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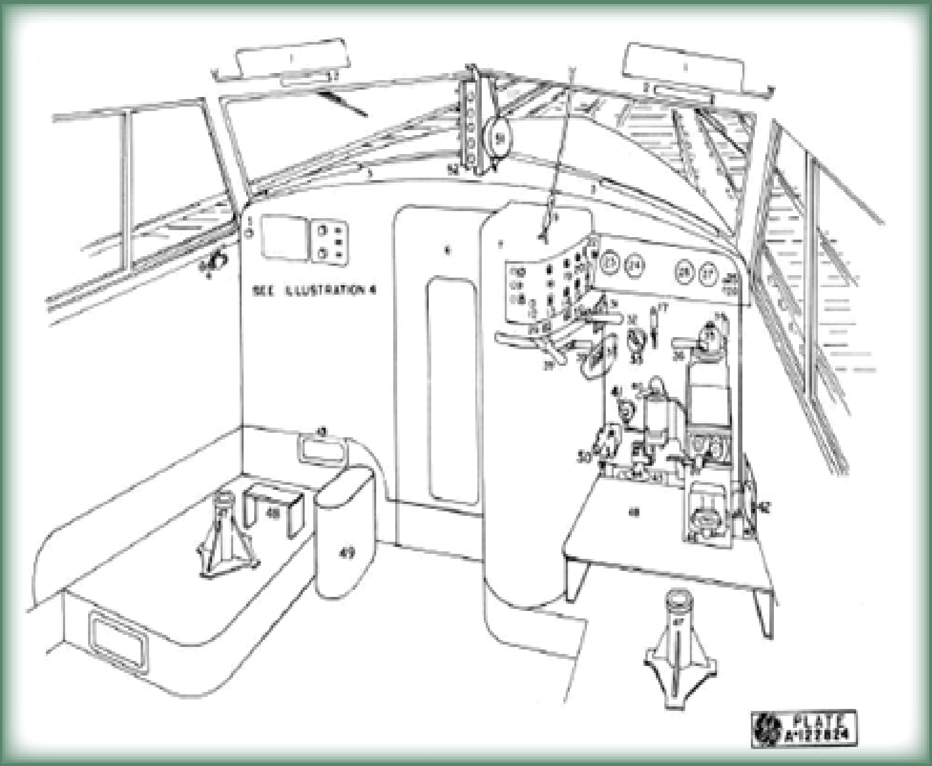
The Future Locomotive

How to Manage What You Have Today with a View to the Future

A Conference

July 30–31, 2013
Omaha, Nebraska



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TRANSPORTATION RESEARCH CIRCULAR E-C212

The Future Locomotive

How to Manage What You Have Today With a View to the Future

A Conference

July 30–31, 2013
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Omaha, Nebraska

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Transportation Research Board
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Preface

This conference was the focus of the Railroad Operational Safety Committee's 2013 midyear meeting. Concerned with human performance and human factors research issues related to railroad operations, the committee draws upon the expertise of researchers and operating personnel to define, encourage, and disseminate results of research that will enhance the safety, performance, efficiency, and comfort of those involved in or using railroad and rail-related transportation systems.

ACKNOWLEDGMENTS

The success of this meeting was made possible through the time and effort of the planning committee and the generous hospitality of the Union Pacific Railroad (UP), which hosted the event. All those involved in developing and participating at this meeting have invested in making railroad operations safety through the advancement of research and practice regarding the role of the human in the system. Key organizing functions of the meeting, and the people responsible for accomplishing them, are as follows:

- General coordination: Richard Pain, Ann Mills, Michael Jones, Lawrence Fleischer, Jackie Keenan, Jeffrey Moller, and Hadar (Rosenhand) Safar.
- Promoters: Gina Melnik, Jeffrey Moller, Richard Pain, and Vijay Kohli.
- Hosts: Bob Grimaila and Jackie Keenan.
- Note takers: Jeffrey Moller and Bianca Mejia.
- Presenters: Nancy Cooke, Jordan Multer, David Mangold, Harvey Boyd, Stephen Gerbracht, Charles Oman, Paul Picciano, Vic Riley, Jeffrey Moller, Aaron Ratledge, Fred Gamst, Jim Grady, Kathleen Voelbel, Ann Mills, Helen Gitmez, Anita Scott, Anand Prabhakaran.

Thanks also go to Ann Mills and Michael Jones for initiating the idea, and to committee members who offered comments after reviewing this e-circular.

The committee especially appreciates the support provided for this conference by the Federal Railroad Administration and the Volpe National Transportation Systems Center.

—Stephen M. Popkin, *Chair*
Ann M. Mills, *Vice-Chair*
Railroad Operational Safety Committee

Cover image: Gamst, F. C. The Diesel-Electric Locomotive as a Work Environment: A Study in Applied Anthropology. *Studies in Cultural Anthropology*, Rice University Studies, Vol. 61, No. 2, 1975, pp. 37–78.

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Introduction

TRB's Railroad Operational Safety Committee is concerned with human performance and human factors research issues related to railroad operations and draws upon the expertise of researchers and operating personnel to define, encourage, and disseminate results of research that will enhance the safety, performance, efficiency, and comfort of those who are involved in or use railroad and rail-related transportation systems.

The purpose of the meeting was to examine North American locomotive cab design in terms of human machine interface theory and railroad applications. The meeting included perspectives from researchers, unions, locomotive engineers, engine manufacturers, and railroad management in a format that encouraged audience participation. Topics included human system integration, the evolution of today's designs, the operator's perspective, sources of human error, workload and automation, energy management, prospective future design features, the European perspective, and active noise cancellation.

The timing of this conference was excellent as it coincided with the start of a new task force involving labor, management, manufacturers, and researchers that will consider revisions to current locomotive designs. While today's cabs are successful, many key elements date from the early 1970s. Recent advances in technology will give designers the freedom to explore new approaches that would not have been feasible a few years ago. Several members of the new task force participated in this conference and concepts discussed here certainly will be included in task force deliberations.

The committee and TRB thank Jackie Keenan and UP for hosting this meeting at the training center in Omaha, Nebraska. The committee also thanks the planning committee who organized this meeting:

- Ann Mills, Rail Safety and Standards Board, United Kingdom, *Chair;*
- Jeffrey Moller, Association of American Railroads;
- Lawrence Fleischer, BNSF Railway;
- Jackie Keenan, UP;
- Michael Jones, U.S. Department of Transportation (DOT); and
- Hadar Safar, U.S. DOT

Human Systems Integration

NANCY J. COOKE
Arizona State University
Chair, National Academies Board on Human Systems Integration

Cooke indicated railroads and train operations are in the midst of many changes. For instance, the transition from mechanical control to positive-control technology with increasing emphasis on automation is similar to changes faced by the aviation industry as cockpits evolved from manually operated systems to glass cockpits with autopilots. These types of changes are accompanied by changes in the operators' tasks. Often the tasks become more cognitively strenuous and the addition of automation can be associated with loss of situation awareness and overreliance on that automation. Human systems integration (HSI) is essential for ensuring that these changes result in safe and effective operations.

HSI is a discipline in which human capabilities and limitations across various dimensions are considered in the context of the design and evaluation of a dynamic system of people, technology, environment, tasks, and other systems with the ultimate goal of achieving system resilience and adaptation, approaching joint optimization. The human dimensions considered include human factors, manpower, training, personnel, safety, survivability, and habitability. Deliberate trade-offs across these dimensions are required to address the needs of multiple system stakeholders. Consideration of human integration into the entire system early and continually through the system engineering process is essential.

SUGGESTED RESEARCH, DEMONSTRATION, AND IMPLEMENTATION ISSUES

According to Cooke, the design and development of railroad technology requires a consideration of human integration into the entire system, early and continually throughout the system engineering process.

TAKEAWAY MESSAGE

Cooke offered the following summary takeaway messages:

- Technology alone is typically NOT the answer.
- HSI is NOT intuitive.
- HSI is highly context-dependent.
- HSI needs to be addressed from the beginning (acquisition) and continue through the life cycle of the system.
- Not only does HSI ensure safer and more-effective systems, but it can result in cost savings.

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DISCUSSION

The participants' discussion began with the mention of the National Research Council's Board on HSI. One participant noted budget is a constant concern, and gave an example from prior experience with the U. S. Navy, where this participant said it seems there is a desire to reduce manpower. However, senior leaders sometimes resist change. It was emphasized that getting a culture change from the top down is difficult, adding that the designs of new systems are sometimes institutionalized and decisions have been made before testing. Cooke acknowledged that budgets are a perennial challenge as is reducing manpower. However, she gave the example of unmanned aviation systems; although this equipment naturally might seem to lead to fewer soldiers, in actuality it takes about 80 people on the ground to support one vehicle.

A participant asked what the best way to instill HSI into a company (other than consultants). Cooke suggested that perhaps HSI needs to be instilled at the undergraduate level, but did acknowledge that there are cultural issues. In her experience as a professor at the College of Technology Innovation, a goal is to ensure engineers come out of the program with at least some knowledge of HSI. She thought it would be great to establish a certificate program for those already in the workforce. Cooke said, "Until decision makers understand HSI, it will be ignored."

Another participant asked for an example of success in industry, noting that when a toy manufacturer creates a new product, the manufacturer provides it to an observed group of children. Cooke discussed how there are many methods of defining success, including observing the user interacting with a system. The participant replied that in some cases, the user may give opinions about the product, but there is still the question of how the designers can know that they are achieving sound human factor principles. Cooke responded that a cognitive task analysis looks at how people perform tasks, what information they need, how it is presented, and the types of errors they make. Gathering this kind of information can help in the design process. During the discussion among participants, it was noted that we often talk about testing and evaluating a system that already exists. A participant asked how we capture relevant information when a design is only in the conceptual stage. Cooke referenced the term "envisioned world problem," giving the example of unmanned aerial system. When unmanned aerial systems were introduced, procedural operations and safety were the first things to be considered thoroughly. In other cases, safety issues can be checked through simulation. For example, it may not be possible to test fly a drone to check for safety issues, so simulation used.

A a participant noted that a challenge for the rail industry is a large capital investment in infrastructure. A different participant then asked "How do you address concerns about new systems when you have significant existing equipment?" Cooke noted this is an example where one does not have the luxury of designing from a clean slate, but it is possible to still use HSI with existing systems. There may be compromises that will need to be made, but there may also be other components you may be able to influence, for example training.

One of the participants asked, “What is the process for identifying requirements when purchasing new equipment? Is it recommendations from a committee or one’s own system engineers that you take to the manufacturers?” A participant who works for a carrier noted that his railroad has a standing committee that meets with employee representatives twice a year to review current and future designs. This participant’s railroad identifies what needs to be changed, how to do it economically, and then consults with the manufacturer. Another participatant who works for a carrier uses a similar process adding that his company looks at all aspects of the locomotive including seats, handbrake designs, etc. A participant noted that several railroads use this committee process to provide input to management as they make decisions. One other participant who works for a carrier noted his company looks forward to the upcoming industry–labor–FRA committee to add some additional expertise to the design of cabs. A similar process was also used in the United Kindom when implementing a new radio system. A major challenge was locating the equipment in existing cabs. The committee identified key requirements and assessed the various cabs to see the key things that needed to be considered. Compromises sometimes had to be made. Scientific literature was reviewed, tasks were identified, and ideas were tested with users. When an idea was rejected, people were asked to articulate why.

A participant who works for a manufacturer noted the challenge of working with many different customer specifications. In response, a participant who works for a carrier discussed the challenging but successful group effort to establish interoperable positive train control and said that “We don’t have room for much more stuff in our cabs. We need to move from old style handles to something new. This is an opportunity to talk about all the issues and make sure we’re in lockstep.”

Cooke’s PowerPoint presentation can be found in Appendix C.

History of the Locomotive Cab and Control Stands

DAVID MANGOLD
University of Akron

Mangold began his history of locomotive cabs and controls by explaining how they have evolved through years of development from mechanical levers, valves, and gages to advanced electronic systems. Accommodations within the cab have also improved considerably. The modern locomotive control stand has evolved significantly to accommodate the control of many operating systems: brakes, throttle, lighting, safety equipment, and electrical devices (see timeline). Future design improvements to locomotive cabs and control stands should understand the past, which will allow for an understanding of the present, so future locomotive cabs will have the necessary functionality to benefit the operators of future locomotives.

The first locomotives used in the United States were from Great Britain, then later U.S. builders assembled locomotives. These original locomotives had vertical boilers and were built without cabs. After many years of refinements horizontal boilers and wooden cabs became standard on locomotives. Operating system controls for brakes, throttle, lighting, safety equipment, and electrical devices were added and controlled from within the locomotive cab. Refinements and design modifications resulted in larger cabs, in which placement varied from the rear of the locomotive, to the middle (camelbacks), and then to a unique cab-forward design that came into use from 1909 to 1940 for crews to avoid smoke from entering the cabin tunnels and snow sheds, a common problem of steam locomotives.

Electric locomotives allowed the placement of cabs at the forward end of the locomotive. These locomotives were known for small cabs and complicated control stands. In Europe, on the Swiss Federal Railways, a desktop control stand evolved into the locomotive type known as the "Crocodile" in 1919.

Dieselization of U.S. locomotives resulted in many design changes to locomotive cabs. Legacy control movements remained similar to steam locomotives. An example of this is the movement of the throttle rearward for increased power and speed. Unique designs were developed, including streamlining—which was common in the 1930s—an example of which is the *Pioneer Zephyr* equipment from 1934. Cab unit-type locomotives came into common use beginning in the late 1940s. The EMD (Electro-Motive Division) model F7 is an example of this type.

The EMD GP7 and GP9, known as general purpose locomotives, came into use as road switchers. A standardized locomotive control stand evolved and was placed in later model upgrades. Some locomotives were equipped with dual control stands, one on each side of the cab.

In the mid-1980s, second-generation diesels were produced, the EMD SD40-2 and the GE (General Electric) B23-7 being prime examples. Improvements were incorporated to the locomotive cabs and control stands. A unique BQ23-7 with a large locomotive cab was designed and built for the Family Lines Railroad. This locomotive was designed at the time cabooses were being eliminated and provided room in the cab for all five crewmembers then mandated by labor agreements.

Modern locomotive cabs (third generation) have changed considerably from the predecessors. The Alstom–ALP45DP used by New Jersey Transit is an example of a modern desk top-type control stand. In Europe modern, perhaps fourth-generation, locomotive cabs are in common use; a variety of locomotive types exist.

Designers of future improvements to locomotive cabs and control stand design can benefit by having an understanding of the past so that future cabs can even better support crew effectiveness and safety.

