Design and Evaluation of a Robust Manual Locomotive Operating Mode

U.S. Department of Transportation: Federal Railroad Administration BAA 2016
Research Topic FRA-HF-002: Human Factors Research in Vehicle and Rail Systems

January 14, 2020

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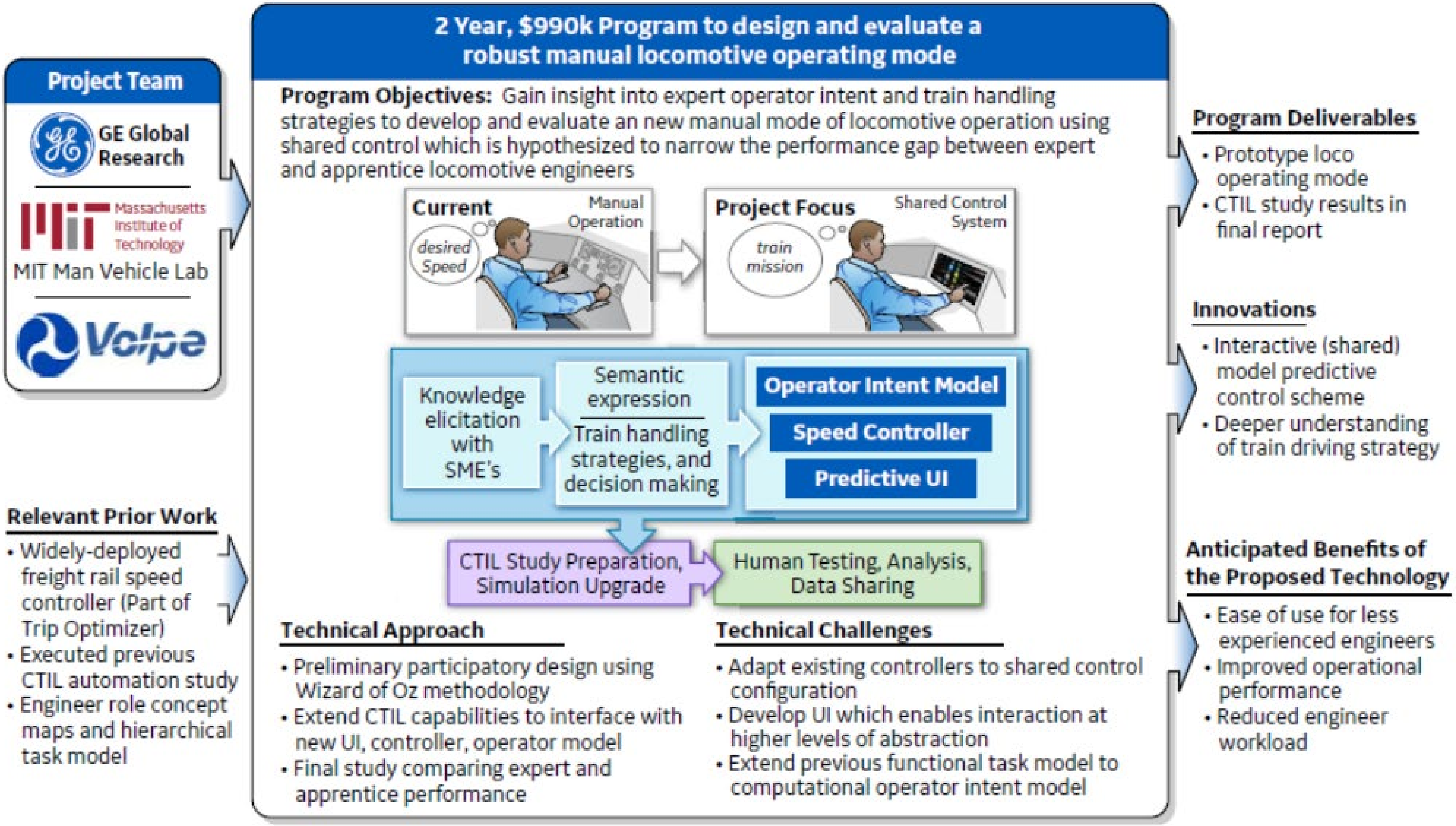
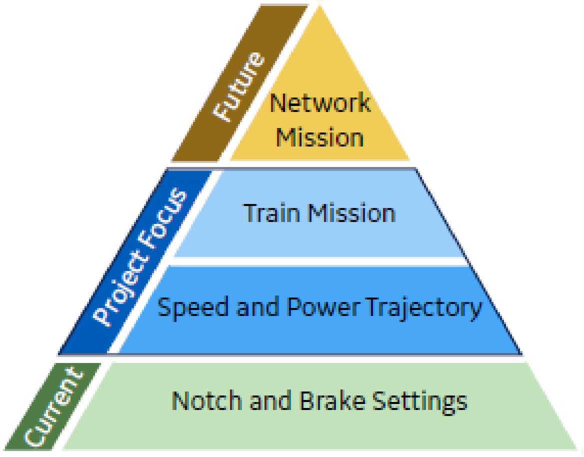


Figure 1. Summary of the proposed Design and Evaluation of a Robust Manual Locomotive Operating Mode project

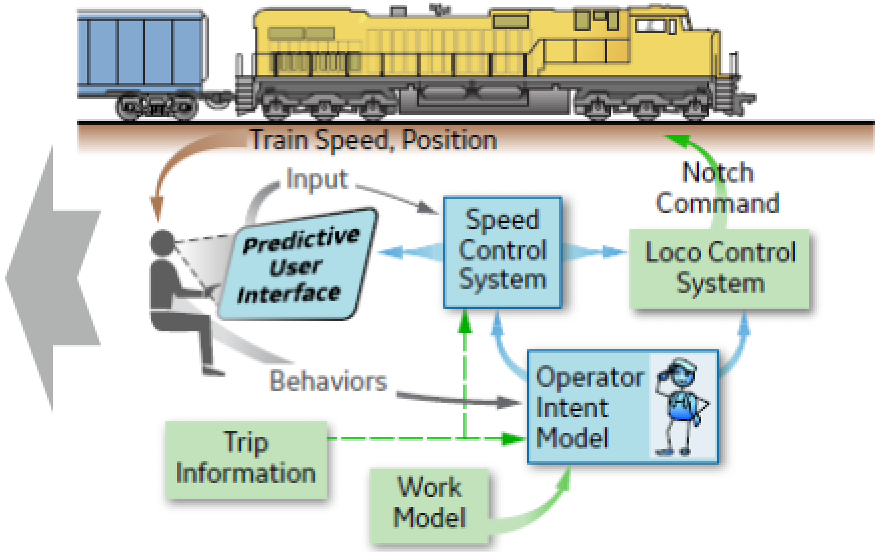
Elements of the Enhanced Manual Mode Concept

