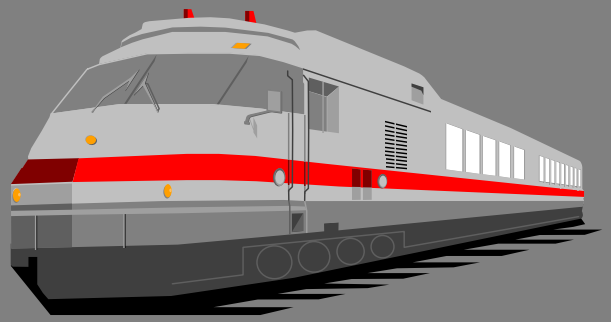
U.S.
D.O.T.



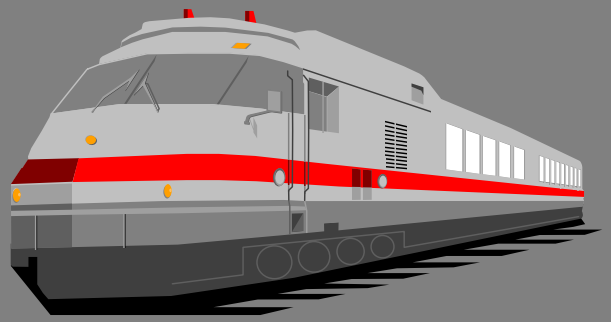
Human / Computer Interface

In High Speed Rail

A Simulation Approach

Center for Human Factors Research in Transportation/High-Speed Rail Simulation

Background

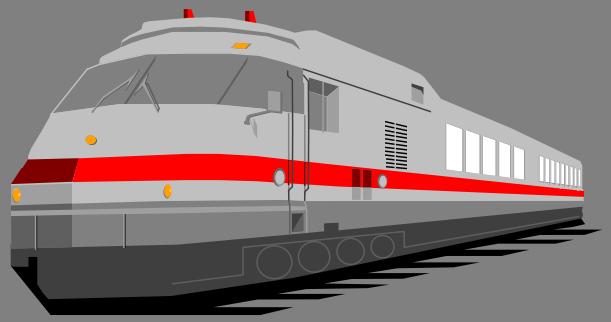


The application of advanced automation to the U.S. passenger and freight rail systems represents a unique challenge.

As the U.S. moves toward high-speed passenger rail service, questions have emerged regarding the appropriate configuration of automation in the locomotive cab.

In particular, European systems rely on a trackside automation infrastructure; recent advances in technology hold the promise of achieving safety and productivity gains through in-cab automation, with minimal reliance on trackside infrastructure.

Background

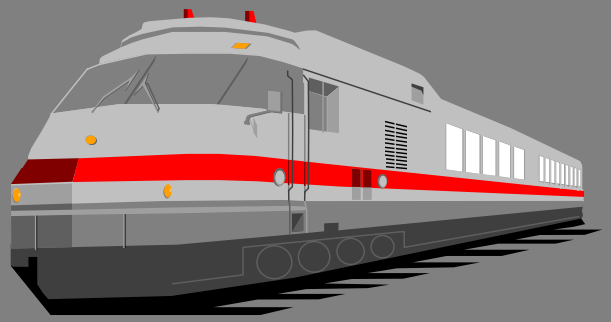


The Federal Railroad Administration has initiated this research to gain a better understanding of the implications of cab automation on human operator performance.

At the heart of the matter are the questions of what tasks are appropriate for a human to perform, what tasks are appropriate for a computer to perform, and what tasks should be shared.

These choices may have signigficant safety implications

Hardware

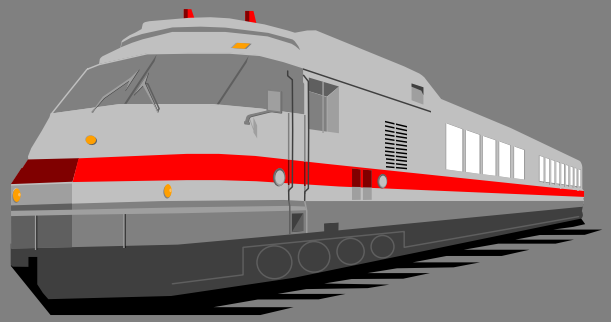


In order to answer questions regarding automation and human performance, the Volpe Center and MIT built an interactive high-speed train simulator.

The simulator hardware consists of a suite of Silicon Graphics (SGI) machines that communicate over a local area network (LAN).

The simulator was constructed at the Center for Human Factors Research in Transportation, which is operated jointly by the Volpe Center and MIT in Cambridge MA.

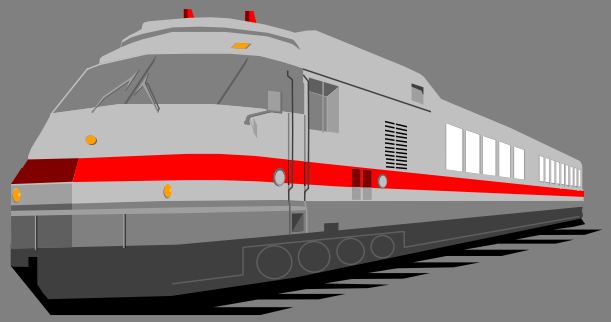
Automation issues



Cab automation can be separated into control automation (which aids the engineer in controlling the train) and display automation (which aids the engineer in gathering and analyzing data).

Research projects have been completed on the relationship between control automation and operator situation awareness, and on computer display decision aids.