Elements of the Locomotive Cab Timeline that Mangold highlighted were as follows:

19th Century

Early 1800s	Development of primitive locomotives without cabs.
1831	First locomotive cabs added to early locomotives.
Mid-1800s	Delivery of British locomotives and construction of early U.S.-built steam locomotives without cabs.
	Advancement in steam locomotive technology.
Mid-1800s	Locomotive refinements including an enclosed wooden cab.
Late 1840s	First camelback locomotives built with large cab to accommodate wide fireboxes and better visibility for the locomotive engineer.
Early 1850s	Locomotive cabs become a standard part of the locomotive.
1870s	Throttle improvements including ratchet and latch.
1880s–1890s	Larger, more-powerful locomotives built.
March 2, 1893	Safety Appliance Act enacted by Congress and signed by President Benjamin Harrison, required air brake controls in cabs.

20th Century

1900s	Larger and faster locomotives with metal cabs in use.
Aug. 1, 1900	Extension of Safety Appliance Act compliance requirement.
1925	Early (box cab) diesel locomotives in use.
1930s	Streamlined steam locomotives in use.
1938	Diesel electric locomotives (GM EMC-F units) built.
1949	Budd Company/EMC-RDC (rail diesel cars or cab cars) and F units in use, in common use on U.S. railroads.
1950s	Train–radio–telephone use begins (on Erie Railroad), use of alerter systems, first-generation diesel road switchers built by EMD (GP7 and GP9).
1967	United Aircraft Turbo Train, a unique locomotive and cab design.
1968	High-speed cab car; *Metroliner* begins scheduled service on PRR
1976	EMD F40PH built and in use by Amtrak.
1990s	Development and use of third-generation locomotives and onboard electronic systems.
1997	Amtrak tests operation ICE train set from Germany.
1998	Amtrak tests operation of X2000 from Sweden.

21st Century

2000s	Modern locomotives in use with improved control stand designs and energy management systems, ECP braking, and DP controls.

DISCUSSION

One comment raised during the discussion concerned a photograph of a European Locomotive cab which showed six different computer screens confronting the engineman. The issue was why there were so many screens in the locomotive cab. A participant from the United Kingdom explained that one of the screens is a camera image for the driver to observe passengers boarding on a platform. In addition, there is the European Rail Traffic Management System Screen (ERTMS), the radio, and a train management system. Another participant referred to high-speed equipment they saw in Shanghai with a very simple cab layout, designed by a German company. It was noted that additional data was accessible by simply scrolling through various screens. It was suggested that stakeholders would possibly benefit by looking at these magnitude-level designs.

A few participants raised larger issues concerning the challenges associated with an engineman in the cab. When questioned about what challenges are seen, Mangold noted several challenges: The first was noise, which is an issue when an engineman needs to communicate with a fellow crew member. Another challenge that has been alleviated with the new designs is vibration which can be an irritant for crewmembers. Challenges also included pinch points, and the horn lever which may be in the way when one is operating the brakes or the reverser. At night cabs are dark, making controls more difficult to perceive.

During the discussion it was asked when the first “dead man” pedal or alerter appeared. Respondents were not sure but Mangold noted that cab signals date from the 1920s and electronic alerters from the 1950s or 1960s.

Mangold’s PowerPoint presentation can be found in Appendix C.

North American Freight Locomotive Cab Development

HARVEY BOYD
Electro-Motive Diesel

Harvey Boyd discussed how locomotive cabs have changed considerably over the past 40 years due to the influence of users, regulatory actions, changing equipment, and changing expectations. This presentation considers some of the tools, inputs, and trade-offs that took a simple general purpose–special duty (GP/SD) cab and turned it into the advanced cab in use today.

In the early 1970s, an industrywide committee gathered to generate improvements to the narrow short-hood, GP/SD-style locomotive cabs. The direct outcomes of their efforts were improvements and standardization to the engineer's control stand. Other improvements included door closure bars, door hinge guards, windshield wiper motor covers, rubber padded horn levers, toilet compartment vents, and stairwell access to the short hood and toilet compartment.

Boyd said that the late 1980s saw a desire for a more office type environment along with increased safety and crew comfort which led to the development of the North American Cab (also called wide cab and comfort cab). These new cabs included air conditioning, better seats, improved crashworthiness, dedicated cleanable toilet compartments, better lighting, comfortable flooring, and desks for both the engineer and conductor. Introduction of electronic information display screens, desires for improved ergonomics, and a push for improved visibility when making reverse moves led to a new cab arrangement in the early 2000s.

DISCUSSION

The audience discussion centered on the topic of human factors principles in the design of locomotives and the feedback process. One participant asked if EMD used human factors engineers as part of the design team and what type of human factors components appear in a typical purchase order. Boyd advised that they have had staff ergonomists in the past but there are none currently. Additionally, purchase specifications typically list specific components (e.g., model of seat, toilet, or floor covering).

Another participant asked if the manufacturers followed a formal or informal method of receiving feedback from their customers after sending them a new product. According to the speaker, surveys consisting of up to 60 questions are sent out when a trial cab is deployed. In addition to the survey, the manufacturer meets with various carrier cab committees and receives feedback from mechanical departments on what they like and dislike. Feedback also comes through the service department.

A participant made an observation that manufacturers tend to build based on old designs, noting that "…it seems as if manufactures start with their original design and make changes, including trade-offs as requests come in." This approach can lead to the need to make collateral fixes, suggesting the only way to break this cycle is to start over with a new design. The speaker noted that although starting from scratch is ideal, compromise has always been a big part of the design, often by necessity done dynamically. Often times, customers specify delivery beginning in 9 months, which is not much time to create drawings, review alternate designs, and approve the design in time for construction. New designs such as the wide-nose design that started without old resources was a result of an industry push. The suggestion was made that new designs should take on a similar approach.

Boyd's PowerPoint presentation can be found in Appendix C.

GE Perspective

STEVEN GERBRACHT
General Electric

DISCUSSION

During the discussion, several questions were raised surrounding the challenges of cab designs. As the discussion started, Steven Gerbracht noted that while design work using 3-D modeling and unigraphs is the same in North American and the European Union (EU), the type and arrangement of controls differs. Implementing EU arrangements in some of the manufactures' domestic models would be a challenge. The discussion continued with a participant noting the desirable goal for interoperability in rail and in aviation, where type ratings for specific crew assignments are typical. The question was raised if interoperability errors have been a problem for locomotive engineers. Although Gerbracht said he has not seen such an error, he noted the layout of the basic controls is uniform and it was acknowledged that the challenge going forward will be when the new designs or new systems are introduced. Challenges might also arise with different signal systems. Participants representing different carriers reinforced that they also had not seen such mishaps.

Operating conditions and electronic distractions were raised during the discussion. A participant noted that there are complaints about cab temperatures. A fellow participant said that all new locomotives are equipped with heating, ventilation, and air conditioning technology to moderate the issue. In terms of electronic distractions (such as the use of cell phones), one question raised was if a hands-free option might be feasible. A participant who works for a carrier noted that their company's operating rules and FRA regulations prohibit the use of cell phones in locomotive cabs except during emergencies, adding that the National Transportation Safety Board opposes cell phone use in automobiles, even when hands free.

Participants continued to discuss how manufactures' market new human systems integration concepts during development, and the differences between how these concepts are developed in North America and in the EU. Although requests may not differ between the two, it was advised that regulations do. Manufacturers work around the basic requests of many carriers, and compromise where needed. For example, a carrier may want the manufacturer to begin their design concept with the inclusion based on their 1975 locomotive, which has worked well and with which many locomotive engineers are familiar.

Challenges dealing with installing new features such as positive train control (PTC) were also discussed. With PTC, there is the initial challenge of setting aside software and physically locating the equipment. Often, opinions on where to put equipment differ, especially since some of this equipment requires precise climate control. Another important consideration is whether the new feature must be stand alone or integrated with existing systems. A challenge for locomotive manufacturers like GE is that carriers will often bring in a vendor's product and ask the manufacturer to integrate it in their construction. Gerbracht suggested the best way to improve integration is to collaborate with industry stakeholders on an agreement on software inclusion and placement. Although it was acknowledged that this in itself was not easy, stakeholder agreement would result in greater concurrences and reduce false starts.

In discussing interoperability again, it was noted that locomotive engineers become frustrated when switches around the console are different among carrier equipment. Although the location of the throttle and brake levers are the same universally, it may be helpful to have the horn and sand lever in the same place in all new console designs. Gerbracht indicated there are standard positions for the horn and bell, which are being kept consistent when possible.

A discussion surrounding the topic of fatigue abatement also arose. Gerbracht said that his company has considered this issue with some of the latest models. They have worked on the console and seat position by increasing comfort and allowing for good access to controls.

Gerbracht's PowerPoint presentation can be found in Appendix C.

Locomotive Engineer's Reactions to the Designer as Phantom Crewmember in Human–Locomotive Systems

FREDERICK C. GAMST
University of Massachusetts, Boston

Gamst began his remarks by saying that in railroading, the effects of a posited phantom crewmember, a designer, constantly channel the ways in which an engineer works on a locomotive. The design of noncomputerized and computerized machines and the procedures for their use could affect human tasks that result in operator errors, even leading to close calls and accidents.

Gamst said that his presentation contributes to the design of the next generation of locomotives and is derived from this report for the conference session "How Do We Manage What We Have Today?"

Gamst's full report builds upon an old maxim in human and social factors: in order to account for efficiency, safety, and comfort, the designer of a machine or procedure must query operators. Incorporating human capabilities and limitations in machinery design requires specialized, esoteric knowledge of how operators in a particular machine domain behave individually and socially. For designer issues and engineers' needs in the human–locomotive interface, Gamst said he used his background knowledge of 58 years as well as input gathered from locomotive engineers regarding designs of locomotives today.

Responses from engineers in the full report have been classified into 59 subject areas, which include the following:

- External lights,
- Small controls,
- Indicators,
- Alerters,
- Automatic and independent brake valves,
- End-of-train switch,
- Throttle and dynamic brake controls,
- Radio,
- Workstation clearances,
- Cab amenities,
- Glazing,
- Kinesthetic feedback,
- Conductor's items,
- Hand signals,
- Designer and implementer issues,
- Field correction of designer issues,
- Overall cab safety,
- Leaning out of right-hand window,
- Engineers' comments about cab environment, and
- Seating considerations.

TAKEAWAY MESSAGE

In comprehending engineers' decisions and resulting actions, an important consideration is the contexts of the social interaction and cultural knowledge in which they reside. Design necessarily has effects beyond human–device interface. When designing locomotives and their cabs, a designer, design approver, and design regulator must recognize the range of the engineer's and interacting teammate conductor's tasks, responsibilities, bodily positions in tasks, protections of the body, visual needs, and hearing needs.

DISCUSSION

One participant noted how Gamst's paper discussed some of the issues with both in-cab and external communications and all the complexities involved with the design of the cabin order to facilitate the engineer's leaning out of the window to improve visibility. Although it was noted that out-of-cab operations and in-cab operations are dependent on the engineer's preference, it was recognized that there are issues dealing with the ability to reset the alerter or answer the radio in the out-of-cab position, in addition to being able to hear other locomotives or seeing ground men during in-cab operations. Although the solution would not be simple, it was noted that in-cab and out-of-cab operations are both necessary, especially for complex switching movements. Although Gamst's report did not include remote control locomotive operations, it was noted that a 2006 study by Gamst and Gavalla did include remote control locomotive operations.

Accident Caused by Human Error
But Which Humans?

PAUL PICCIANO
Aptima, Inc.

Paul Picciano began his remarks by suggesting accident investigation teams regularly attribute fault to the human operators at the front lines of complex system failures. Cognitive lapses are often blamed for the inaccurate perceptions, misaligned mental models, and erroneous actions identified in the causal chain. However, complex systems have many more humans in the life-cycle loop than just the operator sitting at the controls. Engineers and designers are key humans in the development and use of these systems, but are also susceptible to similar cognitive vulnerabilities and sometimes unwittingly include opportunities for failure in their designs. Facilitating system understanding for operators and maintenance personnel must be a design priority. Intentionally making complex systems more transparent and providing useful feedback can help maintain safe operations, according to Picciano.

TAKEAWAY MESSAGE

Picciano summarized his takeaway messages citing Azevedo and Bernard (*1*) and Johnson-Laird (*2*). "Designs can be improved when prioritizing system transparency, feedback, and building user trust in the system. Performance is found to be enhanced with improved mental models and the support of feedback. "

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DISCUSSION

The discussion focused on the take-aways for the railroad industry from an aviation-related incident resulting from human error. Picciano presented several accidents in different modes, but focused on a runway incursion in Providence, Rhode Island, where an aircraft inadvertently encroached on an active runway. The air traffic controller (ATC) disregarded the encroaching plane's radio calls of concern and twice cleared a conflicting flight for take-off. Picciano posed the question "Who was at fault: the taxiway design or the pilot?" Using James Reason's Swiss Cheese Model of system failure, Picciano suggested the pilot who did not accept the take-off instructions was the slice of cheese that prevented this possible accident from occurring. This incident is an example of where it would be easy to blame the front line people for the many mistakes associated with this incident. It is a lesson that can help improve safety procedures and equipment such as ground-based radar. In addition, the system and how people are trained can be implicated. While there may be resource constraints, investigators should be encouraged to look deeper at these types of elements. It was noted that the ATC was under pressure to move planes which overrode the deeper problems of the ATC system and procedures. Furthermore, Picciano said that now such an incident is rare, however, because an ATC would be likely to reflexively stop all movements until things are straightened out.

Picciano's PowerPoint presentation can be found in Appendix C.

Evaluation of Cab Controls

VICTOR RILEY
Consultant

PRESENTATION SCOPE

Victor Riley introduced his presentation as focusing on two common design-related human errors and the potential opportunities for these errors in an early version of the BNSF electronic train management system (ETMS) screen layouts. One of the errors is called substitution error, which happens when the operator intends to actuate a particular control but actuates another one instead due to similarities in the positions, shape, input action, and other attributes of the two controls. The other error is called negative transfer error, which happens when the operator applies expectations formed through experience with one design to another design, leading to an unintended result. The ETMS screen layouts were evaluated for their potential to induce these types of error by analyzing the assignment of functions to function keys across all of the screens. To do this analysis, a spreadsheet was built with the function key positions across the top and the screen formats listed down the side, so that each intersection of screen (row) and function key position (column) listed the function assigned to that position on that screen. The general intent of each function was then abstracted in order to identify cases where the same function key position produced conflicting outcomes on different screens (negative transfer), and to identify cases where adjacent functions on the same screen could have conflicting outcomes (substitution).