- Transition from low level control to mission/trajectory control
- Speed control system that communicates it’s intent/actions
- An predictive and interactive user interface
- An Operator Intent Model that learns the user’s intent and intelligently modifies the UI and control system



Control Input Hierarchy

Program Overview

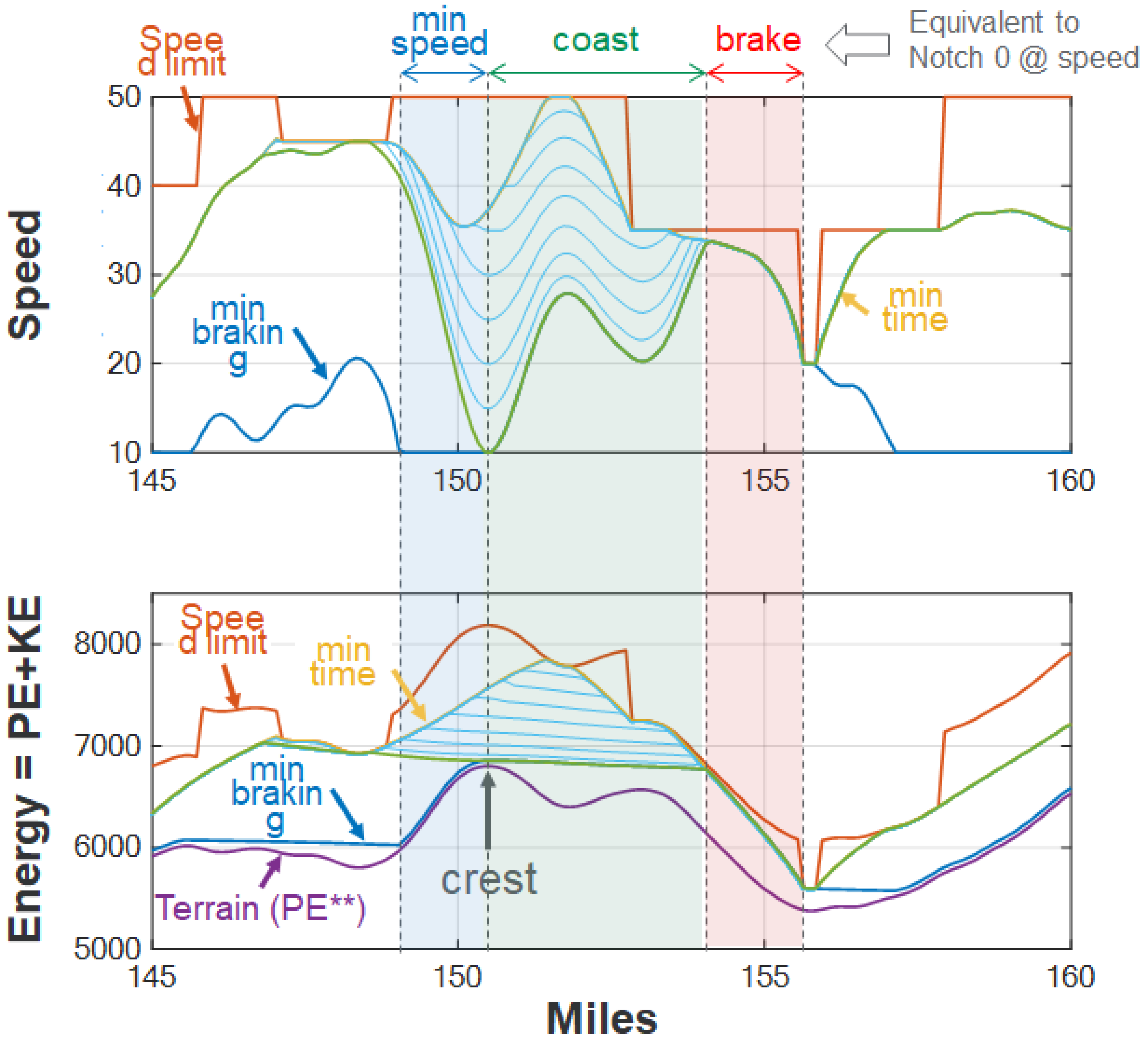


Controller

Trip Optimizer™* – Explainable Plan (TOxP)

* Trip Optimizer is a trademark of GE Transportation, a Wabtec company

Simplified Trip Optimizer™***



Solved via simulation (blue line)

1. Crest hill at min speed (e.g. 10 mph)
2. Coast down hill
3. If Speed Limit exceeded
   a) braking cannot be avoided
   b) Integrate braking power

Solution led to simple plan generation

- Extend coasting back in time* (green)
- Higher "min speed" generates faster plans (light blue)

We're calling it **TO xP (explainable planner)**

- Remarkably similar to TO, although not as smooth… yet
- computationally fast
- explainable in terms RR understand = improved driver interaction = more time in auto

* This is the critical point (fastest plan with min braking)