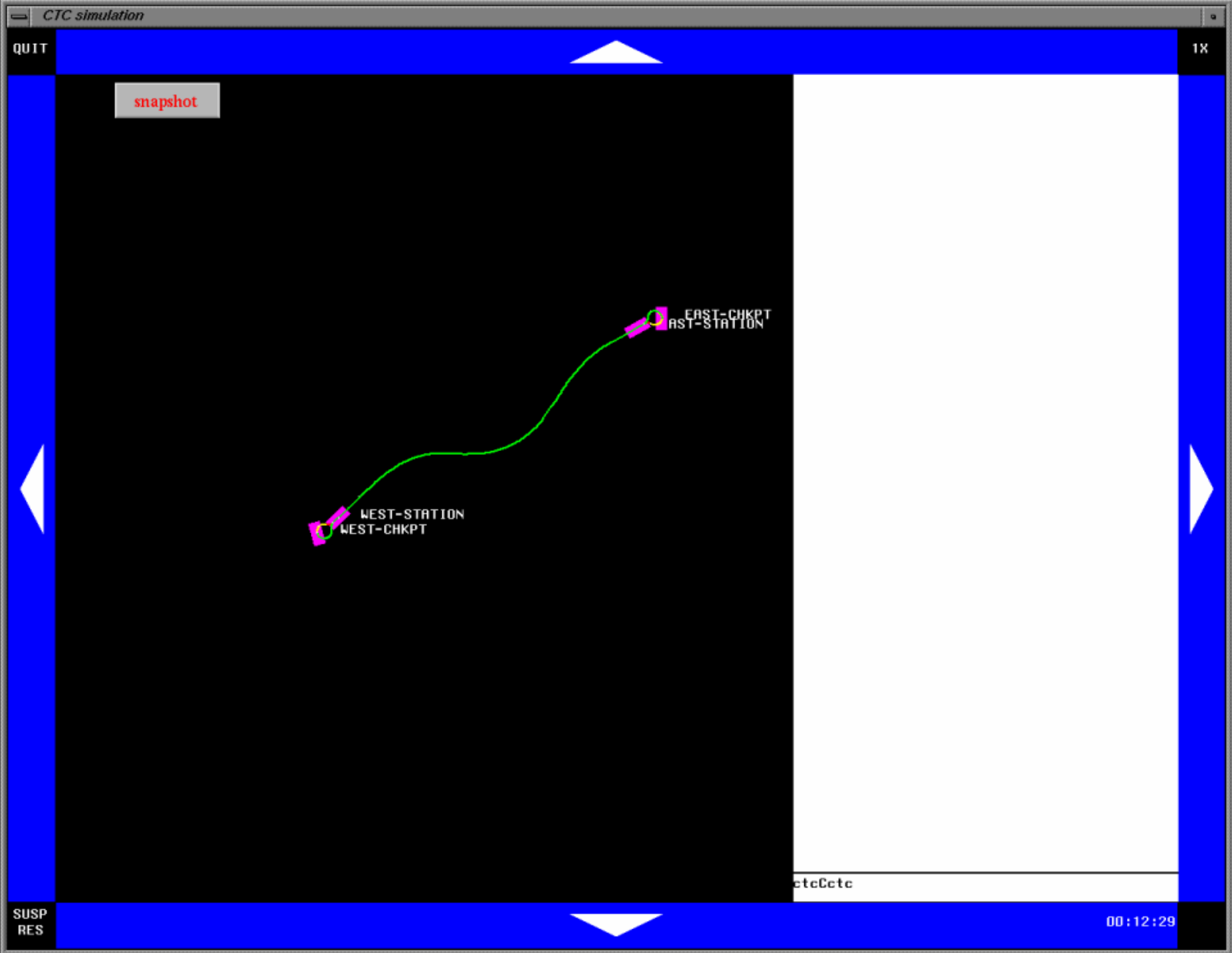
Central traffic control



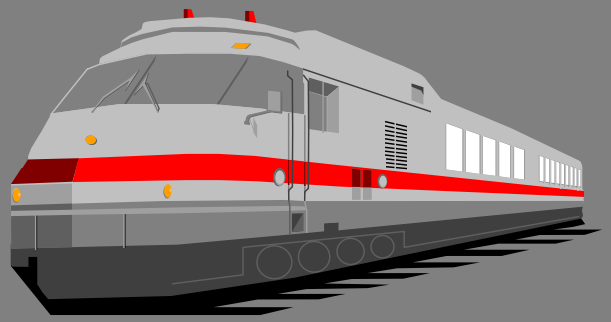
The simulation consists of a central traffic controller (dispatcher) and one or many train operators; these two parts of the simulation can be run separately.

The controller sees an overview of the track network for which he/she is responsible; in this case, the track network consists of only one track between two stations with turn-around loops at either end.

An overview of the track system follows. The left side shows the track, the right provides an electronic comunications notepad.


CTC simulation
QUIT
1X
snapshot
EAST-CHKPT
AST-STATION
WEST-STATION
WEST-CHKPT
ctcCctc
SUSP
RES
00:12:29

Central traffic control (cont'd.)