Riley offered an example where several functions ("yes," "ok," "received," "acknowledged," "verified," "arrived," "done") were confirmatory while others ("no," "cancel," "reject," "quit") were negative. If a single key position hosted primarily confirmatory functions, or the user was accustomed to finding the confirmation step on a particular screen that was used frequently, and that same position were assigned a negative function on a rarely used screen, this could lead to an error where the operator selects the negative function on that screen, expecting it to be confirmatory. To determine the potential for this, each function was assigned to an abstract intent category ("yes," "no," "activate function," "go to new screen," "go back," etc.), then a macro was written to read through the function key categories for each function key position for each screen and to highlight instances of conflicting assignments between screens. An additional macro was written to analyze adjacent function pairs for their potential to induce substitution errors. For example, on the "location selection" screen, the first two function key positions were "Main 1" and "Main 2." These functions were used when the navigation sensors could not determine which of two adjacent tracks the train occupied, so the user had to enter this information into the system. With two adjacent options with very similar labels, there is some potential for substitution, and indicating the wrong track could mislead the protection logic.

SUGGESTED RESEARCH, DEMONSTRATION, AND IMPLEMENTATION ISSUES

As automation and graphical user interfaces with flexible formats become more widespread in locomotive cabs, potential increases for design-related operator errors, including substitution, negative transfer, inadvertent actuation, reversal, etc. Where error opportunities may exist, designers can evaluate the potential impacts of those errors on operational outcomes, including what feedback is available to enable the operator to detect the error, what opportunities the operator has to correct the error, and what would happen if the error were not detected or corrected. Research that would be helpful to industry and designers would focus on the nature of operator errors and guidance on systematically analyzing designs for error opportunities and potential outcomes.

DISCUSSION

The focus of the discussion was on the issues of substitution errors and error transfers. One participant asked for suggestions to prevent substitution errors. As an example, the case of horn buttons and alerter resets was discussed. Horn buttons and alerter reset buttons are similar in location and shape, and in darkened conditions an engineman might mistakenly reset the alerter instead of sounding the horn. One potential solution Riley discussed was where workers modified two similar handles in a control room to be distinct shapes and sizes (like beer tap handles), thereby making them less similar in look and feel.

Similarly, a participant pointed out that in the United Kingdom, a railroad carrier operates two distinct types of train sets, one which notes the inoperative state of the tilting feature by a light coming on, and another where the light comes on when the tilt feature is properly functioning. These two distinct problematic features in the two train sets have been recognized and the operating company is considering type rating for the two systems to reduce the chance of human error. Although no particular solution was given for these scenarios, carriers are working on modifying these cab controls to reduce the chance of human error.

Participants noted during the discussion that manual controls are different in locomotives compared to aircraft controls and it was questioned if the presenter's evaluation criteria should include task or subtask interrupt ability. The main issue is the length of time a person can look away from the task without facing risks and having to reengage. Although no direct answer was given, participants noted error analysis is only a small part of the human factors error statement. While errors are perhaps one of the most important issues to analyze, they are not the whole picture. Currently there is a trend toward installing additional control screens in cabs. One participant asked for guidance on the arrangement and placement of actions on the touchscreens, and on whether there are ways to discriminate between controls on a screen. Although Riley advised that he had no preference for using manual controls or touchscreens, he emphasized that substitution errors and error transfers are two key risks. Riley further suggested requiring more-complex gestures instead of simple taps on the screen might keep these risks at bay.

Riley closed his remarks by stressing the importance of considering the context and application of the cab controls. When asked if there is any data on whether it is better to have multiple gauges on one screen or individual gauges for each screen, Riley noted it highly depends on the purpose of each gauge and whether they are different or contribute to the same mental model.

Riley's PowerPoint presentations can be found in Appendix C.

Automation and Workload

VICTOR RILEY
Consultant

PRESENTATION SCOPE

Riley began his second presentation with some lessons learned about the application of automation to complex systems. For example, a technology-centered allocation of functions and responsibilities between the automation and the human operator can result in giving the operator a combination of tasks that are difficult to manage, may not fully support situation awareness needs. Allocating functions first to the operator to ensure a manageable task load that keeps the operator engaged enough to maintain situation awareness is likely to lead to a safer, better functioning overall system, according to Riley. He also suggested it is important to evaluate the potential for overreliance on automation, and to recognize that different users may use and rely on automation differently. One common research finding in automation studies is that automation-use decisions are highly variable and subject to large individual differences, but that the more users know about how the automation works and its capabilities and limitations, the more likely they are to use it appropriately.

Regarding workload, Riley focused on practical means of analyzing designs for workload impacts. For example, a workload measure that is sometimes used in the certification of aviation systems is "time required/time available." If more time is required to perform a task or combination of tasks than is available, the workload is unmanageable. However, it is often difficult to establish how much time is really available for a task. Even if the amount of time for a task were known, design changes that could improve workload may still prove elusive. For this, Chris Wickens' Multiple Resource Theory (*1*) is a useful tool, because it provides a means of describing the levels of attentional conflict between simultaneously used displays and controls.

For example, Riley explained that looking out the window and listening to the radio is a manageable combination of tasks because one is visual and spatial while the other is auditory and verbal. However, looking out the window and reading a system display would induce a high level of conflict because both are visual and the operator can only look in one place at a time. One way of using this theory to evaluate a crew station design would be to list all of the displays and controls along both sides of a matrix, and assign conflict levels to each combination of display and control. Next, one would calculate the levels of conflict induced by requiring attention to combinations of displays and controls during operational scenarios. For instance, if a particular procedure requires use of the right hand for two controls, workload would be high because of the simultaneous demand on that single operator resource. While this analysis method does not yield a useful overall workload level estimate, it does help identify cases where simultaneous attentional demands cannot be reconciled, thus suggesting design changes that can mitigate these conflicts. One such design change would involve relocating a display to where it would be easier to monitor in combination with another simultaneous task, or changing an alert message from visual to aural.

SUGGESTED RESEARCH, DEMONSTRATION, AND IMPLEMENTATION ISSUES

Research that would be useful to designers would be those with analysis tools that can characterize the degrees of conflict between competing user interface channels, assign attentional channels to displays and controls, and evaluate conflict levels in common operational scenarios. Designers would also be well served by recognizing the potential contribution of errors to workload, rather than evaluating workload only for nominal scenarios, because errors require operators to recover from the error while performing normal tasks. Normal task performance with the addition of error recovery (such as remembering to sound the horn in time for a grade crossing while simultaneously correcting a data entry error) is often the situation that leads to the highest workload levels.

REFERENCE

1. Wickens, C. D. Processing Resources in Attention. *Varieties of Attention* (R. Parasuraman and D. R. Davies. eds.), Academic Press, New York, 1984, pp. 63–102.

DISCUSSION

During the presentation Riley noted that analytical methods can reduce the time needed to conduct a study. For example an error analysis can be conducted in only a few hours. In addition, spending a few days conducting a more detailed analysis is far more efficient than doing a large study at the end.

One question that was brought up during the discussion was whether the method discussed during the presentation has been published as a report, noting that it is a very practical approach to workload analysis. In response, Riley said that such a report has not been published to date, but could potentially be useful. Another question was whether or not there have been instances where the desires of a user conflicts with good principals in design. Riley said that there have been cases where the users' desires do not necessarily correspond to the best human factors design principles. So, although user feedback is beneficial, designs still need to be tested.

The extent to which simulators are used in the industry was another focus of the discussion. Many participants who work for carriers contributed to the discussion, and some remarked that simulators are generally used for training purposes and verifying knowledge but not so much for design. In the United Kingdom, simulators were used to demonstrate whether or not a user interface was successful in reducing errors, which helped sell the concept to regulators and users. Currently the FRA has the Cab Technology Integration Laboratory (CTIL) research simulator at the Volpe Center in Cambridge, Massachusetts.

Riley's PowerPoint presentations can be found in Appendix C.

Distributed Power, Electronic Train Management System, and Energy Management Usage on BNSF Railway

Aaron Ratledge
BNSF Railway

PRESENTATION SCOPE

Aaron Ratledge opened his remarks by saying that over the years, BNSF and other railroads have been faced with human–machine interface (HMI) and screen placement challenges associated with the integrations of distributed power (DP), ETMS (PTC), and energy management systems. This presentation depicts the process that BNSF and their System Cab Committee used to arrive at screen placement designations on various types of locomotives, making HMI to the new technologies as seamless as possible.

TAKEAWAY MESSAGE

Ratledge suggested benefits can be realized when having a productive System Cab Committee. Good decisions result from collective discussions that engage every committee member's perspective when arranging or placing HMI devices in the cab of a locomotive.

DISCUSSION

After the presentation, participants raised a number of questions. A participant asked if there was consideration of context-specific displays where information that is not immediately needed is not displayed. Ratledge indicated efforts have been made to reduce and optimize several displays. BNSF has developed some context menus but information is not automatically removed. One participant asked if mounting screens to control stands by using adjustable brackets has been considered. Although thought was given to this idea, Ratledge said no currently available device would provide a reliable installation.

During the discussion it was noted that an earlier speaker had said that user preference was not always the best choice in terms of cab design, and asked how BNSF's method of cab design committee fit that thought. Ratledge noted that BNSF's cab group represents significant long-term experience, suggesting that its members consider user preference as well as their own judgment. It was also noted that manufacturers develop job aids which are then provided to the crews. Information from local supervision on how much effort is expended to train locomotive engineers on technology changes is then shared with the cab committee, who in turn provides feedback to the manufacturer on how the technology is operating in the field. When asked how the energy management systems have been received by employees and about the training implementation process, Ratledge said that when the systems are deployed, trained mentors accompany engineers on initial runs to acquaint them with the technology. The mentors then provide the engineers with pocket guides. Follow up with the engineers is handled during FRA-mandated annual check rides.

Ratledge's PowerPoint presentation can be found in Appendix C.

Development and Evaluation of Locomotive Moving Map and Planning Displays

KATHLEEN VOELBEL
ANDREW M. LIU
CHARLES M. OMAN
Massachusetts Institute of Technology

Kathleen Voelbel, Andrew Liu, and Charles Oman discussed moving maps and other preview displays that are widely used in the commercial automotive industry and in airplane cockpits. These maps and displays are used to provide drivers and pilots with information for driving–flying functions. Such displays have been considered for locomotive engineers as early as the 1970s, albeit for training, and more recently in displays such as I-ETMS, Quantum Train Sentinel, NYAB Leader, GE Trip Optimizer, etc.

Voebel, Liu, and Oman's presentation highlighted the design process used to develop a prototype moving map display based on display requirements derived from a hybrid Cognitive Task Analysis (hCTA). During this design process of determining functionality and designing a form or platform to address the needs, many questions were asked:

- What information is needed to perform tasks?
- How is the necessary data currently retrieved or recalled?
- What is the most effective way to synthesize and integrate information?
- When is the most effective time to display such information?

While some of the latter questions cannot be fully answered without simulator experiments and field evaluations, this prototype provides a platform on which to investigate the human performance benefits of providing necessary information at the right time.

Voebel, Liu, and Oman's PowerPoint presentation can be found in Appendix C.

Locomotive Alerter Technology Assessment

CHARLES M. OMAN
Massachusetts Institute of Technology

Oman opened his remarks by saying that currently, all U.S. passenger and most freight locomotives are equipped with some type of alerter or dead man system. He indicated his talk will review the limitations of dead man systems; the history of locomotive alerter logic; several fatigue-related accidents (e.g., those that took place in Anding, Mississippi, and Macdona Texas); and National Transportation Safety Board recommendations, technology, and user surveys that led to a 2007 Association of American Railroads standard and the 2012 FRA rule mandating preemptively resettable, speed-linked, control activity-sensitive alerters in all freight locomotives by 2017.

There are no scientific studies of alerter effectiveness, but accident data indicate they are imperfect detectors. Alternative approaches (e.g., eye, eyelid, head, electroencephalography monitoring) also have limitations. Unless positive separation systems like positive train control are universally implemented, fatigue- and alertness-related accidents will continue to occur each year even in alerter-equipped locomotives. The preemptive resetting feature encourages automatic repetitive responses. Simulations suggest that adding even a noisy image-based eye Perclos detector in tandem with conventional activity and speed criteria to reset the locomotive alerter could reduce nuisance alerts tenfold at a minor cost.

According to Oman, rather than using a single camera to reliably detect eye closure even when an operator's head is turned or tilted, it may be easier to detect whether both eyes are open and looking ahead as another activity indicator. Many labs continue to work on machine vision-based human motion tracking using multiple cameras and model-based estimation methods. Oman expects gradual improvement in automobile image-based distraction–drowsiness detectors. However, the cost-effectiveness of retrofitting image-based sensors into 20,000 U.S. locomotives remains a significant issue. Nonetheless, in newer locomotives with software-based alerters, simple logic improvements could reduce automatic resetting behavior at minor cost, and remain within existing rules and standards.

DISCUSSION

During the discussion an attendee asked if the speakers had looked at cognitive alerters. Oman replied that they had and wondered how distracting these alerters might be. Researchers have looked at points where a person has to make a decision and found that such alerters may be more effective, but people don't seem to like the alerters.

On the topic of alerters, one participant asked if the researchers had looked at aviation. The speaker noted that when the 747 (Boeing's first ultra-long-haul aircraft) was introduced, an activity-based alerter was offered. If no cockpit activity was detected after 2 min, the device would activate. While the option remains available, Oman is unaware of any purchasers. It was noted that alerters do not detect if someone is fit to operate, only that they are at some level of wakefulness. Oman said that he believes that with increasing technology, crews may have less to do. Therefore, he thought that the new technology could be used to monitor whether the train is operating normally, thereby focusing less on the human element. As the automotive industry is focusing on lane tracking, a participant suggested that perhaps machine vision could evaluate the appropriateness of driver behavior. Such evaluation would involve not only detecting lid drooping but what the operator should be doing. When asked if there was any data on the number of accidents prevented by an alerter, Oman noted the challenge of not knowing the prevalence of drowsiness. The scientific community notes that napping, fatigue education, and improved scheduling can help. He identified a 2006 study where drivers were asked for opinions on alerters. Results showed that some respondents hated them, while others felt they helped to cut unintentional naps short. While the benefits of alerters remain uncertain, anecdotally, alerters probably have forestalled some accidents.

One participant asked if eye tracking systems work. Oman said that in his experience they work well in controlled laboratory settings, but two students had trouble calibrating and operating a device in a simulator, suggesting it could be more of a challenge in the field. According to Oman, evaluation of this technology cannot be done only in a lab such as the Cab Technology Integration Laboratory; rather, the technology could be bench tested to replicate the physical environment. Ideally though, to really test the concept, researchers would need to have a person experience a drowsiness event. A participant suggested that infrared cameras have evolved and are working a lot better without a complex set up. Although Oman did not dispute this point, he did mention that some people naturally have drooping eyelids or wear contact lenses. Furthermore, he noted that automobile manufactures have conducted large-scale testing but unfortunately, the resulting data are proprietary.