** Potential Energy (generalized, i.e. includes curvature and Davis drag a)

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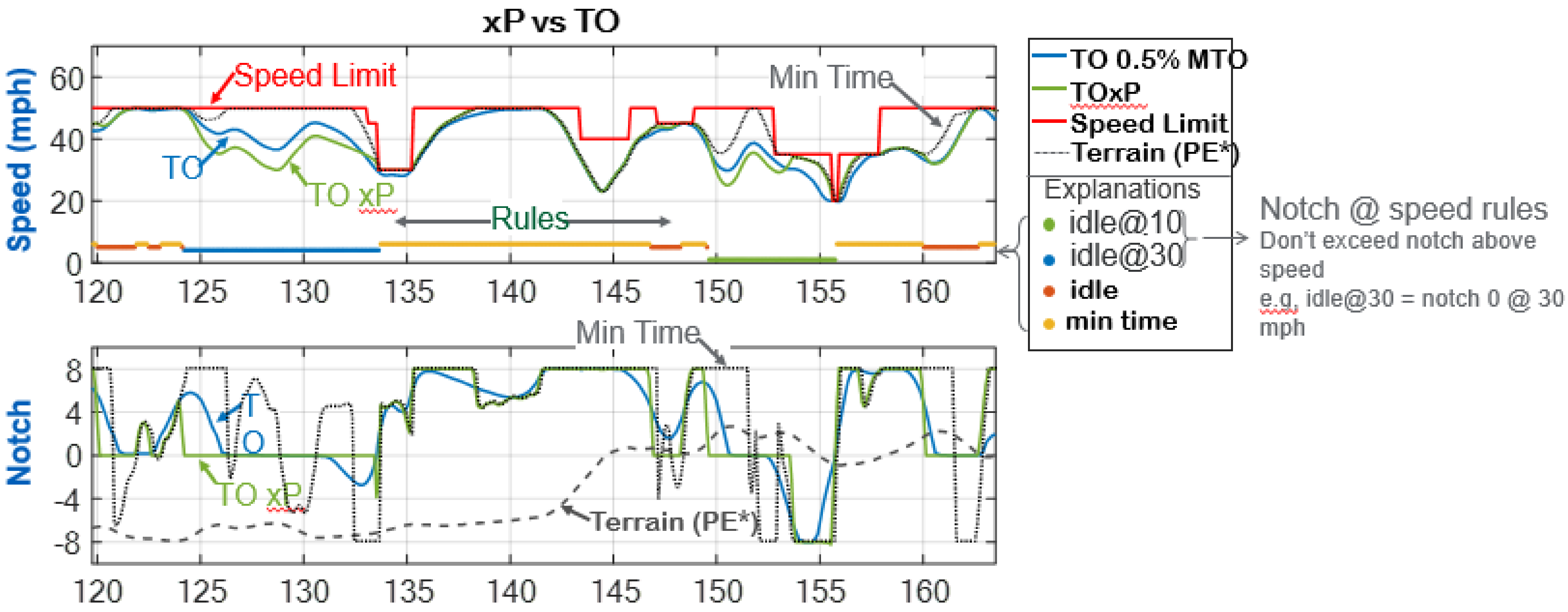
TO xP – Explainable Planner

translates the plan into a sequence of rules that can be modified by the operator



* Potential Energy (generalized, i.e. includes curvature and Davis drag a)

