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Next Generation Locomotive Cab
Task 5 Summary Report: Control Stand Design

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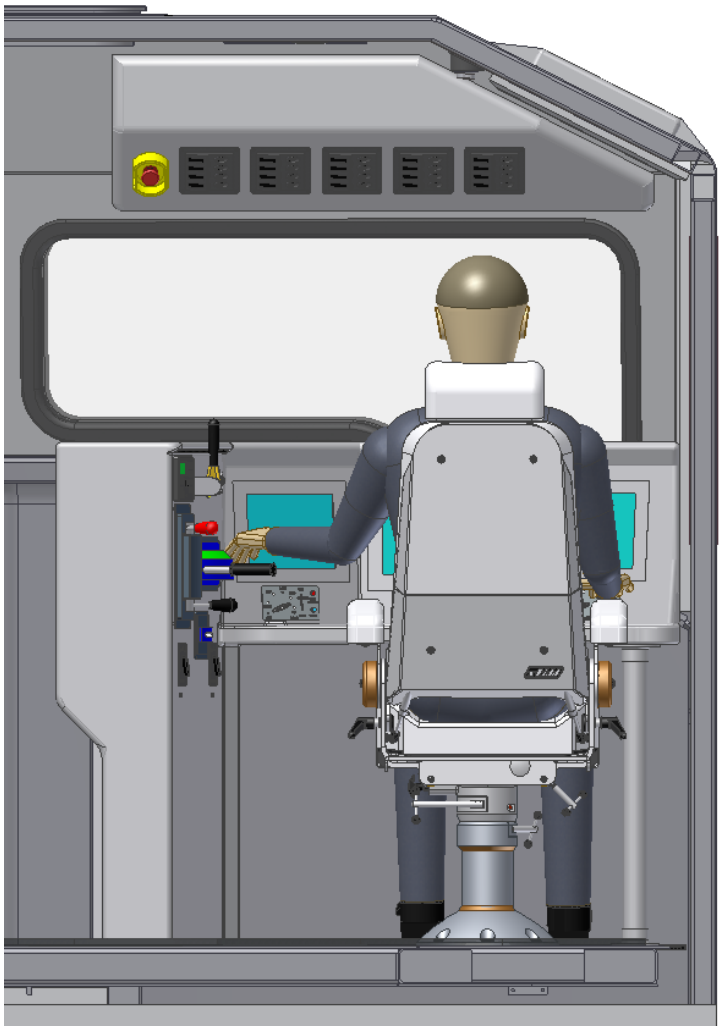

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13. ABSTRACT
This report discusses the development of a user-centered control stand for the Federal Railroad Administration's Next Generation Locomotive Cab Demonstration Program. A "modified" Association of American Railroads 105 side-mounted control stand was used as a starting point to facilitate bidirectional locomotive operation. Researchers applied a variety of qualitative human factor methods, including literature review, naturalistic observation, computer modeling, and heuristic evaluation, to design the improved control stand. Final design includes a decluttered side control stand, a short desktop and three-panel front touch-screen display that can accommodate and integrate current and future locomotive and train technologies, and an overhead ceiling panel that replaces, in part, controls and displays traditionally located behind the engineer on the back wall. Other controls and displays traditionally found on the back panel have been integrated into the touch-screen displays. A mockup of the revised control stand design was fabricated as part of this program to demonstrate the human factors and ergonomic improvements. Researchers also developed several interactive scenarios to use with the touch-screen displays. The mockup and scenarios can be used to demonstrate the control stand's user-centered design and collect user feedback.

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1 inch (in) = 2.5 centimeters (cm)	1 millimeter (mm) = 0.04 inch (in)
1 foot (ft) = 30 centimeters (cm)	1 centimeter (cm) = 0.4 inch (in)
1 yard (yd) = 0.9 meter (m)	1 meter (m) = 3.3 feet (ft)
1 mile (mi) = 1.6 kilometers (km)	1 meter (m) = 1.1 yards (yd)
	1 kilometer (km) = 0.6 mile (mi)
AREA (APPROXIMATE)	**AREA (APPROXIMATE)**
1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)	1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)	1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)	1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)	10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)	
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	= 1.1 short tons
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1 tablespoon (tbsp) = 15 milliliters (ml)	1 liter (l) = 2.1 pints (pt)
1 fluid ounce (fl oz) = 30 milliliters (ml)	1 liter (l) = 1.06 quarts (qt)
1 cup (c) = 0.24 liter (l)	1 liter (l) = 0.26 gallon (gal)
1 pint (pt) = 0.47 liter (l)	
1 quart (qt) = 0.96 liter (l)	
1 gallon (gal) = 3.8 liters (l)	
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)	1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
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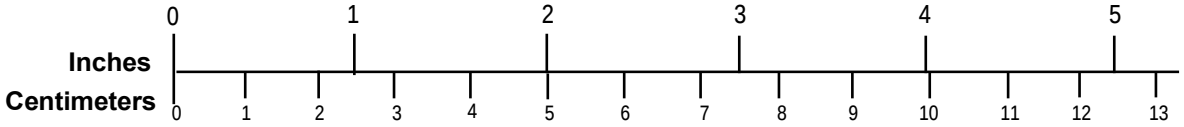

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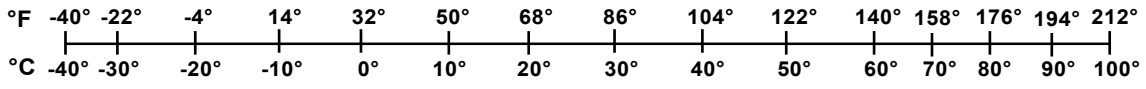

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Executive Summary

This report discusses the design and early stages of development of a user-centered control stand for the Next Generation Locomotive Cab (NGLC) Demonstration Program. The scope of this effort included all locomotive engineer-related controls and displays for freight train operation. Because freight locomotives may be used for bidirectional operation, the "modified" Association of American Railroads (AAR) 105 side-mounted control stand was used as a starting point for any modifications, improvements, or changes. The side location of engineer controls as found on the AAR 105 control stand has historically facilitated locomotive operation in both forward and reverse directions. The scope of this effort was limited to ergonomic/human factors improvements to engineer-related controls and displays. The primary goal of the NGLC demonstration is to visually showcase potential ergonomic and human factors improvements to the control stand and console. A secondary goal is to convey a physical feeling of the design improvements through a limited set of interactions with the control stand and console.

First, researchers focused on collecting information on expected control and display requirements. To this end, researchers reviewed human factor and ergonomic technical reports and journal articles as well as standards related to locomotive cab design. In addition, researchers reviewed several locomotive operating or service manuals to obtain an idea of what information should be included in the NGLC control stand. Researchers also obtained various pieces of information from locomotive cab-related documents available on the Internet. Next, researchers conducted naturalistic observation at two different regional railroads to observe locomotive engineers interacting with the locomotive controls and displays. In addition, with the support of a local participating railroad, researchers boarded several parked locomotives to observe control and display layouts used in a variety of freight locomotives.

Based on the literature review and naturalistic observation, researchers generated an initial concept for a user-centered locomotive cab control stand design. The design included three components: a decluttered control stand, a display console with three highly interactive touch-screen displays, and an auxiliary overhead ceiling panel that contains a set of controls. Researchers then discussed the initial design concept with two subject matter experts (SMEs) to ensure relevancy and logic. Researchers also used a computer-aided design (CAD) tool to investigate initial design concepts (e.g., determine dimensions of the control stand) and verify that the design met Federal Railroad Administration (FRA) human factors locomotive cab design guidelines for seated operator reach and vision. Because it is important that the design be able to incorporate future locomotive and train technologies, researchers also visited FRA's Advanced Concept Train (ACT) to learn about future technologies and their implications for the locomotive engineer and his/her workspace.

Based on SMEs' written and verbal feedback, CAD drawings, and information gleaned from the ACT visit, researchers refined the concept and completed an initial design specification for the control stand, display console and displays, and auxiliary panel. Researchers also validated the initial design by conducting a heuristic evaluation using FRA's human factors guidelines for locomotive cabs. The final design includes a redesigned side control stand, a short desktop and three-panel front display that can accommodate both current and future locomotive and train technologies in an integrated fashion, and an overhead ceiling panel that replaces, in part, controls and displays traditionally located behind the engineer on the back wall. Other controls

and displays traditionally found on the back panel have been integrated into the touch-screen displays.

In addition, researchers designed and developed several interactive scenarios for use with the touch-screen displays to demonstrate user interaction with the touch-screen displays. Some of the control stand's controls—chiefly the throttle, dynamic brake (DB), and reverser—also interact with the touch-screen displays to simulate real interaction with locomotive controls and to convey the look and feel of the overall design concept.

A mockup of the revised control stand design has been fabricated and installed at Foster-Miller's Fitchburg Rail Vehicle Test Facility in Fitchburg, MA. To support fabrication, CAD drawings that contain detailed dimensions for the control stand were drafted.

1. Introduction

This report discusses the design and early stages of development of a user-centered control stand for the NGLC Demonstration Program. Review of modern AAR 105-style locomotive control stands reveals many opportunities for ergonomic and human factors improvements. Among them are the following:

- The throttle and DB movements violate cultural convention. Human factors principles suggest that control movement be consistent with the direction of system movement. Therefore, to move the locomotive forward, an engineer should move the throttle forward, and to slow down, the engineer should pull the DB lever back.
- Location of controls is often legacy-driven and not necessarily user-centered. For instance, the location of the independent and automatic train air brake control handles is similar to that of previous generations of locomotives, where these handles historically connected directly to air valves for releasing air to the atmosphere; the valves, themselves, connected to air pipes that traveled down and below the locomotive to a point where they joined other pipes to connect to an air compressor or to a hose or pipe to pass air on to the rest of the train.
- Locomotive control systems are not necessarily integrated; instead, systems are added as needed. Given a locomotive's lifespan of 40 years or more, over time this often results in a hodgepodge of controls and displays. These may include in-cab signal systems, speedometers, alerter systems, and trip optimization and efficiency systems.

