New Guidance for CAST: Case Study of a US Freight Rail Stop Signal Overrun & Collision

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Objectives & Background
New CAST Guidance
Freight Rail Case Study
Discussion
Objectives

- Apply CAST to a freight rail case study in order to understand systemic causes of stop signal overruns

- Suggest additional guidance for CAST to help analysts understand which types of information to include
Background: Stop Signal Overruns (SSOs)

- Consequences can include derailment or collision; may result in injuries, fatalities, and major property damage
- Railroads tend to blame the operators (engineer, conductor), but many factors contribute to these incidents!
Background: Stop Signal Overruns (SSOs)

- 2 prior studies at passenger railroads examining SSOs
- Focus groups, interviews, and observations
- Identified contributing factors at all levels of the system hierarchy!

(Safar, Multer & Roth, 2017)
Objectives & Background

New CAST Guidance

Freight Rail Case Study

Discussion
Recent work (France, 2017) provided additional guidance for mental model flaws in STPA; can be applied to CAST.

*This presentation uses mental model in place of process model when referring to human controllers.*
Foundation of Mental Model Guidance

STPA – Engineering for Humans Extension

(Thomas & France, 2016; France, 2017)
Guidance for Mental Models

Mental Model of Process State

- Beliefs about modes and mode changes
- Beliefs about the current process stage (for processes with multiple stages)
- Beliefs about system variables (e.g. true/false, on/off)

(France, 2017)
Guidance for Mental Models

Mental Model of Process Behavior

- Beliefs about what the system can do
- Beliefs about how the system will behave in a particular mode or process stage
- Beliefs about if-then relationships between operator input and system output

(France, 2017)
Guidance for Mental Models

Mental Model of Environment & Controllers
- Changes to environmental conditions
- Familiar or unfamiliar environments
- Other controllers’ states and behaviors
- Social and organizational factors

(France, 2017)
Additional Guidance: Contextual Factors

- 1. Safety Roles & Responsibilities
- 2. Unsafe Control Actions (UCAs)
- 3. Mental Model Flaws
- 4. Contextual Factors

*Contextual factors* is a broad category, leaving analysts with potential questions:

- Which types of information belong in “contextual factors”?
- How should findings listed under “contextual factors” be structured?
Foundations of Contextual Guidance

*Note: “PASS” stands for “passing a stop signal” and is synonymous with “Stop Signal Overrun” or SSO.
Guidance for Contextual Factors

Five categories of contextual factors to consider:

- Physical system and technology factors
- Individual and team factors
- Organizational factors
- Regulatory factors
- External / Environmental factors; “Other”

NOTE: This guidance DOES NOT replace the need to create a safety control structure and examine the control and feedback loops specific to YOUR system and controlled process!

This is NOT a checklist; it’s a recommendation to consider factors at all levels of your system!
Guidance for Contextual Factors

Physical System and Technology Factors
- Operating environment design
- Interface design (e.g. displays and alerts)
- Maintenance/operational status of physical systems
- Availability or non-availability of job aids
- Other physical factors (e.g. weather)
Guidance for Contextual Factors

Individual and Team Factors
- Communication and teamwork; coordination
- Distractions / competing demands for attention
- Experience level; qualification and training
- Fatigue; work schedule
- Medical fitness for duty
- Expectations; similar situations encountered
Guidance for Contextual Factors

Organizational Processes

- Supervisory priorities / safety culture
- Resource constraints & production pressures
- Policies and procedures (work schedules, training, discipline, etc.)
- Degree of feedback from employees
Guidance for Contextual Factors

Regulatory Activities

- Degree of support to/control over organizations
- Feedback (data) collected from organizations
- Regulations regarding employees
- Regulations regarding physical systems and technologies
Guidance for Contextual Factors

External Factors
- High-level societal, governmental, etc. influences
- Economic context, funding sources
- Demands for service driving production pressures
- Political climate’s effects on funding, regulation, etc.

**REMINDER:** These lists are not comprehensive, they are simply a set of examples!
Complete CAST Controller Guidance

1. Safety Roles & Responsibilities

2. Safety Constraints Violated or Unsafe Control Actions (UCAs)

3. Process Model (Mental Model) Flaws
Explain why Unsafe Control Actions appeared appropriate to the controller.

A. Mental model of process state
B. Mental model of process behavior
C. Mental model of environment

4. Contextual Factors
Systemic factors that influence controllers’ mental models and decisions.

A. Physical system and technology factors
B. Individual and team factors
C. Organizational processes
D. Regulatory activities
E. External factors
Objectives & Background
New CAST Guidance
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Head-On Collision of Two Union Pacific Railroad Freight Trains

Goodwell, Oklahoma
June 24, 2012, 10:02 a.m

- 3 fatalities
  - Eastbound train’s engineer & conductor
  - Westbound engineer
- 1 survivor
  - Westbound conductor
- 5 locomotives and 32 cars derailed
- $14.8 million in estimated damage

Photo source: the Guymon Daily Herald courtesy of Marit Edwards

(NTSB, 2013)
Accidents and Hazards

ACCIDENT

- A train collides with another train on the same stretch of track

HAZARDS

- A train enters an area of track it was not cleared to enter
- A train enters an area of track already occupied by another train
Dispatchers must use stop and approach signals to alert train crews to areas they do not have clearance to enter.