Operator Interaction

Predictive UI

Predictive UI Concept

STATUS MESSAGES

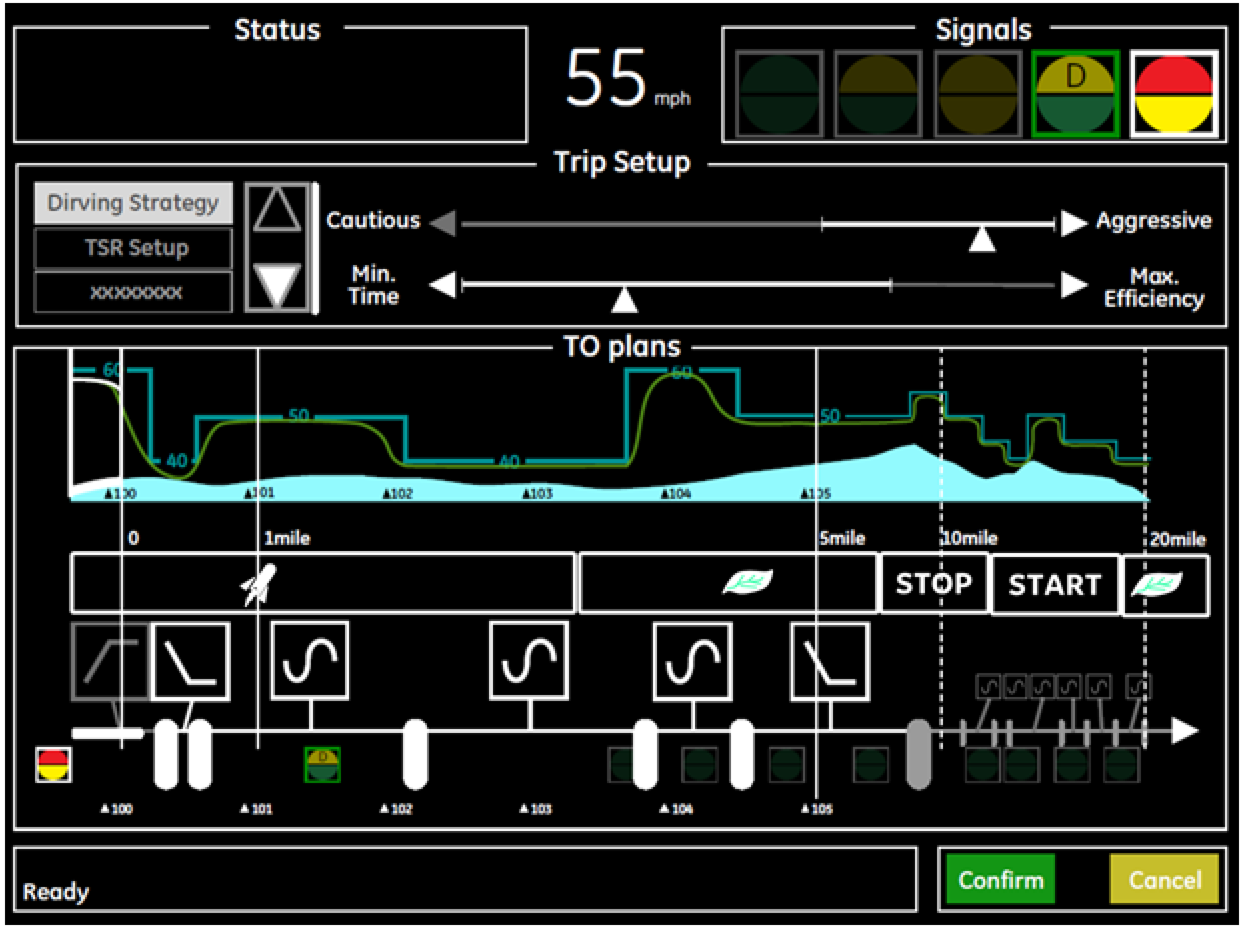
SIGNAL ASPECT INPUT

DRIVING STRATEGY

ROLLING MAP

GOAL

POWER PROFILE



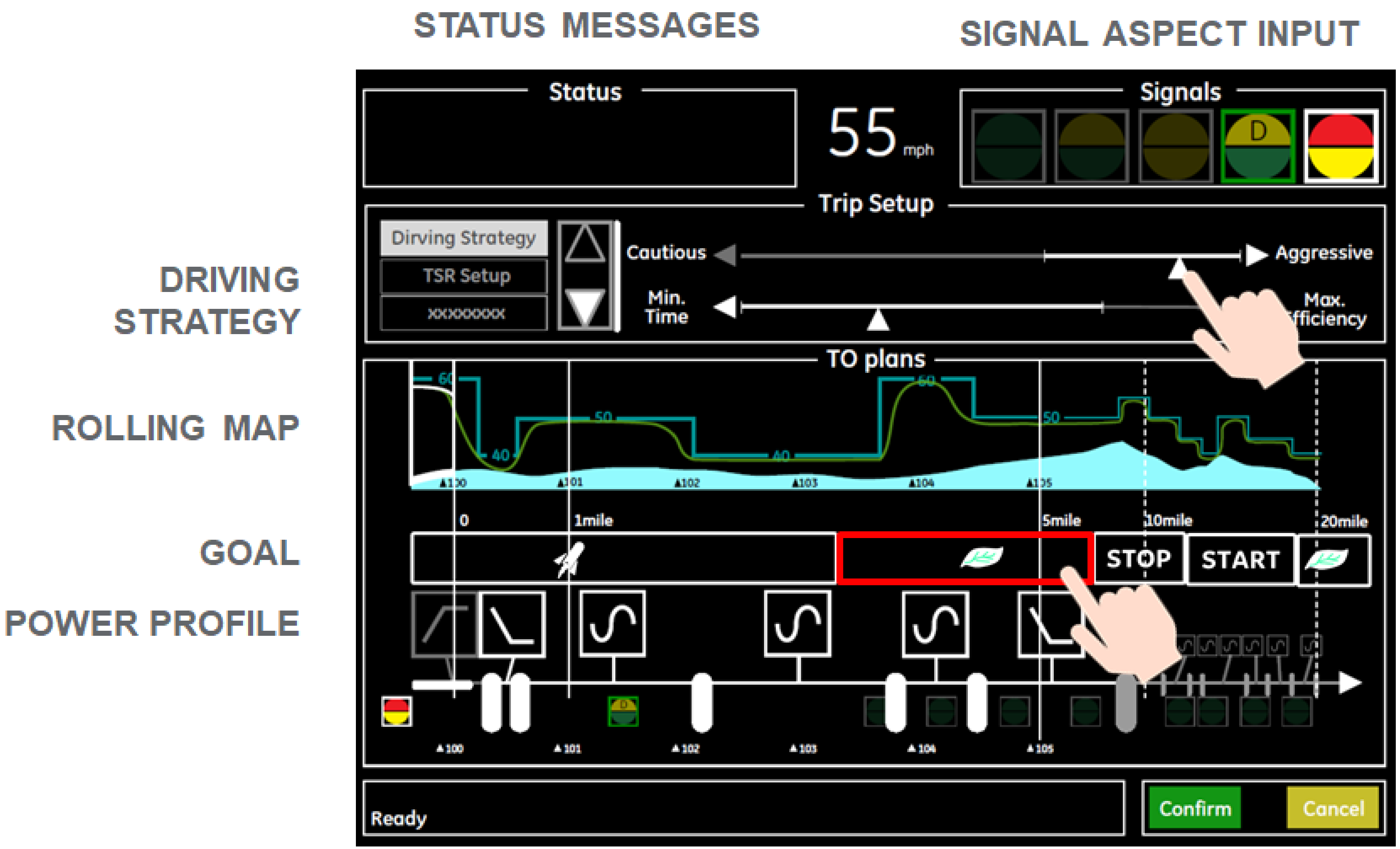
GOAL ICONS

- Fast as possible
- Save Fuel (notch@speed rule)
- STOP Come to a stop
- START Start moving

POWER ICONS

- Speed up
- Regulate to speed limit
- Slow down
- Maintain notch
- Start
- Stop

Predictive UI Concept

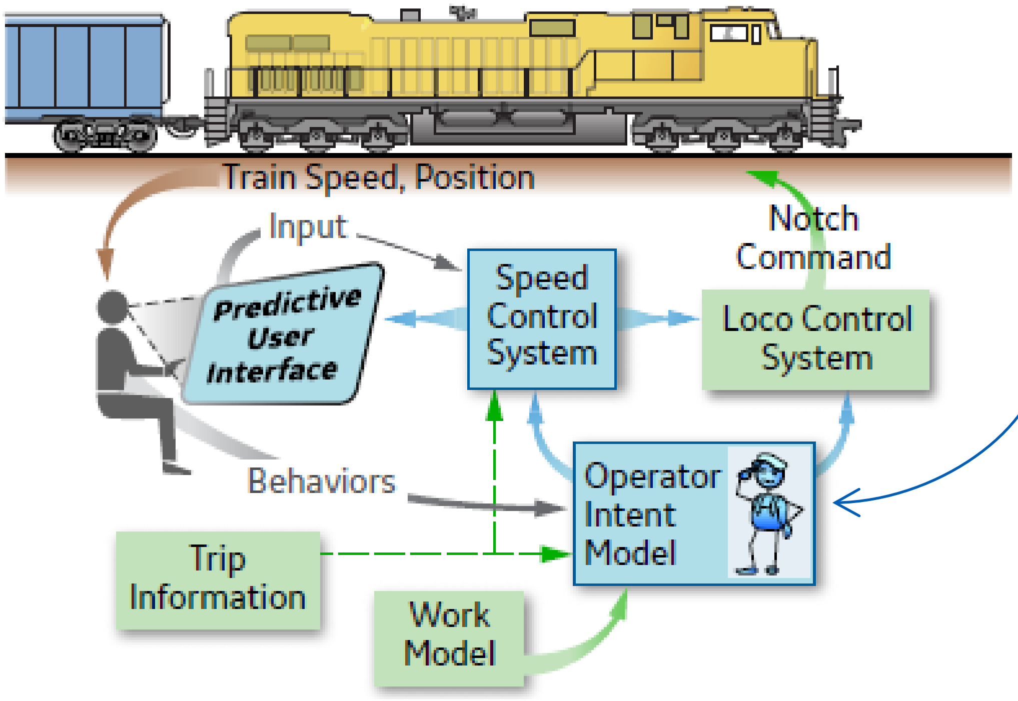


User interaction

- User selects goal/power aspect(s)
  - Touch to select, touch again to deselect
- Then adjusts driving strategy sliders
- Plan updates live
  - For selected aspects or whole trip if none
  - time and fuel impact shown at selectable MP's
- User confirms, cancels or modifies selection/sliders