The remainder of this section is organized into the following sections. Section 1.1 describes the scope of the design and development effort. Section 1.2 presents the overall approach undertaken in this work, whereas Section 1.3 describes the specific methods used to develop a new design for the NGLC demonstration control stand. Last, Section 1.4 describes the organization of the remaining sections of the report.

1.1 Scope

The scope of this effort included all locomotive engineer-related controls and displays. Because freight locomotives may be used for bidirectional operation, the "modified" AAR 105 side-mounted control stand was used as a starting point for any modifications, improvements, or changes. The side location of engineer controls as found on the AAR 105 control stand has historically facilitated locomotive operation in both forward and reverse directions. The scope of this effort was limited to ergonomic/human factors improvements to engineer-related controls and displays. Thus, although future locomotive and railroad operating technologies were considered in making improvements to the engineer's workspace, potential new technologies to enhance an engineer's job were not developed or considered.

Ergonomic and human factors focal areas that were addressed included the following:

- Locomotive engineer reach and access to locomotive controls and displays
- Visibility, audibility, positioning, and labeling of locomotive controls and displays
- Work surface hazards, such as protrusions, sharp edges, etc.

In short, the focus of the development effort was on the engineer's workspace. Although good human factors design principles were followed, the cognitive aspects of interacting with the engineer's controls and displays (e.g., interface design) were not the primary focus of the development effort.

The primary goal of the NGLC demonstration is to visually showcase potential ergonomic and human factors improvements to the control stand and console. A secondary goal is to convey a physical feeling of the design improvements through a limited set of interactions with the control stand and console.

1.2 Overall Approach

The overall approach to developing a design for the NGLC control stand and console involved drawing on several qualitative human factors methods. These included a literature review, naturalistic observation, structured interviews with SMEs, heuristic evaluation, and CAD analysis. The specific approach that was used, as well as the human factors methods employed, to generate the NGLC control stand and console design are discussed in the next section.

Several tenets also guided the overall approach. They included the following:

- The design should be capable of incorporating and integrating future railroad operating technologies and systems to improve engineer performance. Consequently, a significant part of the design improvements involved ample computer capabilities and display space.
- The design should contain sufficient legacy information to enable a locomotive engineer to operate the basic set of controls and displays without a significant amount of training (i.e., an engineer should be able to recognize most controls and displays without any guidance or help).
- The design should be consistent with FRA's human factors guidelines for locomotive cabs (see Multer, Rudich, and Yearwood, 1998).
- The design should declutter and simplify the engineer's workspace. This includes bringing controls and displays closer to the engineer's primary line of sight and reach envelope and reducing the height and overall size of the control stand.
- The design should better organize and locate primary and secondary controls and displays, including moving information closer to engineer's straight-ahead gaze.

1.3 Methods

First, researchers focused on collecting information on expected control and display requirements. To this end, researchers reviewed human factor and ergonomic technical reports and journal articles (e.g., Jankovich, 1972; Gamst, 1975; Multer, Rudich, and Yearwood, 1998; Sheridan, Gamst, and Harvey, 1999; Roth, 2000; and Einhorn, Sheridan, and Multer, 2005) as well as standards related to locomotive cab design (AAR, 2006a and 2006b). In addition, researchers reviewed several locomotive operating or service manuals, including those for a modern General Electric Evolution Series DC locomotive and an older EMD SD40-2 locomotive, to obtain an idea of what information should be included in the NGLC control stand. Researchers also obtained various pieces of information from locomotive cab-related documents available on the Internet.

Next, researchers conducted naturalistic observation at two different regional railroads to observe locomotive engineers interacting with the locomotive controls and displays. In addition, with the support of a local participating railroad, researchers boarded a number of parked locomotives to observe control and display layouts used in a variety of freight locomotives.

Based on the literature review and naturalistic observation, researchers generated an initial concept for a user-centered locomotive cab control stand design. Researchers started with a modified AAR-style control stand and developed the initial design concept based on goals of decluttering the environment and better organizing controls and displays. The design included three components: the control stand itself, a display console with three touch-screen displays, and an auxiliary panel of controls and displays. Researchers then discussed the initial design concept with two SMEs, one a former locomotive engineer and railroad safety researcher and the second a current road foreman of engines at a Class I railroad, to ensure relevancy and logic. Researchers also used a CAD tool to investigate initial design concepts (e.g., determine dimensions of the control stand) and to verify that the design met FRA human factors locomotive cab design guidelines for seated operator reach and vision (see Multer, Rudich, and Yearwood, 1998). Because it is important that the design be able to incorporate future locomotive and train technologies, researchers also visited FRA's ACT outside Chicago, IL, to learn about future technologies and their implications for the locomotive engineer and his/her workspace.

Based on SMEs' written and verbal feedback, CAD drawings, and information gleaned from the ACT visit, researchers refined the concept and completed an initial design specification for the control stand, display console and displays, and auxiliary panel. Researchers also validated the initial design by conducting a heuristic evaluation using FRA's human factors guidelines for locomotive cabs (Multer, Rudich, and Yearwood, 1998). In addition, researchers designed and developed several interactive scenarios for use with the touch-screen displays to demonstrate user interaction with the touch-screen displays. Some of the control stand's controls—chiefly the throttle, DB, and reverser—interact with the touch-screen displays to simulate real interaction with locomotive controls and to convey the look and feel of the overall design concept.

A mockup of the revised control stand design has been fabricated and installed at Foster-Miller's Fitchburg Rail Vehicle Test Facility in Fitchburg, MA. To support fabrication, CAD drawings that contain detailed dimensions for the control stand were drafted. The mockup can be used to demonstrate the control stand's user-centered design and to collect user feedback on the overall design and interaction with the controls and displays, including the three touch screens.

1.4 Organization of Report

Section 2 provides a top-level overview of the control stand design and layout. Section 3 describes the design of the control stand controls and displays in detail, including the modified control stand, display console and desktop, and overhead ceiling panel. Section 4 describes a limited number of interactive scenarios and screen designs that have been developed for use with the touch-screen displays. Section 5 discusses possible future work to further enhance the design of the NGLC control stand. A list of references is presented in Section 6. Last, a list of abbreviations and acronyms used in this report is presented at the end of the report.

2. NGLC Control Stand Overview

The NGLC innovative control stand design includes a redesigned side control stand, a short desktop and three-panel front display that can accommodate both current and future locomotive and train technologies (e.g., electronically controlled pneumatic (ECP) brakes, and positive train control (PTC)) in an integrated fashion, and an overhead ceiling panel that replaces, in part, controls and displays traditionally located behind the engineer on the back wall. Other controls and displays traditionally found on the back panel have been integrated into the touch-screen displays.

The NGLC workstation consists of three primary components (see Figures 1 and 2) as well as a fourth redundant display:

1. *A control stand located to the left of the engineer's seat for primary control of the locomotive*. The control stand design is a modification of the existing modified AAR control stand currently used in many new North American freight locomotives. Compared with the modified AAR control stand, the NGLC control stand is slimmer (depth), shorter (vertical height), and narrower (horizontal length) and has fewer controls. Controls include a combined throttle and DB lever, reverser, independent (locomotive) and automatic (train) air brake controls, radio, horn lever, bell button, and sander. Control locations have been specified to allow a large individual (95th percentile male) to reach each control comfortably while seated and to allow him/her to move in and out of the workspace without bumping any levers, including the air brake controls.
2. *A display console that consists of three liquid crystal display (LCD) touch-screen displays that wrap around the front of the engineer's workstation and a horizontal work surface (desktop)*. The center display is 12.1 inches (in) diagonal and the left and right displays are each 10.4 in diagonal. The NGLC center display serves as the locomotive operating display, per AAR Standard S-591, *Locomotives and Locomotive Interchange Equipment*. The center display conforms to this AAR standard to the extent it was reasonable and practical, given (1) human factors considerations and (2) the goal of the project is to design a next generation display that is not necessarily linked to current locomotive design philosophy other than starting off with the modified AAR-style control stand. Windshield wiper controls are located underneath the left and right displays on the front console. A horizontal work surface (desktop) on which to place and use paperwork such as movement authorities and speed restrictions has also been included. The alerter reset and cab signal acknowledgment controls, as well as a cup holder, are also built into the desktop. Each of these controls is situated on the left or right of the desk so that there is ample desk space to allow the engineer to complete or review paperwork. Taken together, the three touch-screen displays and horizontal work surface are referred to as the display console.
3. *An overhead console*. This overhead console will use a dropped, pitched (sloping) ceiling that contains the emergency fuel cutoff switch as well as locomotive circuit breakers and resets. This location will enable engineers to conveniently access these controls while still located in their primary workspace. To access a control, an engineer will have to partially stand up. A large radio speaker will also be center-mounted above the doorway to the nose of the locomotive cab, to the left of the overhead panel.

4. *A redundant LCD display mounted on the electrical cabinet wall opposite the back of the locomotive engineer's workstation.* Although not included in the demonstration, this 10-inch flat LCD panel would provide primary (redundant) locomotive operating information to the engineer when operating the locomotive in reverse direction. When operating in reverse, critical visual display information ordinarily presented in the right and left auxiliary displays may also be converted to audible messages because the engineer will not be facing the display console.

