# MODELING HUMAN-AUTOMATION FUNCTION ALLOCATION EFFECTIVENESS IN RAIL

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MIT Man Vehicle Lab


FRA/Volpe CTIL

Imagination at work.

# Research Program Overview

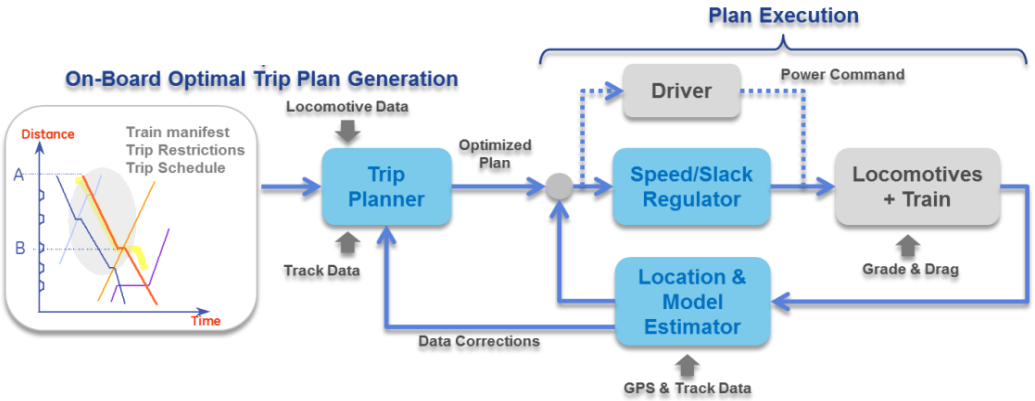
## Goals:

- Can we predict human performance using task models and metrics and use to design control systems?
- First extensive human factors study with GE's Trip Optimizer™

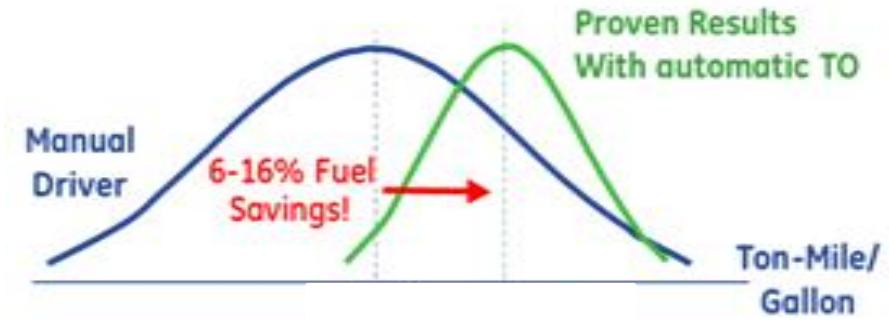
## Executive Summary:

- Evidence that engineer's vigilance can be improved when using appropriate automation
- Operators exceed boundaries of automation system design on 3-6% of mode transitions