Operator Intent Model

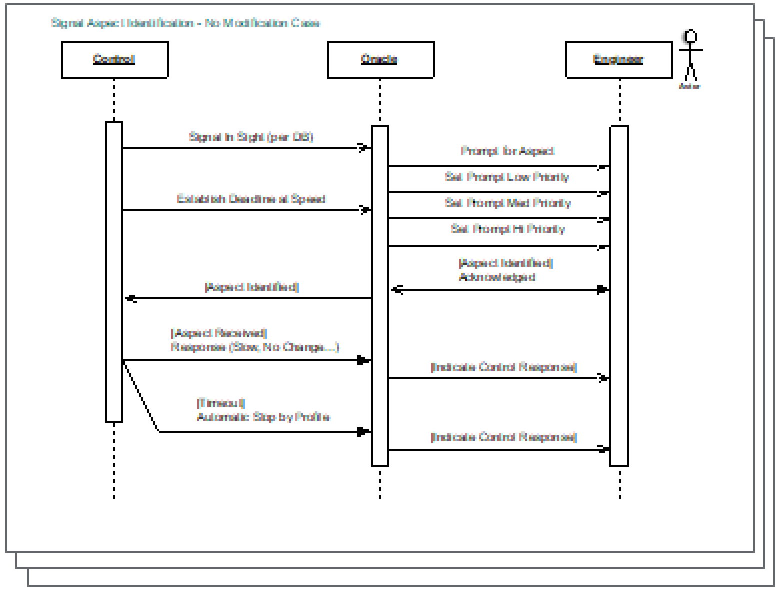
Operator Intent Model



An “oracle” that appears as the system to the user, and the user to the system

- Monitors user behavior
- Infers intent
- Modifies UI or controls system appropriately
  (Preset sliders, highlight situational data, take or delay action)

Use cases



CTIL Study to Inform the Design

CTIL Wizard of Oz (WoOz) Study

We utilize a variation of a WoOz experiment to capture the way an expect drives the train

- Commonly used for human-system interaction research
- Avoids the need to construct a proposed system analysis
- Typically a human plays the role of the system to be built

The experiment is designed to elicit current driving strategies through concurrent think-aloud with expert subjects and apprentice engineers.

Coded based on linguistic theory

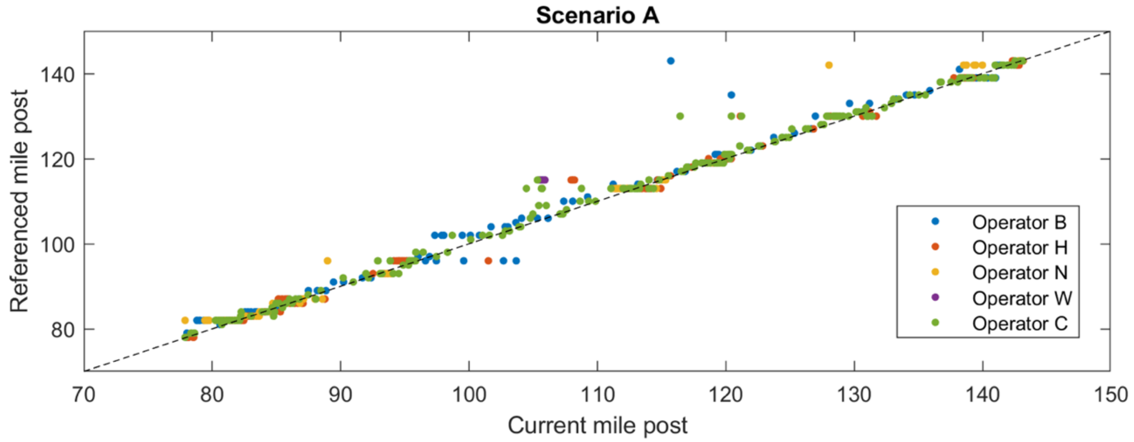
Scenario A – Novice driving

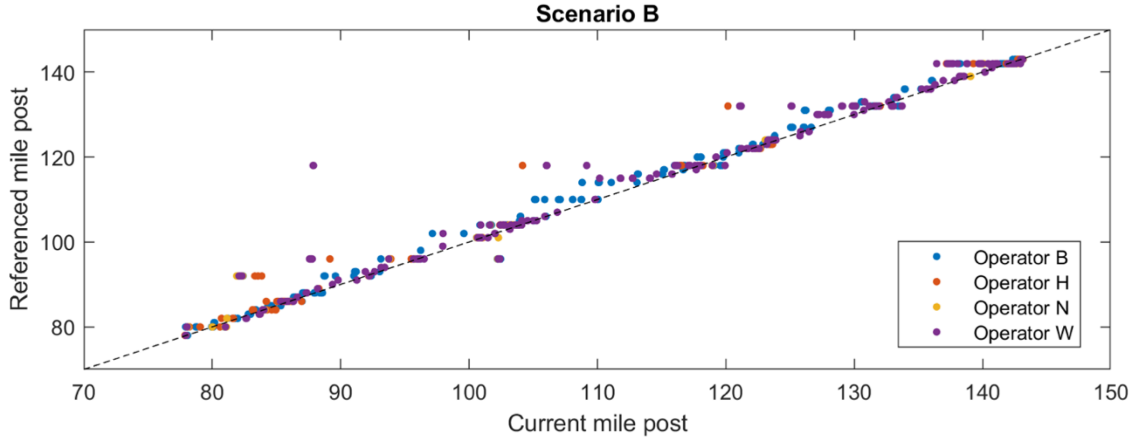
- novice is driving from engineer's seat
- expert is directing from conductor's seat
- Both can see out of the windscreen and both have access to train data

Scenario B – Expert driving

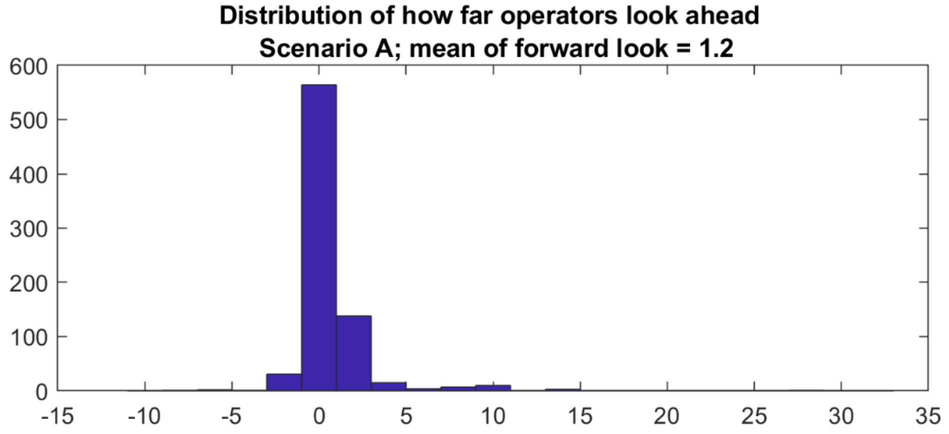
- expert is driving from engineer's seat but cannot see out
- novice is in conductor's seat and answers questions from the expert

