety measures are in place for own protection. [H2] **UCA 7.10:** Track inspector inspects track too soon, before inspection is due. [H3]	**UCA 7.6:** Track inspector inspects track too quickly to detect issues. [H1] **UCA 7.7:** Track inspector stops inspection too soon (before necessary inspection is complete according to regulations or before a section with specific concerns has been inspected). [H1] **UCA 7.11:** Track inspector spends too long inspecting (delays service). [H3]
Track Inspector **8: Identify defect** *(class-limiting FRA defect).*	**UCA 8.1:** Track inspector does not identify a defect when a defect exists. [H1]	**UCA 8.2:** Track inspector identifies a defect as less severe than it is. [H1] **UCA 8.3:** Track inspector identifies a defect as more severe than it is; identifies a defect when it is actually a maintenance condition. [H3] **UCA 8.4:** Track inspector identifies a defect where no issue exists. [H3]	**UCA 8.5:** Track inspector identifies defect too soon, before it is actually a defect. [H3] **UCA 8.6:** Track inspector identifies a defect too late, when severe enough that track speed must be restricted or track removed from service. [H3]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Track Inspector **9: Identify maintenance condition** *(railroad maintenance threshold).*	**UCA 9.1:** Track inspector does not identify a maintenance condition when a maintenance condition exists and should be monitored for progression toward a safety defect. [H1; H3]	**UCA 9.2:** Track inspector identifies a maintenance condition where a maintenance condition does not exist. [H3] **UCA 9.3:** Track inspector identifies a maintenance condition as more severe than it is. [H3]	**UCA 9.4:** Track inspector identifies a maintenance condition too soon, before it is actually a maintenance condition. [H3] **UCA 9.5:** Track inspector identifies a maintenance condition too late to incorporate into maintenance planning. [H3]	N/A
Track Inspector **10: Repair maintenance condition/defect.**	**UCA 10.1:** Track inspector does not repair a defect, when they do not restrict or remove the track from service. [H1] **UCA 10.4:** Track inspector does not repair defect when they have the ability (time, tools, skill) to do so, thus requiring track speed to be restricted or the track removed from service. [H3]	**UCA 10.2:** Track inspector repairs defect/maintenance condition when it affects ability to complete inspection or resulting in service delays. [H1; H3] **UCA 10.3:** Track inspector repairs a maintenance condition/defect incorrectly. [H1; H3] **UCA 10.5:** Track inspector repairs a maintenance condition/defect without safety measures in place. [H2] **UCA 10.6:** Track inspector repairs a maintenance condition when it would be more efficient to wait until later. [H3]	**UCA 10.7:** Track inspector repairs a maintenance condition too early, before repair is needed or practical. [H3]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Track Inspector **11: Restrict track speed.**	**UCA 11.1:** Track inspector does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]	**UCA 11.2:** Track inspector restricts track speed when severe issues are present and track should be removed from service. [H1] **UCA 11.3:** Track inspector restricts track speed incorrectly (e.g., either too strict or not strict enough or wrong location). [H1; H3] **UCA 11.5:** Track inspector restricts track speed when track is not actually a risk to safety (i.e., when there is no issue above threshold for that track class). [H3] **UCA 11.6:** Track inspector restricts track speed when track could have been immediately repaired by the inspector. [H3]	**UCA 11.4:** Track inspector waits too long to restrict track speed, allowing trains to operate over track with a safety issue in the meantime. [H1]	N/A
Track Inspector **12: Remove track from service.**	**UCA 12.1:** Track inspector does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]	**UCA 12.3:** Track inspector removes track from service incorrectly, e.g., when there is no issue present or at the wrong location. [H3] **UCA 12.4:** Track inspector removes track from service when track could have been repaired or restricted. [H3]	**UCA 12.2:** Track inspector removes track from service too late, allowing trains to operate over track with a safety issue in the meantime. [H1]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Track Inspector **13: Log defect.**	**UCA 13.1:** Track inspector does not log a defect when a defect is present. [H1; H3]	**UCA 13.2:** Track inspector logs a defect incorrectly–with incorrect or incomplete information that limits ability to investigate or repair. [H1; H3]	N/A	**UCA 13.3:** Track inspector spends too long logging defects when doing so during an inspection, causing them not to finish inspection, or need to rush inspection; or causing delays to service. [H1; H3]
Track Inspector **14: Log maintenance condition.**	**UCA 14.1:** Track inspector does not log a maintenance condition when it is detected and needs monitored for progression towards a safety defect. [H1] **UCA 14.4:** Track inspector does not log a maintenance condition when it is detected and would impact longer-term maintenance planning activities. [H3]	**UCA 14.2:** Track inspector logs a maintenance condition incorrectly, with incorrect or incomplete information that limits the ability to investigate or repair. [H1; H3]	N/A	**UCA 14.3:** Track inspector spends too long logging maintenance conditions when doing so during an inspection, causing them not to finish inspection, or to need to rush inspection; or causing delays to service. [H1; H3]
Engineering Department **15: Choose where to install aTGMS**	**UCA 15.1:** Engineering Department does not choose to install aTGMS on a track that is most likely to have geometry-related defects (e.g., due to heavy traffic). [H1] **UCA 15.2:** Engineering Department does not choose to install aTGMS on track for which it is difficult for inspectors to get track time. [H1; H3]		**UCA 15.3:** Engineering Department waits too long to choose where to install aTGMS system after one becomes available. [H3]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Engineering Department **16: Provide track parameters to manufacturer.**	**UCA 16.1:** Engineering Department does not provide updated parameter information to manufacturer when the railroad changes the track class or where it will be used. [H1] **UCA 16.3:** Engineering Department does not provide parameters to manufacturer. [H3]	**UCA 16.2:** Engineering Department provides incorrect parameters to manufacturer. [H1; H3]	N/A	N/A
Engineering Department **17: Train /Employ inspectors**	**UCA 17.1:** Engineering Department does not train/employ enough inspectors. [H1] **UCA 17.2:** Engineering Department does not train inspectors with regard to track inspection technology. [H1, H3]	**UCA 17.3:** Engineering Department provides inspectors with unclear, incorrect, or incomplete training. [H1; H2] **UCA 17.7:** Engineering Department trains/employs many more inspectors than the territory requires. [H3]	**UCA 17.4:** Engineering Department trains inspectors too early resulting in loss of knowledge before working in the field. [H1; H2] **UCA 17.5:** Engineering Department (re-) trains inspectors too late, resulting in loss of knowledge in between training. [H1; H2]	**UCA 17.6:** Engineering Department trains inspectors too quickly on practical inspection skills. [H1] **UCA 17.8:** Engineering Department trains inspectors too quickly without enough training on employee safety. [H2] **UCA 17.9:** Engineering Department spends more time on training than is necessary. [H3]
Engineering Department **18: Assign territory.**	N/A	**UCA 18.1:** Engineering Department assigns territory to someone with low likelihood of finding issues. [H1]	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
Engineering Department **19: Assign non-routine inspections *(to track inspectors).***	**UCA 19.1:** Engineering Department does not assign non-routine inspection when there is reason to suspect a defect. [H1]	**UCA 19.2:** Engineering Department assigns a non-routine inspection to an inspector to fill in for someone on territory that inspector is not trained on/familiar with. [H1] **UCA 19.3:** Engineering Department assigns a non-routine inspection at certain location when another location is in more serious need of inspection. [H1] **UCA 19.4:** Engineering Department assigns non-routine inspection at incorrect or unclear location. [H1; H3] **UCA 19.5:** Engineering Department assigns a non-routine inspection by method (on foot/hi-rail/aTGMS) less effective or efficient for the territory. [H1; H3] **UCA 19.6:** Engineering Department assigns special weather inspection when conditions are not safe (e.g., in blizzard). [H2] **UCA 19.7:** Engineering	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		Department assigns non-routine inspection to verify a safety issue when a safety issue is not present. [H3]		
Engineering Department **20: Coordinate with Dispatch.**	**UCA 20.1:** Engineering Department does not coordinate with Dispatch when needed to help get track and time or plan outages for inspectors or aTGMS. [H1; H3]	**UCA 20.2:** Engineering Department coordinates with Dispatch for track and time at incorrect location. [H3]	**UCA 20.3:** Engineering Department coordinates with Dispatch too soon (getting track and time before inspector needs it). [H3] **UCA 20.4:** Engineering Department coordinates with Dispatch too late. [H3]	N/A
Engineering Department **21: Restrict track speed.**	**UCA 21.1:** Engineering Department does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1] **UCA 21.2:** Engineering Department does not restrict track speed when aTGMS finds a safety issue that requires speed restriction. [H1]	**UCA 21.3:** Engineering Department restricts track speed when severe safety issues are present that require track to be removed from service. [H1] **UCA 21.4:** Engineering Department restricts track speed incorrectly (e.g., either too strict or not strict enough or at wrong location). [H1; H3] **UCA 21.6:** Engineering Department restricts track speed when track is not actually a risk to safety. [H3] **UCA 21.7:** Engineering	**UCA 21.5:** Engineering Department waits too long to restrict track speed, allowing trains to operate at track speed over track with a safety issue. [H1; H3] **UCA 21.8:** Engineering Department restricts track speed too early before issue is at/above threshold. [H3]	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		Department restricts track speed when track could have been immediately repaired. [H3]		
Engineering Department **22: Remove track from service.**	**UCA 22.1:** Engineering Department does not remove track from service when a safety issue is present and is not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed.) [H1]	**UCA 22.2:** Engineering Department removes track from service at incorrect location. [H1] **UCA 22.4:** Engineering Department removes track from service when there is no issue present that requires the track to be removed from service. [H3]	**UCA 22.3:** Engineering Department waits too long to remove track from service, allowing trains to operate over track with a safety issue in the meantime. [H1] **UCA 22.5:** Engineering Department removes track from service too early before issue is present that requires track to be removed from service. [H3]	N/A
Dispatcher **23: Grant track and time *(to inspector).***	**UCA 23.1:** Dispatcher does not grant track and time to inspector when visual inspection is needed. [H1] **UCA 23.4:** Dispatcher does not grant track and time to inspector as soon as possible when visual inspection is needed. [H3]	**UCA 23.5:** Dispatcher grants track and time to inspector when it's not safe to be on the track. [H2] **UCA 23.6:** Dispatcher grants track and time to inspector when it would have an excessive impact on scheduling. [H3]	**UCA 23.2:** Dispatcher grants track and time to inspector too late, allowing trains to operate over track when there is a safety issue. [H1] **UCA 23.7:** Dispatcher grants track and time to inspector before track inspector is available to inspect. [H3]	**UCA 23.3:** Dispatcher does not grant enough track and time to inspector and safety issue is not found. [H1]
Upper Management **24: Define territory.**	N/A	**UCA 24.1:** Upper management defines inspection territory that is a non-optimal size (too large or small) and/or complexity for one inspector to cover in	N/A	N/A

Controller(s) Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing or Order	Wrong Duration
		the required timeframe. [H1; H3]		
Upper Management **25: Set performance goals** *(incentive to keep trains on schedule).*	N/A	**UCA 25.1:** Upper management sets performance goals that limit track time for inspectors to complete inspection and make repairs. [H1] **UCA 25.2:** Upper management sets performance goals related to particular track conditions which directs attention more on some safety concerns than others. [H1] **UCA 25.3:** Upper management sets performance goals such that the number of safety concerns that inspectors must detect exceeds attention limits. [H1]	N/A	N/A
Upper Management **26: Provide resources.**	**UCA 26.1:** Upper management does not provide adequate resources when they are needed to efficiently and effectively carry on inspection activities. [H1]	N/A	N/A	N/A

Appendix F.
Scenarios for aTGMS & Visual Inspection Sociotechnical System

These are the scenario factors developed for the aTGMS & Visual Inspection Sociotechnical System described in Section 4.3 of the main report.