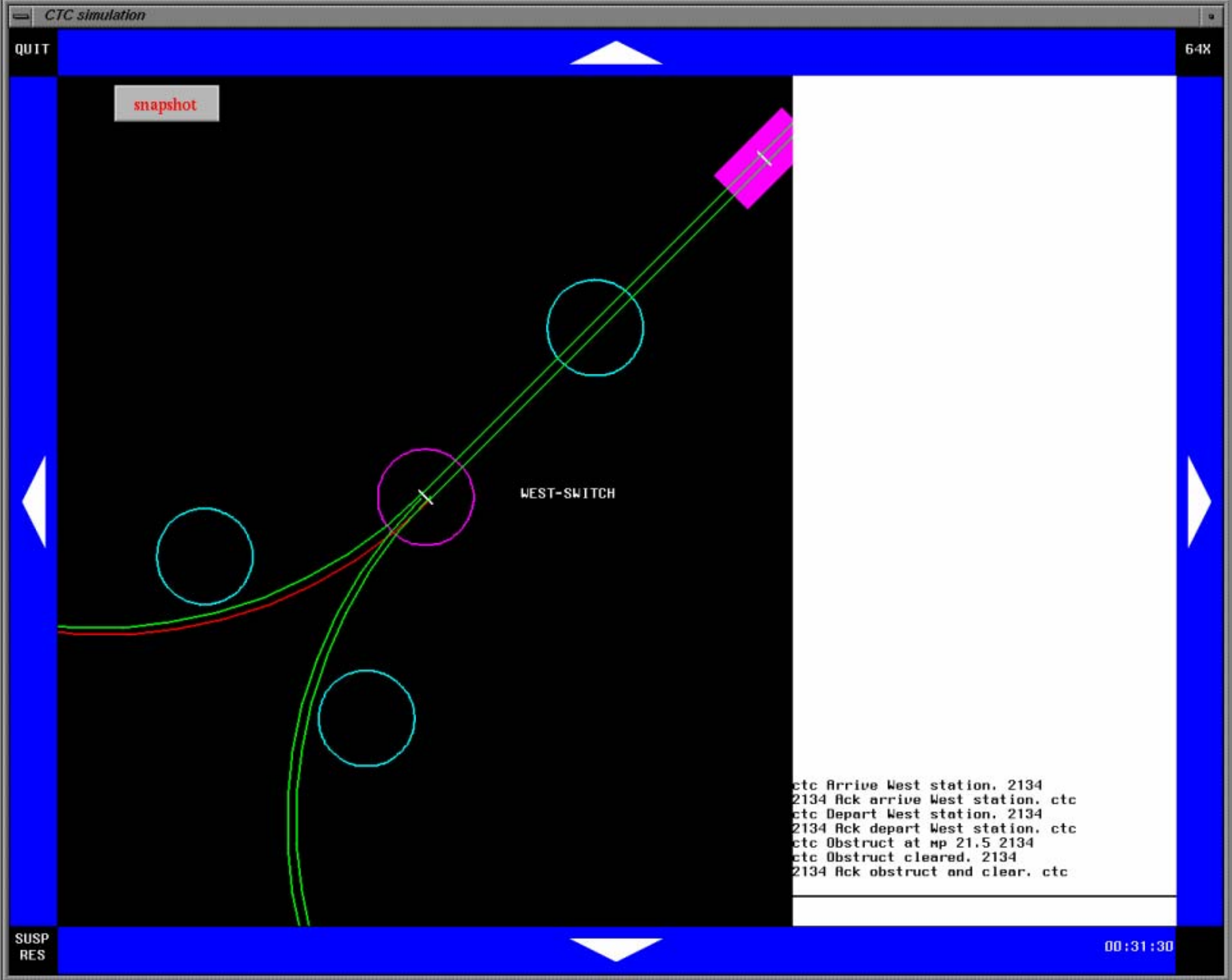


The controller can zoom to a specific region by clicking the mouse in the appropriate area on the screen.

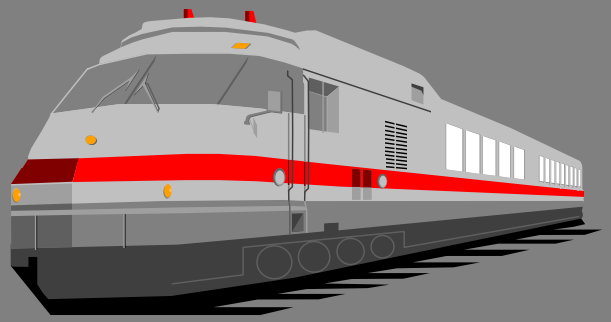
By clicking on/near a switch, the controller can direct a train in either direction.

On the right side of the screen is an area for text-based communications between the controller and the engineer.

A close-up of the dispatcher's screen follows.


CTC simulation
QUIT
64X
snapshot
WEST-SWITCH
ctc Arrive West station. 2134
2134 Ack arrive West station. ctc
ctc Depart West station. 2134
2134 Ack depart West station. ctc
ctc Obstruct at mp 21.5 2134
ctc Obstruct cleared. 2134
2134 Ack obstruct and clear. ctc
SUSP
RES
00:31:30