# GE's Trip Optimizer™ (TO)

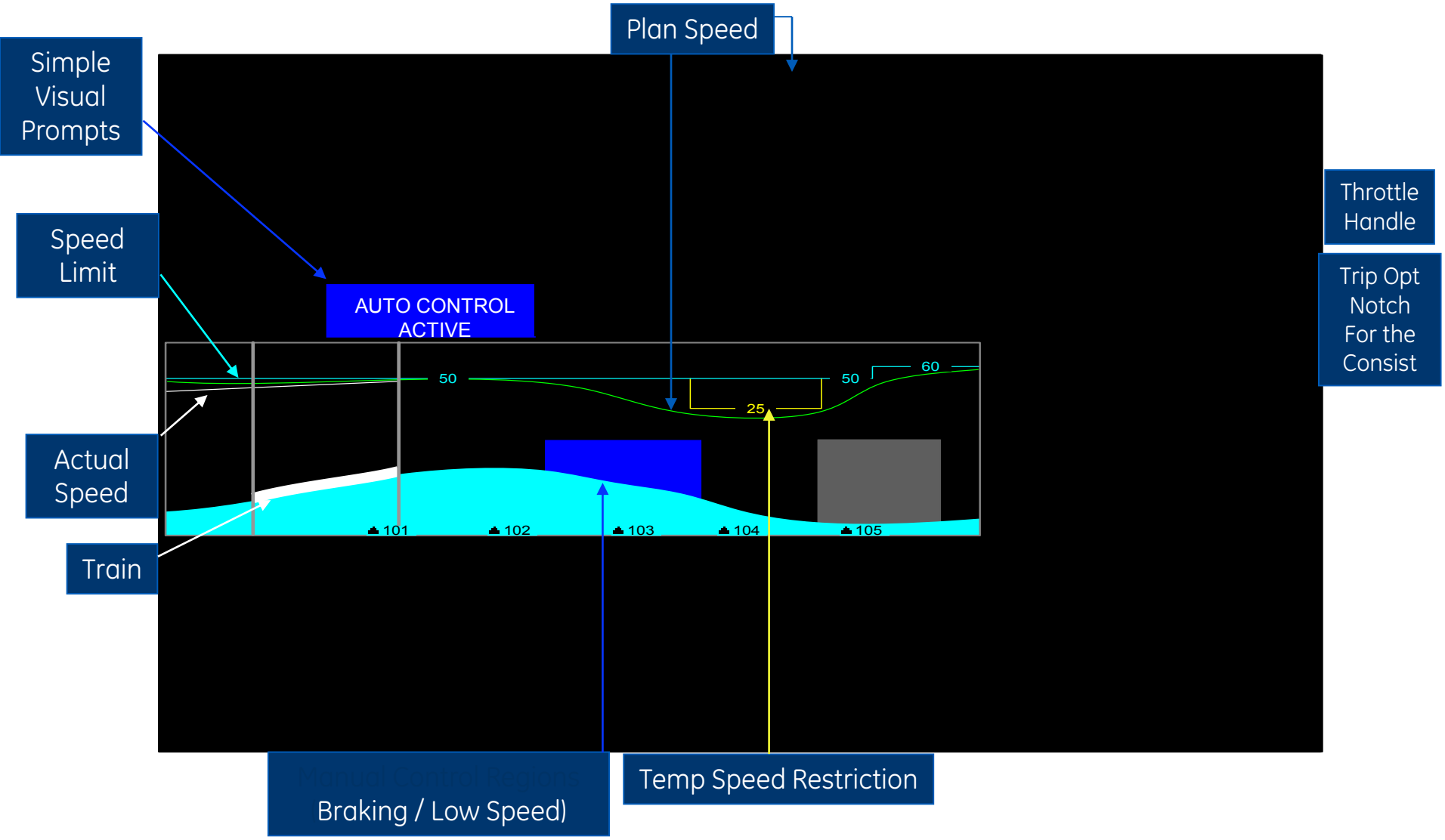

- 10% fuel savings on average
- Driver variability eliminated
- Smoother mechanical loading of locomotive car connectors