Toward the end of the discussion it was noted that if the technology is just being used as an alerter, the worst outcome is that it just buzzes the operator. However, the challenge remains in gaining user acceptance. It is unclear the extent to which implementation would be affected by existing labor agreements. Devices that capture and save images may raise privacy concerns.

Oman's PowerPoint presentations can be found in Appendix C.

Feasibility of Head-Up Displays in Driving Labs

ANN MILLS
RSSB, United Kingdom

Ann Mills' remarks began with her describing how surveying the track ahead is a critical component of the train-driving task. However, all in-cab instruments require the driver to look away from the track, and in-cab signaling systems such as ERTMS may increase the time that drivers spend with heads down. Head-up displays (HUDs) have a proven track record in the aviation and automobile sectors, allowing pilots and drivers to access information without diverting attention from the outside world. Similar benefits may be realized by the installation of HUDs in train cabs. In addition HUDs are one option for upgrading existing train cabs (for instance to meet requirements for ERTMS) without a major redesign.

Mills described the potential benefit of HUDs, which was determined by reviewing the lessons learned from the aviation and automobile domains: how HUDs are used in these industries, and what are their proven benefits and costs? The cost–benefit analysis was combined with a thorough review of the technical and human factors implications associated with the installation and operation of HUDs in train cabs.

In addition to this desk top review, Mills' presentation described a small study involving a HUD being fitted to a high-fidelity, full-task train simulator (Figures 1 and 2), which allowed the potential benefits of these systems for drivers to be assessed. According to Mills, examining the potential benefits was the most important part of the study, as it gave direct feedback about how HUDs would benefit drivers in the driving task.

Sixteen professional drivers from four U.K. train operating companies participated in the simulator trials. Data were collected on the potential value of presenting speed, brake, and automatic warning system (AWS) information in the driver's normal line of sight. Viewing these symbols via a HUD can remove almost all need for a driver to look away from the track ahead. In addition, for more advanced HUD applications, symbols were assessed which prompted the driver as to the locations of signals on the current running line.

FIGURE 1 HUD fitted to a full-task train simulator.

FIGURE 2 Driver's view through HUD.

Drivers participating in the trials provided feedback on the potential value of the HUD for each task demonstrated. In addition, data were collected for driver workload and adherence to the line speed limit.

Mills believes this feasibility study showed there is potential value in fitting HUDs to rail vehicles. Drivers participating in the simulator study subjectively reported benefits associated with presentation of speed and AWS information in the line of sight. In addition, drivers were positive about the potential for cueing the position of signals, a measure judged to be of assistance in reducing the probability of "signal past at danger." Finally, the study also demonstrated that use of a HUD led to a significant reduction in driver workload.

Based on analysis of historical accidents and incidents, the study also judged that a suitably equipped HUD might help prevent up to 10% of incidents and 3% of accidents with an estimated total potential annual saving of £2 million.

The implications for performance were not precisely defined by the study. A significant drop in driver workload was revealed, however no noticeable effect on driver performance was evident. According to Mills, the drop in driver workload not being accompanied with an effect on driver performance was a paradox and further investigation of this observation would be helpful.

In terms of the feasibility of installing HUDs into rail cabs, HUD technologies are relatively mature and varied in Mills' opinion. With over 40 years' service in aviation, a range of HUD systems are available so a sufficient variety likely exists to be adaptable to most rail applications. Some usability issues associated with HUDs may offer reasons for concern, including possible limited range in viewing position for certain HUD technologies and the durability of sensitive optical systems in the driving cab. A range of other issues that were assessed to be of minor consequence included data availability, display legibility, and power and weight considerations.

At the same time, the initial cost benefit analysis suggested that some deployments of HUDs in the rail industry could be financially attractive and merited further consideration.

A link to the full report can be found at http://www.rssb.co.uk/Pages/research-catalogue/PB009650.aspx.

DISCUSSION

A number of questions were brought up after Mills's presentation. An attendee asked if the image box depicting the location of an upcoming signal is an approximation or the actual location of the signal as it comes to view. Mills clarified that it is the actual location of the signal and noted that it would be linked to location-based GPS. A participant thought a potential benefit would seem to be looking out for hazards, and asked if the simulation test evaluated that. Mills explained that the simulator test was merely a feasibility study yet what the participant suggested would be a useful research topic. In addition it was noted the display contained several gauges, prompting another participant to ask if there was an effort to declutter the elements as has been done in aviation. Mills explained the display area is a relatively simple environment consisting of elements such as speed and upcoming signal aspects. The starting point will be ERTMS where there eventually will be no wayside signals or sign posts. Conformal symbols may be great but this was just a simple test of whether this might work or not.

The question was raised that, given the possibilities of HUD to display a lot of data , might one be able to put enough information about the route into the system that there would be an opportunity to reduce or eliminate the amount of time needed to qualify for a particular run. Mills noted this concept encroaches on regulatory issues and did not wish to comment. She did say that based on review of accidents one can identify where people may have lacked route familiarity. If this concept is used, it would not be necessary to know all of the route characteristics at a train's exact location because ERTMS is providing continuous information, therefore a need for less qualification can be expected, and drivers don't need a detailed knowledge of physical characteristics.

In closing, a participant wondered if the study asked drivers what they wanted to see displayed. Mills reiterated it was a feasibility study driven by a review of accidents and that there were no comments about important data being absent from the pilot test. In the future, tasks may include a driver survey.

Mills' PowerPoint presentations can be found in Appendix C.

Energy Management Human–Machine Interface
Evolution of Operator Display

HELEN GITMEZ
GE

AARON RATLEDGE
BNSF Railway

DISCUSSION

Helen Gitmez and Aaron Ratledge explained that the changes in screen design reflected input from BNSF's and others. A participant asked about the reaction of crews when transitioning Cab Committee from trip advisor to trip optimizer. Gitmez and Ratledge replied that the earlier advisement mode did not seem to be well accepted but crews liked trip optimizer, and preferred spending less time looking at the screen. Furthermore, iterative changes had been made to the interface. Another participant then asked why the system was not first introduced to testers before going live. Gitmez and Ratledge explained there were varied requirements from different customers. For example, one customer only wanted auto-dynamic break (DB) up to notch 8. In addition, the manufacturer learned as they introduced new features. It was noted that in the United Kingdom the industry tends to be given products as opposed to the United States where purchasers seem to drive the design decisions.

One participant raised the question of how the design process worked through failure modes. Gitmez explained there was a lot of discussion with customers to develop the failure modes early in the design cycle and a lot of failure simulation was conducted prior to field testing. Moreover, the system informs the operator of a failure during operation and reverts to manual mode. Another participant asked if there is any distinction between issues requiring immediate attention versus an advisory message. Ratledge replied that there are audible tones and flashing text appears on a screen. A participant who works for a carrier noted that his company's system provides 15 s of notice for a pending brake application.

A different participant asked if warnings are provided on the earlier auto-throttle systems. A participant who works for a carrier said that his company's system provides a 5-mi look ahead. In addition, in some areas such as Form B maintenance locations, the auto-throttle is not used and the locomotive engineer is advised they will need to take control.

A participant noted that a recommended speed will likely be a given in the upcoming ETMS and asked if there are differences in ETMS and the power management systems that will need to be reconciled. A participant who works for a carrier added that this integration has already been developed by an industry committee. Another participant cited the importance of trusting a system and asked how to protect against overreliance. Gitmez and Ratledge replied that operator feedback was key during the development. It is human nature to want to get over the road quickly and the ability to demonstrate fuel savings is important. Another important component is feedback to the operator that the system is functioning as intended such as pushing a button and seeing that the system is responding reliably.

One participant noted that energy management is trading time to save fuel. Traditionally crews followed required speeds and worked to arrive safely. In the earlier advisory system crews were prompted to reduce power too soon, affecting the credibility of the system. With this in mind, the question about controlling slack was raised. Gitmez and Ratledge said that a lot was learned during the earlier advisor mode deployment and it was checked during engineering runs. A participant said he believed the largest challenge seems to be to get people to reduce throttle position when climbing hills; it seems counterintuitive and contrary to earlier fuel savings practices. There are many different types of trains such as intermodal, automotive, manifest, and unit trains and each has different fuel consumption characteristics. In the lobby of UP's headquarters building where the conference was held there was a display of all trains currently active on the UP system. The display showed 270 or more trains and they all behave differently. The participant stated that an engineer might use the first few brake applications during his portion of a train's route to gauge how the train will behave, to "get a feel" for how the train handles. This participant then expressed concern about a computer handling the complex challenge of braking different trains. Gitmez and Ratledge explained that the system learns the behavior of each train but only advises the engineer who controls the train, deciding how much braking to apply for example. Gitmez and Ratledge mentioned a long downgrade on their system that requires dynamic and automatic brakes. With the auto-brake system interface the system will determine if the train is braking too hard and will choose an earlier release. These same principles apply to positive train control.

At the end of the discussion, a participant asked if there have been any rules violations incidents or resulting de-certifications associated with the system. A fellow participant responded that the system has worked well.

In addition, another participant asked how railroads would use these systems when training new crews. Would new crews be expected to use it all the time or not at all? In addition, a participant asked if fuel management practices increase workload as the crew is tasked to do things they did not do before. This participant also asked what the biggest obstacle to true cruise control is (which could reduce workload.) Gitmez and Ratledge said that much more will be learned about air brake response when the newer systems are rolled out. Several years were needed to manage dynamic brakes and, of course, air brakes are more complex. Energy management system designers need to master reliable and trustworthy air brakes before looking to the next phase.

Gitmez and Ratledge's PowerPoint presentation can be found in Appendix C.

Designing Future Systems with the End User in Mind
The European Perspective

ANITA SCOTT
RSSB, United Kingdom

PRESENTATION SCOPE

Anita Scott began her presentation by discussing the design of future systems with the end user in mind, as seen by the European perspective. Specifically, Scott's presentation covered the factors that must be considered in order to successfully introduce new systems onto existing railways, including:

- Operability of equipment. How easy or difficult is the equipment to use?
- Physical design of equipment. Does the equipment meet the capabilities of the user?
- Functional safety and system security. Does the system safeguard against human error?
- Staffing and training development. Does the system introduce the need for new knowledge and skills?
- Procedures and staff organization. Does the new system change methods of work?
- Integrating human factors into system development.

Scott used the case study of the introduction of ERTMS to the Great Britain railways to explore the application of these factors. ERTMS is an automatic train protection system.

SUGGESTED RESEARCH AND IMPLEMENTATION ISSUES

Scott discussed how the implementation of ERTMS is prompting emerging areas of research including:

- How to successfully integrate the indications and controls of legacy train systems with the new system, without overburdening the engineer. This research is important because trains will be required to operate over both legacy and newly fitted infrastructure.
- Understanding the risks associated with data entry mistakes at the start of a train journey and the management of ERTMS data more broadly.
- Understanding the impact of ERTMS on the knowledge and skill requirements of the engineer, signaller, and maintainer.
- How to manage the transition from an imperially measured railway to a metric railway because ERTMS is a metric system.

TAKEAWAY MESSAGE

Scott summarized her presentation with the takeaway message that the customers for new systems are actually the end users (e.g., engineers, signallers, maintainers, station staff).

DISCUSSION

The discussion began with a participant asking about implementing four different technologies made by four different manufacturers. Scott responded that such implementation is being done in Spain, while in the United Kingsom there are only two. The challenge is that ERTMS is an EU-wide approach but all railroads have slight differences due to their legacy systems, though, in many cases the technology is being installed on completely new lines.

Scott was also asked if, with the 20-year implementation plan, systems installed toward the end of the 20 years might be much different than the ones being installed today. She responded that new versions will include backward compatibility, even though such compatibility can sometimes be difficult to achieve. The goal is to allow trains to run throughout the EU using the ERTMS system.

In response to a question about the Channel Tunnel operation, Scott explained that the Channel Tunnel system is a unique installation but that it is also geographically isolated from other systems in the United Kingdom and France. Freight accessing the Channel Tunnel will be transloaded at either end which will avoid interoperability issues. When ERTMS is more widespread integration into all operations will be easier.

The final participant question was about the amount of initial data needing to be entered by the driver. Scott replied that for passenger trains, the task would be relatively simple; the operator would work from a discrete list of train types that could be accessed by the driver. For freight, some more flexibility will be needed.

Scott’s PowerPoint presentations can be found in Appendix C.

Active Noise Cancellation

ANAND PRABHAKARAN
Sharma & Associates, Inc.

PRESENTATION SCOPE

Anand Prabhakaran's began his presentation by citing U.S. DOT's *Human Factors Guidelines for Locomotive Cabs* published in 1998, which alluded to the potential safety benefits of the implementation of active noise cancellation (ANC) and active vibration control (AVC) techniques in the locomotive cab. Several techniques have been incorporated to mitigate cab noise and vibration, including the attempt of physical isolation of the cab from the under frame via rubber pads, for example. Unfortunately, the exposure to lower frequency engine noise and vibration has not significantly decreased as a result of these efforts.

Prabhakaran presented on a FRA-sponsored project studying the potential for ANC techniques to increase locomotive engineer hearing comfort. He explained that ANC systems work by actively measuring the noise in a locomotive and counteracting the measured noise by delivering the appropriate negative noise through optimized speakers. The systems are adaptive and are designed to vary the counteracting noise based on the input noise level, and are better focused to address low-frequency tonal noise issues that are not fully addressed by passive methods.

Two implementations of a prototype ANC system, one on an EMD locomotive and one on a GE locomotive were evaluated in the study. The installation on the EMD unit was evaluated under test track conditions, and the installation on the GE unit was evaluated under revenue service conditions. In each case, the ANC system measured cab noise using microphones, processed the noise data using an onboard controller, and delivered the counteracting noise using strategically mounted speakers. In each installation, system performance was evaluated by measuring noise levels with the ANC system on and off. In addition, during the revenue service tests, locomotive engineers reviewed and assessed ANC system performance, albeit, subjectively. Prabhakaran indicated his presentation describes the underlying methodologies and techniques, the implementation, and the results.

SUGGESTED RESEARCH, DEMONSTRATION, AND IMPLEMENTATION ISSUES

The evaluation of the ANC system showed that operation of the system resulted in measureable reductions in interior cab noise, which could translate to both safety and comfort benefits for operating train crews, including potential reductions in hearing loss and fatigue. The evaluation also demonstrated the system was particularly effective when implemented on noisier locomotives.

Prabhakaran's research suggestions are longer-term field testing, potential system performance optimization, and effective quantification of long-term benefits.

TAKEAWAY MESSAGE

Due consideration to crew comfort in locomotive cabs, particularly in the noise, vibration, and harshness domains, is important during the design, procurement, and operating phases in a locomotive's life cycle. The resulting crew comfort level can have significant safety and operational benefits, including potential reductions in hearing loss and fatigue.