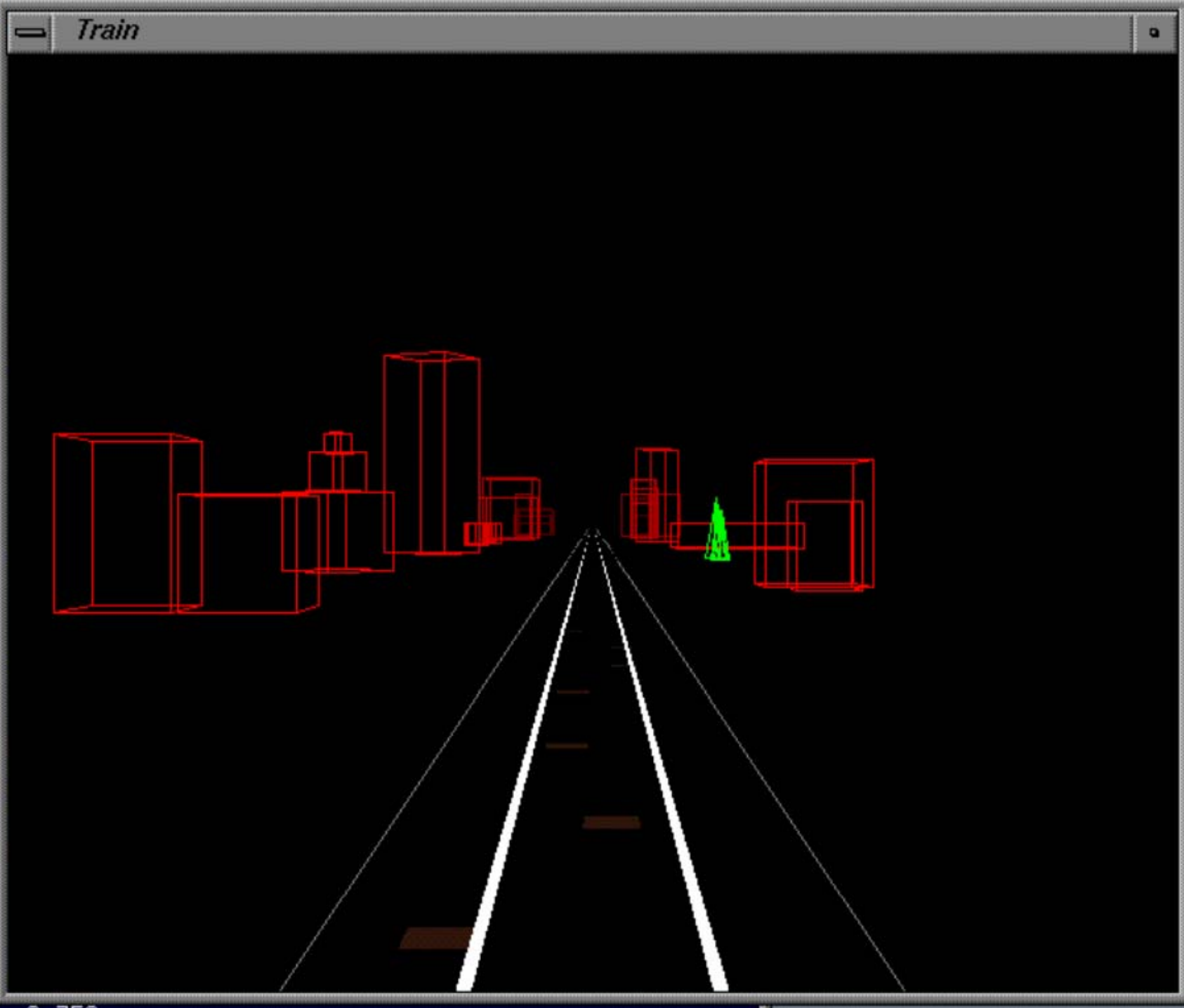
Out-the-window view



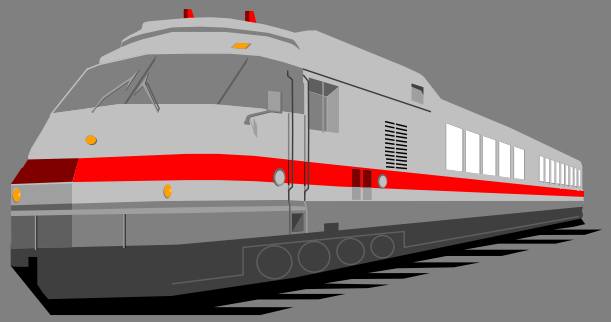
The next slide shows a detailed static view of the cab display.

In the experiment, this “cab instrument view” view is generated on one monitor, while the “out-the-window” is generated on a second monitor.

The video tape accompanying this presentation shows a representative night trip at simulated speeds of up to 300 km/h (187mph).


Train

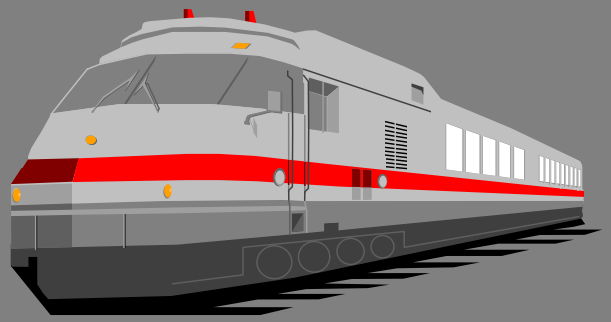
Control automation experiment



In the experiment examining the relationship between control automation and operator situation awareness, three types of control automation were investigated:

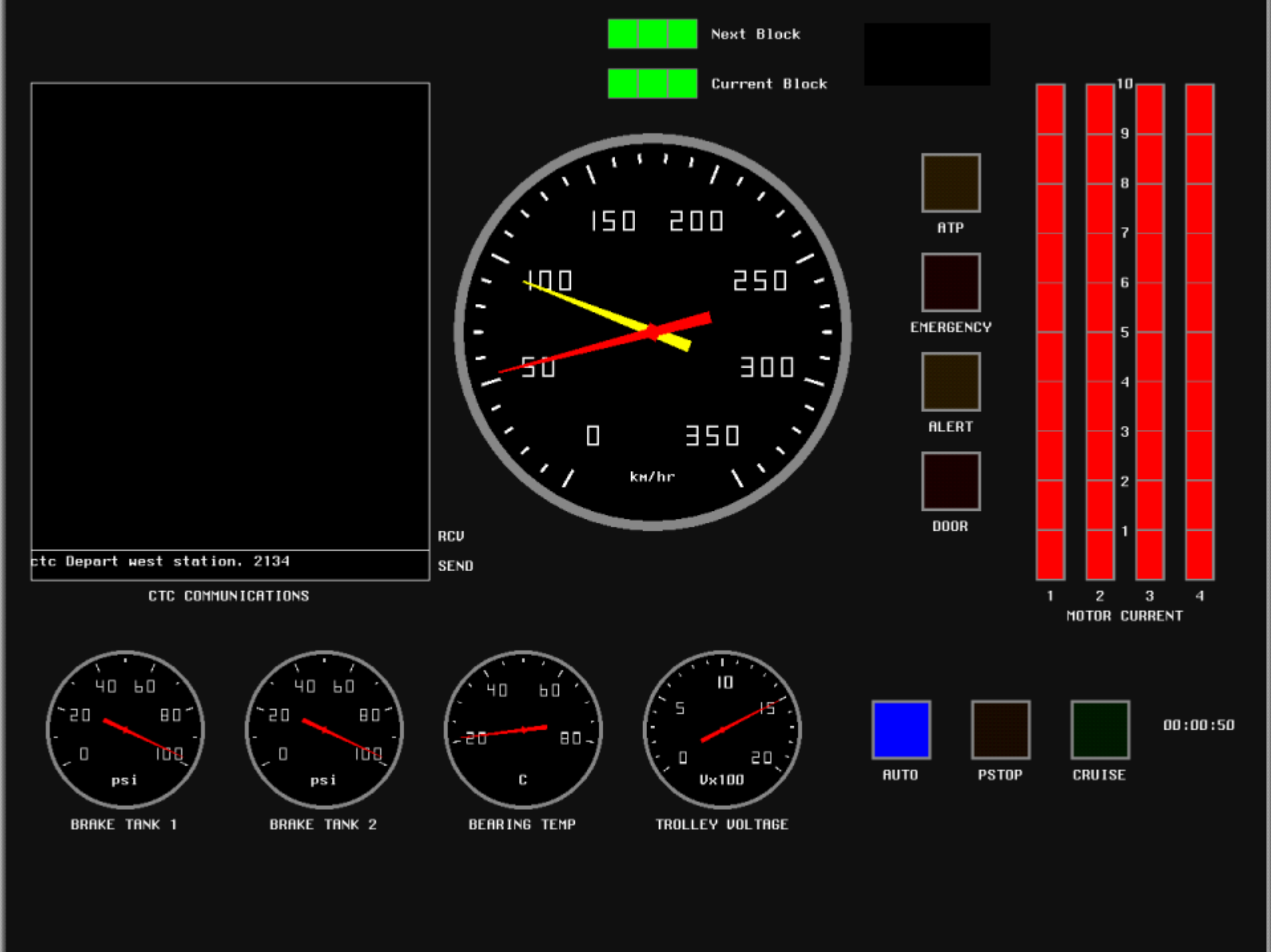
- Cruise control (which is found in many passenger locomotives being built today);
- Programmed stop (a future technology that will stop the train at a pre-specified location); and
- Autopilot (a future technology that follows a specified speed trajectory).