**Over 84 million gallons of fueled saved to date**

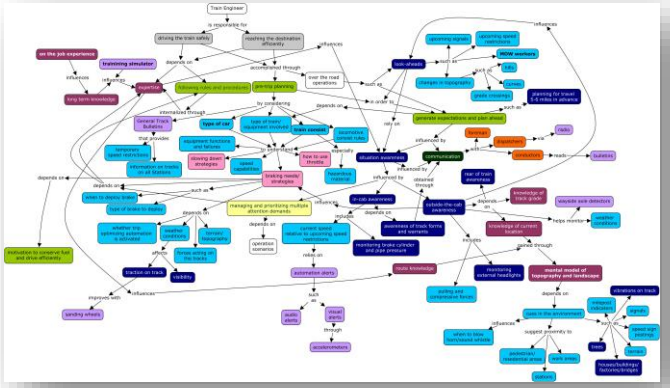
# TO Integrated Running Screen…

## Keep it Simple

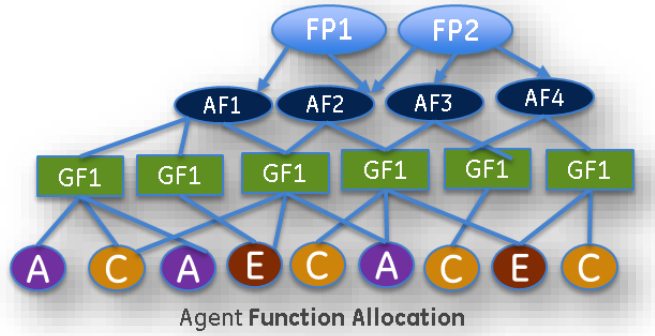


# Human-Centered Design Approach

**Research**
Literature Review, Interviews with Domain Experts, Task Analysis



**Conceptual Model**
Domain Functional Decomposition Model



Agent **Function Allocation**

**Static Metrics**

**Coherence:** How related are the tasks?

**Operator Workload:** Based on cognitive & perceptual inputs & outputs

**Compare Metrics**
Across Agents and Operational Scenarios

**Evaluate prototype in HITL Platform**

# Trip Optimizer Plus (TO+)

## In-Cab Signaling Display:

- Distance to next signal shown
- When 1mi ahead, signal aspect will be shown

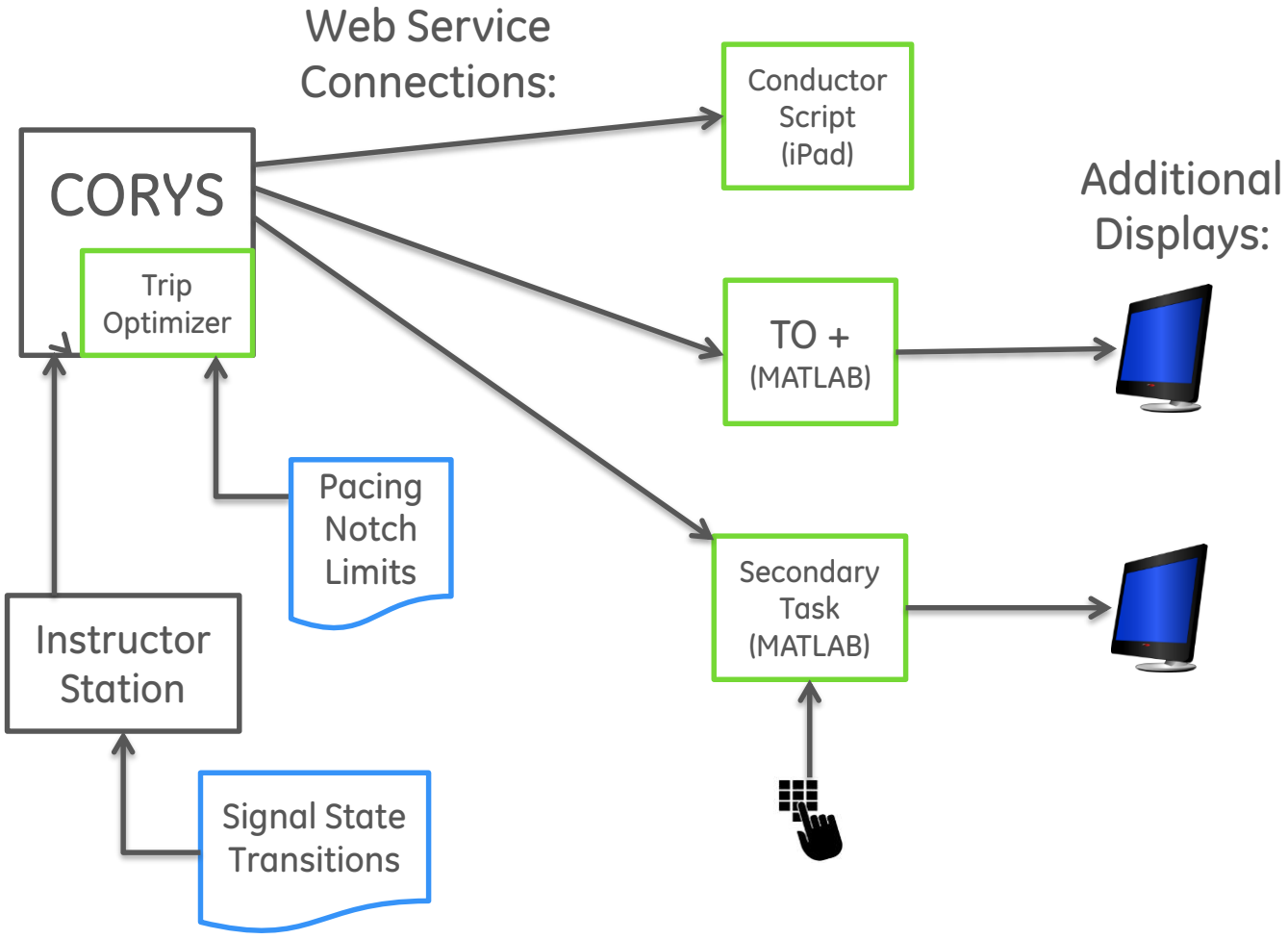
## Auto Pacing:

- Limits max power to slow the pace to avoid catching up to train ahead when needed

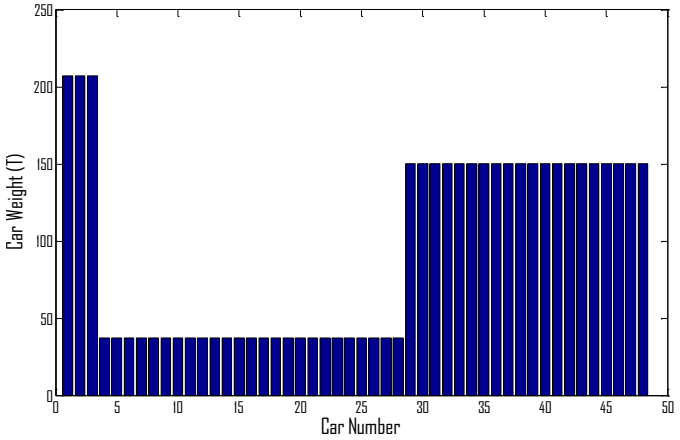
## Auto Horn:

- Distance to next crossing shown
- Is aware of quiet zones, private crossings

# CTIL Architecture



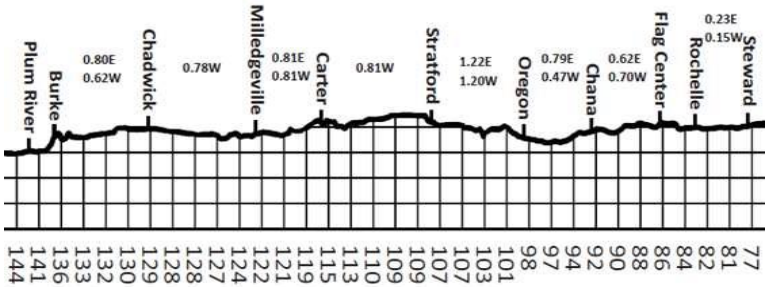
# Scenario Overview




Train: 3 head-end locos, 3144 ft, 4296 tons

Scenario: Following low HPT train
(no oncoming traffic)

Paperwork:
MOW (1), Slow Orders (2, both received en-route via dispatcher)



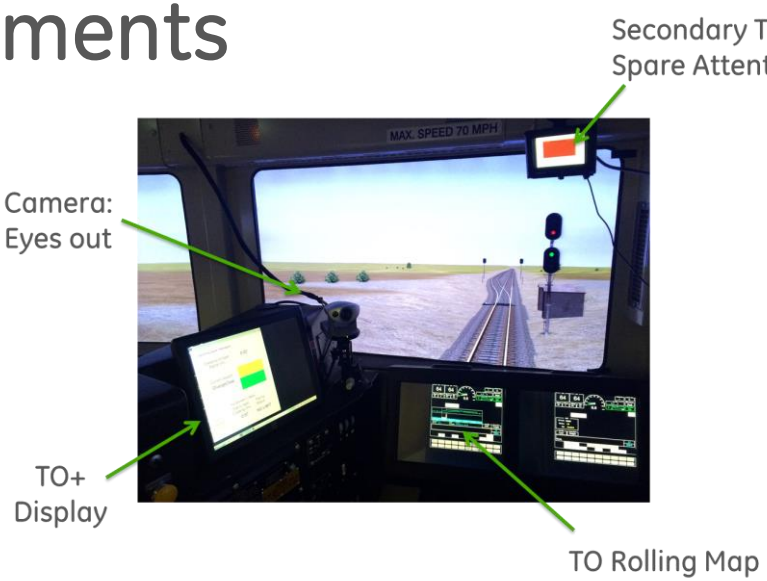

Instructions:
Drive as you normally would (use TO/TO+ as much as possible), use conductor as needed, report any equipment failures (e.g., faulty gate)