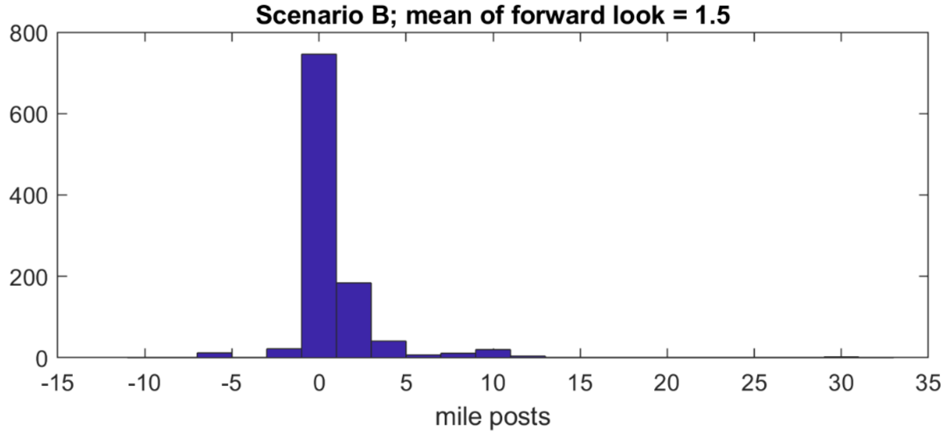
Look ahead





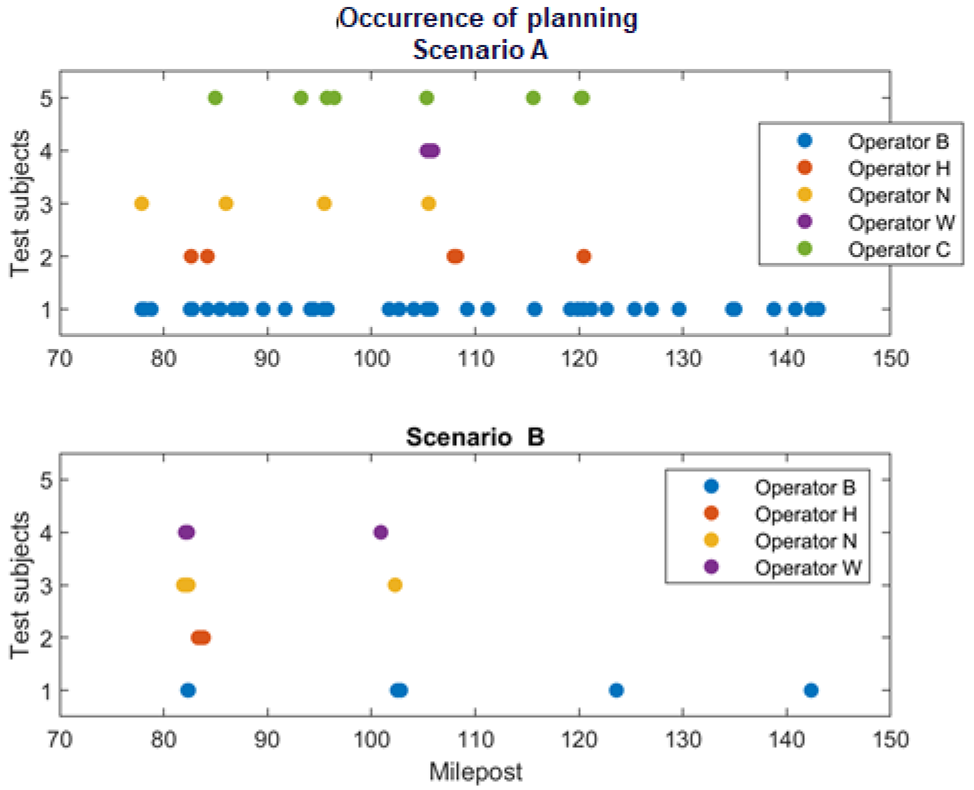
Mile post referenced in dialog vs. current mile post at the time of the utterance.



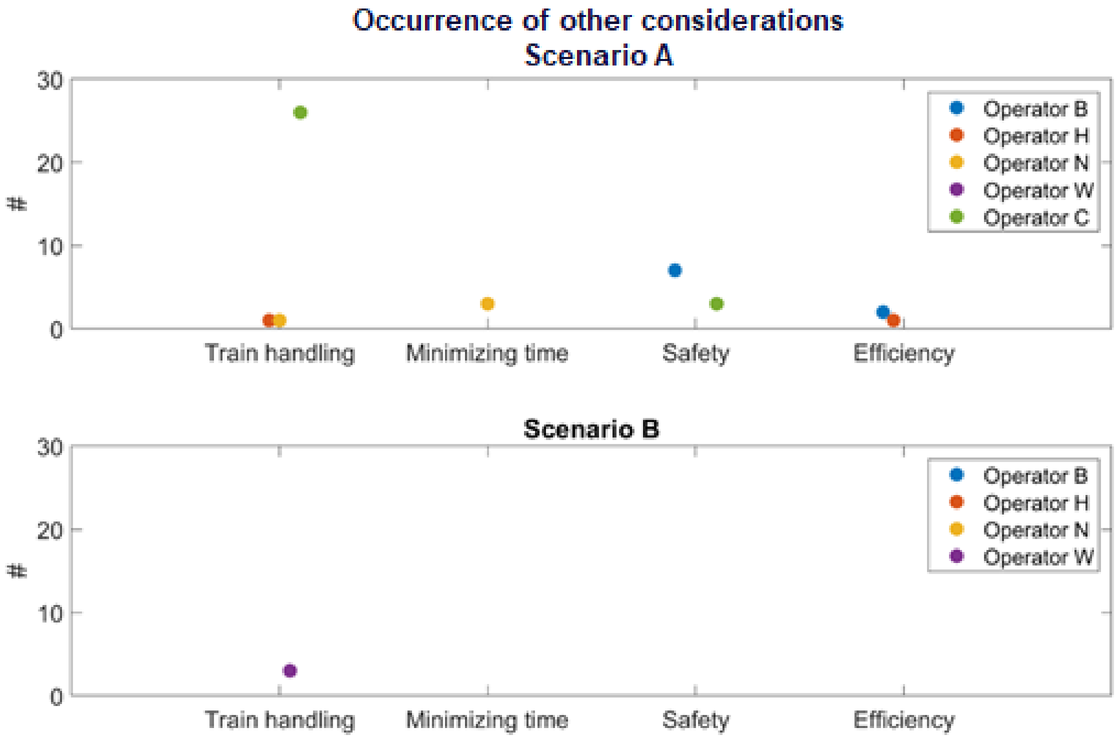


Distribution of look-ahead distances over all subjects in Scenarios A (top) and B (bottom)