General display panel

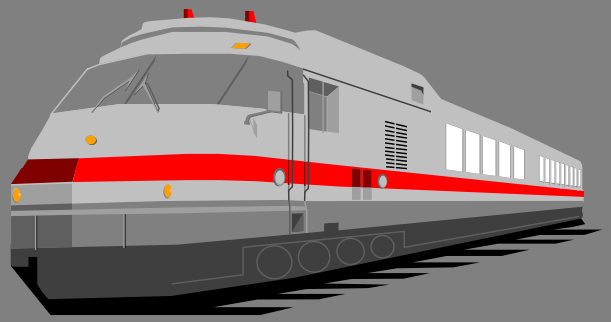


This basic panel displays speed, brake pressure and traction information; with the exception of the “next-block signal” and the text-based communication, all of these items are found in present-day locomotive cabs - no aiding was used.

In the next slide, we see the train being operated in autopilot mode (note the “autopilot” light is lit). The train tries to track the target speed indicated by the yellow needle.


Next Block
Current Block
ctc Depart west station. 2134
CTC COMMUNICATIONS
RCV
SEND
150 200
100 250
50 300
0 350
km/hr
ATP
EMERGENCY
ALERT
DOOR
10
9
8
7
6
5
4
3
2
1
1 2 3 4
MOTOR CURRENT
40 60
20 80
0 100
psi
BRAKE TANK 1
40 60
20 80
0 100
psi
BRAKE TANK 2
40 60
20 80
C
BEARING TEMP
10
5 15
0 20
Vx100
TROLLEY VOLTAGE
AUTO
PSTOP
CRUISE
00:00:50

Failure scenarios

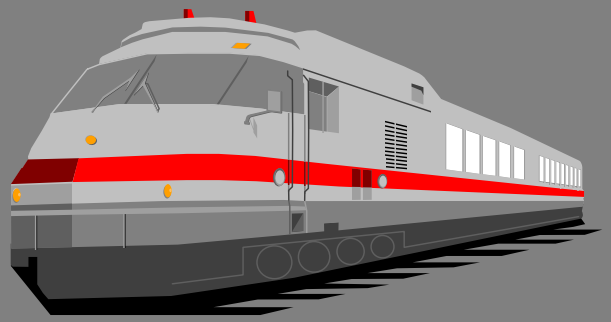


While the subject operates the train under varying levels of automation, a variety of failure scenarios occur, and the subjects' responses to the failures are recorded.

In one scenario, there is a car stopped in the grade crossing -- the operator of the train must stop the train before the crossing to avoid an accident.

Other failure scenarios include loss of brake pressure (noted by a drop in one of the gauges in the lower left of the dash display) and loss of traction.

Display aiding experiment

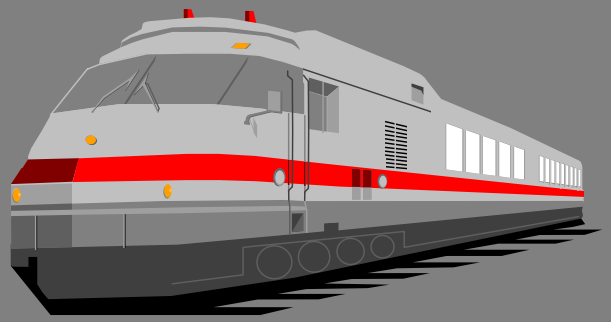


For the investigation of “computer display decision aiding,” four different displays were used, with only one level of control automation - manual control:

- Basic (no aiding)
- Preview (preview of track information)
- Predictor (predicts future train position and brake response)
- Advisor (presents optimal speed trajectory)

(Each display incorporates all information from previous display.)