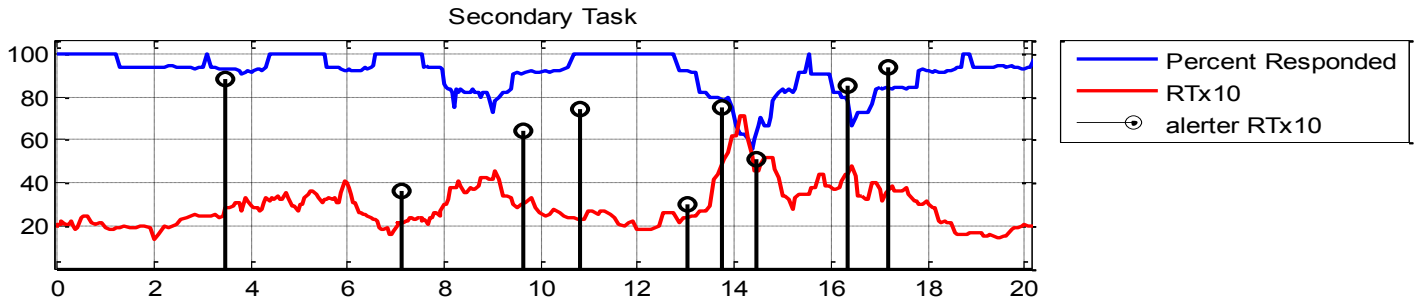
# Human-in-the-Loop Experiments

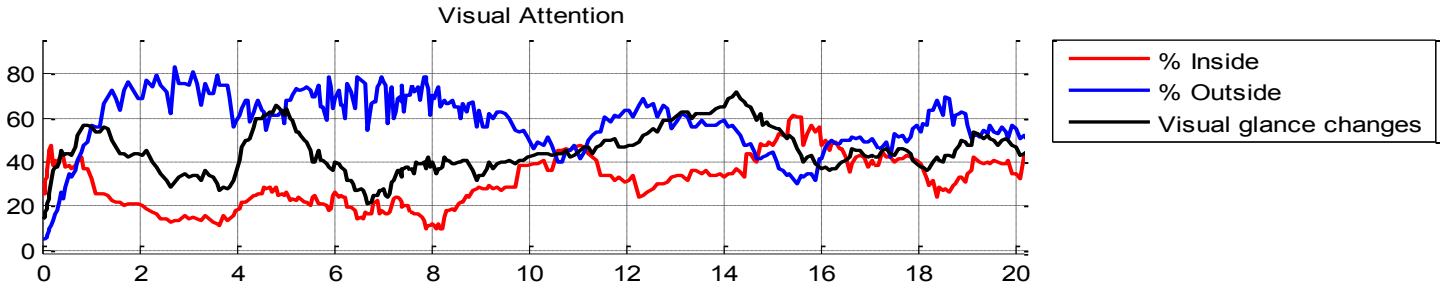
11 subjects (from 4 Class 1's; 9.9 years avg. experience), 3 conditions (Manual, TO, TO+).

For each run (65mi, 1.5hr) :

- Standard event recorder
- In-train forces
- Contextual information (e.g., signal state)
- Video (4 streams)
- Human Performance Data:



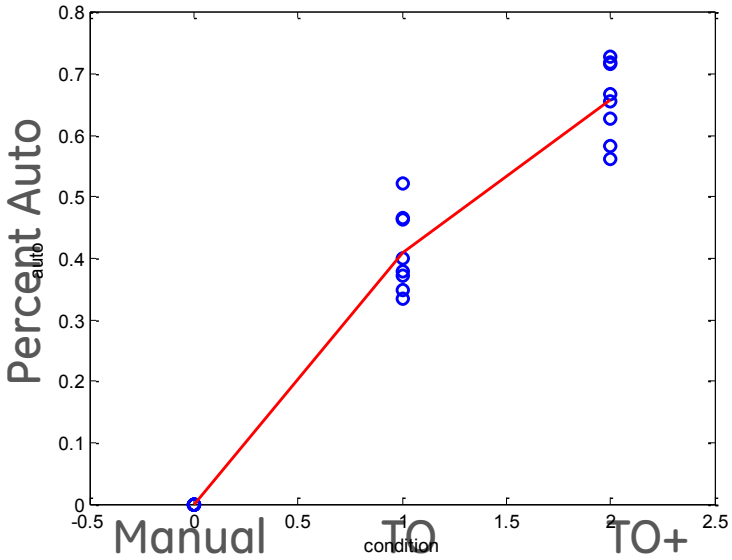



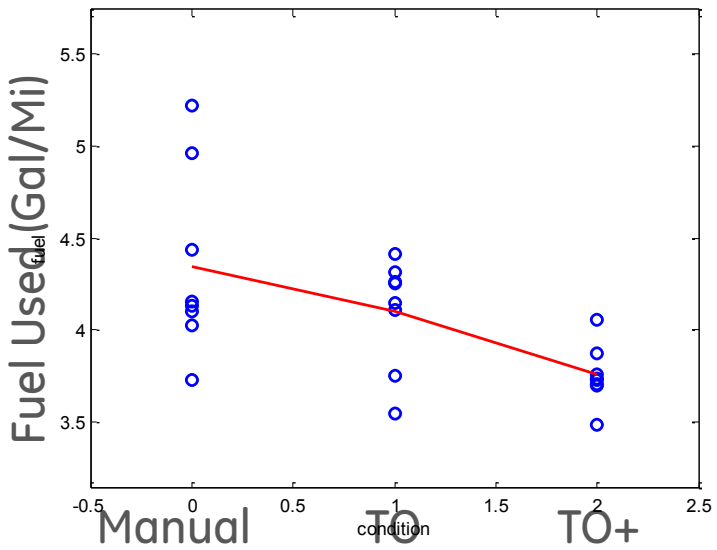
# Overview Statistics

Comparable average travel times (1hr 36min – 1hr 39min avg.)