REFERENCES

1. Multer, J., et. al. Human Factors Guidelines for Locomotive Cabs. Report DOT/FRA/ORD-98/03. U.S. Department of Transportation, 1998.
2. Code of Federal Regulations, Title 49, Part 229, Section 121, Locomotive Cab Noise.

DISCUSSION

The discussion began with a participant asking about the frequency range of the system. Prabhakaran indicated it is most effective at 250 Hz and below. Another participant noted the system might be most accurate at the microphone, which is located above the side window. Prabhakaran stated they had placed test microphones by the engineers' ears when evaluating the system.

Participants were interested to know if feedback was received from the engineers. Prabhakaran noted the system was operated in revenue service for 90 days. In the surveys, 63% of respondents thought the system made a difference; the remainder of the respondents saw no difference and no one complained about crew communication.

Prabhakaran's PowerPoint presentation can be found in Appendix C.

PANEL DISCUSSION

What Will the Future Look Like?

At the end of the meeting, a panel, comprised of the presenters still present, responded to additional participants' questions and discussed next steps. To begin, one of the panel members raised the issue of standardization and suggested that AAR form a committee. An AAR member responded that a committee is already underway and includes members from the FRA, various railroad carriers, the Volpe Center, and labor representatives.

A panel member noted that various human factors and social dimensions were discussed and asked if there is an industrial relations dimension as well. This panel member explained that crews are paid by the mile or by trip rate and there is an incentive to get over the road promptly, because crews are not paid by time on duty. As a result, people exhibit rational behavior in wanting to get over the road as quickly as they can. This comment led the discussion to the topic of fuel savings.

Another panel member noted that carriers are investing in energy management systems because they can result in significant fuel savings. Data demonstrated the overall trip times are longer with fuel management, even with all the meets and passes on a typical run. Fuel savings is a topic that is communicated through training and is a frequent discussion point during check rides. It was brought up that certain carriers have various incentive programs or competitions to save fuel. Crews are typically rewarded, often with gift cards, for operating efficiently. When energy management becomes more widespread, it may be possible to link individual performance to signal indication or look at what percentage of the time people are using the optimizer.

During the discussion, a participant asked about the extent to which an energy management system can provide feedback to operators so the operators can learn to operate more efficiently even on equipment without energy management. A panel member noted there have been performance improvements even for people who have more than 20 years of experience. The system showed experienced crews that they can improve their efficiency and still manage in-train forces. For example, a railroad engineer might habitually have handled a train a certain way at a location and find that the system shows them a method of handling the train better. An engineer who sometimes operates trains with a fuel management system noted that even when handling an unequipped locomotive, he is able to do a better job than before.

A participant later asked about whether the fuel management system provides information about in-train forces. A panel member responded that one supplier's system displays a force estimator while another performs the calculations, but does not display the results to the operator. Another participant commented that the system is only as good as the underlying simulations which typically are not detailed on end-of-car cushioning devices. A panel member agreed that lack of detail in simulation inputs can be an issue but that a supplier has partnered with a simulation company to address these issues. Another panel member added that the addition of physics-based modeling seems to have successfully dealt with train handling challenges.

Toward the end of the discussion, a participant mentioned that crews do not need the button in exactly the same place on every engine. This participant used an example from his home state, in which a driver's license entitles the driver to operate a variety of motor vehicles and assumes they can handle different controls in different cars. He commented that interoperability is helpful and a crewman with a question can always contact a supervisor. A panel member agreed, mentioning that when a locomotive engineer gets in a different cab, he needs a few minutes to familiarize himself with the controls, just like in a rental car. The panel member went on to suggest that future cab designs should consider seat comfort, noise reduction, and good visibility.

The discussion ended with a panel member noting that there are important steps in designing a cab, but that designers already have a design to work with and only a few months to complete drawings with various modifications. Not unlike other engineering challenges, a locomotive manufacturer functions as a system integrator by making sure all of the components together comprise a safe and efficient operating system.

APPENDIX A

Conference Agenda

TUESDAY, JULY 30, 2013

9:00–9:15 a.m.
Welcome–Safety Briefing
Bob Grimalia, *Union Pacific Railroad*

9:15–9:25 a.m
Opening Remarks
Stephen Popkin, *Chair of AH-1 and AR070, Volpe Center*

9:25–10:00 a.m.
Human System Integration
Nancy Cooke, *Arizona State University, Chair of National Academies HSI Committee*

10:00–10:15 a.m
Refreshments

10:15 a.m.–12:00 p.m.
Panel Discussion: How Do We Manage What We Have Today?
Moderator: Jordan Multer, *Volpe Center*

The History of the Locomotive Cab and Control Stand
David Mangold, *University of Akron*

North American Freight Locomotive Cab Development
Harvey Boyd, *Electro-Motive Division*

GE Perspective
Stephen Gerbracht, *General Electric*

12:00–1:00 p.m.
Lunch

1:00–2:30 p.m.
Panel Discussion: How Do We Manage What We Have Today? (continued)
Moderator: Charles Oman, *Massachusetts Institute of Technology*

The Operators Perspective
Fred Garnst

Accident Caused by Human Error: But Which Humans?
Paul Picciano, *Aptima, Inc. (via web)*

Evaluation of Cab Controls
Vic Riley, *Boeing Commercial Airplanes*

2:30–2:45 p.m.
Refreshments

2:45–4:15p.m.
Panel Discussion: Positive Train Control
Moderator: Jeff Moller, *AAR*

Workload and Automation
Vic Riley, *Boeing Commercial Airplanes*

Distributed Power, ETMS, and Energy Management Usage on BNSF
Aaron Ratledge, *BNSF Railway*

4:15–5:15 p.m.
Panel Discussion; The Future of Cab Displays
Moderator: Jim Grady, *AAR*

Development and Evaluation of Locomotive Moving Map and Planning Displays
Kathleen Voelbel, Andrew Liu, and Charles Oman, *MIT*

WEDNESDAY, JULY 31, 2013

8:30– 8:40 a.m.
Welcome
Union Pacific Railroad

8:40–10:00 a.m.
Panel Discussion; The Future of Cab Displays (continued)
Moderator: Jim Grady, *AAR*

HUDS (RSSB's research)
Ann Mills, *RSSB, United Kingdom*

Energy Management HMI–Evolution of Operator Display
Helen Gitmez, *GE*, and Aaron Ratledge, *BNSF Railway*

10:00–10:15 a.m.
Refreshments

10:15–10:45 a.m.
Designing Future Systems with the End User in Mind: The European Perspective
Anita Scott, *RSSB, United Kingdom*

10:45–11:15 a.m.
Active Noise Cancellation
Anand Prabhakaran, *Sharma & Associates*

11:15 a.m.–12:00 p.m.
Panel Discussion: What Will the Future Look Like?
Moderator: Lawrence Fleischer, *BNSF Railway*
Discussion of next steps and concluding remarks.

APPENDIX B

Conference Participants

David Blackmore
Federal Railroad Administration
Washington, D.C.

Harvey Boyd
Electro-Motive Diesel
LaGranga, Illinois

Kathy Breindel
Cory's Thunder Inc.
Jacksonville, Florida

Mark Burris
Amtrak
Wilmington, Delaware

Lionel Cantu
Union Pacific Railroad
Crowley, Texas

Nancy Cooke
Arizona State University
Mesa, Arizona

Cecil Copeland
Union Pacific Railroad
Omaha, Nebraska

Doug Corbin
Norfolk Southern Corporation
Atlanta, Georgia

Randy Eardensohn
Union Pacific Railroad
Omaha, Nebraska

Lawrence Fleischer
BNSF Railway
Fort Worth, Texas

Frederick Gamst
University of Massachusetts, Boston
Los Osos, California

Jim Garret
United Transportation Union
Creston, Iowa

David Gengel
Norfolk Southern Corporation
Norfolk, Virginia

James Grady
Association of American Railroads
Washington, D.C.

Randall Hanks
Union Pacific Railroad
Omaha, Nebraska

Mark Hartong
Federal Railroad Administration
Washington, D.C.

Philip Hess
Norfolk Southern Corporation
Atlanta, Georgia

Michael Iden
Union Pacific Railroad
Melrose Park, Illinois

Eddie Jameson
Kansas City Southern Railway
Shreveport, Louisiana

Keith Jensen
Union Pacific Railroad
Taylorsville, Utah

Michael Jones
Federal Railroad Administration
Washington, D.C.

Jacqualyn Keenan
Union Pacific Railroad
Omaha, Nebraska

Vijay Kohli
Fulcrum Corporation
Arlington, Virginia

Phillip Langan
Electro-Motive Diesel
LaGrange, Illinois

David Mangold
DHM, University of Akron, NS Corp
Randolph, Ohio

Shannon Mason
Norfolk Southern
Atlanta, Georgia

Bianka Mejia
Volpe National Transportation
Systems Center
Cambridge, Massachusetts

Ann Mills
Rail Safety and Standards Board
London, United Kingdom

Jeff Moller
Association of American Railroads
Washington, D.C.

Jordan Multer
Volpe National Transportation
Systems Center
Cambridge, Massachusetts

Charles Oman
Massachusetts Institute of Technology
Cambridge, Massachusetts

George Page
Page Engineering, Inc.
Jackson, Michigan

Richard Pain
Transportation Research Board of the
National Academies of Sciences,
Engineering and Medicine (retired)
Washington, D.C.

Anthony Perl
Simon Fraser University
Vancouver, British Columbia, Canada

Stephen Popkin
Volpe National Transportation
Systems Center
Cambridge, Massachussetts

Aaron Ratledge
BNSF Railway
Ft. Worth, Texas

Don Robinson
Norfolk Southern Corporation
Atlanta, Georgia

Ranjot Sandhu
Canadian Pacific
Calgary, Alberta, Canada

Hadar (Rosenhand) Safar
Volpe National Transportation
Systems Center
Cambridge, Massachusetts

Scott Schafer
BNSF Railway
Overland Park, Kansas

Anita Scott
Rail Safety and Standards Board
London, United Kingdom

Matthew Sowers
CSX Transportation
Jacksonville, Florida

James Udvare
Union Pacific Railroad
Omaha, Nebraska

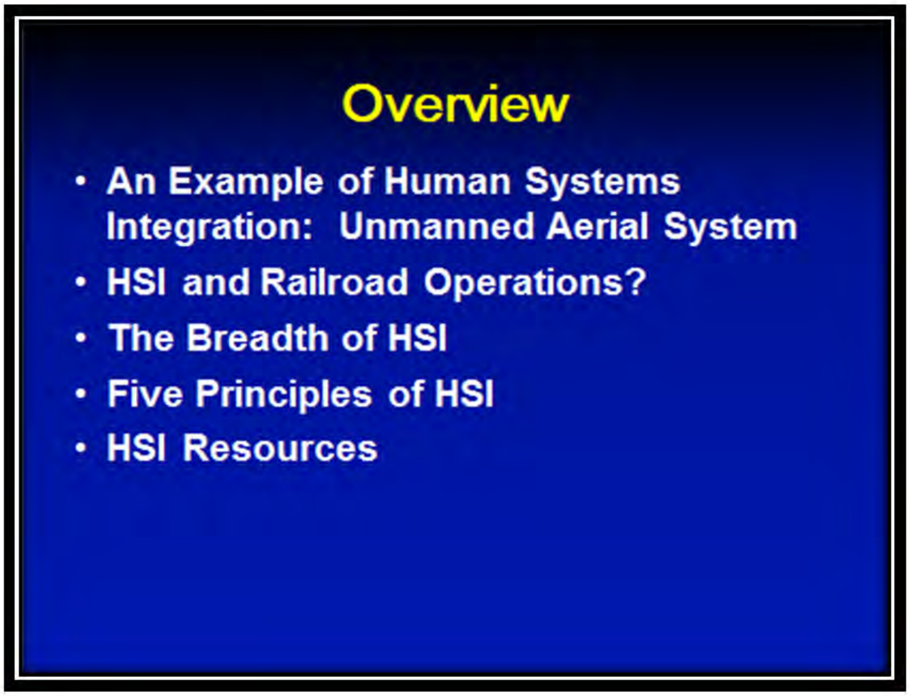
Vince Verna
Brotherhood of Locomotive
Engineers and Trainmen
Washington, D.C.