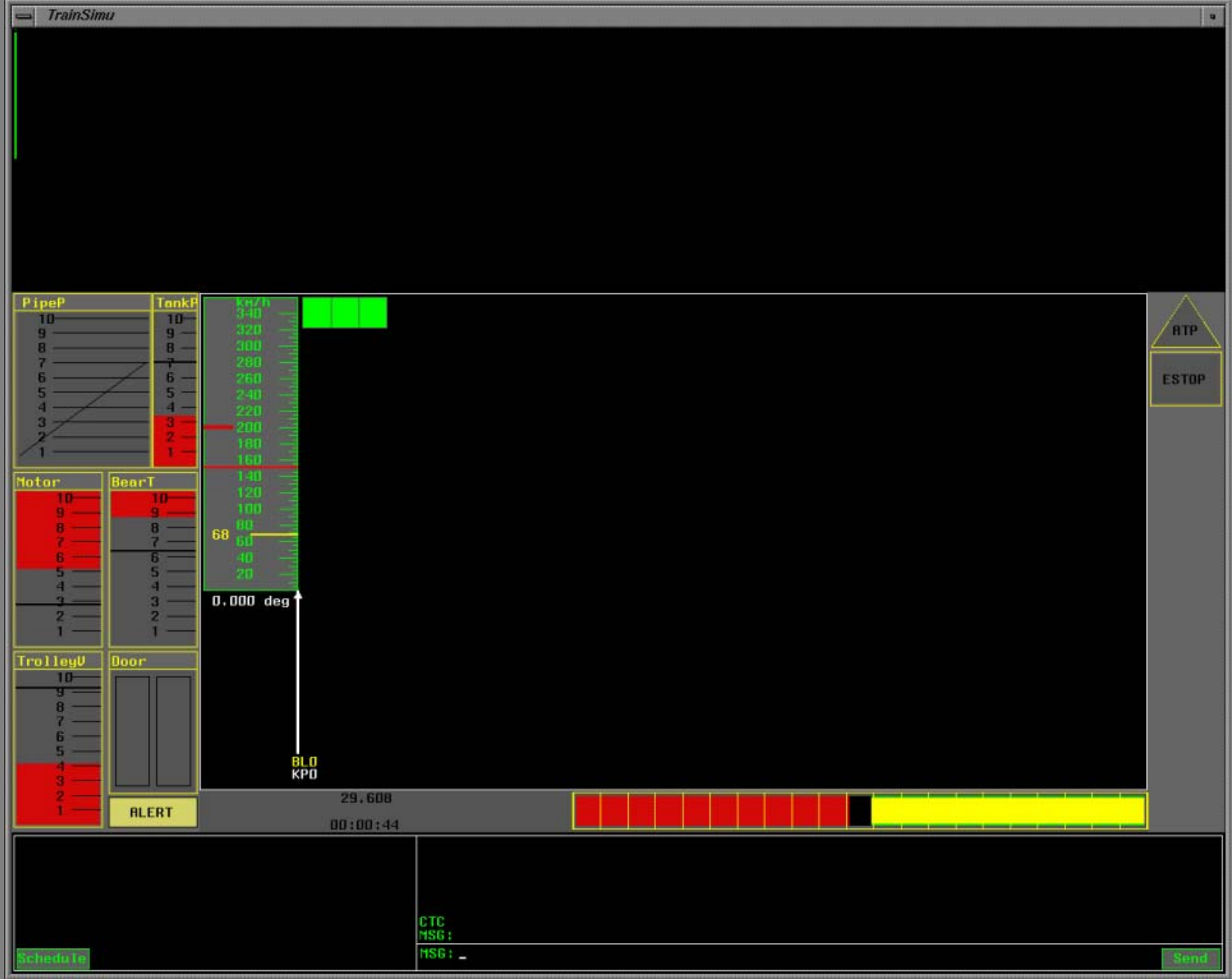
Basic display



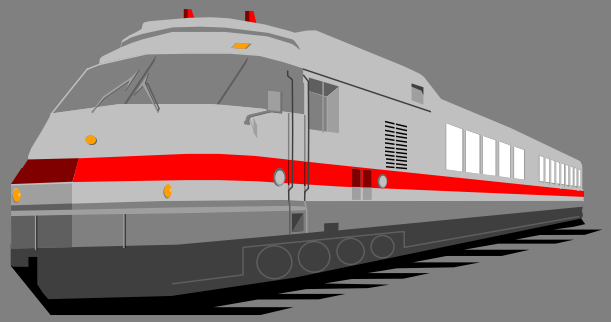
Next, we see the basic display, with only that information found in many cabs being built today:

- brake pressure;
- motor power;
- in-cab signal aspect;
- line voltage; and
- wheel bearing temperature.

Text-based communications were used, and a schedule is printed in the lower-left corner in lieu of a hard copy.

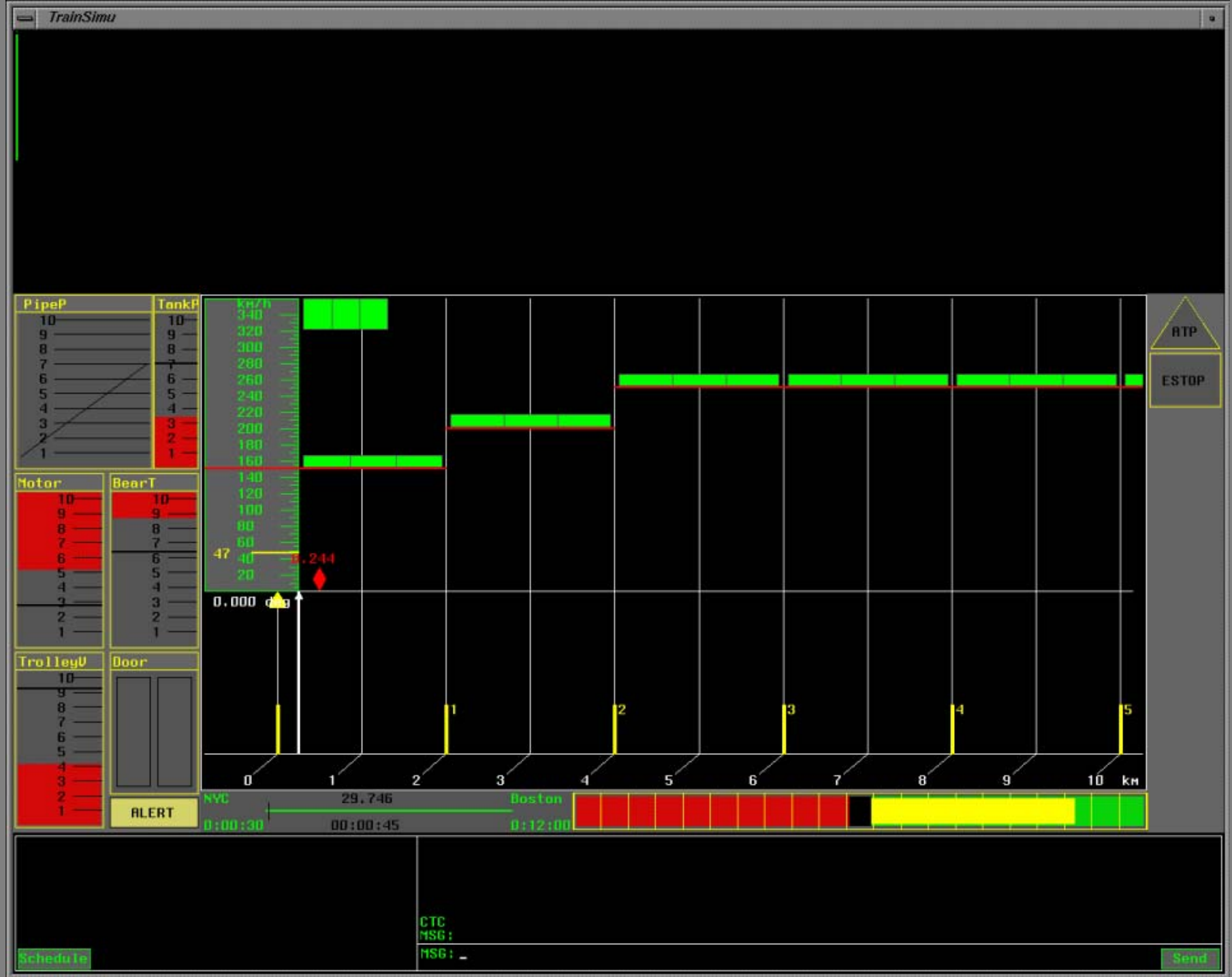

TrainSimu
PipeP
TankP
Motor
BearT
TrolleyV
Door
ALERT
km/h
68
0.000 deg
BLO
KPO
29.608
00:00:44
ATP
ESTOP
CTC
MSG:
MSG:
Schedule
Send

Preview Display

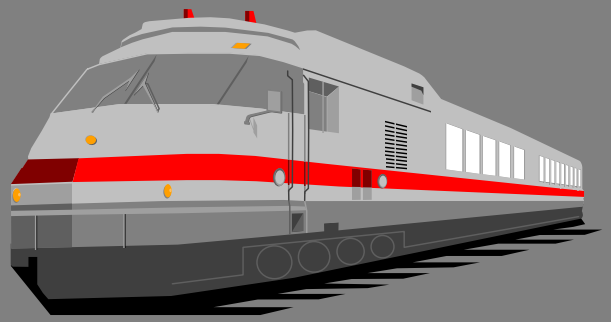


This display is one step higher than the “basic” display, and incorporates all information found in the “basic” display as well as a preview.