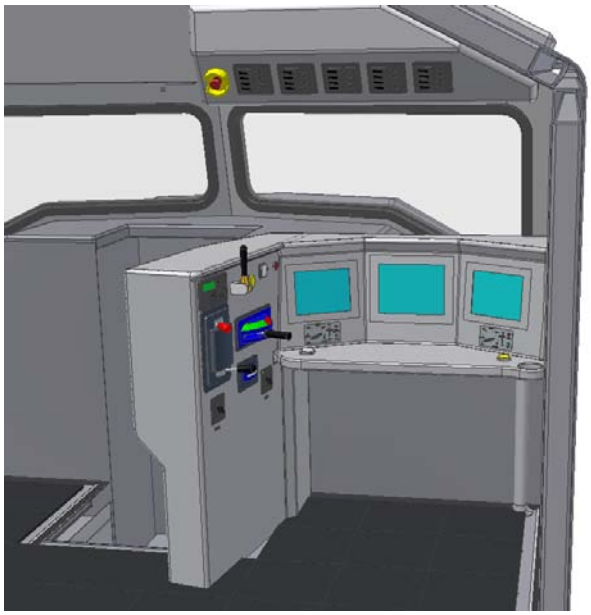

Figure 1. CAD Model of NGLC Engineer Workstation

Figure 2. NGLC Engineer Workstation

3. NGLC Control Stand Controls and Displays

This section discusses the location of locomotive controls and displays in the NGLC. The following sections identify specific control and display elements based on their location in the NGLC, on either the modified control stand to the left of the engineer's seat or the display console and desktop in front of the engineer's seat.

3.1 Modified Control Stand

Briefly, the control stand looks similar to a modified AAR-style control stand with controls to the left of the engineer's seat. The control stand interface includes a simplified set of controls. There is a short lip at the top of the control stand that houses a panel of several small, red LED lights that shine down to provide nighttime visibility of controls.

The following controls and displays are located in the modified control stand:

- *Combined throttle and DB power controller.* This control includes both the locomotive's throttle and DBs. A software-based gate is used to delay switchover from one mode to the other too rapidly, which can cause damage to the locomotive. The delay is approximately 2 seconds (s). For power, there are nine discrete positions, starting with Idle toward the center and proceeding backward from "notch" one to eight (i.e., you pull the handle back to apply more power). For DB, a user moves the control level forward to apply DBs. Like the throttle, there are nine positions; however, movement is continuous rather than discrete, starting with Setup toward the center and proceeding forward from 1 to 8.[1] A "Throttle" label is located above throttle positions, and a "DB" label is located above the DB positions. Labels are equal in height above the control. Specific power/DB position is also indicated to provide feedback to the engineer regarding in what mode and position the locomotive is currently operating.
- *Reverser*. The NGLC's reverser uses the standard round controller found on all current locomotives. It includes a "Reverser" label above the control as well as "F" and "R" labels in the appropriate locations to indicate Forward and Reverse directions. The specific reverser setting is also indicated to provide feedback to the engineer.
- *Air brake system.* The NGLC's air brake controls are similar to those found on operational locomotives. They are described more fully below.
    - *Automatic (train) air brake control lever*. The automatic air brake control lever is located above the independent air brake controller and includes an "Auto Brake" label above the control. The center of the automatic air brake controller is 35½ in above the floor, very close to the recommended practice found in AAR RP-5132, which suggests the center of the automatic air brake control handle be 34 in, give or take ½ in, above the locomotive floor. Release position is back; to apply brake, an engineer pushes forward.[1] From left to right, labels include "Rel," "Min

[1] The auto and independent air brake control actuation direction (i.e., to push forward to slow down) is counter to human factors design principles, but a design decision was made to keep consistent with historical design rather than risk inducing errors due to incompatibility with other locomotives in service.

Serv," "Full Serv," "Supp," "Handle Off," and "Emerg.[2]" Control movement is discrete for Release, then continuous from Min Serv to Full Serv, then discrete again for Supp, Handle Off, and Emergency settings. Furthermore, there is a détente between Handle Off and Emergency to prevent inadvertent activation of the emergency brakes.

- *Independent (locomotive) air brake control lever.* The independent air brake control lever is located below and slightly off-centered from the automatic train air brake control lever and includes an "Ind Brake" label above the control. The center of the independent air brake controller is 28¾ in above the floor, within the recommended practice found in AAR RP-5132, which suggests the center of the independent air brake control handle be 29 in, give or take ½ in, above the locomotive floor. Release position is back; to apply brake, an engineer pushes forward. Control movement is continuous. Labels include Rel (release; left side) and Full (right side).

- *Wireless radio*. The NGLC radio includes a dedicated, stand-alone radio console integrated into the top-left corner of the control stand. This permits left control of the radio and right control of the locomotive throttle and brakes, and it enables easy access to the radio in both directions of locomotive travel. A large speaker located above the doorway to the nose of the cab broadcasts radio messages to all cab occupants. Because the radio is not functional for the demonstration, however, the speaker is not included in the demonstration. Central location of the speaker allows all cab occupants to hear the broadcasts. Communication input is via a wireless Bluetooth headset (one for each crewmember) so that each crewmember can make outgoing calls and respond to incoming calls from anywhere in the cab. If engineers do not like to use Bluetooth headsets, or if a railroad's operating rules do not permit use of a Bluetooth device (e.g., if the engineer must wear hearing protection), there is a standard 2.5-millimeter headphone jack available so that a wired headset can be plugged in and used. A third option is to provide a standard handset at the end of the control stand near the radio. This latter option is common among current locomotive cab designs. The control stand radio contains a limited number of controls: a 12-button (4 rows × 3 columns) telephone keypad, channel up/down buttons, volume up/down buttons, and a push-to-talk button. The radio also contains a two-line monochrome LCD display. This design is smaller than current, off-the-shelf locomotive radios, such as those provided by locomotive equipment suppliers like Motorola.

- *Horn*. The NGLC's horn control is a spring-centered lever located at the top of the control stand, to the immediate left of the radio. A "Horn" label is presented below the lever. The horn is pulled down and held to activate. The bell would be interlocked with the horn, such that whenever the horn is activated, the bell would be activated, too. To silence the bell while the horn is sounding, an engineer would press and release the bell button. A small blue light next to the horn lever illuminates when the horn is sounding. A redundant horn icon appears in the center display as well.

[2] When the automatic brake is placed into emergency, the train air will be released from the rear EOT device as well. Therefore, it is not necessary to provide a separate EOT emergency control to release the air from the rear of the train since this function is now automatic.

- *Bell*. The NGLC's bell control is a large, yellow, round pushbutton located to the right of the horn control. A "Bell" label is presented below the button. An engineer pushes and releases the button to activate the bell and pushes and releases again to shut off the bell. This push and release logic is used to allow engineers to ring the bell for an extended time without requiring him/her to continuously hold down the control. A small blue light next to the pushbutton illuminates to indicate that the bell is active. A redundant bell icon appears in the center display as well.
- *Sander*. The NGLC's sander control is a large white square pushbutton with rounded edges located to the right of the round bell pushbutton. A "Sand" label is included below the button. An engineer pushes and releases the button to start sanding all locomotive lead axles in the trainlined consist, and he/she pushes and releases the button again to stop sanding.[3] A small blue light next to the sand button illuminates to indicate when sanding is active. A redundant SAND icon appears in the center display as well.
- *Automatic collision and emergency notification (ACEN) system panic button.* The red, round ACEN button is approximately 1 inch in diameter and sits flush with its housing to prevent inadvertent activation. The housing also contains a backlit ring that illuminates when the ACEN button has been pressed. An "ACEN" label is included below the button.
- *Locomotive headlight controls*. Rear (left) and forward (right) headlight controls are located below, and to the left and right of, the Reverser for relatively quick access to these controls. Each control is a rotary dial with the following options: low+ditch/off/low/medium/high, where ditch lights are automatically turned on when the headlight is set to high. The low+ditch options is for occasions where an engineer wants, or is required to have, his/her ditch lights on but wants to dim the headlight as a courtesy to an oncoming train.

Figure 3 presents an existing modern locomotive control stand, whereas Figure 4 presents the NGLC control stand design.

[3] Current locomotive designs often have two sanding options, one control to active lead locomotive axle sanding only and a second control to activate all axle sanding. On the basis of the discussions with SMEs, engineers rarely distinguish when they need only the lead axle sanded versus all axles; rather, they simply sand all axles as needed. If preference is given to having two sanders, options include side-by-side controls or one three-way positional rocker or toggle switch to conserve space.

Figure 3. Existing Modified AAR Control Stand

Figure 4. NGLC Control Stand

A control/display found in several current locomotives that was not included in the NGLC control stand design is worth mentioning for completeness. This is the attendant call button. It is a legacy control or display that is not needed in the next generation of locomotives because of advances in technology.