Planning

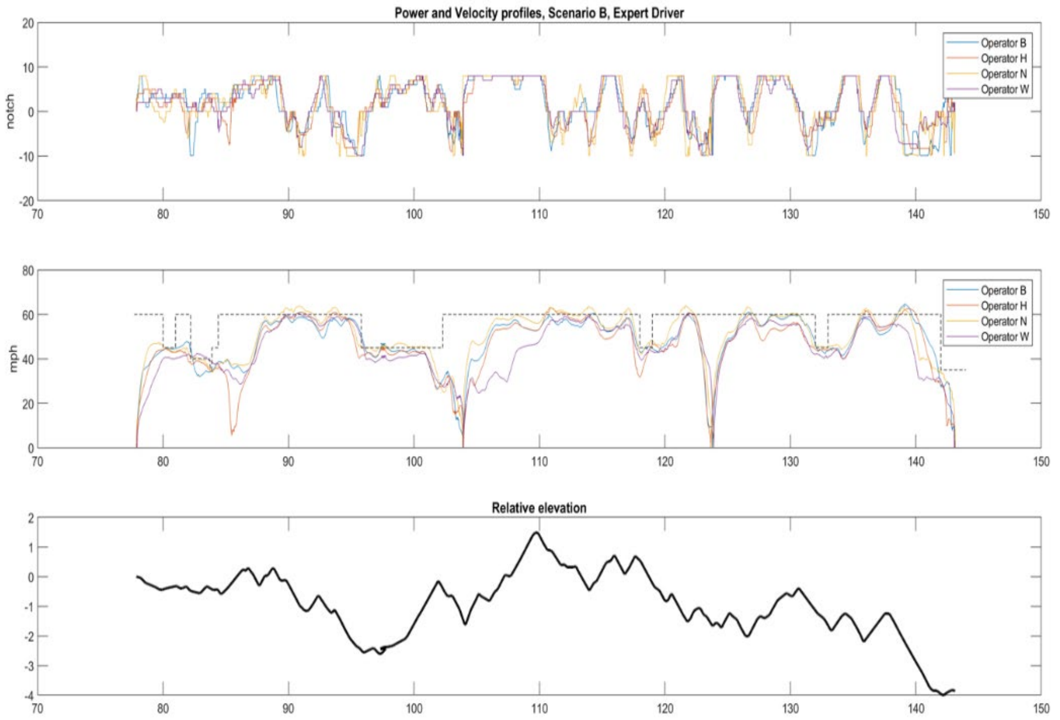


Location of utterances that suggest planning.

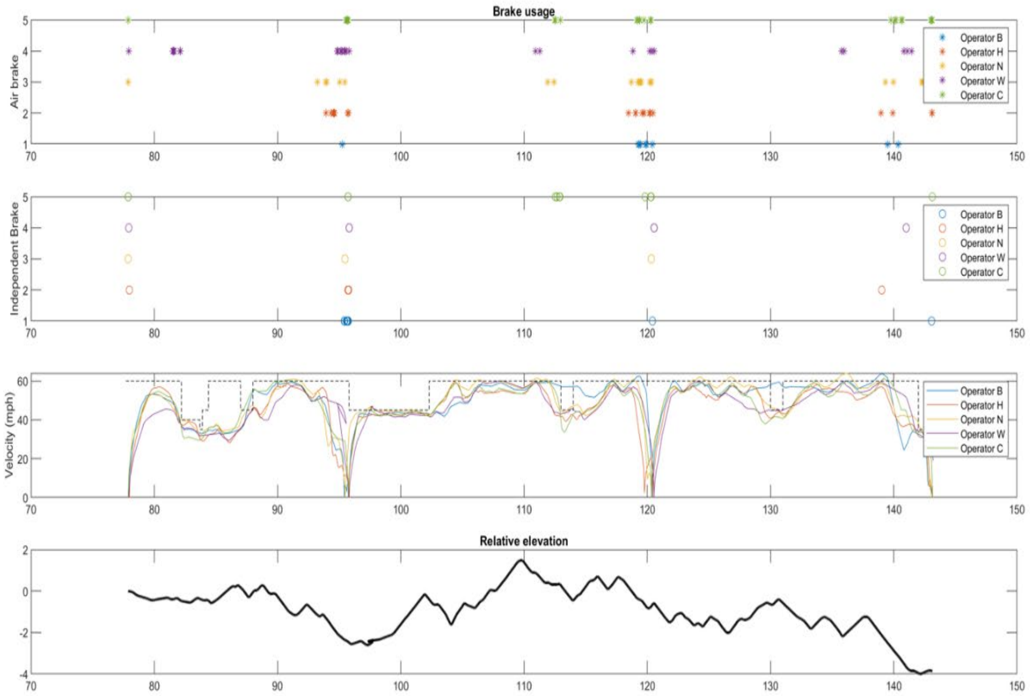


Number of occurrences of discussion about high-level goals.

Driver Variation



Power profiles (notch), velocity profiles (mph), and relative elevation for Scenario B. Segment near mile post 113 is magnified to show variation in behaviors when driving downhill while targeting the track speed limit.



Usage of air brakes and independent brakes, with velocity profiles and elevation shown for reference.