The “preview” display adds a preview of the track grade, future signal aspects, and previewed speed limits.

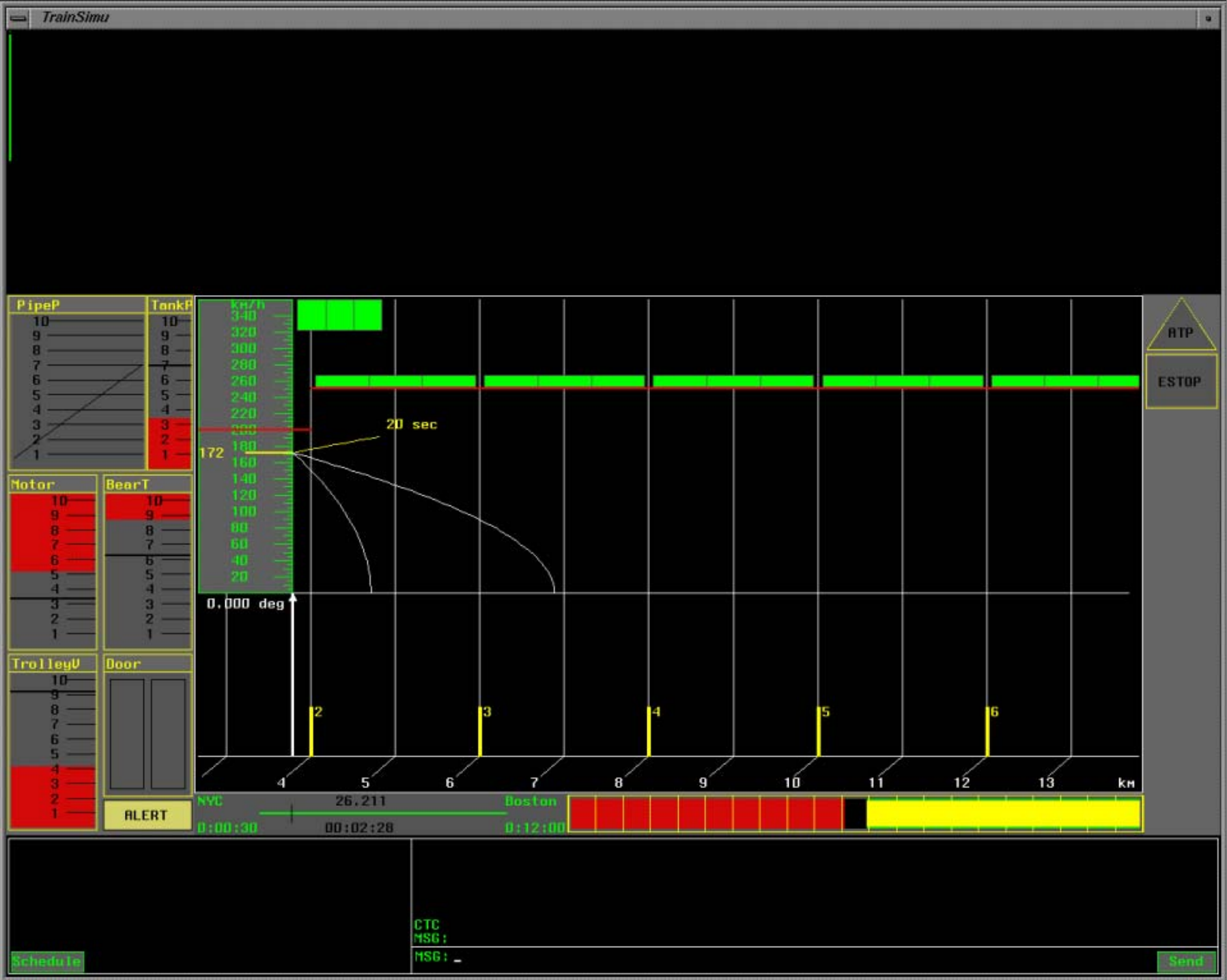

TrainSimu
PipeP
TankP
Motor
BearT
TrolleyV
Door
ALERT
km/h
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
47
0.244
0.000
ATP
ESTOP
0
1
2
3
4
5
6
7
8
9
10
km
NYC
29.746
Boston
0:00:30
00:00:45
0:12:00
CTC
MSG:
MSG:
Schedule
Send

Predictor Display

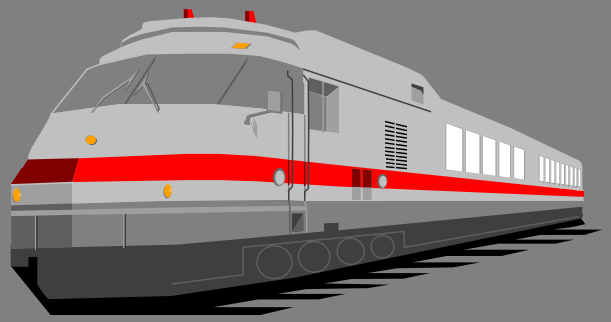


The next slide shows the predictor display. It is one step higher than the “preview” display, and incorporates all information found in the “preview” display.

The “predictor” display adds a prediction of where the train will be (and at what speed) in 20 seconds (given current inputs and grade), how long it will take to stop the train using full-service braking, and how long it will take to stop the train using emergency braking.