- *Attendant call button*. The NGLC control stand design does not include an attendant call button found on previous generations of locomotives. This legacy control is no longer functionally needed based on current crew configurations, technologies, and operating practices. For instance, train and engine crews no longer include an attendant (a firefighter or roundhouse employee capable of engine troubleshooting and repair). Furthermore, crews communicate primarily via radio and/or hand signal. Given the design of modern locomotives, crewmembers are also not expected to be found inside a locomotive engine; they are either in the cab or outside on the catwalk or other area.[4]

3.2 Display Console and Desktop

The display console is made up of three LCD touch-screen displays encased in a wrap-around console as well as windshield wiper controls located beneath the left and right displays. The console also includes a lip above the displays to protect against glare coming in from the front window. The desktop includes space for an engineer to work on, the alerter reset and cab signal acknowledger controls, and a cup holder. An optional high-friction surface coating treatment can be added to the desktop surface edge to reduce the likelihood of papers sliding off the edge of the desktop. A lip located at the edge of the desktop to prevent paper slippage was considered, but the raised surface was expected to be uncomfortable if/when engineers place their forearms or legs on the desk. Specific display console controls include the following:

- *Windshield wiper controls.* Two identical sets of controls are located under the left and right displays. The forward windshield wipers are controlled by the controls under the right display, whereas the rear window wipers are controlled by the set of controls under the left display. Each set of controls includes a knob, a slider, and two pushbuttons. The knob controls the following wiper modes: off, automatic, intermittent, low, medium, and high. Wiper knob setting labels are OFF, AUTO, INT, LOW, MED, and HI. The automatic setting is a rain-sensing mode for the windshield wiper controls. Setting the control to automatic would cause the wipers to move dependent on the volume of rain and could help to minimize the engineer's interaction with the wiper controls by automating wiper speed. The slider controls intermittent wiper speed, with SLOW and FAST anchor labels. A red pushbutton (on/off) controls the heating element on the window to melt ice that has built up (label: HEAT ELEMENT). A blue pushbutton (on/off) activates the windshield wiper cleaning fluid and a short wiper cycle to clear fluid and debris from the windshield (label: CLEAN).

[4] If desired, some type of control that functions similar to the old Attendant Call button could be introduced into the NGLC design. This control would sound a warning or alarm in all multiple unit locomotive cabs and could be built into the control stand design either as a dedicated button, radio control, or soft control (i.e., embedded in one of the three LCD displays).

Specific desktop controls include:

- *Alerter reset.* The alerter reset is a large white, square pushbutton with rounded edges located on the left side of the desktop with the following label, ALERTER RESET.
- *Cab signal acknowledgment control.* The cab signal acknowledgment control is a large yellow round pushbutton located on the right side of the desktop with the following label, CAB SIGNAL ACK.
- *Cup holder.* A cup cutout to accommodate a standard size drink is located on the far right side of the desktop. The cup holder is located on the far right side to reduce the likelihood of an engineer accidentally bumping the cup while interacting with the cab signal acknowledger or right display soft keys.

One control that was considered but not included in the NGLC design is the horn sequencer control. A tradeoff was made to exclude all nonessential controls to have a cleaner, less cluttered control stand and desktop. An option not included in the NGLC demonstration would be to add a horn sequencer foot control located underneath the desktop. The horn sequencer control is a redundant control that blasts the horn sequence required before entering a highway-rail grade crossing and is provided for convenience when engineers may otherwise be busy with their hands when they need to sound the horn as they approach a grade crossing. To prevent inadvertent activation in mechanical shops (e.g., where a mechanic may be working under the desktop or in the general control stand area), the control would only work above a predetermined speed, such as 1 mile per hour (mph).

Figure 5 presents an existing modern locomotive display console, whereas Figure 6 presents the NGLC display console design for comparison purposes. Figure 7 combines the NGLC control stand and display console and contains labels to identify the various controls and displays.

Figure 5. Existing Locomotive Display Console

Figure 6. NGLC Display Console

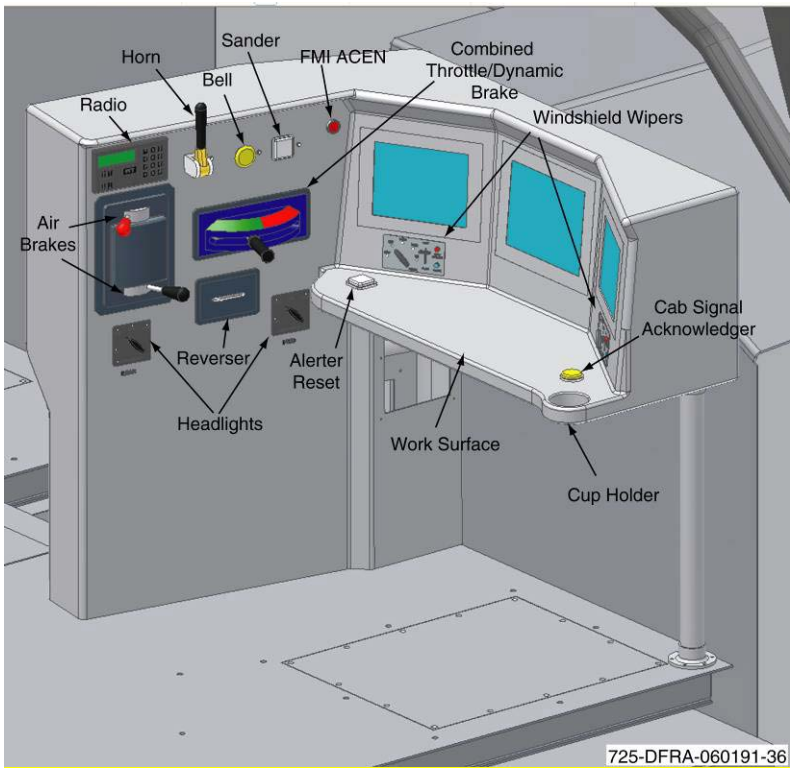

Figure 7. NGLC-Combined Control Stand and Display Console with Component Labels

3.3 Overhead Ceiling Panel

The third major component of the NGLC control stand design is the overhead ceiling panel, which consists of the following functional sections:

- *Emergency fuel cutoff switch.*[5] The switch is a medium (approximately 2-inch diameter) red, round pushbutton encased in a protective yellow guard to protect against accidental activation. A yellow "Emergency Off" label is also embedded behind the switch.
- *Resets, breakers, and relays.* The remaining portion of the ceiling panel is dedicated to housing various circuit breakers and resets. These include the following:
    - *Ground relay reset*
    - *Fuel pump reset*
    - *Air filter reset*
    - *Water cooler reset*
    - *Heating, ventilating, and air-conditioning (HVAC) reset*
    - *Headlights reset*
    - *Cab lights reset*
    - *Auxiliary generator reset*
    - *Train control reset*

Figure 8 presents a side-by-side comparison of a modern locomotive's rear wall engine panel and the NGLC overhead ceiling panel that contains a simplified set of switches and resets. Figure 9 presents the final overhead ceiling panel recently fabricated and located in Fitchburg, MA. Most other physical controls found on the rear engine panel have been incorporated into one or more touch screens, described more fully in the next section.

Figure 8. Existing Locomotive Rear Wall Engine Control Panel vs. NGLC Overhead Panel Design

[5] On current locomotive designs, this switch is located on the back wall, so relocating the fuel cutoff switch to the overhead ceiling panel is better, because it is closer to the seated engineer.

Figure 9. NGLC Overhead Ceiling Panel Mockup

3.4 NGLC Displays

The NGLC console consists of one primary 12.1-inch touch-screen display flanked on both sides by smaller 10.4-inch touch-screen displays. The center display serves as the primary locomotive integration display, whereas PTC, route guidance, condition monitoring, and other information will be displayed on the left and right displays. The console also includes a top lip or visor to protect against unwanted glare from the displays onto the windshield or from bright sun onto the displays. Although physically apart from the front console and not included in the demonstration cab, a redundant 10-inch display that shows center display information should be positioned to the rear of the engineer's seat and mounted on the electrical cabinet wall to support reverse movements.

3.4.1 Display Interaction Style

A goal of the NGLC demonstration is to illustrate a new style of engineer interaction with the control stand computers. More and more, computers are being integrated into locomotive systems to provide operational support. The overall interaction style for each display takes advantage of the touch screen. With the NGLC displays, users touch a particular onscreen soft key, label, or icon to access additional information about the selected item, for instance, to obtain additional information on a particular car or locomotive. In certain displays, users can also use their fingers to sweep left and right to interact with the information. Each display has a number of soft keys to directly drill down to a particular function (e.g., HVAC and lighting controls). Some of the soft keys are the same in each display whereas others are display-specific. Those soft keys that are repeated in each display include two dedicated brightness control soft keys and a Home soft key. These soft keys are positioned in the same location in each display to facilitate use. The following sections further describe each of the three front displays.

3.4.2 Center/Rear Locomotive Operating Home Display Elements

The center display consists primarily of many separate display areas. Each display area, in turn, is made up of one or more display elements. Display areas include speed and acceleration information, air brake information, load information, throttle and reverser display, alerter bar, icon block, message center, and soft keys (see Figure 10). Although most display areas are similar in location to AAR standard S-591, some of the display areas deviate from the AAR standard. The primary reason for the deviation is that the NGLC display console makes use of three displays rather than the current one to two displays found in most modern locomotives; therefore, there is more opportunity in the NGLC displays to present information elsewhere.

Human factors design principles were used to layout the screen designs. Because this is the primary operating display, all elements in the display are considered essential, and therefore, they are always presented to the engineer. He/she may access and view messages through the lower portion of the screen; otherwise, all elements in the center display are always presented.