ID	UCA Statement	Scenario Factors
1.1	aTGMS sensors do not collect data while in operation. [H1, H3]	Sensor Failure - Physical component of aTGMS sensor broken during operation and stops collecting data. Inadequate Sensor Response - Something interferes with sensor data collection (e.g., environmental conditions like sun, water, snow, etc.).

1.2	aTGMS sensors collect incorrect data. [H1, H3]	Inadequate Sensor Response
		
		- Something interfering with sensor data collection (e.g., environmental conditions like sun, water, snow etc.) cause sensors to interpret data incorrectly.
		- Speed is too low to collect accurate data.
		  - E.g., revenue trains always slow down and/or stop at station platforms, trains operating during rush hour may go slower due to congestion.
		- aTGMS improperly/not calibrated.
		  - aTGMS was not calibrated properly during maintenance.
		  - aTGMS maintenance schedule does not exist or is not adequate to ensure accurate calibration.

2.1	aTGMS computer does not identify a defect when a defect exists. [H1]	Incorrect Sensor Inputs Sent to aTGMS Computer - Sensor does not provide computer with ANY measurements (speed too low, sensor component failure, etc.). - Sensor provides incorrect measurements (GPS or calibration issue, inaccuracies due to environmental factors like glare, etc.). Correct Sensor Input Is Not Received by aTGMS Computer - Sensor data not received by aTGMS computer due to transmission issues (e.g., not set up to properly receive signal, poor signal in tunnels, etc.). aTGMS Computer Has Incorrect Process Model - aTGMS computer programmed with incorrect inputs (maintenance thresholds). - Wrong parameters (track class, location); perhaps railroad provided data that is outdated and did not update or aTGMS on different track than intended. - aTGMS computer programmed with incorrect algorithm; does not apply maintenance thresholds appropriately and gives wrong output.
2.2	aTGMS computer identifies a defect at an incorrect location. [H1; H3]	GPS Failure

ID	UCA Statement	Scenario Factors

		- GPS is not working properly and therefore output contains incorrect location information (e.g., known to happen in the terminal).
		
		aTGMS Computer Has Incorrect Process Model
		
		- Wrong parameters (track class, location)
		   o Railroad provided data that is outdated and did not update.
		   o aTGMS on different track than usual/intended

3.1	**aTGMS computer does not identify a maintenance condition when a maintenance condition is present and should be monitored for progression towards a safety defect. [H1]**	Incorrect Sensor Inputs Sent to aTGMS Computer - Sensor does not provide computer with ANY measurements (speed too low, sensor component failure, etc.). - Sensor provides incorrect measurements (GPS or calibration issue, inaccuracies due to environmental factors like glare, etc.). Correct Sensor Input Is Not Received by aTGMS Computer - Sensor data not received by aTGMS computer due to transmission issues (e.g., not set up to properly receive signal, poor signal in tunnels, etc.). aTGMS Computer Has Incorrect Process Model - aTGMS computer programmed with incorrect inputs (maintenance thresholds) for railroad maintenance standards. - Wrong parameters (track class, location); perhaps railroad provided data that is outdated and did not update or aTGMS on different track than intended. - aTGMS computer programmed with incorrect algorithm; does not apply maintenance thresholds appropriately and gives wrong output.

4.1	**aTGMS central server filters out exceptions that were not false alarms. [H1]**	- Incorrect Process Model: Filtering Algorithm Is Incorrect
		   o Engineering Department provides incorrect track parameters.
		   o Engineering Department provides correct track parameters, but manufacturer programs filtering algorithm incorrectly.
		   o Filtering algorithm is not sensitive enough (e.g., because filtering algorithm takes out known anomalies/false alarms without adequately addressing legitimate exceptions close to known false alarm locations).

4.2	**aTGMS central server filters data correctly but presents it in a way that is confusing to the end-user. [H1; H3]**	Manufacturer Has Poor/Incorrect Understanding of Who the End-User(s) Is (Are) and End-Users' Knowledge/Skills/Abilities - Railroad does not provide (correct) information about end-users and their needs to manufacturer. - Railroad does provide information about end-users but manufacturer does not take them into consideration/solicit feedback. Training - End-users do not receive training (from manufacturer or railroad) about aTGMS output.

ID	UCA Statement	Scenario Factors

5.1	**aTGMS analyst dismisses exceptions when they are NOT false alarms. [H1]**	Knowledge/Experience
		
		- Inadequate training
		   o aTGMS analyst does not know when exceptions are not false alarms.
		   o Not enough familiarity with territory
		      ▪ Remembering false alarm situation on another track (e.g., frog)
		- Misleading expectations: exception is close to a false alarm.
		   o Analyst correctly remembers that there's something at that location that triggers false alarms; but there is also a legitimate exception right next to it. Analyst ends up deleting both records because of the correct expectation there is a false alarm in that location.
		   o Missing relevant information (e.g., aTGMS analyst was not made aware of past inspection logs or special weather events that have occurred that would make this exception more likely to NOT be a false alarm)
		- Inexperience
		   o Experienced analyst is out on leave so a less experienced analyst is working; inexperienced analyst may have less intimate knowledge of the territory/aTGMS output/etc.
		
		Expectations
		
		- Analyst expects to see a lot of false alarms based on previous experience so he/she may be more likely to attribute exceptions to being FAs.
		
		Analyst Error
		
		- Analyst made a mistake in using the system.
		   o Dismissed the wrong row/exception record
		      ▪ Hit the wrong key/clicked the wrong place on screen
		   o Was trying to do something else and accidently selected the option to dismiss the exception
		
		Inadequate Mental Model
		
		- Analyst has incorrect knowledge about train location (GPS did not work correctly).
		
		Supervisory Practices/Production Pressures
		
		- aTGMS analyst dismisses exceptions that are less severe because of pressure to not report issues that cannot be fixed immediately.

6.1	**aTGMS analyst does not provide exception data to engineering department. [H1]**	Distraction/Workload - aTGMS analyst gets distracted/is overloaded and forgets to send exception data to engineering department. - aTGMS analyst thought they already sent it, but they didn't. Mental Model - aTGMS analyst thinks because exception data is not critical (e.g., no track removals/restrictions) sending the data to engineering

ID	UCA Statement	Scenario Factors
		department can wait (maybe more likely when in conjunction with other production pressures).
		Technology
		- Manufacturer sends/intends to send exception data but it does not reach the aTGMS analyst/railroad (e.g., email/server issues).
		- aTGMS analyst sends/intends to send exception data but it does not reach engineering department (e.g., Email/server issues).
		Staffing
		- aTGMS analyst is unavailable when the information comes from manufacturer/central server so the information does not get passed on to staff.
		o Analyst is unexpectedly out of the office (e.g., illness, family emergency).
		o Analyst is out of the office on planned leave.
		- There are no backup procedures in place for what to do if analyst is suddenly unable to perform his/her job (or leaves the railroad).
		Knowledge/Skills
		- aTGMS analyst makes a mistake in determining that a 2-class drop exception (those sent by the server for immediate consideration for verification) was invalid/false alarm when really it was valid.
		o Analyst does not have enough skill in reading strip chart information sent along with the exception.
		▪ Training provided on reading strip charts was not provided or was not sufficient.
		▪ Analyst has had sufficient training on reading strip charts but needs more practice using them to make real-world decisions.
		▪ Analyst is relatively new to the position or is filling in for the regular analyst.
		▪ Analyst doesn't know the territory well enough.
		Pressure to Not Sent False Alarms
		- Analysts have a slight bias toward determining that a 2-class drop exception is not actually a defect.
		o Mangers that supervise the analyst and/or track supervisors may put pressure on the analyst to reduce the number of verification requests that end up being false alarms (since they will waste time and resources).
6.2	**aTGMS analyst provides the incorrect exception data to Engineering Department. [H1; H3]**	Distraction/Workload
		- aTGMS analyst gets distracted/is overloaded and sends incorrect exception data.
		Technology
		- aTGMS analyst receives incorrect exception data from server and does not verify it before sending to engineering department.

ID	UCA Statement	Scenario Factors

		System has incorrect information and therefore provides files with incorrect name (e.g., date/time is incorrect on the server, file is saved and named with that incorrect information).
		
		Organization
		
		- Analyst sent an old file from a previous day.
		    o New exception files are put in the same computer location as older exception files.
		    o Exception file names do not immediately make it clear what day the file is from (so neither analyst nor Eng. Dept. noticed when looking at the file name).

6.3	**aTGMS analyst provides exception data in a way that is not easily used by field personnel as-is. [H1; H3]**	Mental Model - aTGMS analyst does not have a correct understanding of who will use the exception data/what their training & comprehension of the exception data is (e.g., thinks field personnel are trained on aTGMS specific data output but they are not). - aTGMS analyst does not have a correct understanding of how field personnel use the exception data. Workload - aTGMS analyst is overloaded and makes the decision to provide exception data that is not ideally formatted (e.g., only providing GPS coordinates instead of a link to google map) because wants to get data out ASAP; leaves in a lot of extra information they don't need/want to know and it makes it hard for them to find what they do need/want).

6.4	**aTGMS analyst provides exception data too late, data is not accessible to inspectors/supervisors/maintenance, allowing trains to operate over track in the meantime. [H1]**	Knowledge/skills
		
		- aTGMS analyst takes a long time to determine if the 2-class drop exception (sent by the server for immediate consideration for verification) should go out to supervisors for verification.
		    o Training provided on reading strip charts was not provided or was not sufficient.
		    o Analyst has had sufficient training on reading strip charts, but needs more practice using them to make real-world decisions.
		    o Analyst is relatively new to the position or is filling in for the regular analyst.
		    o Analyst doesn't know the territory well enough.
		
		Pressure to Not Send False Alarms
		
		- Analyst feels pressure to not send out any exceptions for verification that could be false alarms. This results in spending too much time analyzing the information/situation.