Train crews must slow down at approach signals and stop at stop signals.

Train crews must have adequate visual acuity and color vision to recognize signal indications.

Railroads must ensure that crews are adequately qualified and medically fit for duty.
Event Overview: Planned Route

The eastbound train was supposed to wait at the stop signal for the westbound train to enter the siding.
Event Overview: Planned Route

The eastbound train could then proceeded forward safely, followed by the westbound train.
Instead, the eastbound train passed the stop signal and collided with the westbound train before it reached the siding.
Event Timeline: Eastbound ZLAAH 22

9:56 am

- **Advanced Approach**
  - Flashing yellow
  - Reduce speed to 40 mph

9:58 am

- **Approach**
  - Solid yellow over solid red
  - Reduce speed to 30 mph; prepare to stop

10:00 am

- **Stop**
  - Solid red
  - Stop until given clearance to proceed

<2 miles

- **Collision**

10:01 am

- **AAMMLX 22 Westbound Train**
Event Timeline: Eastbound ZLAAH 22

“...the engineer appeared to make throttle and dynamic brake adjustments that maintained train speed close to the 70 mph limit, as would be expected for a train operating on a clear signal”

(NTSB, 2013)
Physical System Analysis

Safety Controls and Equipment

- Stop signals indicate where trains must not go
- “Approach” signals warn of upcoming stop or speed restrictions
- Sidings allow trains to pass safely on single track

Safety Constraints Violated

- Two trains moving opposite directions were allowed on a single track

(NTSB, 2013)
Physical System Analysis

Failures and Unsafe Interactions
- Signals functioned as intended, but the eastbound train did not obey them
- No Positive Train Control (PTC) present

Contextual Factors and Additional Questions
- **Individual**: If signals were properly functioning, why did the engineer pass a stop signal?
- **Organizational**: Why wasn’t positive train control installed?

(NTSB, 2013)
Controller Analysis: Engineer

- Speed controls (throttle & brake)
- Current speed
- Signal indication

Physical System (Trains and Signals)
Controller Analysis: Engineer

Roles and Responsibilities
- Control train speed in accordance with posted signals; call out signal indication to conductor
- Be medically fit to operate a locomotive

Unsafe Control Actions
- Did not slow down as required by approach signals or stop at the stop signal
- Operated while knowing he had inconsistent color vision and diminished visual acuity
Controller Analysis: Engineer

Mental Model Flaws

Model of Process State:
- Incorrectly believed signals were “clear” (green)

Model of Process Behavior:
- N/A – understood meaning of signals & required actions

Model of Environment & Controllers:
- May have incorrectly believed conductor would intervene
- Likely unaware of the presence of another train
Controller Analysis: Engineer

Individual Contextual Factors:
- **Perceptual limitations**: engineer had severe visual impairments from multiple conditions; had failed a color vision test in 2009
- **Coordination**: should have been coordinating with conductor to call out signals and ensure proper speed; what was conductor doing?
- **Expectations**: signals may be typically clear, high-visibility
- **Fatigue**: fatigue possible based on irregular work schedule

Organizational Contextual Factors:
- What organizational factors allowed (or incentivized) operating despite severe visual severe limitations?
Controller Analysis: Conductor

- Conductor
- Engineer
- Emergency brake
- Signal indications
- Call out signals
- Current speed
- Physical System (Trains and Signals)
Controller Analysis: Conductor

Roles and Responsibilities
- Call out signal indications; ensure engineer obeys signals; use emergency brake if necessary

Unsafe Control Actions
- Apparently did not call out the approach and stop signals; did not warn engineer
- Did not pull the emergency brake
Controller Analysis: Conductor

Process Model Flaws

Model of Process State:
- Was likely unaware that signals were in a restrictive state

Model of Process Behavior:
- *N/A – would have understood meaning of signals*

Model of Environment & Controllers:
- Was likely unaware that the engineer was not responding to signals; likely believed engineer could read the signals
Controller Analysis: Conductor

Individual Contextual Factors:
- Distraction / inattention: conductor may have been asleep or absent
- Expectations: signals may be typically clear, high-visibility conditions, may have believed engineer was capable of recognizing signals
- Fatigue: fatigue possible based on irregular work schedule
- Coordination: engineer may have allowed conductor to rest

Organizational Contextual Factors:
- What organizational factors contributed to lack of required coordination between the engineer and conductor?
Controller Analysis: Dispatcher

- Conductor
- Engineer
- Train Crew
- Physical System (Trains and Signals)
  - Clearances & instructions
  - Location/issues
  - Set signals & switches
  - Signal & switch status
  - Train positions?
  - Train speeds?
Controller Analysis: Dispatcher