Percent Auto: TO (41%), TO+ (66%)

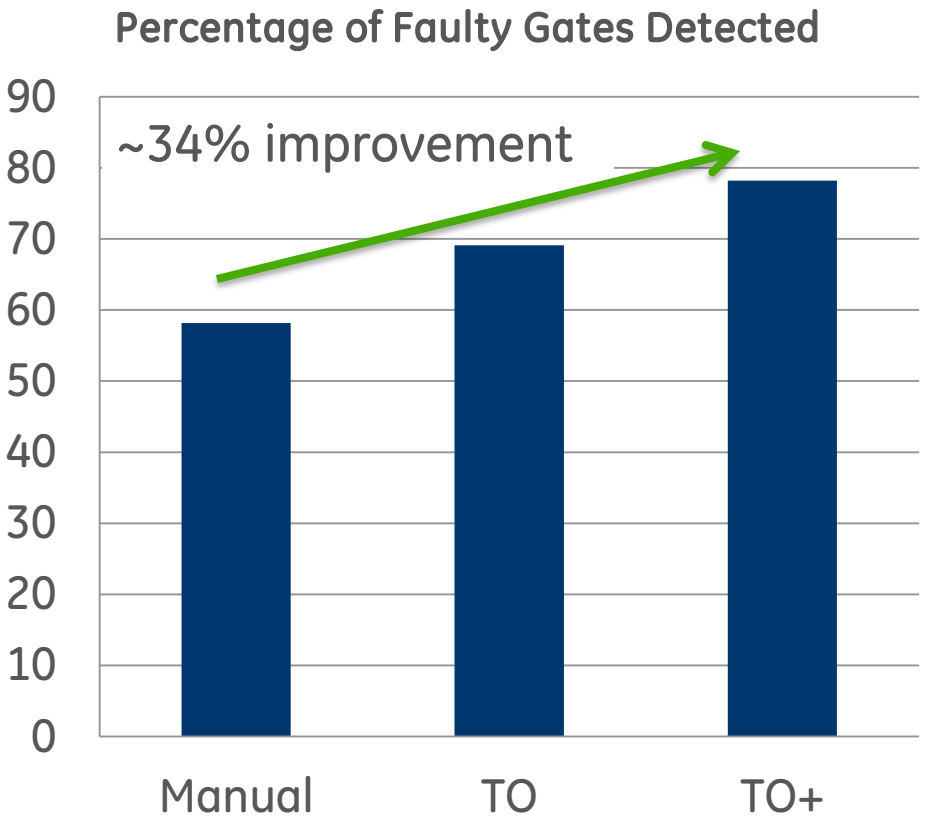
Fuel Savings vs. Manual: TO (6%), TO+ (14%)



# Vigilance Performance

In each run, there were 5 faulty gates to be reported (different for each):



# Preliminary Visual Attention Data

Visual allocation across automation conditions (1 subject):

| | Manual | TO | TO+ |
|---|---|---|---|
| Secondary | 2.9% | 3.3% | 4% |
| Inside | 27% | 31% | 30% |
| Outside | 68% | 64% | 65% |
| Conductor | 1.5% | 1.7% | 1% |

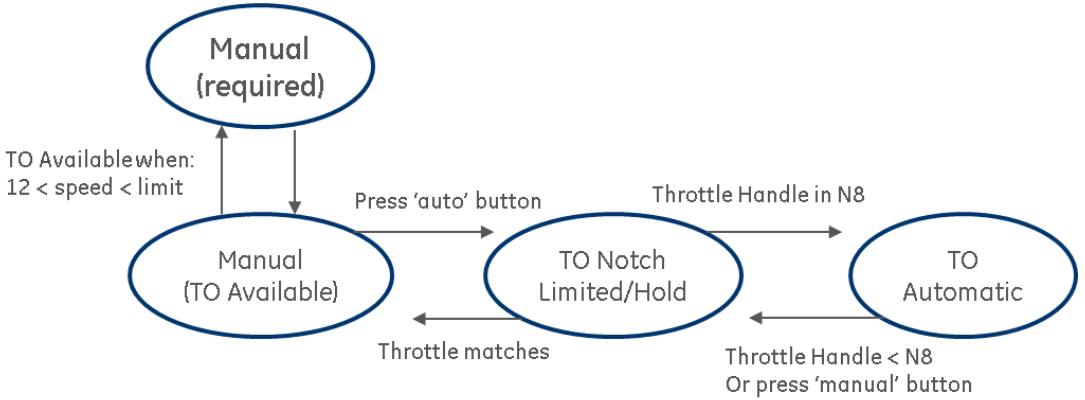
Some extra attention with TO/TO+ (up to ~30% more to secondary task)

Small difference in visual allocation outside the cab during TO and TO+

→ But better vigilance (just looking out the window isn't enough!)