7.1	**Track inspector does not inspect track when inspection is needed (to meet frequency regulations and/or because issues could have arisen). [H1, H3]**	Weather - Because its's unsafe to inspect (e.g., tornado warning, blizzard). - Because it's impractical to inspect (e.g., changing daylight conditions – e.g., sun going down early in winter – not enough light during inspection hours). o Severe weather elsewhere changes the inspectors schedule so he/she goes to inspect where the severe weather

ID	UCA Statement	Scenario Factors
		happened instead of the track he/she would normally inspect on that day. Mental Model/Experience - Inspector does not know that inspection is due. o Record keeping is unclear so inspector doesn't know when inspection is due. o Inspector knows when inspection is due but lost track of the current date. - Inspector incorrectly thought track was already inspected. o Not the regular inspector, filling in for an inspector who was sick/on leave, did not check inspection logs to see which track had already been inspected. - Inspector knows inspection is due but thinks somewhere else is in more serious need of inspection and does not realize importance of meeting frequency requirements. Production Pressures - Dispatcher does not give inspector track time. - Dispatcher took away track time halfway through inspection causing track inspector to have to delay inspection on section of track. - Unexpected track event (derailment/signal problems/etc.) Crew Assignment/Scheduling - Track inspector calls in sick to work; replacement not available OR replacement does not know inspection due at location. - Inspector couldn't go out without protection and no one was available at the time needed. - Inspector had planned to get it done right before it was due but then was out with illness or emergency. No one else was available that was qualified to inspect that track. Workload/Distraction - Inspector got behind on inspections this period and couldn't catch back up. o Didn't pace/manage workload effectively - Inspector intended to inspect track but got distracted by other workload/got called away to verify a more pressing issue/had to stop inspection because of weather. Supervisory Practices - Supervisor tells inspector to inspect elsewhere. - Other crew called in suspected issues elsewhere (e.g., bridge & building inspectors called in to say they saw a potential defect elsewhere). - Supervisor asks inspector to check somewhere else instead. o Supervisor incorrectly thinks a different inspector or inspection vehicle will inspect territory.

ID	UCA Statement	Scenario Factors
		Lack of Proper Tools/Equipment - Tools needed are not present (e.g., forgot; broke while out and no replacement handy; could not carry). - Hi-rail vehicle is not available when needed.

7.2	**Track inspector does not conduct field verification of issue when instructed to do so and a safety issue is present. [H1]**	Incorrect Mental Model
		
		- Reads aTGMS output incorrectly and misinterprets severity (not trained to read output/output is confusing)
		- Reads location of issue incorrectly, cannot find issue
		- Understands severity but incorrectly thinks issue is not worth verifying based on type of issue
		    o Because of training/experience/production pressures/supervisory practices (inspector believes he/she would not report issue even if verified)
		
		Knowledge/Experience
		
		- Does not know how to verify (training issue)
		
		Lack of Proper Tools
		
		- Tools needed are not present (e.g., forgot; broke while out and no replacement handy; could not carry).
		- Issue not visible without being under load.
		
		Weather/Environmental Conditions
		
		- Because it's unsafe (e.g., tornado warning, blizzard).
		- Because it's impractical.
		    o Changing daylight conditions (e.g., sun going down early in winter – not enough light)
		
		Production Pressures
		
		- Dispatcher did not give track inspector sufficient track time.
		
		Distraction/Workload
		
		- Inspector got behind on inspections this period and couldn't catch back up.
		    o Didn't pace/manage workload effectively
		    o Territory too large
		- Forgets to because of workload/interrupted by Dispatch/personal reasons (fatigue, etc.)
		
		Crew Assignment/Scheduling
		
		- Inspector couldn't go out without protection and no one was available at the time needed.
		- Inspector had planned to get it done right before it was due but then was out with illness or emergency. No one else was available that was qualified to inspect that track.

ID	UCA Statement	Scenario Factors

7.3	**Track inspector inspects track using a method that is less effective or efficient for the territory (on foot vs. hi-rail) [H1; H3]**	Production Pressure
		
		- Dispatcher cannot give ample track time to do walking inspection so inspector inspects via hi-rail even though walking is most effective.
		- Engineering Department needs to move a piece of equipment and as a time-saving measure asks inspector to move it while inspecting. (May be more likely on tracks where inspector knows aTGMS operates over frequently.)
		
		Weather
		
		- Weather conditions cause inspector to need to take hi-rail (rain/snow/thunderstorm) even though walking is most effective.
		- Weather conditions cause inspector to walk (flooding, etc.) even though hi-rail is more efficient.
		
		Physical Environment
		
		- Inspector knows he/she will need to make a repair along the way and therefore needs to bring tools, so has to use hi-rail vehicle even though walking is most effective.
		- Track inspector has an injury/physical impairment that makes walking long distances difficult so needs to use hi-rail even though walking is most effective.
		- Inspector knows that going on-foot would be better for finding certain types of defects, but the territory is large and it's not possible to get through it all without using a hi-rail vehicle.
		- Inspector has been tasked with bringing along someone that's learning how to inspect and so had to change the way the inspector would prefer to inspect.
		    o Has to go on foot instead of hi-rail (as preferred) so can show the trainee certain things up close.
		    o Has to take hi-rail instead of going on foot (as preferred) because there isn't enough time to go on foot with a trainee slowing things down.
		
		Individual Factors
		
		- Inspector prefers walking inspections to hi-rail so walks the territory even though hi-rail is more efficient.
		
		Technology Problems
		
		- Hi-rail truck is broken so inspector goes on foot instead even though it's not ideal.

7.4	**Track inspector inspects or verifies track at incorrect location [H1; H3]**	Knowledge/Experience
		
		- Reads location wrong
		    o Confusing data output/not trained how to read output/instructions provide vague location (e.g., near the station platform around milepost xyz).
		    o New or fill-in employee is confused by instructions and goes to wrong location for regular inspection.

ID	UCA Statement	Scenario Factors

		Distraction/Workload
		
		- Inspector forgets where to go, was distracted by other work when being told about the issue, didn't write it down.
		
		Incorrect Mental Model
		
		- Thinks inspection is needed at incorrect location.
		  o Did not check inspection logs to see where inspection is due
		  o Is a new/different (fill-in) inspector so this is not his normal territory
		  o Prior experience leads to an expectation that this is a worsening of an issue the inspector has noticed before at a different location. This expectation shapes what the inspector hears when told or what the inspector remembers when out there.
		
		Incorrect Information
		
		- Inspector given incorrect location to inspect.
		  o Because aTGMS GPS coordinates were incorrect or aTGMS not correctly calibrated.
		  o Incorrect information given by a supervisor/other inspector/etc.
		
		Communication
		
		- Inspector was told the correct location but hears it wrong (e.g., static on the radio; radio crowding).

7.5	**Track inspector inspects track when another section of that inspector's territory is in more serious need of inspection. [H1]**	Production Pressures
		
		- Dispatcher does not give inspector track time in section that is in more serious need of inspection.
		
		Weather
		
		- Bad weather (e.g., flood) makes it impossible to conduct inspection activities in section in more serious need of inspection.
		
		Supervisory Practices
		
		- Supervisor tells inspector to inspect elsewhere.
		  o Other crew called in suspected issues elsewhere (e.g., bridge & building inspectors called in to say they saw a potential defect elsewhere).
		- Supervisor thinks a different inspector or inspection vehicle will inspect territory so asks inspector to check somewhere else.
		  o Supervisor thinks aTGMS will inspect track; does not know aTGMS is not working/being maintained.
		
		Knowledge/Experience
		
		- Inspector deliberately chooses to inspect elsewhere.

ID	UCA Statement	Scenario Factors
		○ Because thinks other location is in more serious need (thinks other location is due for inspection, has more potential defects, etc.)
		Distraction/Scheduling
		- Inspector intends to inspect both locations but runs out of track time.
		- Inspector intends to inspect both locations but gets distracted by defects/repairs elsewhere.
		Tools/Equipment/Technology
		- Inspector needed a high-rail to inspect the track in serious need and the hi-rail wasn't available.
7.6	**Track inspector inspects track too quickly to detect issues. [H1]**	**Production Pressures**
		- Dispatcher can only give inspector certain amount of track time which causes inspector to inspect too quickly.
		- Dispatcher granted enough time initially but then took the track back.
		- Dispatcher granted enough time but took too long to do it and inspector was not available during part of the time granted.
		Knowledge/Experience/Training
		- Training insufficient. Inspector does not inspect thoroughly or inspector not taught time management, spends too long in certain places leaving not enough time elsewhere.
		Territory/Physical Characteristics
		- Territory is too large/complex to cover so inspects quickly in order to complete entire inspection in one day.
		Workload/Supervisory Practices/Performance Goals
		- Supervisor tells inspector that inspector needs to do regular inspection plus verify other suspected defect but needs to inspect quickly in order to do both.
		- Inspector is incentivized to inspect quickly in order to do multiple inspections (performance incentive over safety).
		○ Because inspector is trying to avoid overtime, which he/she does not get paid for.
		Weather
		- Shortened the time available to inspect
		○ Impending weather causes inspector to rush inspection in order to not get caught in rain/snow/etc.
		○ Light too low/sun going down (less daylight in winter)

ID	UCA Statement	Scenario Factors
		Distraction/Personal - Inspector has personal issues to attend to and wants to leave work as soon as possible so inspects too quickly. - Inspector was out and now behind on inspection, tries to get caught up quickly. Technology-Related: - Inspection technology recently ran over this track and didn't find any issues related to the issue so inspector is a bit more lax in looking for those issues, may look for those things less closely and/or skip some measurements, assuming that technology already measured it and would have found any issues. - aTGMS runs over this track daily so inspector feels less pressure to inspect carefully for geometry-related defects.
7.7	**Track inspector stops inspection too soon (before necessary inspection is complete according to regulations or before a section with specific concerns has been inspected). [H1]**	Production Pressures - Dispatcher takes away track and time without verifying inspection is complete or making a plan to find additional time to complete inspection. Equipment - Hi-rail vehicle breaks down mid-way through inspection and inspector cannot complete inspection by foot. - Tool needed for inspection breaks. - Inspector wastes time trying to input inspection log data into Toughbook and does not have time to finish inspection. Incorrect Mental Model - Inspector incorrectly thinks inspection is complete. - Inspector incorrectly thinks there is no more track time remaining. Distraction/Workload - Inspector chooses to make a repair which causes him to run out of track time for remaining inspection. Weather - Impending weather causes inspector to stop inspection mid-way through in order to not get caught in rain/snow/etc. Supervisory Practices - Supervisor asks inspector to stop inspection in order to verify more pressing issue elsewhere. Emergency Interruption - Inspector had a personal emergency and needed to leave immediately (e.g., own health or health of a family member).