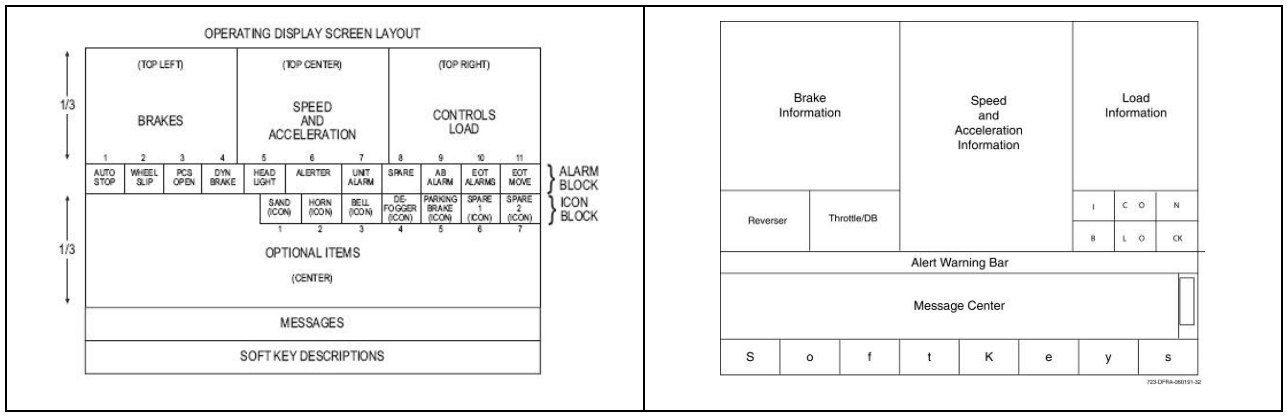

Figure 10. Comparison of AAR S-591 Locomotive Operating Display (left) and NGLC Center Display (right) Layouts

Specific display elements include the following:

1. *Air brake information*. This includes equalizing reservoir and brake pipe pressure gage, main reservoir and brake cylinder air pressure gage, rear-car end-of-train (EOT) trainline pressure, and trainline air flow.
2. *Speed and acceleration information*. Speed is digitally presented as an analog speedometer gage and numeric readout, while acceleration is presented as a center-neutral (0 mph/minute (min)), horizontal tape bar that extends to the right to indicate acceleration and to the left to indicate deceleration. Acceleration display is presented directly beneath the speedometer at the center of the display.
3. *Load information* and *tractive effort*. This section of the center display includes an integrated power/DB ammeter gage indicating traction motor current and a tractive effort (kilopounds) numeric display box beneath the ammeter. The ammeter gage face is color-coded as follows (values are selected for demonstration only; actual values would be determined by the railroad and/or locomotive manufacturer): ammeter values are green

from 0 to 1200 amperes (amp), after which there is a red zone (excessive current) from 1200 to 1800 amp. The braking scale has a long yellow zone from 0 to 600 amp, after which there is a red zone (excessive current) from 600 to 900 amp.

4. *Reverser and power information.* This section of the center display includes a reverser position (F, N, or R; white font) display box and a power display box that presents throttle or DB position. Throttle is displayed as Idle (white font) or 1–8 (green font). DB is displayed as Set Up (white font) or 1–8 (white font) for DB positions.
5. *Icon block.* The icon block includes redundant horn-and-bell activation warnings, wheel slip, active sanding, and other to-be-determined (TBD) locomotive warnings.
6. *Alerter warning bar*. The alerter warning bar is a large horizontal bar that illuminates to inform the engineer that he/she must respond to the alerter warning. Although not functional for the demonstration, there are three levels of warning. First, between 20 and 10 s before a planned penalty brake application, the alerter bar flashes yellow for 200 milliseconds (ms), followed by 100 ms off (cycle). There is no audible warning associated with this first level of warning. The time remaining before the penalty brake application is presented in the bar in black font to aid the engineer in knowing exactly how much time remains before a penalty brake application. Next, between 10 and 5 s before a penalty brake application, the alerter bar flashes red for 200 ms followed by 100 ms off (cycle). The font for the time remaining changes from black to white. A slow audible warbling alarm accompanies this second level of warning.[6] Finally, from 5 to 0 s before an expected penalty brake application, the alerter bar flashes red for 100 ms, followed by 50 ms off (cycle). A fast audible warbling alarm accompanies this warning. The numeric font remains white. Alerter functionality would be tied to other controls so that the alerter counter would be reset upon engineer interaction with these other controls.
7. *Message center*. The message center includes space for alphanumeric messages that support locomotive operation.
8. *Soft keys.* Up to eight soft keys are available at the bottom of the screen. The first two are dedicated contrast buttons. Currently, only a Menu and Home button are also presented. Four soft keys remain undefined. To select a particular function, the engineer presses the soft key directly on the display.

In addition, the following information will be provided at the top of the center display:

9. *Locomotive ID.* The locomotive ID number is presented at top left of display and includes both the railroad initials and locomotive number (e.g., FMIQQ 9999).
10. *Date and local time.* The current date and time are presented in the top right of the center display.

Figure 11 presents an illustration of the NGLC center display elements.

[6] It is recognized that engineers likely do not like to hear the audible alarm; thus, an attempt has been made to provide ample time for the engineer to respond to the visual-only warning. Furthermore, the audible is separated into a slow-frequency alarm, which is expected to be less of a nuisance. A high-frequency audible warning is presented only when there are a few seconds that remain before the system applies an undesired penalty brake application.

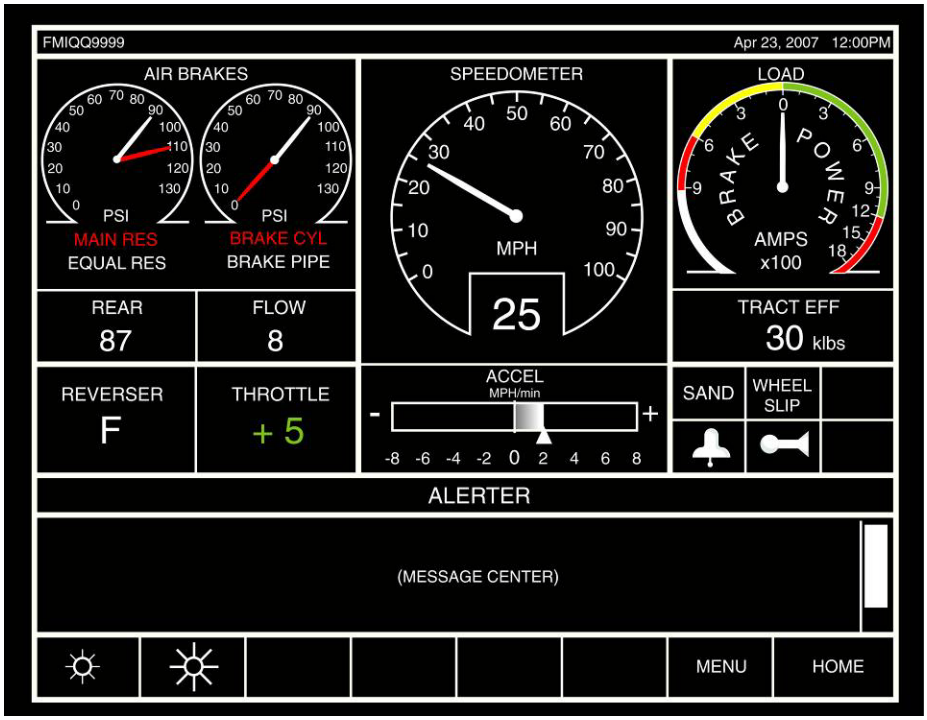

Figure 11. NGLC Center Display

3.4.3 Left Auxiliary Home Display Elements (PTC, Route Guidance, and Operating Information)

The left auxiliary display presents weather conditions; route guidance, PTC, and track authority information; and operating efficiency information. An operator may interact with this display to access a variety of functions. The Home menu will contain top-level information that an engineer can be expected to use frequently. All other information will be accessed via drill down menus or function keys.

Specific display elements included in the NGLC demonstration include the following:

- *PTC, route guidance, and track authority information:*
  - *Global positioning system signal* (online versus offline)
  - *In-cab signal aspect* (current and next block)[7]
  - *Current (and access to past and upcoming) track authorities and speed restrictions*
  - *Method of operation* (e.g., centralized traffic control, automatic block signal, and PTC)
  - *Work zone limits*

[7] The in-cab signaling display is independent of the type of PTC or communication/signaling system (e.g., automatic cab system or automatic block signal) in use.

- *Main-line switch position* (normal versus reverse)
- *Grade crossing occupancy information* (open versus occupied)
- *Track grade information*
- *Track curvature information*
- *Other meaningful route guidance and profile landmarks and items* such as at-grade crossings, over/underpasses, tunnels, switches and signals, mileposts, wayside signs such as W(histle), restricted speeds, maintenance-of-way crew in the area, etc.

- *Fuel consumption information*. Information is displayed in gallons per hour consumed, in white font. As fuel consumption reaches a TBD rate spanning a certain amount of time that is unacceptable to a railroad, the font could change from white to amber or red.
- Weather and rail condition information (current and forecasted)
  - *Current outside temperature and precipitation.*[8] Temperature is presented in degrees Fahrenheit, and precipitation is conveyed via representative icon.
  - *Crosswind information*. The wind speed and wind direction (e.g., 5 mph SSE) could be displayed. Weather source may include nearby weather reporting station(s). At some TBD-by-railroad speed, the display could flash red.
  - In addition to temperature and crosswind information, the following three weather items have been suggested but are not currently included in the design (these questions should be addressed via focus group or other user input):
    - *Frost advisory*
    - *Interior temperature*[9]
    - *Flash flood warning*[10]
- *Soft keys*. Up to eight soft keys are available at the bottom of the screen. The first two are dedicated contrast buttons. The next two soft keys are used to increase or decrease the length of viewable track in the track profile window. A Menu and Home button are also included. Two soft keys remain undefined. To select a particular function, the engineer presses the soft key on the screen.

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[8] Grade-crossing ice buildup warning, slippery rail condition, and snow drift warning were originally proposed but according to one SME, this information is inherent in the temperature, precipitation, and wind information and therefore redundant (e.g., an engineer can conclude that slippery rail exists if the temps are low and precipitation exists).