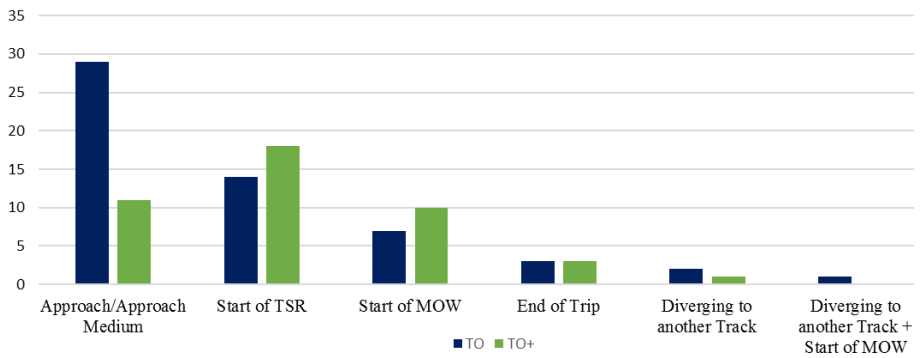
# Mode Transition Analysis

Basic mode flow:

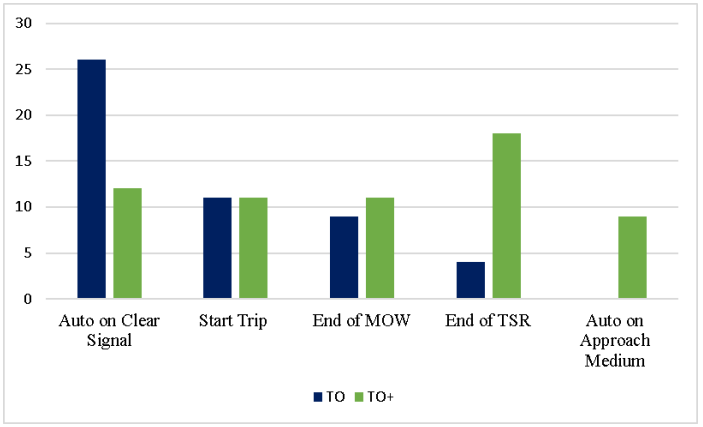



Classification of (expected, normal) Transitions:

Automatic → Manual




Manual → Automatic

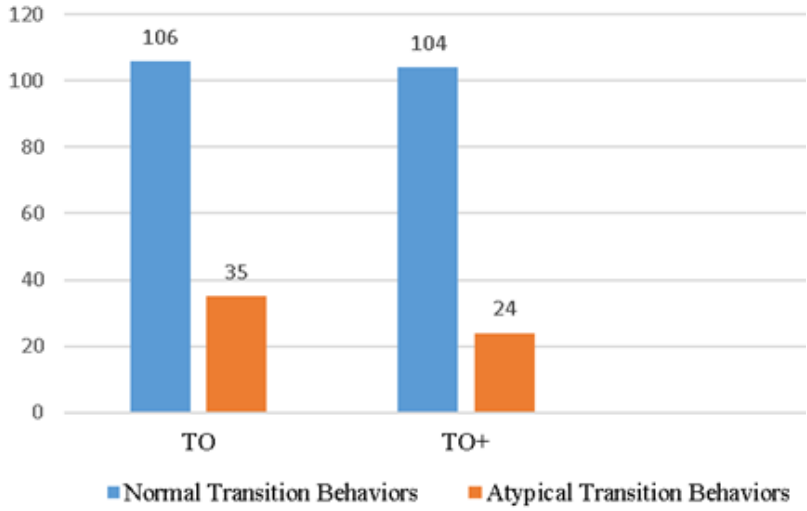


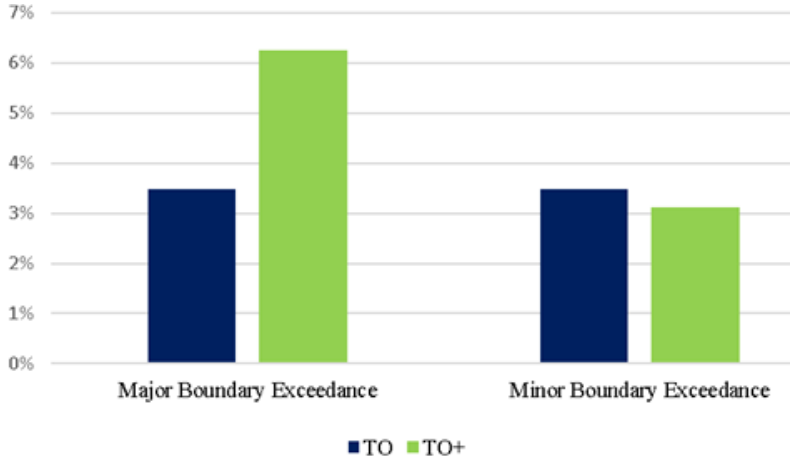
# Mode Transition Analysis - Atypical

Several transitions were not explainable, cautious, or not according to the design intent of the system.