ID	UCA Statement	Scenario Factors
		Remaining Distance - Inspector is very close to being done and feels that the inspection is "pretty close" to complete. *(Especially combined with low expectations for a problem, below)* Low Expectations for a Problem on Remaining Section of Track - Last time the inspector inspected that part of the track, it was in very good condition; and so far the inspector has not been seeing much change in the track. Leads inspector to believe it's going to continue being fine for that last little bit of the track. - Automated inspection technologies have recently traveled over this track and the inspector knows that the technology didn't find anything of concern. Time Pressure: - Inspector is very close to the deadline and doesn't expect that there's going to be anything wrong on the last stretch of track. Decides it's better to just get it done on time and avoid getting in trouble because the risk of a problem feels low in this case. *(Especially if combined with above factor of low expectations.)*

8.1	**Track inspector does not identify a defect when a defect exists. [H1]**	Training/Experience
		
		- Track inspector does not have knowledge/experience to detect defect.
		- Track inspector used tool incorrectly.
		- Track inspector used incorrect tool.
		
		Equipment
		
		- Track inspector does not have proper tools to detect defect (e.g., walking inspection and could not carry tools, forgot, broke while out and no replacement, railroad does not supply).
		- Tool is used correctly but not functioning correctly (e.g., miscalibrated, starting to break).
		- Defect can only be detected under load.
		
		Weather
		
		- Weather conditions make it difficult for inspector to identify/measure issue in order to detect that it is a defect (e.g., snow is covering tracks, low light).
		
		Production Pressures
		
		- Dispatcher did not give track inspector track time or gave too little of it.
		- Time pressure/constraints caused track inspector to rush or not complete inspection.
		   o Spent too long repairing defects then had to rush through remaining inspection
		   o Size/complexity of territory
		   o Inefficient inspection method (walking vs hi-rail)

ID	UCA Statement	Scenario Factors
		Time pressures cause inspector to only look for certain defects (that are most visible/obvious). Inadequate Mental Model - Incorrect/insufficient/information previously communicated misleads or shapes expectations (e.g., inspection logs from supervisor/other inspector). Distraction/Workload - Inspector is distracted by personal issues or workload (by own thoughts, by someone calling/interrupting, etc.). - Inspector is tired, e.g., because has been working lots of overtime. Incorrect/Insufficient Sensory Cues Caused by Sensor Limitations - Inspector has sensory limitations that require correction to be at 100% (i.e., glasses, hearing aid). - May not be possible to detect defect with human senses.
8.2	**Track inspector identifies a defect as less severe than it is. [H1]**	Training/Experience - Track inspector does not have knowledge/experience to detect defect. - Track inspector used tool incorrectly. - Track inspector used incorrect tool. Equipment - Track inspector does not have proper tools to detect defect (e.g., walking inspection and could not carry tools, forgot, broke while out and no replacement, railroad does not supply). - Tool is used correctly but not functioning correctly (e.g., miscalibrated, starting to break). - Defect can only be detected under load. Weather - Weather conditions make it difficult for inspector to identify/measure issue in order to detect severity (e.g., snow is covering tracks, low light). Production Pressures - Inspector does not want to identify defect because will cause track to be removed/restricted and does not want dispatcher/supervisor to get angry; waits to let the next inspector or aTGMS report it. Inadequate Mental Model - Incorrect/insufficient/information previously communicated misleads or shapes expectations (e.g., inspection logs from supervisor/other inspector).

ID	UCA Statement	Scenario Factors
		Distraction/Workload - Inspector is distracted by personal issues or workload (by own thoughts, by someone calling/interrupting, etc.). - Inspector is tired e.g., because has been working lots of overtime. Because of Incorrect/Insufficient Sensory Cues Caused by Sensor Limitations - Inspector has sensory limitations that require correction to be at 100% (i.e., glasses, hearing aid). - May not be possible to detect defect with human senses

9.1	**Track inspector does not identify a maintenance condition when a maintenance condition exists and should be monitored for progression toward a safety defect. [H1; H3]**	Training/Experience
		
		- Track inspector does not have knowledge/experience to detect maintenance condition.
		- Inspector may be so focused on detecting FRA level defects that they do not look for maintenance conditions.
		- Inadequate training
		    o Inadequate OJT using measurement tools and identifying defects
		        ▪ Tool is functioning correctly, but is used incorrectly.
		    o Inadequate/incorrect knowledge of maintenance thresholds
		
		Equipment
		
		- Track inspector does not have proper tools to detect maintenance condition (e.g., walking inspection and could not carry tools, tools broken, forgot to bring, etc.).
		    o Tool is used correctly, but it's not functioning correctly (e.g., starting to break; miscalibrated).
		- Railroad does not supply adequate tool to measure that condition's maintenance threshold.
		- Maintenance condition can only be detected under load.
		
		Production Pressures
		
		- Time pressures cause inspector to only look for FRA level defects (because thinks looking for FRA defects and maintenance conditions will take too long).
		- Time pressures cause inspector to only look for obvious/visible conditions.
		
		Weather
		
		- Weather conditions make it difficult for inspector to identify/measure issue in order to detect that it is a maintenance condition (e.g., snow is covering tracks).
		
		Because of Incorrect/Insufficient Sensory Cues Caused by Sensor Limitations
		
		- Inspector has sensory limitations that require correction to be at 100% (i.e., glasses, hearing aid).

ID	UCA Statement	Scenario Factors
		- May not be possible to detect maintenance condition maintenance threshold with human senses (may be able to be measured but too subtle to the human senses to notice that something needs checked).

10.1	**Track inspector does not repair a defect, when they do not restrict or remove the track from service. [H1]**	Distraction/Workload
		
		- Track inspector intends to repair/restrict/remove but gets distracted by workload/other defect/radio communication.
		- Inspector thought he/she could do the repair, but then discovered he/she could not then inspector forgot.
		   o Didn't have everything needed (i.e., parts, tools, someone to assist)
		   o Didn't have the skill level needed for that problem
		
		Teamwork/Communication/Incorrect Process Model
		
		- Track inspector incorrectly believes someone else will repair/restrict/remove.
		- Believes maintenance gang will come while track still belongs to inspector and repair it, so no trains will operate over
		- Believes supervisor/other track inspector will call Dispatch to restrict/remove
		- Track inspector cannot repair defect (lack of tools/skills/time) but is unable to reach dispatcher by radio/phone communication to remove/restrict track.
		
		Knowledge/Experience
		
		- Track inspector does not realize that the defect requires track to be removed/restricted if not repaired.
		- Inspector thought he/she had repaired it but the repair was not complete/correct.

10.2	**Track inspector repairs defect when it affects ability to complete inspection or resulting in service delays. [H1; H3]**	Knowledge/Experience - Track inspector knows the repair will affect ability to complete inspection but thinks the repair is more important than completing inspection. - Track inspector does not have the knowledge/experience to know that doing the repair will affect ability to complete inspection. - Repair takes longer than expected, which affects ability to complete inspection. - Track inspector is new/inexperienced. - Repair is more difficult because of unanticipated circumstances/missing tools/weather. Pressures from Supervisor/Dispatcher - Pressure to repair defects since maintenance gang is unavailable/too busy and/or supervisor/dispatcher pressure inspector to not remove/restrict track. Other - Inspector thought he/she had enough time to repair and still finish inspection but then circumstances changed.

ID	UCA Statement	Scenario Factors
		o Dispatch needed to take track back. o Incoming weather made it unsafe for inspector to be on the track during allotted time.

10.3	**Track inspector repairs a maintenance condition or defect incorrectly. [H1; H3]**	Knowledge/Experience
		
		- Inadequate training for making repairs
		- Little experience making repair
		- Inspector thinks he/she had repaired it but the repair wasn't complete/correct.
		- Repair more difficult than expected
		- Repair is more difficult because of unanticipated circumstances or adjacent defects/weather.
		
		Production Pressures
		
		- Time pressures causes inspector to rush and make a mistake.
		   o Dispatcher pressuring inspector to work quickly because Dispatch needs to take track back so inspector takes shortcuts and repairs incorrectly.
		   o Pressure from supervisor to not leave issues unaddressed, even though inspector was in a hurry.
		
		Tools/Equipment
		
		- Inspector does not have adequate tools/people to make the repair.
		- Whoever last used the hi-rail vehicle used up the materials inspector needed and did not replace.
		- Inspector attempted repair without assistance but it required more than one person.

11.1	**Track inspector does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]**	Distraction/Workload
		
		- Track inspector intends to restrict but gets distracted by workload/other defect/radio communication.
		
		Teamwork/Communication/Incorrect Process Model
		
		- Track inspector incorrectly believes someone else will restrict or remove track from service.
		   o Someone (e.g., track supervisor or another inspector/foreman) was there and then left. Inspector thought they called on their way out.
		   o Inspector called supervisor and thought supervisor was going to take it from there and call Dispatch.
		- Track inspector is unable to reach dispatcher by radio/phone communication to restrict track.
		
		Knowledge/Experience
		
		- Track inspector does not realize that the defect requires track to be restricted if not otherwise addressed.
		- Was not feeling confident in his/her assessment so was stalling on calling it in
		- Inspector is filling in, waits for the regular inspector.

ID	UCA Statement	Scenario Factors
		Production Pressures - Track inspector does not want to bother/anger the dispatcher by restricting track, especially if the issue present does not seem severe and/or is borderline.

11.2	**Track inspector restricts track speed when severe issues are present and track should be removed from service. [H1]**	Knowledge/Experience
		
		- Track inspector incorrectly thinks that restricting track is adequate for the issues present (training/experience).
		- Track inspector does not know that severe issues are present.
		    o Misdiagnosed issues as less severe than they really are.
		    o Lack of proper tools to measure
		    o Used proper tools, but incorrectly.
		
		Production Pressures
		
		- Track inspector correctly diagnosis issues but restricts, rather than removes, track because of pressure from dispatcher and/or supervisor to keep trains moving.
		
		Supervisory Practices
		
		- Supervisor disagrees with inspectors assertion that track needs removed from service and so inspector defers to supervisor's opinion and restricts instead.
		
		Distraction/Workload
		
		- Inspector called Dispatch intending to remove track from service, but then was momentarily distracted/confused and ended up just asking to restrict track speed.
		
		Communication
		
		- Track inspector correctly stated to remove track from service but dispatcher misunderstood and restricted track speed instead.
		    o Because of radio issues (e.g., static, poor signal)
		    o Because of expectations (e.g., restricting speed is more common)

11.3	**Track inspector restricts track speed incorrectly (e.g., either too strict or not strict enough, or wrong location). [H1; H3]**	Knowledge/Experience/Mental Model - Inspector incorrectly thinks defect is more or less severe than it is. - Track inspector does not know correct restriction, lacks accessible reference info. - Track inspector has incorrect knowledge about track class (which determines speed restrictions). o New on territory/not qualified on territory/or hasn't inspected that territory in a long time Production Pressures - Makes restriction less restrictive so as not to slow trains/traffic too much due to pressures from dispatcher/supervisor

ID	UCA Statement	Scenario Factors

		Communication
		
		- Inspector intended to say the correct track speed/location but misspoke, saying the incorrect degree of restriction (not strict enough) or incorrect location for the restriction.
		- Inspector said the correct (more strict) track speed and at the correct location but Dispatch heard the incorrect restriction information (not strict enough) or heard the incorrect location (e.g., due to static).
		- Inspector does not or cannot call supervisor for guidance
		   ○ Doesn't want supervisor to think he/she can't handle it.
		   ○ Bad relationship with supervisor
		   ○ Can't reach supervisor – supervisor tied up or communications not working properly.
		