Kathleen Voelbel
Massachusetts Institute of Technology
Cambridge, Massachusetts

Tobin Zerfas
BNSF Railway
Overland Park, Kansas

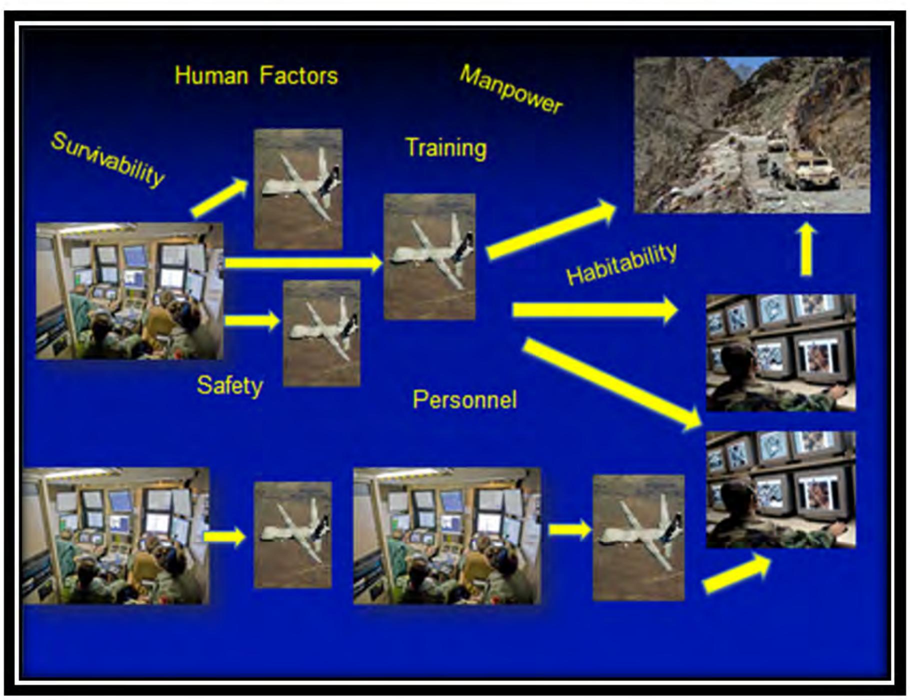
APPENDIX C

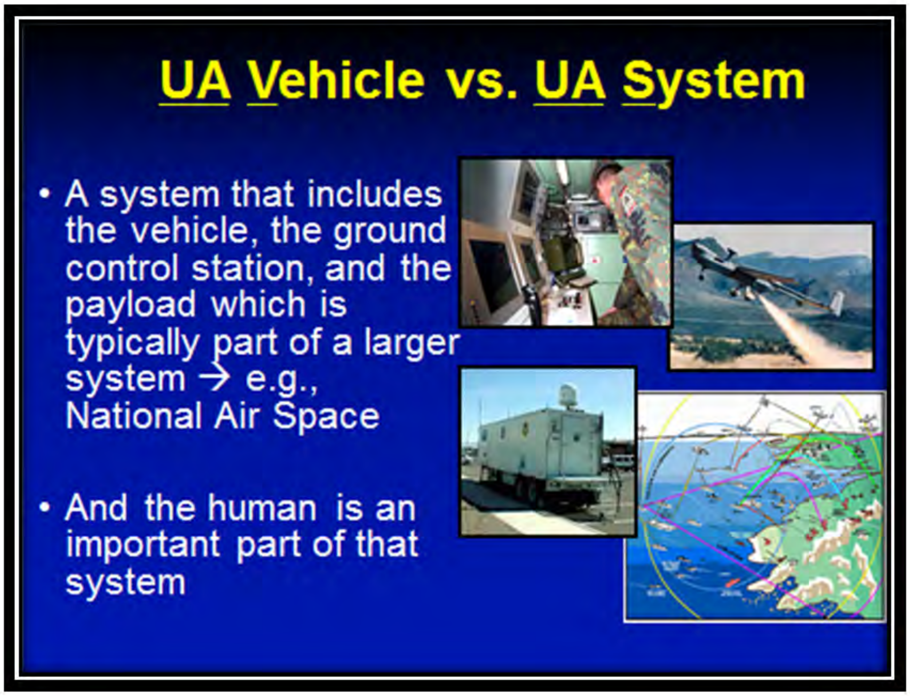
Guest Speaker PowerPoint Presentations

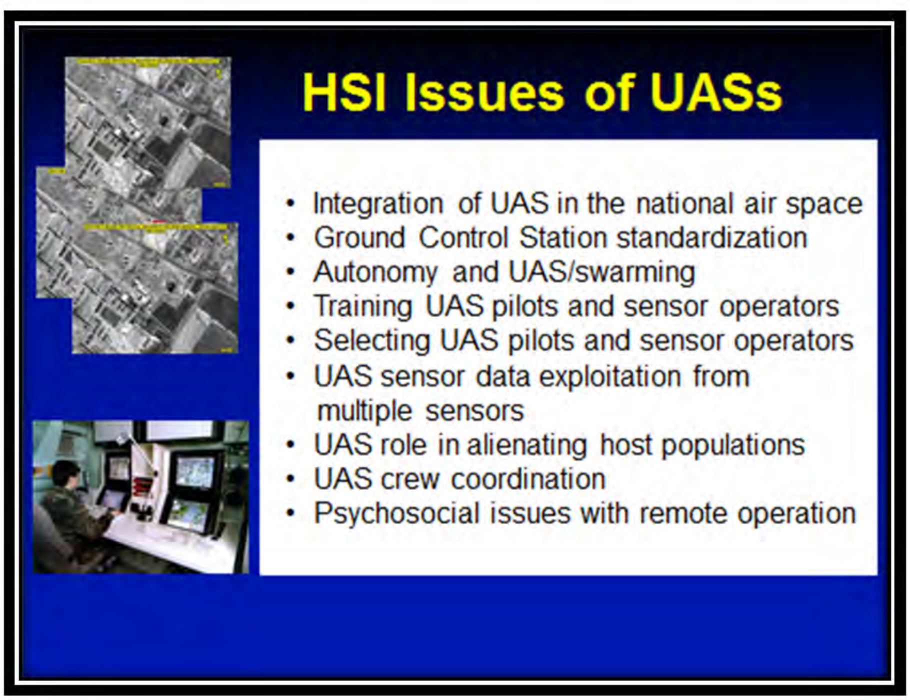

Overview
• An Example of Human Systems Integration: Unmanned Aerial System
• HSI and Railroad Operations?
• The Breadth of HSI
• Five Principles of HSI
• HSI Resources


Human Systems Integration
User-centered system engineering in which human capabilities and limitations are taken into account throughout the system life cycle to maximize system performance and safety

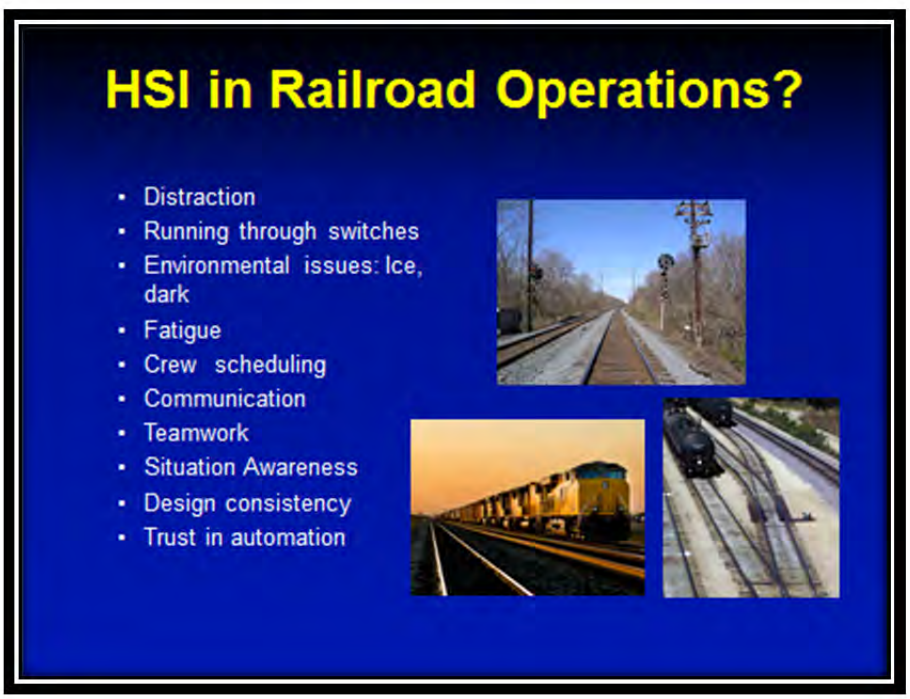

MQ-1/9 Operator Control Station

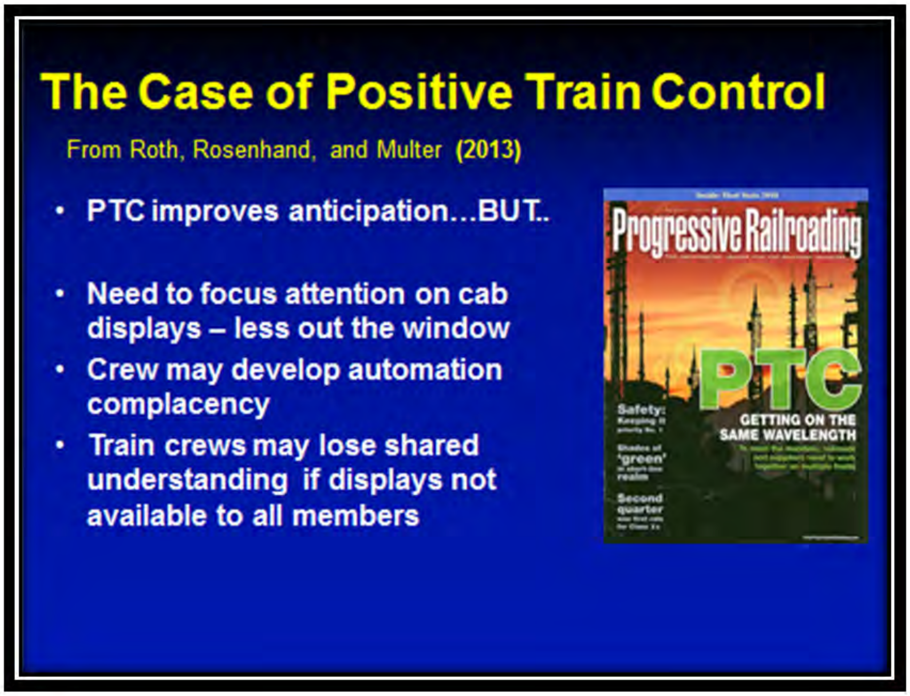

Human Factors
Manpower
Survivability
Training
Habitability
Safety
Personnel


UA Vehicle vs. UA System
• A system that includes the vehicle, the ground control station, and the payload which is typically part of a larger system → e.g., National Air Space
• And the human is an important part of that system


HSI Issues of UASs
• Integration of UAS in the national air space
• Ground Control Station standardization
• Autonomy and UAS/swarming
• Training UAS pilots and sensor operators
• Selecting UAS pilots and sensor operators
• UAS sensor data exploitation from multiple sensors
• UAS role in alienating host populations
• UAS crew coordination
• Psychosocial issues with remote operation

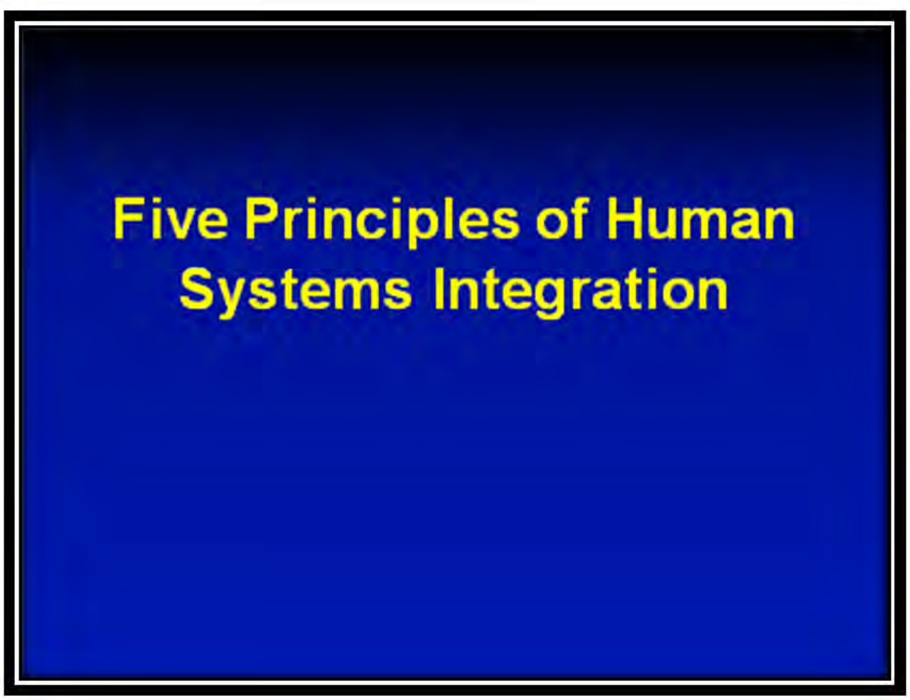

Without a focus on the larger system and interactions of system components you are open to:
Local Success, but Global Failure
UAS Examples:
• Multiple UAS Control
• Laptop UAS Interface

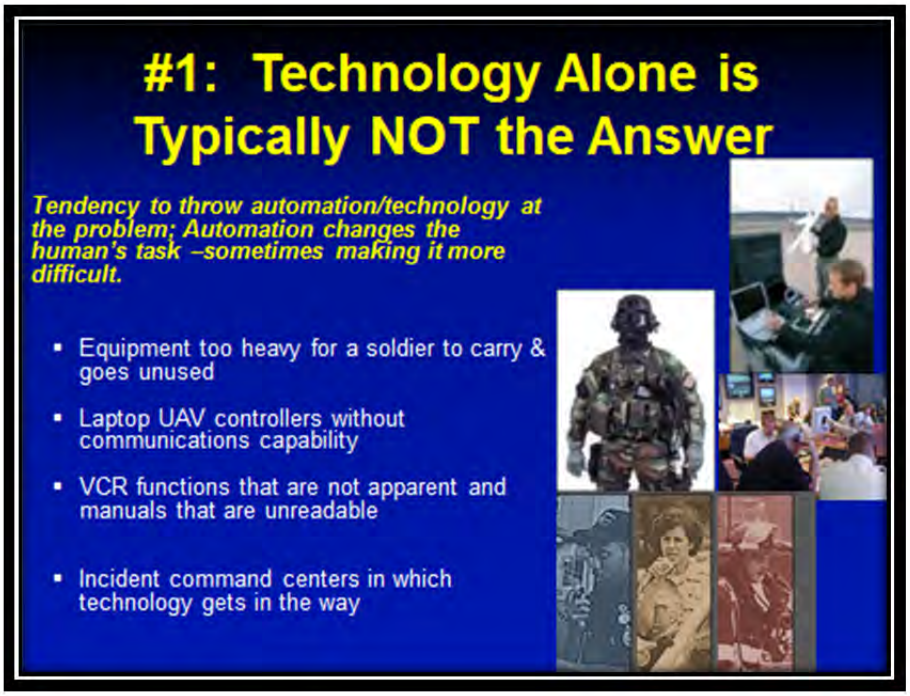

HSI in Railroad Operations?
• Distraction
• Running through switches
• Environmental issues: Ice, dark
• Fatigue
• Crew scheduling
• Communication
• Teamwork
• Situation Awareness
• Design consistency
• Trust in automation


The Case of Positive Train Control
From Roth, Rosenhand, and Multer (2013)
• PTC improves anticipation…BUT..
• Need to focus attention on cab displays – less out the window
• Crew may develop automation complacency
• Train crews may lose shared understanding if displays not available to all members
Progressive Railroading
PTC
GETTING ON THE SAME WAVELENGTH
Safety:
Second quarter

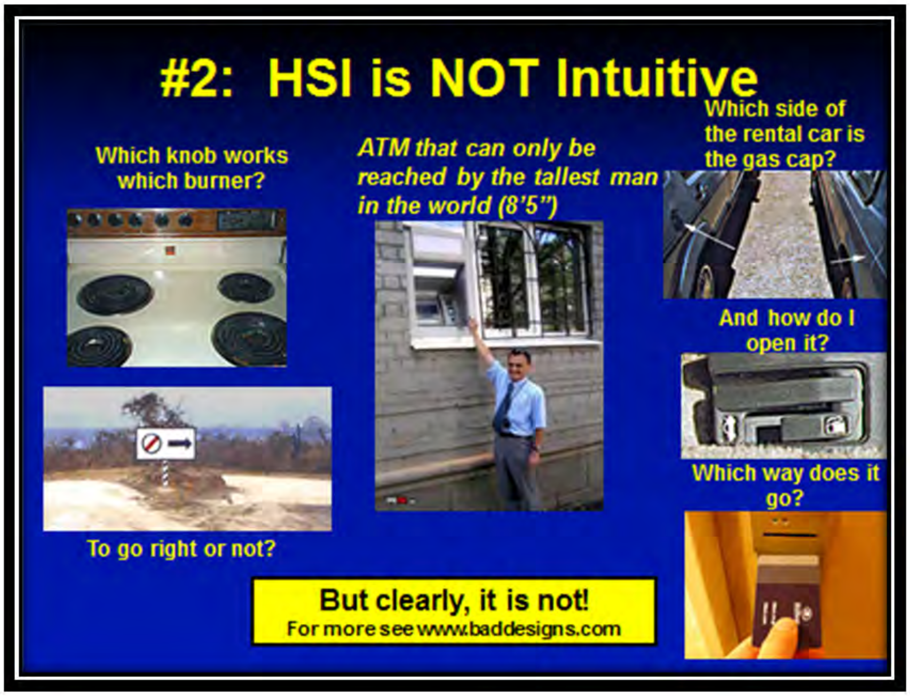

The Breadth of HSI
Beyond Chairs and Stove Tops
Comfort
ERGONOMICALLY CORRECT


The Breadth of HSI
...To Wherever Technology and Humans Meet
• Aviation
• Communications
• Computing
• Energy
• Highway Safety
• Medicine/Health
• Military Systems
• Homeland Security