Cautiousness

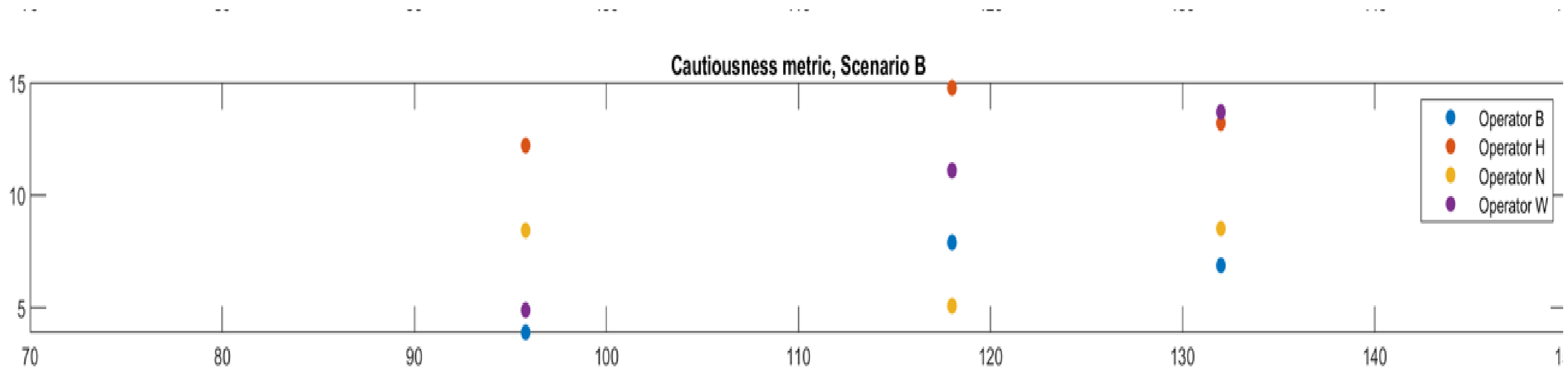


Figure 6: Cautiousness metric (arbitrary units) at three locations approaching speed restrictions.

This metric was computed as the integral of the difference between the speed limit and the actual speed within one mile of a speed restriction. This was computed for three speed restrictions that were sufficiently distinct from other restrictions and stops – at mileposts 96, 118, and 132.

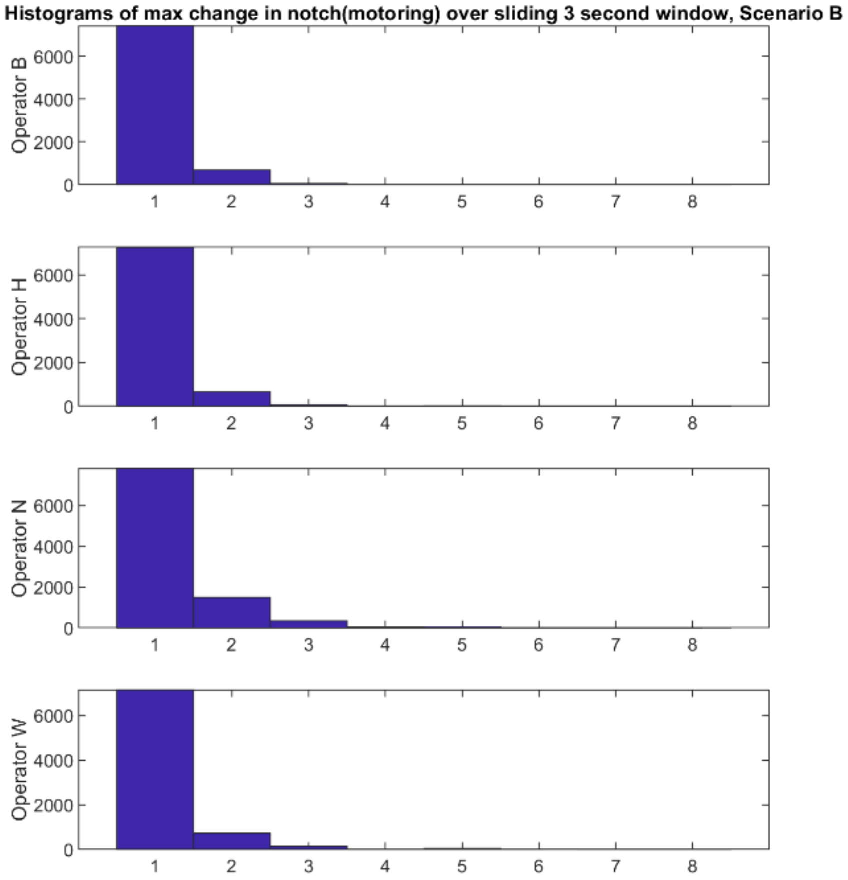


Figure 7: Histograms of rate of notch change

Conclusions Informing System Design

Feature in data analysis	Result/Observations	Corresponding UI/system Feature
Distribution of how far into distance events are anticipated based on Level 3 coding	15 mileposts capture most of the forward-looking considerations, in both A and B scenarios	Extent of displayed rolling map
Occurrence of planning ahead in Level 3 coding	There was a range of attention given to planning. Minimally: planning was always discussed for startup and meet and pass. Maximally: one operator engaged in persistent planning related to upcoming terrain.	Suggests variation in how much an operator would want to make proactive adjustments
Occurrence of goal considerations	Sparse overall but varied among operators. Most frequent were train handling and safety. This makes sense, since the study did not offer incentives for operators to be concerned with time or fuel.	Supports "avoid idle" option for train handling; may support use of TO to re-plan and comply to new speed restrictions; weakly supports efficiency vs. time slider
"Cautiousness metric" derived from velocity profiles	Within-operator variation was less than operator-to-operator variation for three out of four operators.	This validates having an adjustment for driver preference (aggressiveness slider)
Qualitative observation of stopping profiles when expert is driving (scenario B)	Stopping location and speed trajectory vary among operators.	Supports adjustable braking profile
Qualitative observation of power profile when expert is driving (scenario B)	Variation during an instance of using idle on a downhill while maintaining track speed. Three out of four operators coasted. One was more aggressive, motoring on the downhill, resulting in overspeeding.	Adjustments to Notch-at-speed rule, or "fuel saving" goal
Usage of air brake and independent brake	All used AB/IB for stops. Three out of four used AB for meeting speed restriction. Of those, one used IB as well, and one used AB more frequently than the others.	Supports aggressiveness adjustments; informs usage of braking in controller implementation
Rate of change of notches (motoring only) over a sliding 3-second window	One out of four operators appeared more aggressive (used a higher rate more frequently)	Supports aggressiveness adjustments
Single dialog instance	operator in B scenario was preparing to stop when signal was still unknown	Supports automatic stopping after critical point is passed
Single dialog instance	Operator in A scenario was explaining usage of notch 1 vs. idle to improve train handling	Supports "comfort" or "avoid idle" option
Single dialog instance	Operator expressed some effort to determine an ETA	Supports need for display of calculated ETA