Roles and Responsibilities

- Set signals and switches for safe routing of trains
- Communicate route information to train crews

Unsafe Control Actions

- Apparently did not warn eastbound train crew about the upcoming stop signal & other train
Controller Analysis: Dispatcher

Process Model Flaws

Model of Process State:
- Did not realize eastbound train had passed the signals

Model of Process Behavior:
- May have believed that if crews passed a signal, he would be alerted and have time to intervene

Model of Environment & Controllers:
- Assumed crew would obey signals even if not given warning
Controller Analysis: Dispatcher

Physical System Contextual Factors:
- Dispatcher was not notified that the train was over the speed limit
- Dispatcher was only notified once the switch at the end of the siding was pushed out of alignment by the eastbound train

Individual Contextual Factors:
- **Expectations**: did not expect crews to pass a stop signal (very rare)
- **Coordination**: dispatcher was responsible for 10-12 crews
- **Timing**: accident occurred approx. 5 mins after first missed signal, and less than 2 minutes after the dispatcher received an alert
Controller Analysis: UP Management

- **Railroad Management**
  - Training, Policies, etc.
  - Safety issues

- **Dispatcher**
  - Training, Policies, etc.
  - Safety issues

- **Engineer**
  - Train Crew
  - Visual Acuity
  - Diagnoses & Treatments of Eye Conditions

- **Conductor**
  - Train Crew
  - Visual Acuity

- **Train Crew**
  - Documentation of Vision Test Results

- **Outside Medical Providers**
  - Safety issues

- **Physical System (Trains and Signals)**
Controller Analysis: UP Management

Roles and Responsibilities
- Ensure that employees are medically fit for duty and adequately trained on job tasks, including coordination
- Ensure that physical system complies with regulations

Unsafe Control Actions
- Did not have PTC installed on the route
- Did not provide training on crew resource management
- Did not require documentation of engineer’s visual acuity results; did not require follow-up testing
- Used a color vision test of unknown validity / reliability
Controller Analysis: UP Management

Mental Model Flaws

- May have incorrectly believed engineer’s vision was okay
- May have believed that engineer’s vision would not be a problem with the conductor assisting by calling out signals
- May have believed resources were not available to implement safety measures, or that safety measures were not as urgent as other priorities (CRM, PTC)
Controller Analysis: UP Management

Organizational Contextual Factors:

- **Resource constraints**: PTC / CRM require large amount of resources
- **Staffing constraints**: may have needed engineers badly, decided to keep the engineer despite visual limitations
- **Policies**: did not uniformly apply policy for verifying visual acuity was to obtain written documentation
- **Scheduling practices**: irregular schedules are common in rail industry; may contribute to fatigue despite hours of service limitations

Regulatory Contextual Factors:

- Was UP in violation of regulations, or were regulations inadequate?
Controller Analysis: FRA

Federal Railroad Administration

Regulations
Safety data

Railroad Management

Outside Medical Providers

Dispatcher

Train Crew

Engineer

Conductor

Physical System (Trains and Signals)
Controller Analysis: FRA

Roles and Responsibilities

- Regulate railroads to ensure safety standards

Unsafe Control Actions

- Allowed retaking vision tests without validating railroad’s testing methods
- Did not mandate PTC installation sooner
- Did not mandate CRM trainings
Controller Analysis: FRA

Process Model Flaws
- Believed timeline for PTC implementation was appropriate
- Believed railroads had adequate resources for CRM
- Believed railroads would use a valid vision testing method

Regulatory Contextual Factors:
- FRA already required implementation of PTC by 2015
- FRA conducted research into CRM, provided railroads with funding for pilot programs

External Factors
- Desire to maintain positive relationships with railroads & work within their resource constraints (e.g. PTC regulation timing)
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Enhanced CAST Controller Guidance

1. Safety Roles & Responsibilities

2. Unsafe Control Actions (UCAs)

3. Process Model (Mental Model) Flaws
   A. Mental model of process state
   B. Mental model of process behavior
   C. Mental model of environment

4. Contextual Factors
   A. Physical system and technology factors
   B. Individual and team factors
   C. Organizational factors
   D. Regulatory factors
   E. External / environmental factors; “other”

- Provides additional guidance on what types of content to include
- Useful for new practitioners of CAST
- Revealed interesting results in our freight case study
References

Thank you for your attention!

Contact:
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Backup Slides: PTC Implementation
Positive Train Control Timeline

Source: https://www.fra.dot.gov/ptc
PTC Implementation in Freight RR

Source: https://www.fra.dot.gov/ptc
PTC Implementation at UP

As of December 31, 2017

Source: https://www.fra.dot.gov/ptc
Ongoing/Future Work on SSOs

- Current study focuses on freight environment
  - CAST analyses are a preliminary step
  - Follow-up with interviews, focus groups, etc. and briefing to railroad management

- Other ongoing work
  - Improving SSO data collection using a common form template
  - Communicating findings to railroads in a “Good Practice Guide”