Minor/major boundary exceedances (i.e., remaining in auto mode beyond an approach signal)

- No SPAD errors resulted
- Many co-occurred with radio communications or near the beginning/end of a trip
- None of these exceedances are possible with TO-PTC integration

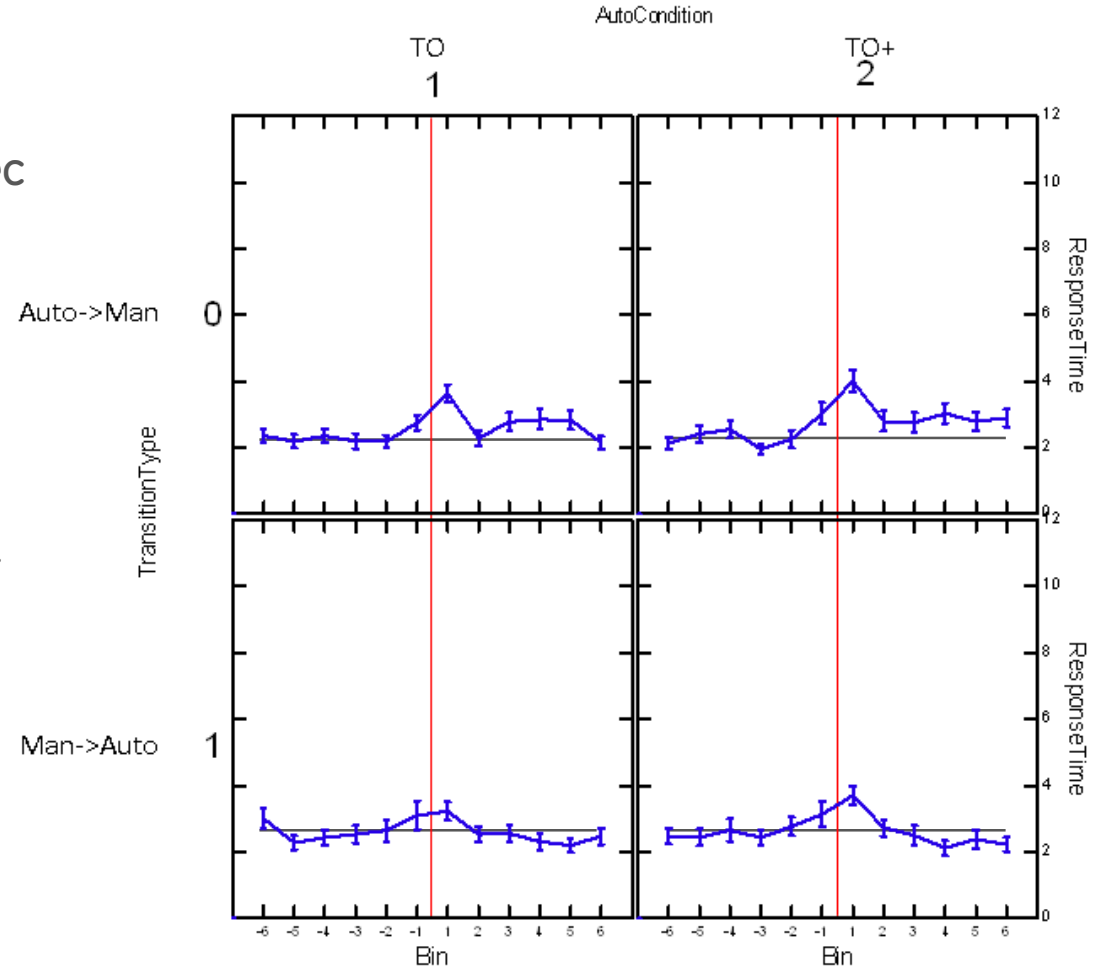


# Transition Workload

Secondary task reaction times significantly increase in the 10-sec periods just before and after a mode transition

Also significant increase between 50-60 and 20-30 seconds before transition → possible evidence of planning for transition



# Takeaways

Automatic control has little effect on eyes out window

Well-designed automation can improve operator performance (better vigilance)

Opportunities to improve training on boundary conditions

Workload spikes at automation mode transitions are short-lived and relatively small when operator-initiated

Questions? brooksja@ge.com