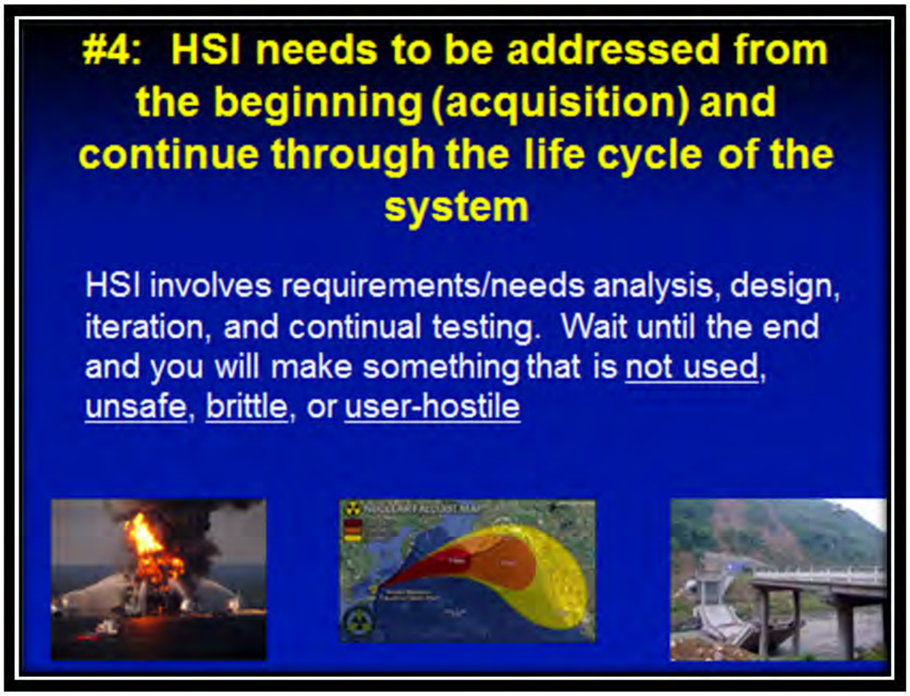

Five Principles of Human Systems Integration

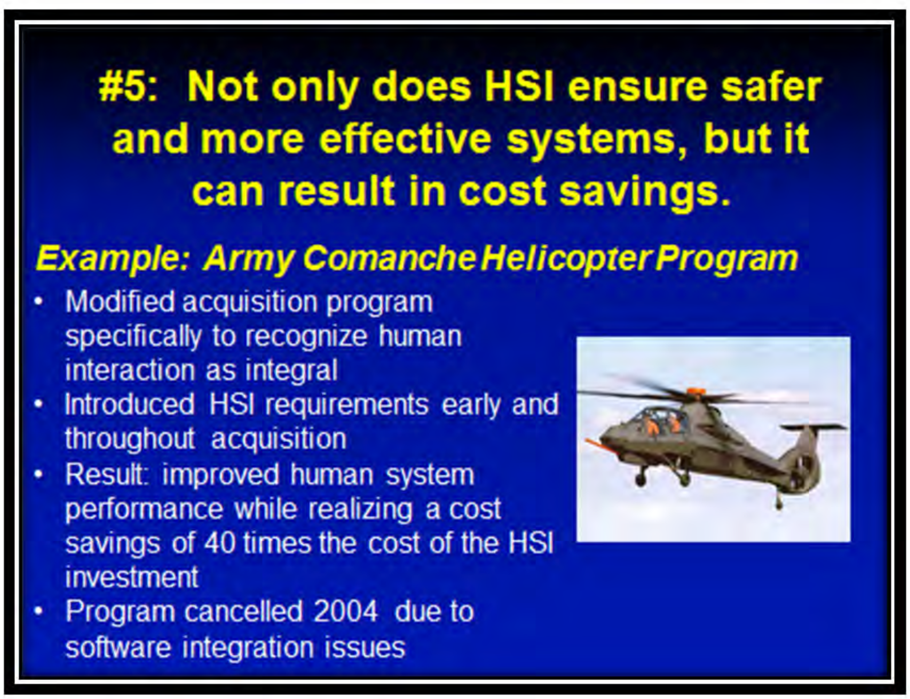

#1: Technology Alone is Typically NOT the Answer
Tendency to throw automation/technology at the problem; Automation changes the human's task –sometimes making it more difficult.
▪ Equipment too heavy for a soldier to carry & goes unused
▪ Laptop UAV controllers without communications capability
▪ VCR functions that are not apparent and manuals that are unreadable
▪ Incident command centers in which technology gets in the way


An Example: Airport Incident Command Technology that Gets in the Way


#2: HSI is NOT Intuitive
Which knob works which burner?
ATM that can only be reached by the tallest man in the world (8'5")
Which side of the rental car is the gas cap?
And how do I open it?
Which way does it go?
To go right or not?
But clearly, it is not!
For more see www.baddesigns.com

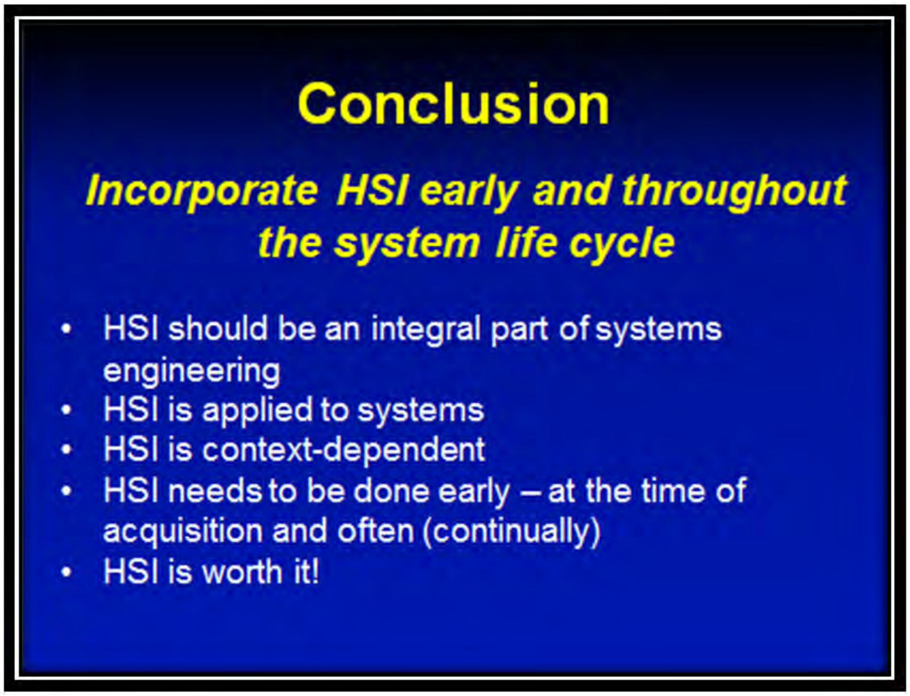

#3: HSI is highly context dependent.
It depends on:
• Task
• Technology
• Other people
• Culture
• Policy
• Environment
• Training
• THE TOTAL CONTEXT
The Task

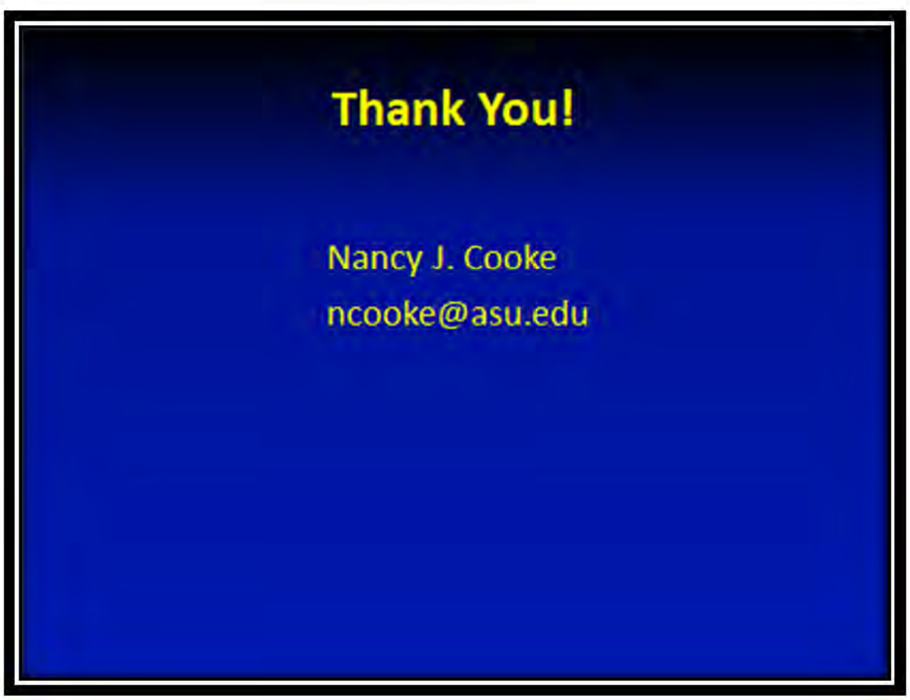

#4: HSI needs to be addressed from the beginning (acquisition) and continue through the life cycle of the system
HSI involves requirements/needs analysis, design, iteration, and continual testing. Wait until the end and you will make something that is not used, unsafe, brittle, or user-hostile


#5: Not only does HSI ensure safer and more effective systems, but it can result in cost savings.
Example: Army Comanche Helicopter Program
• Modified acquisition program specifically to recognize human interaction as integral
• Introduced HSI requirements early and throughout acquisition
• Result: improved human system performance while realizing a cost savings of 40 times the cost of the HSI investment
• Program cancelled 2004 due to software integration issues


HSI Resources
HSI Research Community
McDonald, J.D., Kazi, S., Darling, C.M., Durso, F.T., and Glover, K. (in press). A Human Factors Audit of a Locomotive Remote Control Device. *Ergonomics in Design*.
Roth, E., Rosenhand, H. & Multer, J. (2013). Using Cognitive Task Analysis to Inform Issues in Human Systems Integration in Railroad. Technical Report, US Department of Transportation, DOT/FRA/ORD-13/XX


HSI Resources
National Research Council's Board on Human Systems Integration
IMPROVING SELF-ESCAPE FROM UNDERGROUND COAL MINES
Human-System Integration in the System Development Process
A NEW LOOK
The Effects of Commuting on Pilot Fatigue
How can BOHSI help?


Conclusion
Incorporate HSI early and throughout the system life cycle
• HSI should be an integral part of systems engineering
• HSI is applied to systems
• HSI is context-dependent
• HSI needs to be done early – at the time of acquisition and often (continually)
• HSI is worth it!


Thank You!
Nancy J. Cooke
ncooke@asu.edu

TRB - Railroad Operational Safety Committee
Mid-Year Themed Meeting

10:15am-12:00 Panel Discussion;
How do we Manage What We Have Today?
Moderator: **Jordan Multer**, Volpe Center

The History of the Locomotive Cab and Control Stands **- David Mangold**, Univ. of Akron

EMD Perspective, Harvey Boyd, EMD
GE Perspective, Chris Geffros, GE

Locomotive Cab Timeline

Nineteenth Century

Early1800s	Development of primitive locomotives without cabs
1831-	First locomotive cabs added to early locomotives
- Mid 1800s	Delivery of British locomotives and construction of early US built steam locomotives without cabs.
	Advancement in steam locomotive technology
Mid 1800s -	Locomotive refinements including an enclosed wooden cab
Late 1840s -	First "Camelback" locomotives built with large cab and better visibility for the locomotive engineer
- Early 1850s -	Locomotive cabs become a standard part of the locomotive
1870s -	Throttle improvements including ratchet and latch
1880 – 1890s	Larger more powerful locomotives built
March 2, 1893	Safety Appliance Act enacted by congress, signed by President Benjamin Harrison – required air brake controls in cabs

Twentieth Century

1900s -	Larger and faster locomotives with metal cabs in use
Aug. 1, 1900	Extension of Safety Appliance Act compliance requirement
1925 -	Early (box cab) diesel locomotives in use
1930s -	Streamlined steam locomotives in use
1938 -	Diesel electric locomotives (GM EMC - F units) built
1949 -	Budd Company / EMC - RDC - Rail Diesel Cars (cab cars) and F units in use, in common use on US railroads
1950s -	Train-radio-telephone use begins (on Erie RR), use of alerter systems, first generation diesel road switchers built by EMD (GP 7 and GP 9s)
1967 -	United Aircraft Turbo Train – unique locomotive and cab design
1968 -	High speed cab car - *Metroliner* begins scheduled service on PRR
1976 -	EMD F40PH built and in use on Amtrak
1990s -	Development and use of third generation locomotives and onboard electronic systems
1997 -	Amtrak tests operation of *ICE* train set from Germany
1998 -	Amtrak tests operation of *X2000* from Sweden