		Distraction/Workload
		
		- Inspector is distracted (by own thoughts, by someone calling/interrupting, etc.) and says the wrong information.

11.4	**Track inspector waits too long to restrict track speed, allowing trains to operate over track with a safety issue. [H1]**	Workload/Distraction
		
		- Track inspector busy attending to other work/distracted by phone call, etc., and forgets to call dispatcher until too much time has passed and trains have operated over track with safety issue.
		
		Incorrect Mental Model
		
		- Track inspector thinks he/she has the track long enough so can wait to call to restrict, but in fact does not have track long enough or track gets taken back.
		- Inspector believes someone else is dealing with it.
		- The inspector thinks the issue will be fixed before track is active again, but realize later that they should still tell Dispatch to restrict it.
		- They've told the engineering department and they think the engineering department will tell Dispatch.
		- They are waiting for a second opinion from their supervisor or another inspector before restricting.
		
		Communication
		
		- Track inspector unable to reach dispatcher in time
		   ○ Dispatcher busy with other work/not at desk
		   ○ Issues with radio/phone
		
		Production Pressures:
		
		- Inspector isn't comfortable restricting track (because of concern that Dispatch will give inspector a hard time then or in the future) so inspector delays taking action.
		- Inspector wants to allow a train to pass prior to restricting because Dispatch will be unhappy if that train is delayed (e.g., rush hour).

ID	UCA Statement	Scenario Factors

12.1	**Track inspector does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]**	Distraction/Workload
		
		- Track inspector intends to remove track from service but gets distracted by workload/other defect/radio communication.
		
		Teamwork/Communication/Incorrect Process Model
		
		- Track inspector incorrectly believes someone else will remove track from service.
		   o Believes supervisor/other track inspector will call Dispatch to remove track from service
		- Track inspector is unable to reach dispatcher by radio/phone communication to remove track from service.
		
		Knowledge/Experience
		
		- Track inspector does not realize that the defect requires track to be removed from service.
		   o Thinks the defect is less severe (or doesn't know it is there) and so no action is needed
		   o Thinks someone else will take an alternate action (repair or restrict speed)
		- Inspector wasn't feeling confident in his/her assessment so decided not to remove track from service (especially if aTGMS had recently run over the track and not found the issue).
		
		Production Pressures
		
		- Inspector wants to allow a train to pass prior to removing track from service because Dispatch will be unhappy if that train is delayed or rerouted.

12.2	**Track inspector removes track from service too late, allowing trains to operate over track with a safety issue in the meantime. [H1]**	Workload/Distraction - Track inspector busy attending to other work/distracted by phone call etc. and forgets to call dispatcher until too much time has passed and trains have operated over track with safety issue. Communication/Teamwork - Inspector cannot reach dispatcher in time (dispatcher busy/issues with radio). - Inspector thinks someone else will coordinate with Dispatch, e.g., supervisor or maintenance gang. Incorrect Mental Model - Track inspector thinks he/she has the track long enough/no other trains will operate on the track for a long time so can wait to call to remove track from service. - Inspector is unsure of severity and waiting on a supervisor or second inspector's opinion before removing track from service. Communication - Track inspector unable to reach dispatcher in time.

ID	UCA Statement	Scenario Factors
		o Dispatcher busy with other work/not at desk o Issues with radio/phone

13.1	**Track inspector does not log a defect when a defect is present. [H1; H3]**	Technology
		
		- Track inspector intends to/tries to log a defect but does not.
		    o The technology (e.g., Toughbook) is difficult to use and defect does not get logged.
		    o The technology requires you to hit save (does not automatically save when you close out of a record/report) and the inspector does not.
		- Inspector doubts own assessment of the geometry issue because aTGMS just ran over the same track and didn't find the issue.
		
		Distraction/Workload
		
		- Inspector forgets.
		    o Intends to log a defect but is too busy during the inspection (e.g., because dispatcher could only give a short window of track time) so decides to wait and log at the end of inspection but forgets
		    o Something or someone interrupts inspector and inspector forgets (e.g., someone calls with an emergency).
		
		Knowledge/Experience
		
		- Inspector does not know there is a defect to log (see UCA 9.1).
		
		Communication/Teamwork
		
		- Inspector calls supervisor or maintenance gang to tell them about defect and arrange for a repair but does not log the defect because thinks it will be resolved.

13.2	**Track inspector logs a defect incorrectly–with incorrect or incomplete information that limits ability to investigate or repair. [H1; H3]**	Technology
		
		- Track inspector intends to/tries to log a defect correctly but the technology (e.g., Toughbook) is difficult to use and defect does not get logged correctly/completely.
		
		Operator Error
		
		- Track inspector logs defect incorrectly by mistake.
		    o Because of a typo/bad handwriting
		    o Because he/she waited to log it (until later in the shift or when the shift was done) and some of the information was misremembered.
		- Track inspector logs defect incompletely by mistake.
		    o Because he/she forgot to fill in certain information.
		        ▪ Because was in hurry and got distracted
		        ▪ Because doesn't have a protocol for double checking before submitting log
		        ▪ Because inspector has logged this issue before (e.g., may have logged it as a maintenance condition several times before it became a defect) and so is used

ID	UCA Statement	Scenario Factors
		to filling it in and got a little sloppy (especially if trying to move quickly).
		Knowledge/Experience/Training
		- Track inspector logs defect correctly but has incorrect/incomplete information, e.g., incorrect GPS location or defect type, because of inexperience/training.

13.3	**Track inspector spends too long logging defect when doing so during an inspection, causing them not to finish, or need to rush inspection; or causing delays to service. [H1; H3]**	Technology
		 - Track inspector wastes time trying to log defect correctly because of the technology (e.g., Toughbook).
		  o Technology freezes, have to re-start logging multiple times.
		  o Technology interface difficult to figure out correct way to input.
		 - Lack of technology, e.g., inspector needs to handwrite everything which can be time consuming.
		
		 Knowledge/Experience
		 - Inspector is new/inexperienced and does not know shorthand/tips/tricks for logging quickly.
		  o E.g., maybe experienced inspectors will jot down quick notes during inspection and then when returning to field office complete the inspection log, to ensure adequate time to complete inspection – because this inspector is new, does not know to do this, writes out complete descriptions of defects while on the track.
		  o Inspector includes too much information, more than is needed/useful, which takes longer.
		 - Inspector didn't get sufficient training on the computer system being used.

14.1	**Track inspector does not log a maintenance condition when it is detected and needs monitored for progression towards a safety defect. [H1]**	Supervisory Practices
		 - Supervisor prefers/pressures inspector not to log these types of issues.
		  o Because it makes the defect logs too long/cumbersome to read and prioritize.
		  o Because supervisor doesn't want inspector to log more things than can be addressed.
		
		 Inspector Chooses to Ignore Protocol/Training
		 - Inspector doesn't think it's important because it's only barely over the maintenance threshold of a maintenance condition.
		  o Inspector chooses to not report the geometry condition since it's not safety-critical (not a defect) and aTGMS will be coming through soon. Will let aTGMS report it. (Particularly likely if inspector is concerned that supervisor will be unhappy with inspector for reporting more than can be fixed/kept track of.)
		 - Inspector knows it won't be repaired anytime soon anyway.
		 - Inspector knows that once it gets reported, he/she will have to write it up at every inspection for quite a while (before it's finally

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		repaired) so inspector doesn't like to report conditions that seem very mild.
		- Inspector feels that he/she can simply keep an eye on it and monitor it on their own without having to do the work of logging it each time (especially when issue is barely over maintenance threshold and logging is time consuming and inspector may have plenty to write up each time anyhow and not want to keep adding more).
		
		Knowledge/Experience
		
		- Inspector does not realize that it is helpful for the engineering department to know of the maintenance condition so it can be monitored.
		
		Workload/Distraction
		
		- Inspector intends to log the maintenance condition but because it is low priority waits until end of shift and gets distracted and forgets.
		
		Technology
		
		- Inspector intends to log the maintenance condition but technology is being difficult and so inspector does not want to waste any more time and thinks since it is only a maintenance condition he/she does not need to waste time trying to input.
		- Inspector intends to log it but the technology requires you to hit save (does not automatically save when you close out of a record/report) and so the inspector does not actually log it.
		  - Overreliance on technology
		     o Inspector chooses not to log it because he/she doubts own assessment of the geometry issue because aTGMS just ran over the same track and did not find anything there.

14.2	**Track inspector logs a maintenance condition incorrectly, with incorrect or incomplete information that limits ability to investigate or repair. [H1; H3]**	Technology
		
		- Track inspector intends to/tries to log a maintenance condition correctly but the technology (e.g., Toughbook) is difficult to use and defect does not get logged correctly/completely.
		
		Operator Error
		
		- Track inspector logs maintenance condition incorrectly by mistake.
		    o Because of a typo/bad handwriting
		    o Because he/she waited to log it (until later in the shift or when the shift was done) and some of the information was misremembered.
		- Track inspector logs maintenance condition incompletely by mistake.
		    o Because he/she forgot to fill in certain information.
		       ▪ Because was in hurry and got distracted
		       ▪ Because doesn't have a protocol for double checking before submitting log

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		• Because inspector has logged this maintenance condition before several times and is so used to filling it in that he/she got a little sloppy (especially if trying to move quickly).
		   o Track inspector logs maintenance condition incompletely on purpose.
		      • Inspector has logged it in detail many times before and assumes that if someone is ready to fix/look at it, they can pull up the info in the other records. (May be especially likely if inspector is in a hurry and inspector thinks its unlikely someone will be ready to address it yet.)
		
		Knowledge/Experience
		
		- Track inspector logs maintenance condition correctly but has incorrect/incomplete information, e.g., incorrect GPS location or condition type, because of inexperience/training.

14.3	**Track inspector spends too long logging maintenance conditions when doing so during an inspection, causing them not to finish inspection, or to need to rush inspection; or causing delays to service. [H1; H3]**	Technology
		
		- Track inspector wastes time trying to log maintenance condition correctly because of the technology (e.g., Toughbook).
		   o Technology freezes, have to re-start logging multiple times.
		   o Technology interface difficult to figure out correct way to input.
		- Lack of technology, e.g., inspector needs to handwrite everything, which can be time-consuming.
		   o Technology that is user-friendly can be easy to input condition information (e.g., pre-populated fields, uploading pictures, carryover conditions from previous inspection logs that have not been repaired so do not need to re-enter).
		
		Knowledge/Experience
		
		- Inspector is new/inexperienced and does not know shorthand/tips/tricks for logging quickly.
		   o E.g., maybe experienced inspectors will jot down quick notes during inspection and then when returning to field office complete the inspection log, to ensure adequate time to complete inspection – because this inspector is new, does not know to do this, writes out complete descriptions of defects while on the track.
		   o Inspector includes too much information, more than is needed/useful, which takes longer.
		- Inspector didn't get sufficient training on the computer system being used.