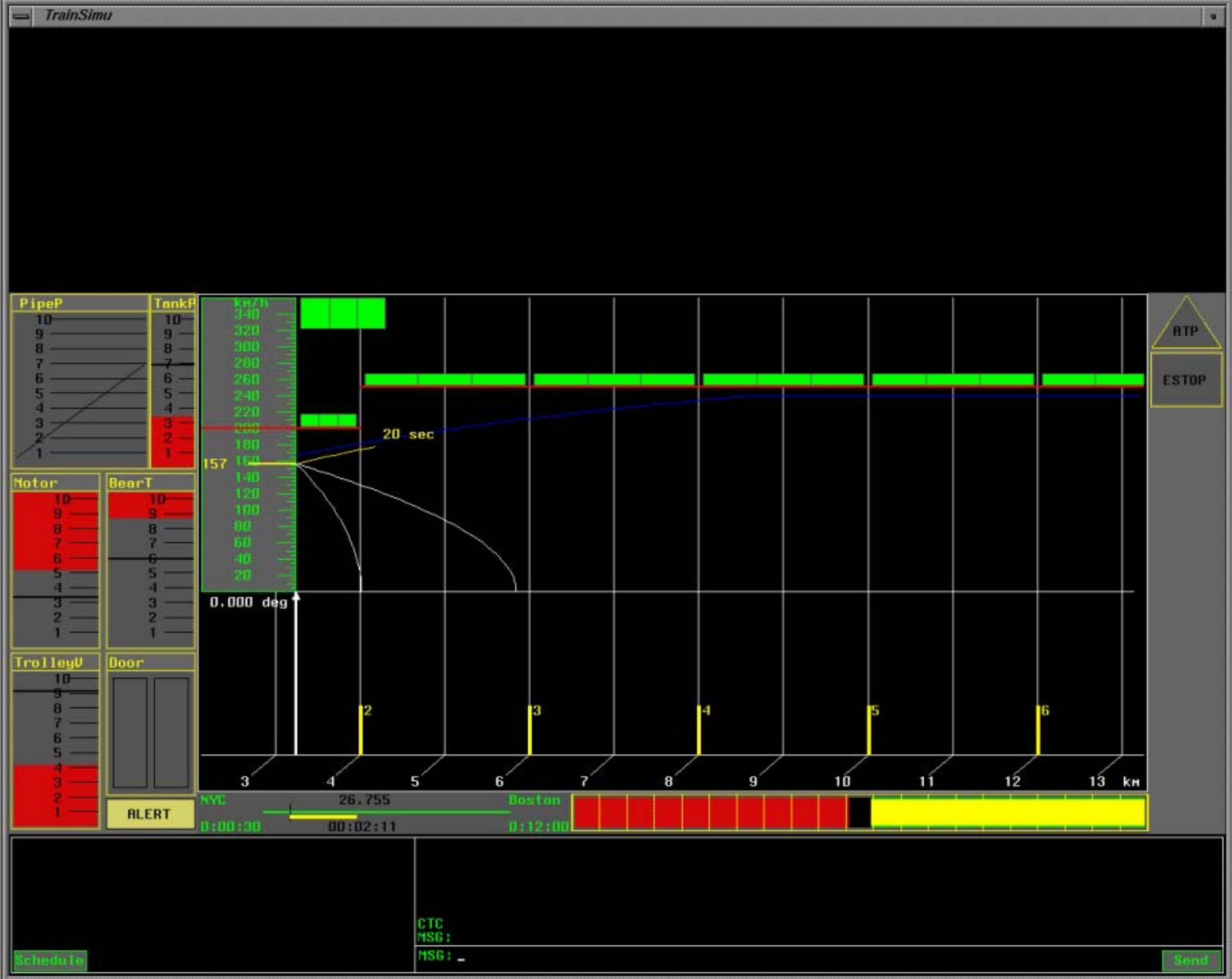

TrainSimu
PipeP
TankP
Motor
BearT
TrolleyV
Door
ALERT
km/h
172
20 sec
0.000 deg
ATP
ESTOP
km
NYC
26.211
Boston
0:00:30
00:02:28
0:12:00
CTC
MSG:
MSG:
Schedule
Send

Advisor Display

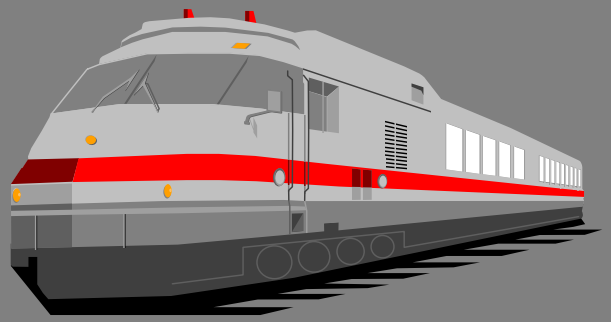


The next slide show the advisor display. It is one step higher than the “predictor” display, and incorporates all information found in the “predictor” display.

The “advisor” display adds an “optimal speed trajectory,” which advises the operator as to what speeds he/she should follow to optimize the total cost of the trip (in terms of energy consumption plus a weighted schedule deviation) under the constraints of schedule, speed limits, passenger ride quality, and train propulsion and braking capacities.


TrainSimu
PipeP
TankP
Motor
BearT
TrolleyV
Door
ALERT
km/h
157
20 sec
0.000 deg
ATP
ESTOP
km
NYC
26.755
Boston
0:00:30
00:02:11
0:12:00
CTC
MSG:
MSG:
Schedule
Send

Future simulator use

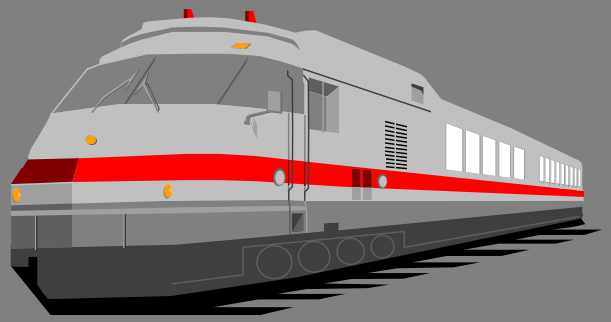


Ongoing research includes engineer stress and fatigue, central traffic control and wayside automation.

Future display alternatives, and upgrades to the system which will include sound, limited motion, and a projection of the out-the-window view.

These enhancements will allow more detailed examinations of future railroad automation scenarios.

Acknowledgments



- FRA:
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- MIT:
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