[9] Interior temperature was suggested so that an engineer can have a better sense of just how cold it is outside by comparing to the in-cab temperature. It was felt that this information may be most helpful to a conductor who must occasionally be outside tending to a train issue.

[10] Currently, specific information about flash floods would be transmitted by a dispatcher to the train crew. And flash flood conditions are already covered through temperature and precipitation information already. A warning could inform engineers of flash flood conditions or flash floods that have been reported in the area.

3.4.4 Right Auxiliary Home Display Elements (Condition Monitoring and Security)

The right-hand auxiliary display contains locomotive and train security and condition monitoring information. Failures and other problems that are detected in the consist, either onboard a car or onboard a locomotive, are conveyed to the engineer via graphical alerts that will require the engineer's attention. The engineer can select the alert icon to troubleshoot and fix the problem. An engineer can directly interact with this display to access a variety of functions simply by pressing an onscreen panel or button, similar to the left auxiliary display. The Home menu will contain top-level information that an engineer can be expected to use frequently. All other information is accessed via drill down menus or function keys.

Display elements that are included in the NGLC design include the following:

- *Train consist.* A graphical depiction of the train is presented onscreen. To see part of the train that is currently off the screen, an engineer places his/her finger on the train and sweeps it in one or the other direction to move the train forward/backward. A preview display is presented to the engineer at the top left of the display to show how much of the full train is within view of the display. This graphic is the primary conduit to see information about locomotive and car health and security information. To select information about a particular locomotive or car, the engineer presses and releases the icon that represents the locomotive or car of interest. All locomotive and car health and condition monitoring information (described in greater detail below, although not implemented in this demonstration) can be accessed through this train consist graphic. In addition to being able to drill down into any car or locomotive to obtain health and security information, the train consist displays top-level, always present information about locomotives, cars, and the consist. This always-present information includes the following:
    - *Locomotive and car number.*
    - *Lead locomotive headlight status*. It shows status of lead locomotive's headlight and ditch lights.
    - *DB information*. Information includes locomotive numbers (for each locomotive in the consist), whether each locomotive is contributing power (p) or DB, total tractive effort in kilopounds,[11] and whether a conflict exists between two locomotives (i.e., where one locomotive is in power mode and another locomotive is in DB mode).[12]
    - *Train consist connectivity status.* It shows status of couplers, air hoses, and hand brakes. Through this display, it would also be possible to remotely set and release

[11] This information is a duplication of tractive effort information presented in the center display.

[12] AAR S-5509 *Locomotive DB Status Reporting* standard contains information on DB display elements to include. The standard includes (1) a summary display (Section 3.1 of the standard) and (2) a detailed display (Sections 3.2–3.4). This standard specifies information elements and their format on a two-line alphanumeric display. The NGLC design includes the required information elements but presents them in a format other than that specified in the AAR standard. Summary information is presented on the Home display, whereas detailed information would be available upon drilldown. See AAR S-5509 pp. 156–158 for more information.

handbrakes for all locomotives and cars in the consist.

- *Information panels*. Some health and security information can also be accessed more directly through specific information panels on the Home display. These include the following:
    - *EOT information*. EOT information includes EOT identification number, Armed/Not Armed, air brake pressure in last car (pounds per square inch), EOT brake release (Yes/No), EOT moving or not, and low-battery warning. The EOT could be armed from the head end through this display.
    - *ECP brake information*. ECP brake information that is presented on the Home display includes whether the system is offline or online or has no signal; and if online, the number of cars reporting a healthy signal. Additional information on ECP brakes could be accessed via a series of drill-down displays.
    - *Security information*. Security information includes which individuals have authorization to operate the locomotive. Although not included in the demonstration, additional information could be incorporated here.
    - *Distance meter*. The distance meter is an engineer-programmable distance counter located beneath the air brake display area. The distance meter is presented as a horizontal tape meter. The counter is capable of counting up or down from zero or counting up or down from a preset distance (e.g., train length or siding distance). Maximum distance is 99,999 or –99, 999 feet. The counter can also be reset at anytime. The counter increases with movement in the forward direction and decreases when moving in the reverse direction.[13]
- *Soft keys*. Up to eight soft keys are available at the bottom of the screen. The first two are dedicated contrast buttons. Additional buttons include direct access to EOT, Lights, HVAC, Security, Menu, and Home display. To select a particular function, the engineer simply presses the desired soft key on the screen.

The goal of the NGLC project is to demonstrate new locomotive concepts. In the process of exploring functionality and design possibilities that should be demonstrated, researchers identified a number of additional features that, although not part of the demonstration, should be a part of the NGLC design, and in particular, the right auxiliary display. These features include the following:

- *Locomotive health and security information*
    - *Headlight and ditch light set up and status indicator*. Through a display, an engineer can set up the headlights and ditch lights for all locomotives in a consist, including leading, middle, and trailing locomotives. Lighting requirements differ according to where in the consist a locomotive is located. An engineer would be able to simply press an icon of a locomotive on the screen to set up the locomotive's lights. If the system detects that the lead locomotive forward

[13] The NGLC design includes a duplicate display on the rear cab wall; therefore, an engineer will be able to see distance meter information when he/she is operating in reverse. If the rear display is not implemented, an audible counter should be implemented when the locomotive is operating in reverse mode.

headlight is shut off when the locomotive initiates movement in forward direction, the system can also provide an audible warning. A duplicate set of physical headlight controls for the controlling locomotive is located inside the cab on the control stand so an engineer can quickly and easily dim the headlights of the controlling locomotive when in yards and when approaching an oncoming train.

- *Engine controls and displays for starting and isolating locomotives and cutting out motors and DBs*
  - *Engine isolation switch*: start/isolate/run
  - *Engine start button*
  - *Generator field:* on/off
  - *Multiple unit (MU): leading/trailing*
  - *Traction motor cutout.* The design should enable an engineer to cut out traction motors on any and all locomotives in the consist from the lead locomotive. For each locomotive in the consist, a simple axle diagram (i.e., either four- or six-axle) can be displayed and an engineer could then interact with the display to take axles offline as needed. Axle 1 would correspond to the first leading axle.
  - *DB cutout switch.* This control should enable an engineer to cutout the DB on any and all locomotives in the consist from the lead locomotive.
- *Lead locomotive condition monitoring and security information.* Information may include any of the following:
  - *Engine (water) temperature*
  - *Engine speed (revolutions per minute)*
  - *Oil pressure/temperature*
  - *Water level*
  - *Fuel level*
  - *Fuel pressure/fuel pump*
  - *Fuel filter information*
  - *Air filter information*
  - *Sand level (e.g., low sand)*
  - *Odometer*
- *Locomotive security information.* Locomotive security information might include a requirement for proper authorization (e.g., Smartcard ID) to operate the locomotive as well as a periodic requirement to reauthorize the system, as well as other TBD functions. If an engineer fails to reauthorize within an allotted time, the system could apply a penalty brake application to stop the train.
- *Trailing locomotive (MU) and distributed power (DP) status and information.* MU and DP displays and associated controls could show the engineer complete

condition-related information on all locomotives in the entire consist. This would enable the engineer to easily discern the status of all locomotives from his/her cab and diagnose (troubleshoot) problems on any locomotive. He/she could also isolate or bring online any locomotive in the consist rather than having to check each locomotive manually to discern, diagnose, and fix the particular problem. Under current U.S. freight train operations, the lead locomotive's display may indicate a problem with one or more locomotives in the consist (i.e., MU or DP), but the display does not isolate which locomotive is experiencing the problem, nor what precisely is the problem, so the engineer must manually check each locomotive to identify and diagnose the problem.

- *Brake health and information*, including conventional air brakes, DBs, and ECP brakes.
- *Car status and health information (continuous monitoring of) other than brake systems.* Similar to the ability to assess all locomotives in the train consist, this set of functions shows the engineer condition-related information on all cars in the consist. Access will be through the train consist graphic. An engineer can drill down to obtain information, or if there is a problem, the system will provide a warning associated with the inflicted car. Furthermore, the problem car will be auto-centered on the display. Car status and health information:
    - *Wheels and wheel axles (flat and out-of-round wheels, cracked axles, or wheels)*
    - *Bearings and journals (overheating)*
    - *Brake piston travel*
    - *Trucks (ride quality and hunting)*
    - *Car ride quality/truck hunting (x-, y-, and z-axes)*
    - *Information on tank/container car integrity/security*
    - *Derailment monitoring and notification*
    - *Dragging item (based on wayside detection) notification*
    - *Shifted good (on-car or wayside detection?) notification*
    - *High/wide load (based on wayside detection) notification*
    - *Car monitoring information, such as refrigerated car temperatures and HAZMAT tank car pressure readings and valve conditions*
    - *Connectors status and information:*
        - *Automatic/remote (from cab) coupling and uncoupling (including cut levers and angle cocks)*
        - *Other information on air and wired connectors between cars, locomotives, or between car and locomotive?*

4. NGLC Control Stand Demonstration Interaction Scenarios

To simulate locomotive console functionality, several interactive scenarios were developed for implementation in the NGLC mockup. Each scenario involves some type of user interaction with the left or right auxiliary display, for example, obtaining information on a simulated problem with a piece of equipment. Interactive scenarios include the following:

1. *Preview track profile.* A user can interact with the left touch screen to zoom in and out to preview upcoming track profile and characteristics. The Home display default preview is a 5-mile view down the track. Users can zoom in and out among the 5-, 10-, and 20-mile look-ahead preview maps. See Figure 12 for a view of the left display with the 5-mile preview map presented. All remaining display elements remain the same when zooming in and out of different map previews. Also, see Figure 13 for a view of the right display.