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15.1	**Engineering Department does not choose to install aTGMS on a track that is most likely to have geometry-related defects (e.g., due to heavy traffic). [H1]**	Environment/Technology - Terrain on the track most likely to have geometry-related defects is also more likely to have environmental conditions that prohibit aTGMS sensors from collecting data (e.g., more prone to flooding). - aTGMS must be installed on locomotives, but different territories use different locomotive power types so not all aTGMS-equipped locomotives can be used on all territories. Production - Track that is most likely to have geometry-related defects contains more track that requires trains to go at speed that is unable to pick up data (e.g., lot of curves/terminals/stations). Mental Model - Engineering Department does not know which track is most likely to have geometry related defects. - Engineering Department does not consider this in determining where to install aTGMS. - Engineering Department uses incorrect data to determine which track is most likely to have geometry related defects (intends to install aTGMS on track most likely to have geo related defects but chooses incorrectly).
15.2	**Engineering Department does not choose to install aTGMS on track for which it is difficult for inspectors to get track time. [H1; H3]**	Environment/Technology - Terrain on track that is most likely to be difficult to get track time on is also more likely to have environmental conditions that prohibit aTGMS sensors from collecting data (e.g., more prone to flooding). Production - Track that is most likely to be difficult to get track time on contains more track that requires trains to go at speed that is unable to pick up data (e.g. lot of curves/terminals/stations). Mental Model - Engineering Department does not know which track is most likely to be difficult for inspectors to get track time / does not consider this in determining where to install aTGMS (do not coordinate with inspectors/dispatchers to obtain information). - Engineering Department uses incorrect data to determine which track is most difficult to get track time on (intends to, but chooses incorrectly).
16.1	**Engineering Department does not provide updated parameter information to manufacturer when the railroad changes the track class or where it will be used. [H1]**	Process Model - There is no standardized process in place for working with the manufacturer to move/re-install aTGMS. - Railroad maintenance department thinks they can simply move/re-install on a new train, does not consider parameters?

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16.2	**Engineering Department provides incorrect parameters to manufacturer. [H1; H3]**	Mental Model - Engineering Department has incorrect parameters for track. - Engineering Department does not know what parameters are required.

17.1	**Engineering Department does not train/employ enough inspectors. [H1]**	Training Resources
		
		- Lack of applicants
		   o Poor financial incentives to become track inspector.
		   o Poor working conditions for track inspectors (physically demanding, difficult schedule)
		   o Too many constraints on who can bid for track inspector job.
		- Not enough foremen hired to grow the ranks sufficiently.
		- Enough foremen are hired (or as many as possible), but too many foremen leaving railroad (for jobs at other railroads or for other careers).
		- Not enough foremen are decided to be ready/qualified/able to take on inspection duties.
		- Engineering Department does not have enough resources (money, training instructors) to train enough inspectors.
		
		Job Assignment
		
		- Railroad loses inspectors to other territories shorty after getting them trained on it. Results in constant need for new training.
		
		Applicants Cannot Pass Track Inspector (MOW) Exam
		
		- Training not up to par/exam too difficult
		
		Supervisory Practices
		
		- Engineering Department has incorrect beliefs about how many inspectors they need.

17.2	**Engineering Department does not train inspectors with regard to track inspection technology. [H1; H3]**	Incorrect Mental Model
		
		- Engineering Department believes inspectors do not need to understand how track inspection technology works and/or read inspection technology output.
		- Inspectors often switch jobs soon after passing exam so engineering department believes that training them on track inspection technology is too costly.
		- Because engineering department does not understand how it would be useful.
		   o Because they have not spent enough time in the field since these technologies have been deployed and their output worked with on a regular basis.
		   o Because no one is passing up the information that it would be helpful for inspectors to have a better understanding of how it works.
		
		Resources
		- Engineering Department does not have resources to train inspectors with regard to track inspection technology.
		- Inadequate financial resources, missing training instructors who understand track inspection technology.

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17.3	**Engineering Department provides inspectors with unclear, incorrect, or incomplete training. [H1; H2]**	Limitations in Trainer Knowledge/Skill/Abilities
		
		- Trainers are not up-to-date on proper training/inspection methods.
		- Trainers lack experience/not qualified (e.g., have never worked as inspectors themselves).
		
		Training Does Not Include Enough Hands-On Experience to Properly Train Inspectors Regarding OTJ Inspection Methods
		
		- Inadequate resources
		  o Trainers are not significantly more experienced than trainees.
		  o Not enough trainers available because people don't want to do it/lack of incentive to become a trainer.
		  o Not enough time to spend on OJT because it's costly to double up and railroad wants new inspectors to go work their own territories.
		- Railroad relies on informal mentorship.
		  o Incorrect beliefs about how long OJT should be.
		  o Railroad thinks current OJT is adequate/informal mentorship is sufficient.
		
		Incomplete Curriculum Does Not Cover Everything Inspector Needs
		
		- Because curriculum has not been updated as the inspection system has evolved.
		  o E.g., does not include things like how to understand the output generated from automated systems nor giving inspectors a general sense of how automated systems work. That info wasn't needed when course was developed or when instructor started teaching.
		- Because some things are expected to be intuitive so they don't make it into training.
		  o E.g., not enough training on software where they log in defect records.
		- Because certain topics, though important, are awkward to cover explicitly because to do so formally admits the existence of problems in the system.
		  o E.g., how to handle it in the event someone tries to pressure the inspector into not logging something/not taking the level of action that's needed (e.g., a two class drop/not giving you access to the track).
		
		Training Materials Contain Inaccuracies
		
		- Typographical errors
		- Outdated information (e.g., railroad now uses stricter maintenance standards than when materials were developed)
		- Lack of resources to update training materials.

17.4	**Engineering Department trains inspectors too early resulting in loss of knowledge before working in the field [H1; H2]**	Engineering Department Has Incorrect Beliefs - About how many inspectors they will need. Incorrectly believe many inspectors will retire/bid on different jobs. - About how long inspectors can retain knowledge without using it

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		Training - Training offered very infrequently, so inspectors may have to take training early to ensure they can take it before it's needed. Scheduling Practices - Inspectors trained and qualified on territory but may not work it regularly; then have forgotten knowledge before being asked to fill in or being assigned to that territory.
17.5	**Engineering Department (re) trains inspectors too late, resulting in loss of knowledge in between training. [H1; H2]**	Incorrect Beliefs/Priorities - Engineering Department has incorrect beliefs about how long inspectors can retain knowledge without using it. - Engineering Department doesn't see refresher training as very important and believes inspectors don't really need it. It's viewed as mostly a formality. Resources - Engineering Department lacks adequate resources to do requalification training.

17.6	**Engineering Department trains inspectors too quickly on practical inspection skills. [H1]**	Resources
		
		- Engineering Department does not have resources to properly train inspectors.
		- Training is not long enough to adequately train.
		- Training does not include enough hands-on experience to properly train inspectors with regard to on the job inspection methods.
		- Because they don't have enough funding to train longer.
		  o Because the number of people they have to train is so high (given job bidding and frequency of people changing jobs) that they can't afford to do longer training for all those people.
		
		Incorrect Beliefs
		
		- Engineering Department incorrectly believes that training is long enough to adequately train inspectors.
		  o Because they believe they covered everything.
		  o Because they believe that that classroom training isn't that important and most of important learning happens OTJ anyhow.

18.1	**Engineering Department assigns territory to someone with low likelihood of finding issues. [H1]**	Lack of Resources
		
		- Do not have enough inspectors who are trained on/familiar with territory.
		- Inspector trained on that territory is not present/available.
		
		Knowledge/Beliefs/Mental Models
		
		- Engineering Department believes that inspector is trained/familiar enough with territory when he/she is not.
		  o Believes just because inspector received training they are suitable, but training does not produce adequately trained/experienced inspector.
		  o Receives incorrect feedback from inspector supervisor or trainer that inspector is qualified/completed training (e.g.,

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		completed classroom training but are doing OJT with mentor but get sent to do a real inspection). o Inspector personnel files do not contain information about which territory they are familiar, or information is unclear. - Engineering Department is unaware that this inspector's skill/knowledge of inspection is not up to par (regardless of the territory). - Engineering Department feels that this is an emergency and they need someone out there ASAP and this is the inspector that can be there the fastest. Job Assignment - It's out of the hands of the Engineering Department. Someone that's not a strong inspector bid onto a challenging territory. - Scheduling policies preclude more qualified inspectors from working (because of amount of hours they have already worked).

19.1	**Engineering Department does not assign non-routine inspection when there is reason to suspect a defect. [H1]**	Production Pressures
		
		- Engineering Department does not want to take track and time and disrupt train service.
		
		Communication and Mental Models
		
		- Engineering Department does not know non-routine inspection is needed.
		    o Because they did not receive information about suspected track geometry defects, or received the information too late.
		- Engineering Department unable to reach inspector in time.
		    o Phone/radio not working
		    o Inspector too busy to pick up phone/radio.
		- Engineering Department receives incorrect information about track condition.
		    o Other inspectors (e.g., B&B, C&S) did not recognize a track issue that should have merited special inspection.
		    o Incorrect aTGMS data does not reflect an issue that should have merited special inspection.
		- Engineering Department receives correct information about defect but interprets it incorrectly.
		    o Interprets it to believe it does not need to be inspected
		    o Interprets it to believe it will be inspected by other means (TGMS/other inspection vehicle/maintenance department)
		
		Inadequate Resources
		
		- Lacking inspector availability
		    o Inspector on that territory is already busy or behind for that period.
		    o Territories very large and/or complex
		    o No other inspectors available (short-staffed)
		- Maintenance crews already have too much on their plate and supervisor doesn't want to add to the list and risk having known defects go unaddressed.

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		Staffing/Scheduling
		
		- Engineering Department does not have an available inspector to assign non-routine inspection to.
		- Inspector on that territory is already swamped, possibly behind for that period.
		- Not enough available inspectors qualified on the territory.
		- Not enough available inspectors with experience to look for specific defect.
		- No other inspectors available
		    o Understaffed
		    o Too much on inspectors' plates; territories very large and/or complex
		- Maintenance crews already have too much on their plate and supervisor doesn't want to add to the list and risk having known defects go unaddressed.
		
		Workload
		
		- Engineering Department gets busy/distracted by other issue to contact inspector in time.
		    o Engineering Department meant to assign the non-routine inspection but then got busy/distracted and forgot.
		    o Supervisors are understaffed/oversee too large of a territory.

19.2	**Engineering Department assigns a non-routine (substitute) inspection to an inspector who is not trained on/familiar with the territory. [H1]**	Engineering Department Does Not Have Adequate Resources
		
		- Do not have enough inspectors who are trained on/familiar with territory.
		- Inspector who IS trained on that territory is not present/available (e.g., because of schedule / hours already worked).
		
		Incorrect information/beliefs
		
		- Engineering Department incorrectly believes that inspector is trained/familiar with territory.
		    o Believes just because inspector received training they are suitable
		    o Receives incorrect feedback from inspector supervisor or trainer that inspector is qualified/completed training (e.g., they completed classroom training but are doing OJT with mentor but get sent to do a real inspection)
		    o Inspector personnel files do not contain information about which territory they are familiar, or information is unclear.
		- Engineering Department feels that this is an emergency and they need someone out there ASAP and this is the inspector that can be there the fastest.

19.3	**Engineering Department assigns a non-routine inspection at certain location when other location is in more serious need of inspection. [H1]**	Physical Environment - The other location's environmental conditions are not conducive to inspection (e.g., track is flooded). Supervisory Practices - Engineering Department prioritizes a potential safety issue over meeting regulations.

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		o The track getting the non-routine inspection is a situation where there is the potential or strong likelihood for something very serious and that was given precedent over being a little late on getting the mandated inspection done.
		- Engineering Department is trying to make good use of maintenance crew time.
		   o The maintenance crew is already working right near the area of the non-routine inspection and could quickly address any issue uncovered
		   o Engineering Department is trying to make good use of limited crew time so they don't spend all their time traveling around.
		- Engineering Department thinks it's unlikely that an FRA inspector will show up at the other track that's due soon before they can get to it.
		
		Knowledge/Communications
		
		- Engineering Department has lost track of when that inspection is due so just sends inspector out to deal with that non-routine issue without thinking about the fact inspector has a track in serious need.
		- Engineering Department doesn't know/realize that there's another area is greater need of inspection. (E.g., inspector is somewhat new and doesn't feel comfortable telling his/her boss that he/she can't go do the non-routine inspection.)
		
		Missing or Wrong Feedback/Information
		
		- Engineering Department receives incorrect information about conditions at the two locations.
		   o From inspector/supervisor e.g., after special weather event
		- Engineering Department receives correct feedback/information but interprets it incorrectly/ignores it.
		- Engineering Department does not receive feedback/information before assigning inspection (delayed/never received).
		
		Traffic/Production Pressure
		
		- Traffic influences where Engineering Department sends inspection.
		   o Because traffic in the non-routine area is higher so they are concerned that the potential issues there are more likely to get worse quickly and/or would result in greater likelihood of having a derailment.
		   o Because traffic in the area that is in more serious need of inspection (to meet FRA regulations) is so backed up that they don't think they'll be able to get in so targeting the non-routine area rather than waiting around and wasting time where they don't think they can get track and time.

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19.4	**Engineering Department assigns non-routine inspection at incorrect or unclear location. [H1; H3]**	Missing or Wrong Feedback/Information
		
		- Engineering Department receives incorrect information about: track condition at particular location (e.g., that track is degraded) OR receives incorrect location information – e.g., wrong GPS location.
		  - Inspector handwriting is illegible.
		  - Inspector incorrectly enters data into Toughbook because Toughbook interface is difficult.
		  - TGMS dataset is difficult to interpret.
		- Engineering Department receives correct feedback/information but interprets it incorrectly/ignores it.
		- Engineering Department does not receive feedback/information before assigning inspection (delayed/never received).
		- Missing or wrong feedback/information about where inspection is necessary according to FRA regulations.
		
		-Communication Errors:
		
		- Engineering Department accidently said the wrong thing – meant to say the correct location information but then misspoke.
		- Engineering Department said the location in a way that could have different interpretations.
		  - Because inspector did not repeat back his/her own understanding for confirmation, this miscommunication went undetected.
		
		Skill/Experience
		
		- Engineering Department employee does not have enough experience.
		  - Not enough field-experience to know best way to explain it to inspector.
		  - Not enough supervisory experience to know best way to assign non-routine inspections clearly.

19.5	**Engineering Department assigns a non-routine inspection by method (on foot/hi-rail/TGMS) less effective or efficient for the territory. [H1; H3]**	Production Pressures - Engineering Department needs to move a piece of equipment and as a time saving measure asks inspector to move it while inspecting. - Dispatcher unable to give adequate time for most effective inspection method (e.g., dispatcher cannot give enough time for a walking inspection but can give enough time for a hi-rail inspection). - It's not possible to do via the preferred method right now and the railroad wants to have a record of having followed up on the non-routine situation (even if the inspection might not be very effective). Knowledge/Experience - Engineering Department does not know effective/efficient methods for each territory. - Engineering Department employees have never worked as track inspectors/have not worked as track inspectors for a long time.

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		Weather - Impending weather forces engineering department to assign non-routine inspection a certain method (i.e., impending thunderstorms so need inspection to be quick/covered so assign hi-rail.
20.1	**Engineering Department does not coordinate with Dispatch when needed or at incorrect location to help get track and time or plan outages for inspectors. [H1; H3]**	Teamwork/Communication - Engineering Department does not know that they need to help coordinate with Dispatch. - Inspector does not inform supervisor that they need help obtaining track and time. o Bad relationship with supervisor o Can't reach supervisor by phone o Inspector doesn't want to look like he/she can't handle it; wants to try to deal with it on his/her own. Supervisory Practices - Engineering Department does not think it is their job to help coordinate with Dispatch. - Has a bad rapport with dispatcher and does not want to coordinate with them; possibly due to past disagreements on prioritizing schedule vs. inspection - Thinks the inspector should handle coordination with Dispatch (maybe it isn't explicitly part of supervisor's job, or supervisor is not taught to do it) Workload - Engineering Department intends to but gets busy/distracted by other issue to coordinate with Dispatch. o Supervisors are understaffed/oversee too large of a territory. o It's a particularly busy time for supervisor and/or something has happened that impacts traffic flow/Dispatch (e.g., weather slowing down traffic, derailment elsewhere in system that same dispatcher deals with). Communication - Engineering Department unable to reach Dispatch o Phone/radio not working o Dispatcher too busy to pick up phone/radio.
21.1	**Engineering Department does not restrict track speed when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track nor by removing it from service). [H1]**	Communication/Teamwork - Engineering Department incorrectly believes someone else will, or already did, restrict track (e.g., track inspector). - Engineering Department incorrectly believes maintenance crew was going to fix it immediately, therefore track does not need to be restricted. - Engineering Department thinks no more trains will operate on track before maintenance gang has a chance to repair it, so does not bother calling dispatcher to restrict speed. - Engineering Department is unable to reach dispatcher by radio/phone to restrict track.

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		- Engineering Department receives information from track inspector about safety issue but does not realize that track needs to be restricted and/or does not realize it is their job to call Dispatch to restrict track in this case.
		   o Engineering Department doesn't think it's their job because the inspector usually takes care of this.
		   o Inspector did not clarify that they expected the engineering department to restrict track if needed.
		
		Distraction/Workload
		
		- Engineering Department intends to restrict but gets distracted by workload/other communication.
		
		Technology
		
		- Recent aTGMS output shows the defect as only a maintenance condition, so engineering department is hesitant to restrict track until they can get another inspector out there to take a look.
		   o Because first inspector that was relatively inexperienced
		   o Because management has a bias to always trust the technology.
		
		Production Pressures
		
		- Engineering Department does not want to bother/anger the dispatcher by restricting track speed if the issue does not seem severe and/or is borderline.

21.2	**Engineering Department does not restrict track speed when aTGMS finds a safety issue that requires speed restriction. [H1]**	Communication/Teamwork - aTGMS analyst does not tell engineering department that a defect exists that requires track to be restricted. - Engineering Department incorrectly believes someone else will, or did, restrict track (e.g., aTGMS operator). - Engineering Department incorrectly believes maintenance crew was going to fix it immediately, therefore track does not need to be restricted. - Engineering Department thinks no more trains will operate on track before maintenance gang has a chance to repair it, so does not bother calling dispatcher to restrict speed. - Engineering Department is unable to reach dispatcher by radio/phone to restrict track. - Engineering Department waiting for inspector to verify before restricting track speed. - Engineering Department receives information from aTGMS analyst about safety issue but does not realize that track needs to be restricted and/or does not realize it is their job to call Dispatch to restrict track. o Engineering Department employee may not realize aTGMS analyst doesn't call Dispatch directly (e.g., employee is new, or used to working with a TGMS operator who DID call Dispatch and would just notify Eng. Dept.).

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		Distraction/Workload - Engineering Department intends to restrict but gets distracted by workload/other communication.

21.3	**Engineering Department restricts track speed when severe safety issues are present that require track to be removed from service. [H1]**	Knowledge/Experience
		
		- Engineering Department does not realize that severe safety issues require track to be removed from service.
		    o Incorrect knowledge about the defect's severity
		    o Incorrect knowledge about track class at that location
		    o Incorrect knowledge about what needs to be done/regulation.
		
		Production Pressures
		
		- Engineering Department supervisor knows track should be removed from service but knows Dispatch and/or supervisor's own manager will get angry if track is removed from service/traffic disrupted so restricts track instead.
		
		Supervisory Practices
		
		- Supervisor disagrees with inspectors assertion that safety issue is a defect that requires track to be removed from service, thinks it is less severe, so restricts instead.
		
		Distraction
		
		- Engineering Department called Dispatch intending to remove track from service, but then was momentarily distracted/confused or too busy and ended up just asking to restrict track speed.
		
		Communication
		
		- Engineering Department correctly stated to remove track from service but dispatcher misunderstood and restricted track speed instead.
		    o Because of radio issues (e.g., static, poor signal)
		    o Because of expectations (e.g., restricting speed is more common)

21.4	**Engineering Department restricts track speed incorrectly (e.g., either too strict or not strict enough or at wrong location). [H1; H3]**	Knowledge/Experience
		
		- Engineering Department does not know correct restriction and lacks readily accessible reference information.
		- Engineering Department has incorrect knowledge about track class (which determines speed restrictions).
		- Engineering Department employee is new in the position/has little experience, or has not been trained as an inspector; or hasn't worked as an inspector in a long time.
		- Engineering Department is restricting based on information gathered from aTGMS.
		    o Reads output incorrectly or as a different defect (therefore restricts incorrectly) or at incorrect location
		    o aTGMS output for GPS location of defect, or severity reading, is incorrect.

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		Supervisory Practices - Supervisor disagrees with inspectors assertion of how track should be restricted and overrides inspector (but inspector was correct). Communication/Error - Engineering Department receives incorrect information from inspector – e.g., static on the radio, misspeak, inspector has incorrect information. - Engineering Department receives correct information from inspector/aTGMS but information is incorrect when it is transmitted to dispatcher – e.g., static on the radio, misspeak. - Engineering Department received the correct information from inspector/aTGMS and said the correct (more strict) track speed and at the correct location, but Dispatch heard the incorrect restriction information (not strict enough) or heard the incorrect location. - Engineering Department reads aTGMS output incorrectly. o No training or experience on reading output; aTGMS analyst usually reads and interprets the output but is on vacation/sick. Distraction/Workload - Engineering Department called Dispatch with the correct track restriction information and location in mind, but then was momentarily distracted/confused and ended up saying the wrong information.