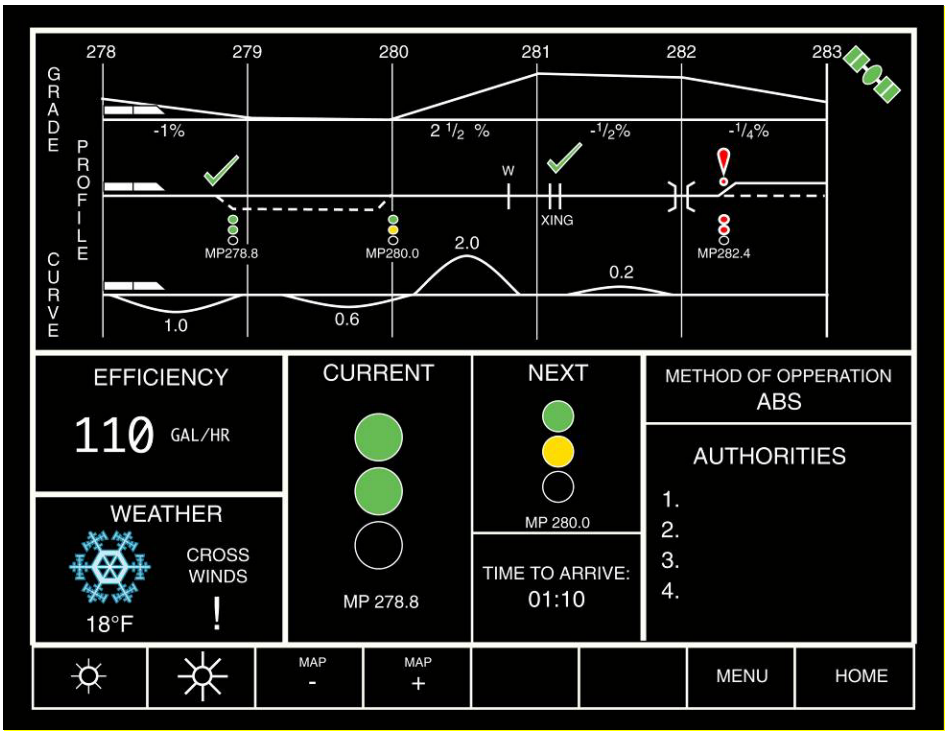

Figure 12. Left Auxiliary Display

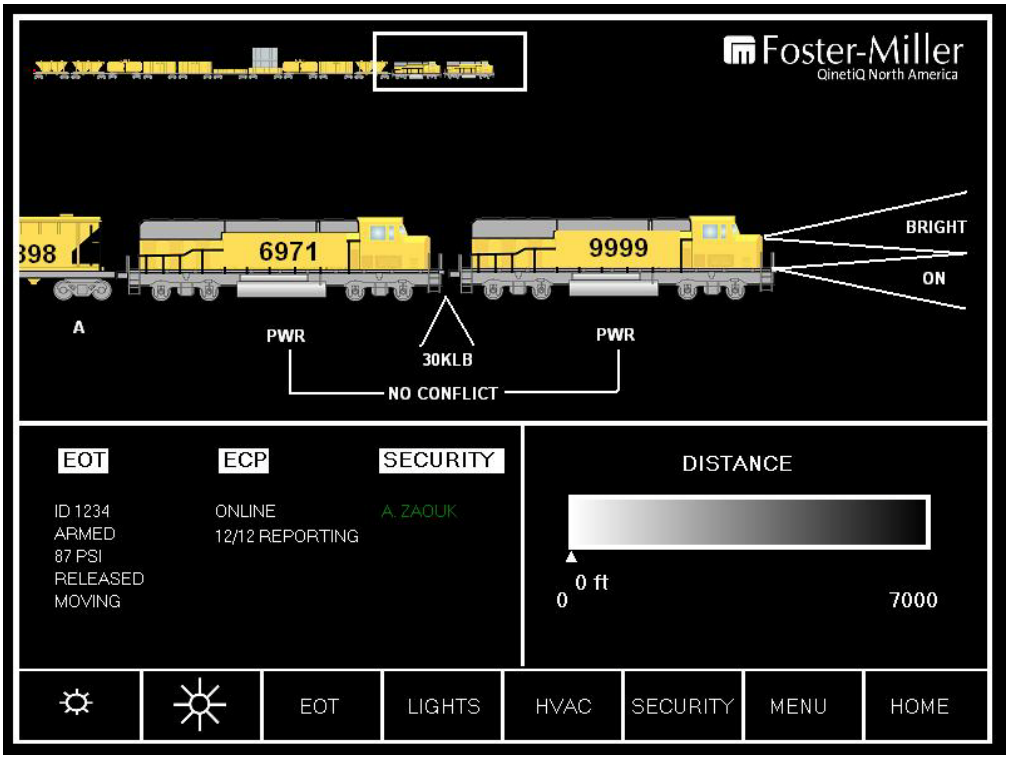

Figure 13. Right Auxiliary Display

2. *Set distance meter*. A user can interact with the right touch screen by pressing the distance counter box to reset the counter or set the starting and stopping distance to count up or down from a preset distance to a second preset distance. See Figure 14 for a screen shot of the distance counter.

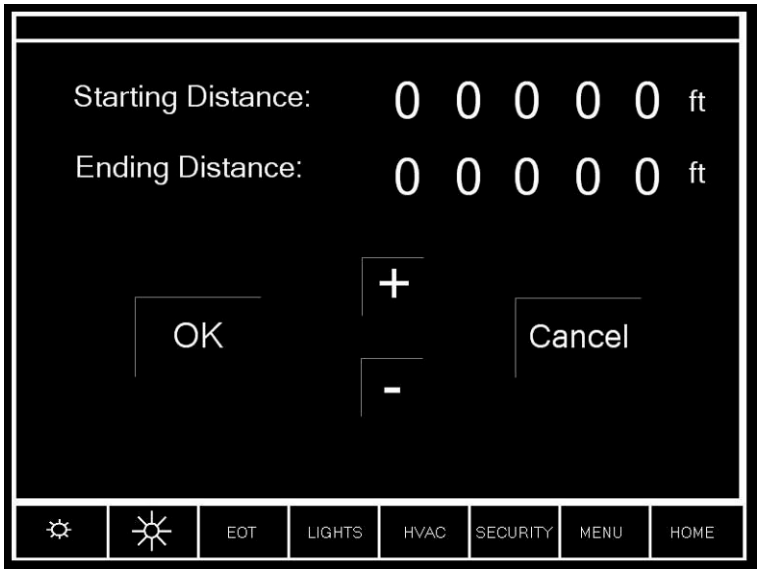

Figure 14. NGLC Distance Counter Display Screen

3. *Obtain locomotive health information.* A user can interact with the right touch screen to select a particular locomotive to obtain basic health information on that locomotive. See Figure 15.

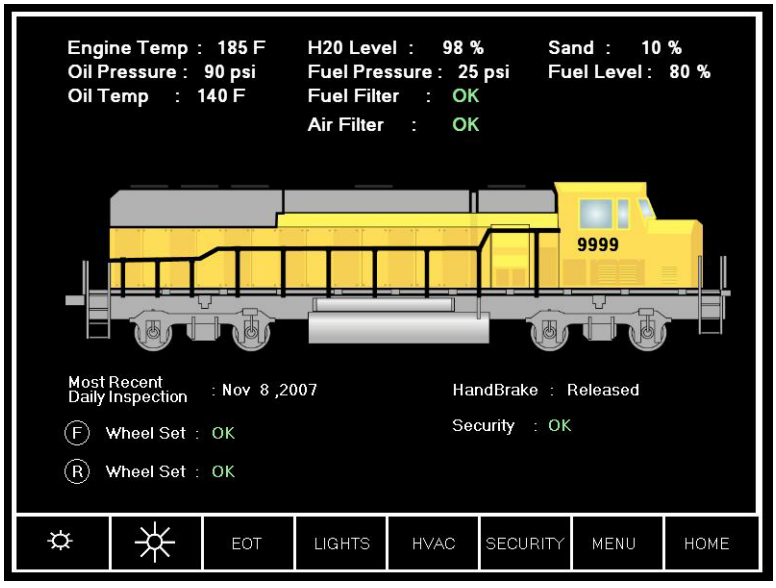

Figure 15. NGLC Locomotive Health Display Screen

4. *Obtain car health information.* A user can interact with the right touch screen to select a particular car in the consist to obtain basic health information on that car.
5. *Troubleshoot car health.* A user can interact with the right touch screen to view a

problem with one of the cars in the train consist. A user presses the Home and Menu buttons one after the other to trigger a simulated problem with one of the cars in the consist. An alert is provided to the engineer (see the left screen in Figure 16 in which a red Alert box is presented over the problem car). The user can then drill down two additional screens to further identify the problem. Figure 16 presents the screen sequence simulating engineer drilldown to determine the source of the alert.