21.5	**Engineering Department waits too long to restrict track speed, allowing trains to operate at track speed over track with a safety issue [H1; H3]**	Communication/Teamwork
		
		- Engineering Department cannot reach dispatcher in time because dispatcher is busy or because of issues with radio/phone.
		
		Workload/Distraction
		
		- Engineering Department busy dealing with other issues, put off calling dispatcher because of more pressing issues.
		    o Engineering Department is understaffed.
		
		Incorrect Mental Model
		
		- Engineering Department employee does not realize urgent nature of calling the dispatcher, thinks it can wait until other work is complete.
		    o Because engineering department is inexperienced or has no experience working as track inspector to understand implications of defect.
		    o Because engineering department employee was not well trained on this.
		    o Because engineering department employee hasn't worked as an inspector in a long time and knows other priorities as a supervisor are urgent.

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		- Engineering Department employee is unsure of the severity of the defect and waiting to restrict track speed until they can get a second opinion.
		   ○ Because they don't have confidence in the first assessment.
		   ○ Because no actual measurements were taken so they do not have actual numbers to compare with requirements until someone can verify.
		
		Engineering Department Believes Someone Else Is dealing with It and Realizes Too Late
		
		- The issue has been assigned to a maintenance crew to fix right away, and so Engineering Department doesn't think it needs to be reported to Dispatch as well; they think it will be fixed before track is active again.
		- They assume inspector will tell Dispatch, so they don't have to.
		   ○ Inspector and Engineering Department miscommunicate about who is going to call.
		
		Production Pressures
		
		- Engineering Department waits to restrict to let more trains pass through the track quickly (E.g., during rush hour).

22.1	**Engineering Department does not remove track from service when a safety issue is present and not otherwise addressed (i.e., not addressed through repairing track and too severe to address through restricting track speed). [H1]**	Knowledge/Experience
		
		- Engineering Department does not realize that severe safety issues require track to be removed from service.
		   ○ Incorrect knowledge about the defect's severity
		   ○ Incorrect knowledge about track class at that location
		   ○ Incorrect knowledge about what needs to be done/regulation.
		
		Communication
		
		- Engineering Department thinks someone else will remove track (inspector or maintenance gang).
		- Engineering Department thinks no more trains will operate on track before maintenance gang has a chance to repair it, so does not bother removing track from service.
		- Engineering Department is unable to reach dispatcher by radio/phone to remove track from service.
		
		Production Pressures
		
		- Engineering Department knows track needs to be removed but does not because of production knows Dispatch will get angry if track is removed from service.
		
		Supervisory Practices
		
		- Supervisor disagrees with inspectors assertion that safety issue is a defect that requires track to be removed, thinks it is less severe.

ID	UCA Statement	Scenario Factors
		Distraction/Workload - Engineering Department intends to remove track from service, but gets distracted by workload/other issue/radio communication.

22.2	**Engineering Department removes track from service at incorrect location. [H1]**	Communication/Error
		
		- Engineering Department receives incorrect information from inspector – e.g., static on the radio, misspeak, inspector has incorrect information.
		- Engineering Department receives correct information but information is incorrect when it is transmitted to dispatcher – e.g., static on the radio, misspeak.
		- Engineering Department receives correct information from inspector/TGMS but then Dispatch heard the incorrect location for where track should be removed.
		    o Because Dispatch did not repeat it back again, it went unnoticed.
		
		Expectations
		
		- Engineering Department recalls information about other defects and thinks/expects that is the location where track should be removed.
		
		Distraction/Workload
		
		- Engineering Department called Dispatch with the correct location information for where to remove track from service in mind, but then was momentarily distracted/confused and ended up saying the wrong information.
		
		Technology
		
		- Engineering Department is removing track from service at that location based on information gathered from aTGMS.
		    o Reads correct location information incorrectly
		        ▪ Because was not given sufficient training
		        ▪ Because not enough experience (usually someone else does this, but that person is unavailable)
		        ▪ Because it is confusing.
		    o Location information provided by aTGMS is incorrect.

22.3	**Engineering Department waits too long to remove track from service, allowing trains to operate over track with a safety issue in the meantime. [H1]**	Knowledge/Experience
		
		- It takes a while for Engineering Department to realize that track needed to be removed from service.
		    o Insufficient knowledge about defect's severity
		    o Insufficient knowledge about track class at that location
		    o Insufficient understanding of/experience with aTGMS output

ID	UCA Statement	Scenario Factors

		Communication/Teamwork
		
		- Engineering Department cannot reach dispatcher in time (dispatcher busy/issues with radio).
		- Engineering Department thinks someone else will remove track from service, e.g., track inspector or maintenance gang.
		
		Workload/Distraction
		
		- Engineering Department busy dealing with other issues, puts off calling dispatcher because of more pressing issues.
		  o Engineering Department is understaffed.
		
		Incorrect Mental Model
		
		- Engineering Department employee does not realize urgent nature of calling the dispatcher, thinks it can wait until other work is complete.
		  o Because engineering department is inexperienced or has no experience working as track inspector to understand implications of defect.
		
		Production Pressures
		
		- Engineering Department waits to remove track to let more trains pass through the track quickly/until not so busy.
		  o E.g., it is rush hour, so they wait until rush hour is over to remove track.

23.1	**Dispatcher does not grant track and time to inspector when visual inspection is needed. [H1]**	Production Pressures/Workload
		
		- Dispatcher is tired of inspector going out and finding issues on the track which will potentially cause track restrictions or removals.
		- Dispatchers incorrectly believe on-time performance is more important than inspection/safety.
		  o Because performance goals and/or training prioritize on-time performance over safety (incorrect feedback).
		- Evaluation of dispatcher performance focus more on on-time performance than safety.
		- Dispatcher incorrectly believes aTGMS reduces need for / urgency of visual inspections.
		
		Relationship to Inspectors
		
		- Dispatcher hopes inspector will give up on waiting and try another day when someone else is working Dispatch for that track.
		  o Because dispatcher believes inspector is likely to hold up traffic based on past experiences with him/her inspecting slowly and/or judging defects very strictly so that speeds often need to be reduced or track taken out of service more often than with other inspectors.
		  o Because the dispatcher knows that he/she will have a hard time getting track back from that inspector if needed.
		  o Because that dispatcher does not like to work with inspectors at all.

ID	UCA Statement	Scenario Factors

		o Because the dispatcher believes that it is not that hard for inspectors to just come again another day since they are out inspecting all the time anyhow.
		
		Supervisory Practices
		
		- Dispatcher is less prone to listen to inspector when they request track time but supervisor did not step in to call Dispatch and request track and time.
		    o The dispatcher may have a poor relationship with this inspector due to past experience (e.g., inspector taking too long, restricting "too much").
		    o The dispatcher may be reluctant to grant track and time to the inspector if they are new to the territory or inexperienced.
		
		Scheduling/Workload/Non-Routine Inspections
		
		- Dispatchers are less likely to give track and time to non-routine inspections because they have no bandwidth to figure out alternate routes/scheduling.
		    o If Dispatch center is understaffed it could be easier to refuse track time than to think of alternate ways to move traffic.
		- Dispatcher feels overwhelmed due to other factors (e.g., previous derailment or other issues, weather, etc.).
		
		Dispatcher Experience/Training
		
		- Dispatcher lacks experience.
		- Not taught strategies in training to accommodate non-routine inspections.
		
		Physical Characteristics of the Track
		
		- Weather conditions were unsafe (e.g., thunder/lightning) for inspector to do walking inspection (territory is walking inspection only) so dispatcher thinks it's better to keep trains moving over the tracks.

23.2	**Dispatcher grants track and time to inspector too late, allowing trains to operate over track when there is a safety issue. [H1]**	Production Pressures
		
		- Dispatcher is tired of inspector going out and finding issues on the track which will potentially cause track restrictions or removals so waits to grant track and time out after all trains have passed.
		- Dispatchers incorrectly believe on-time performance is more important than inspection/safety.
		    o Because performance goals and/or training prioritize on-time performance over safety.
		
		Supervisory Practices
		
		- Dispatcher waited until supervisor stepped in to grant track and time.
		    o The dispatcher may have a poor relationship with this inspector due to past experience (e.g., inspector taking too long, restricting "too much").

ID	UCA Statement	Scenario Factors
		o The dispatcher may be reluctant to grant track and time to the inspector if they are new to the territory or inexperienced. Dispatcher Experience/Training - Dispatcher lacks experience/training to consider best practices for granting track and time. - Does not realize that inspector can use hi-rail for inspection which can go up to 30 mph

23.3	**Dispatcher does not grant enough track and time to inspector to complete inspection. [H1]**	Production Pressures
		
		- Dispatchers incorrectly believe on-time performance is more important than inspection/safety
		   o Because performance goals and/or training prioritize on-time performance over safety.
		- Territory is busy but dispatcher tries to give track when available even if it means smaller timeframes in which inspector cannot complete inspection.
		
		Incorrect Mental Models about Inspection
		
		- Dispatcher assumes that inspector has time/availability to pick up inspection again another time.
		- Dispatcher does not know how long inspection will take (e.g., due to inexperience).
		- Dispatcher does not realize inspection practices will make inspection take longer.
		   o Inspector stopped to repair something and/or took more time than initially asked for.
		   o Inspector had to stop to do more measurements than anticipated.
		   o Inspector did a walking inspection instead of using hi-rail even though time was limited.
		
		Communication
		
		- Dispatcher thought inspector was inspecting via hi-rail (therefore inspection would be quicker) rather than by foot.
		- Inspector did not give an estimate of time needed; or estimated too little.
		- Inspector did not update dispatcher when inspection took longer than planned.

Appendix G.
Example Sociotechnical System Safety Constraints

These safety constraints apply to all three track inspection sociotechnical systems studied.

UCA Statement	Safety Constraint
Upper management defines inspection territory that is a non-optimal size (too large or small) and/or complexity for one inspector to cover in the required timeframe. [H1; H3]	Upper management should define inspection territory of optimal size and complexity for one inspector to cover in the required timeframe.
Upper management sets performance goals that limit track time for inspectors to complete inspection and make repairs. [H1]	Upper management should not set performance goals that limit track time for inspections to complete inspection and make repairs.
Upper management sets performance goals related to particular track conditions which directs attention more on some safety concerns than others. [H1]	Upper management should set performance goals such that employees are incentivized to inspect for all safety concerns.
Upper management sets performance goals such that the number of safety concerns that inspectors must detect exceeds attention limits. [H1]	Upper management should set performance goals such that the number of safety concerns that inspectors must detect does not exceed attention limits.
Upper management does not provide adequate resources when they are needed to effectively and efficiently carry on inspection activities. [H1]	Upper management should provide adequate resources to effectively and efficiently carry out all inspection activities.

Abbreviations and Acronyms

ACRONYM	DEFINITION
aTGMS	Automated track Geometry Measurement System
FRA	Federal Railroad Administration
SCS	Safety Control Structure
STPA	Systems-Theoretic Process Analysis
TGMS	Track Geometry Measurement System
UCA	Undesirable Control Action