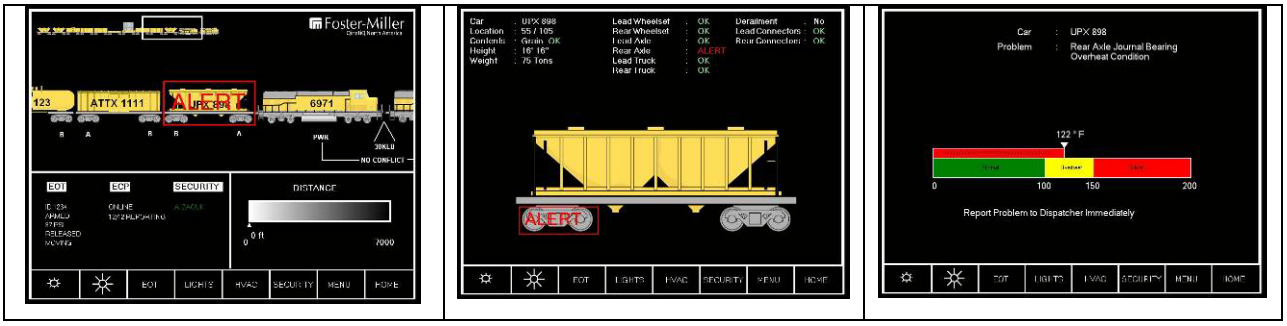

Figure 16. NGLC Hot Journal Bearing Troubleshooting Screen Sequence

6. *Review weather information*. A user can select the weather box located in the left touch screen to review a weather forecast for the simulated run, including hour-by-hour information as well as radar (precipitation) and satellite (cloud coverage) information.
7. *Preview HVAC and light control and display screens.* A user can interact with the right touch-screen soft keys to access the nonfunctional HVAC and lighting control and display screens. Bathroom lights and the conductor's side lights are not included in the design since they do not directly impact the engineer's workstation and therefore are considered beyond the scope of the demonstration. The lights Home display screen is separated into two primary categories, interior cab lights and exterior locomotive lights. Both the lighting and HVAC Home displays are described below. See Figures 17 and 18.

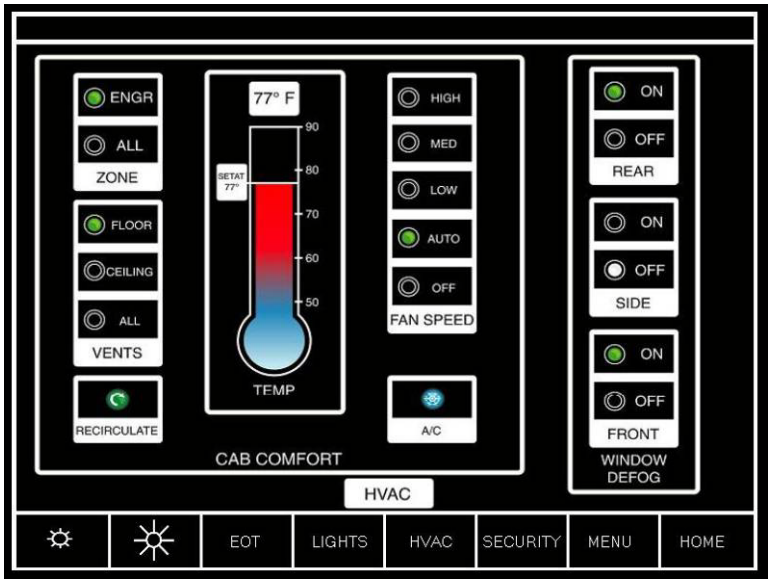

Figure 17. NGLC HVAC Home Display Screen

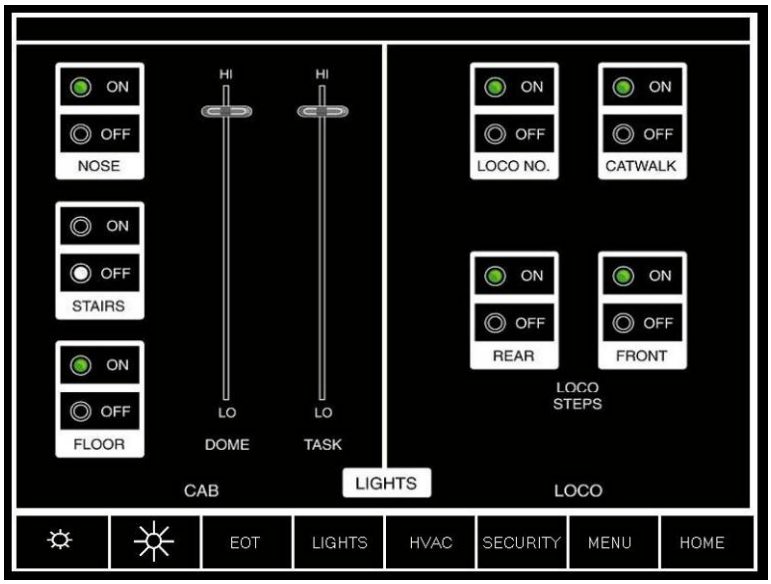

Figure 18. NGLC Lighting Home Display Screen

In addition to interacting with the demonstration through the touch screens, a user can interact with the following control stand controls:

- *Reverser*. A user can adjust the locomotive's orientation of travel to (F)orward, N(eutral), or (R)everse. The orientation of travel is synchronized with the distance counter such that, if in the middle of counting up in one direction, a user stops the locomotive and switches direction, the counter will reverse its direction as well.

For instance, the center display will also reflect the current position of the control stand reverser.

- *Throttle/DB.* A user can adjust the throttle/DB control to change the speed of the simulated NGLC. The center display speedometer, acceleration display, and throttle/DB display will reflect inputs to the control stand combined throttle/DB controller.
- *Air brakes*. A user can adjust the independent and/or automatic air brake controls to slow the speed of the simulated NGLC. The center display air gages, speedometer, and acceleration display will reflect control stand air brake inputs.

5. *Horn and bell*. A user can sound the horn and/or bell by using the control stand controls. An audible horn or bell will play and the center display will reflect the current position of the horn and bell controls (i.e., active or not).

5. Additional Considerations

A majority of current freight train operations in North America utilize a two-person train crew—the locomotive engineer who operates the locomotive's controls and a conductor who is responsible for the overall train and its consist. Although the focus of this report has been on the development of an improved locomotive engineer workstation as part of the NGLC, it is important to at least briefly consider the conductor's workstation. The locomotive engineer typically operates on the right side of the locomotive while the conductor sits on the left side (also referred to as the "fireman's" side). The conductor's next generation workstation might have the following elements:

- A redundant, programmable display to provide operating information to the conductor. The default display should be the center operating display, but the conductor should be able to access information contained in both the left and right auxiliary displays to support the conductor's tasks and responsibilities as well as situation awareness.
- Additional controls (some of which already exist on modern locomotive) that support the conductor's tasks and responsibilities such as the following:
    - Horn
    - Bell
    - Radio
    - Emergency fuel cutoff switch
    - HVAC controls for conductor's side
    - Emergency brake application (e.g., mushroom button)
    - Clipboard, short desk, and a place to hold paperwork such as a vertical file or bin
    - Electrical outlet to charge a portable computer or other electrical device used for work (e.g., computer-transmitted movement authorities)

A second consideration in developing an NGLC is the possible use of wide-angle video cameras mounted on both ends of a locomotive. A participating SME suggested that it may be beneficial to place wide-angle (i.e., fish eye) charge-coupled device cameras on both ends of the locomotive, looking down toward the couplers, to provide situation awareness information to the engineer.

A third and final consideration in developing a NGLC is to explore the benefits of installing a small microwave oven and refrigerator in new locomotives. Train crews typically operate 8–12-hour shifts and rarely leave the cab except to perform work-related duties such as setouts and inspections. Thus, train crews must bring with them all of their provisions. Although not directly related to safety, a small microwave oven to heat up water for coffee, tea, soup, etc., and a small refrigerator to house train crew's meals and water can be expected to improve the comfort of the locomotive cab space and increase overall crew satisfaction.

6. References

Association of American Railroads. (2006a). *Diesel locomotive control stand for new locomotives recommended practice RP-5132.* Manual of Standards and Recommended Practices Section M: Locomotives and Locomotive Interchange Equipment. Washington, DC.

Association of American Railroads. (2006b). *Locomotive system integration operating display standard S-591.* Manual of Standards and Recommended Practices Section M: Locomotives and Locomotive Interchange Equipment. Washington, DC.

Einhorn, J., Sheridan, T., & Multer, J. (2005). *Preview information in cab displays for high-speed locomotives.* (DOT/FRA/ORD-04/12). Washington, DC: Federal Railroad Administration

Gamst, F. (1975). *Human factors analysis of the diesel-electric locomotive cab.* Human Factors, 17(2), 149-156. Santa Monica, CA: Human Factors Society.

Jankovich, J. (1972). *Human factors survey of locomotive cabs*. (FRA-OPP-73-1). Washington, DC: Federal Railroad Administration.

Multer, J., Rudich, R., & Yearwood, K. (1998). *Human factors guidelines for locomotive cabs*. (DOT/FRA/ORD-98/03). Washington, DC: Federal Railroad Administration.

Roth, E. (2000). *Notes on Locomotive Engineer Cognitive Demands Based on Preliminary Observations and Interviews of Locomotive Engineers.* Unpublished notes prepared as part of a Cognitive Task Analysis Program of Locomotive Engineers being conducted for the Volpe National Transportation Systems Center, U.S. Department of Transportation. February 2000.

Sheridan, T., Gamst, F., & Harvey, R. (1999). *Reliance and distraction effects in PTC automation*. White paper. Available at www.fra.dot.gov/downloads/research/reliance.pdf.

Abbreviations and Acronyms

AAR	Association of American Railroads
ACEN	automatic collision and emergency notification
ACT	Advanced Concept Train
amp	ampere(s)
CAD	computer-aided design
DB	dynamic brake
DP	distributed power
ECP	electronically controlled pneumatic (brakes)
EOT	end-of-train
FRA	Federal Railroad Administration
HVAC	heating, ventilating, and air-conditioning
in	inch(es)
LCD	liquid crystal display
min	minute(s)
mph	mile(s) per hour
ms	millisecond(s)
MU	multiple unit
NGLC	Next Generation Locomotive Cab
PTC	positive train control
s	second(s)
SME	subject matter expert
TBD	to-be-determined