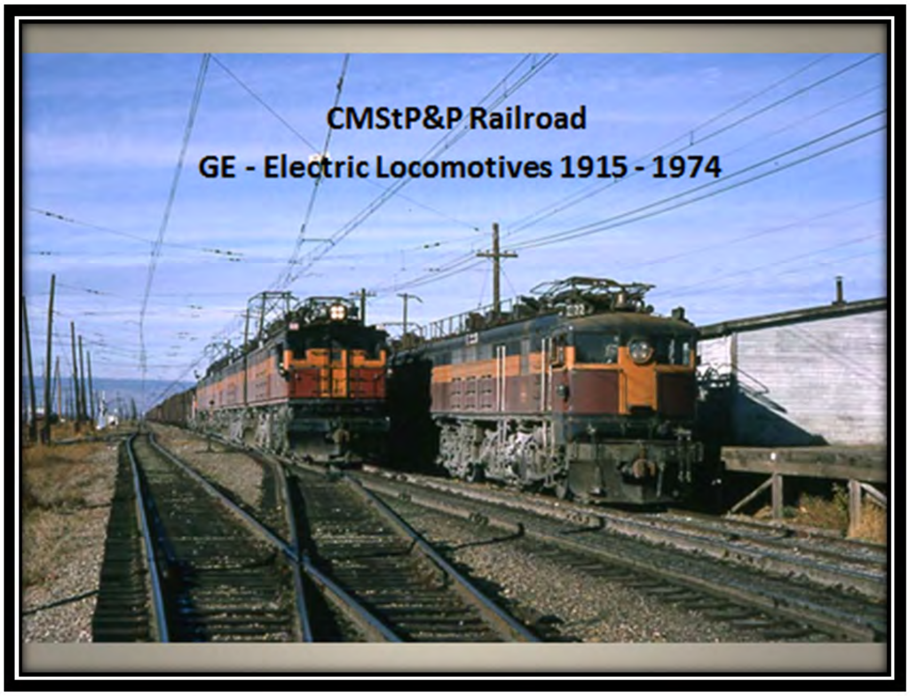
Twenty-first Century

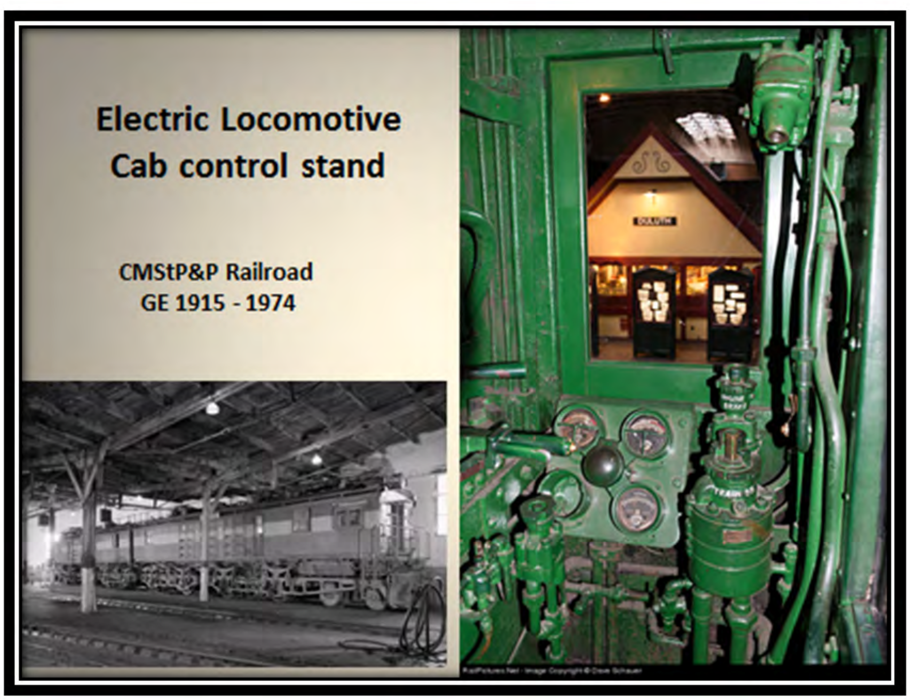
2000s -	Modern locomotives in use with improved control stand designs and energy management systems, ECP braking and DP controls

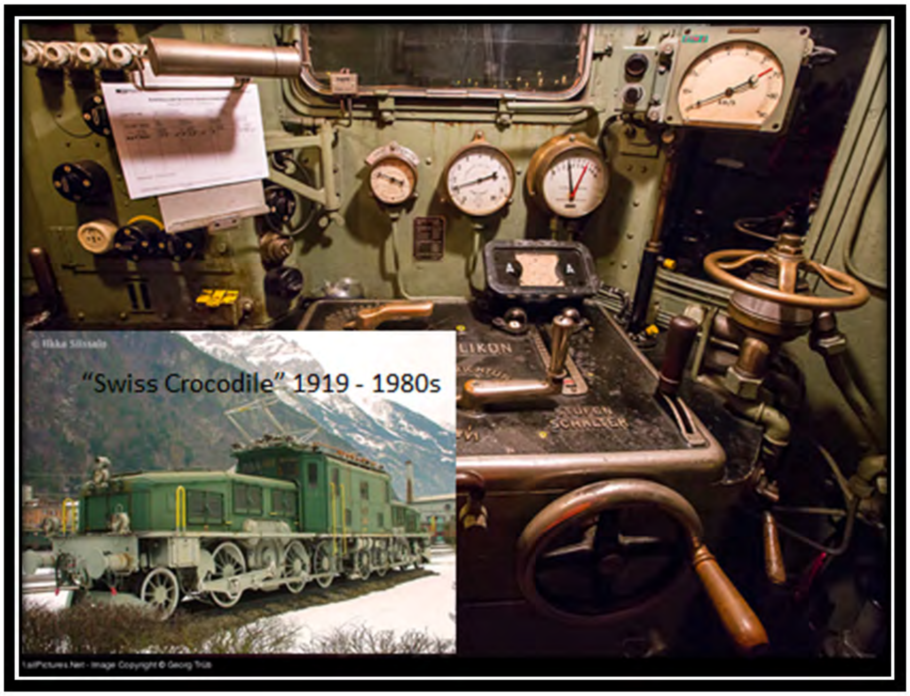
Steam Locomotive Cabs Considerable Evolution

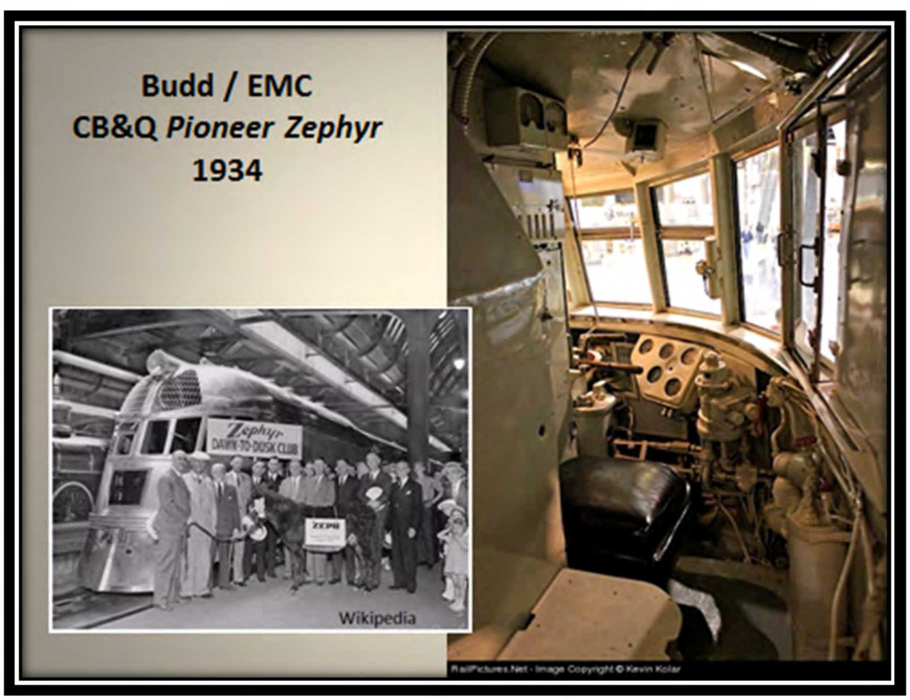
B&O – W. Norris & Co. - *Lafayette* horizontal boiler with no cab 1837 -

SP - Baldwin - Cab-forward design 1909 - 1940s

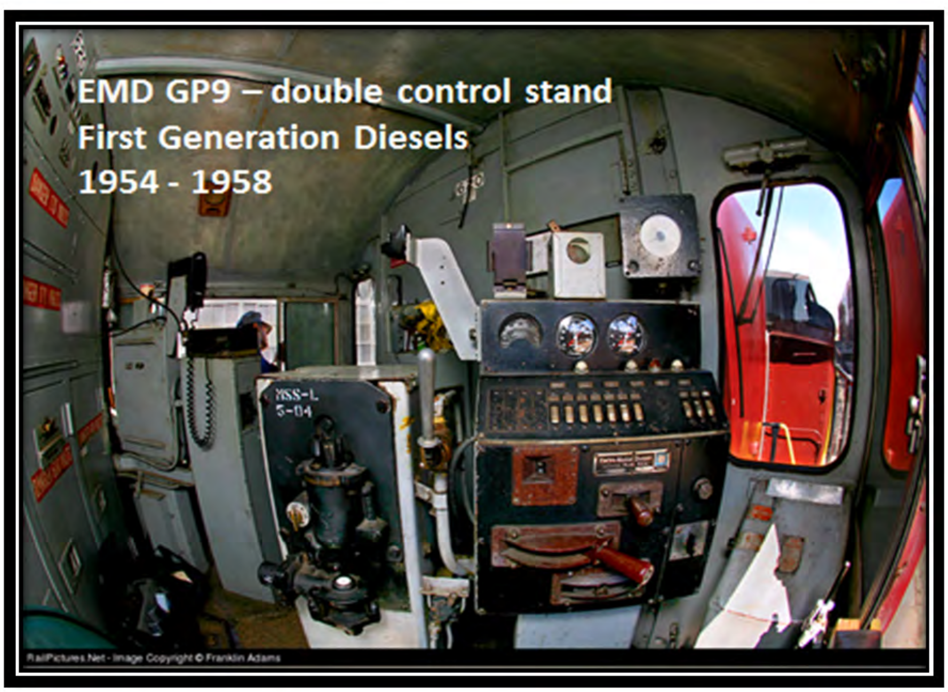

CMStP&P Railroad
GE - Electric Locomotives 1915 - 1974


Electric Locomotive
Cab control stand
CMStP&P Railroad
GE 1915 - 1974

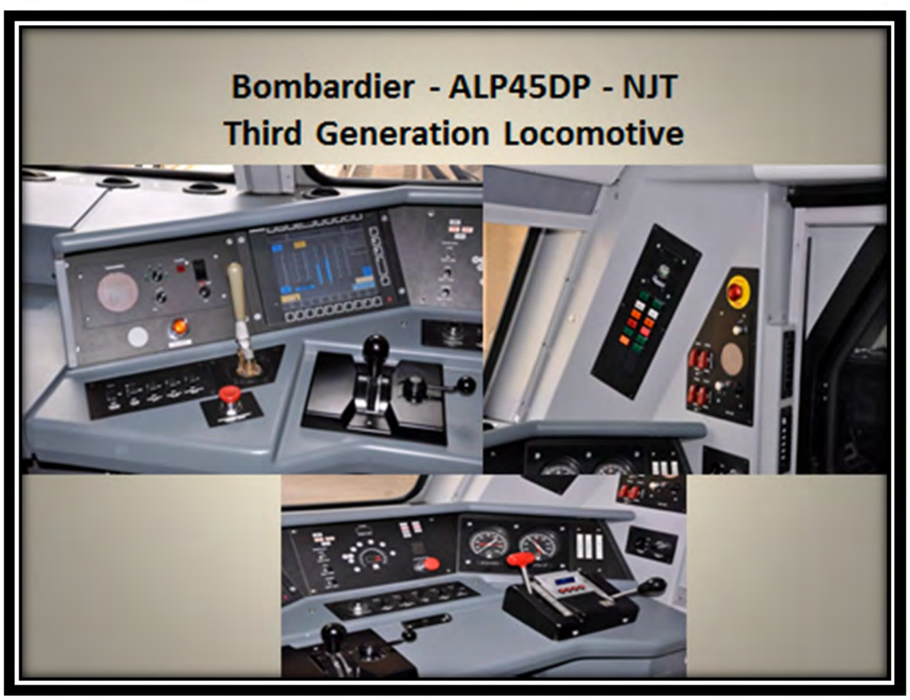

“Swiss Crocodile” 1919 - 1980s
RailPictures.Net - Image Copyright © Kevin Kolar


Budd / EMC
CB&Q *Pioneer Zephyr*
1934
Wikipedia
RailPictures.Net - Image Copyright © Kevin Kolar


EMD F7
1949 - 1953
913
WESTERN PACIFIC


EMD GP9 – double control stand
First Generation Diesels
1954 - 1958


EMD SD40-2 and GE BQ23-7
Second Generation diesel locomotives 1980s


Bombardier - ALP45DP - NJT
Third Generation Locomotive

Conclusion

Future improvements to cabs and control stand design can benefit by having an understanding of the past so that future cabs can even better support crew effectiveness and safety.

Thanks to the Following Photographers

WWW.Railpictures.Net and Classic Trains magazine

David Schauer
Georg Trüb
Kevin Kolar
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Curt Tillotson Jr.
David C. Warner

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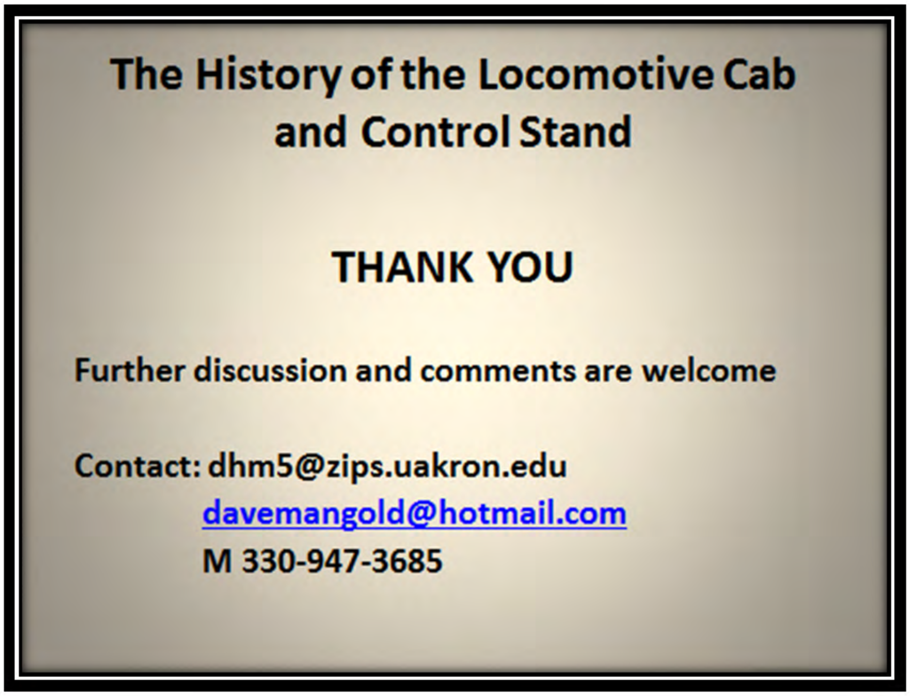
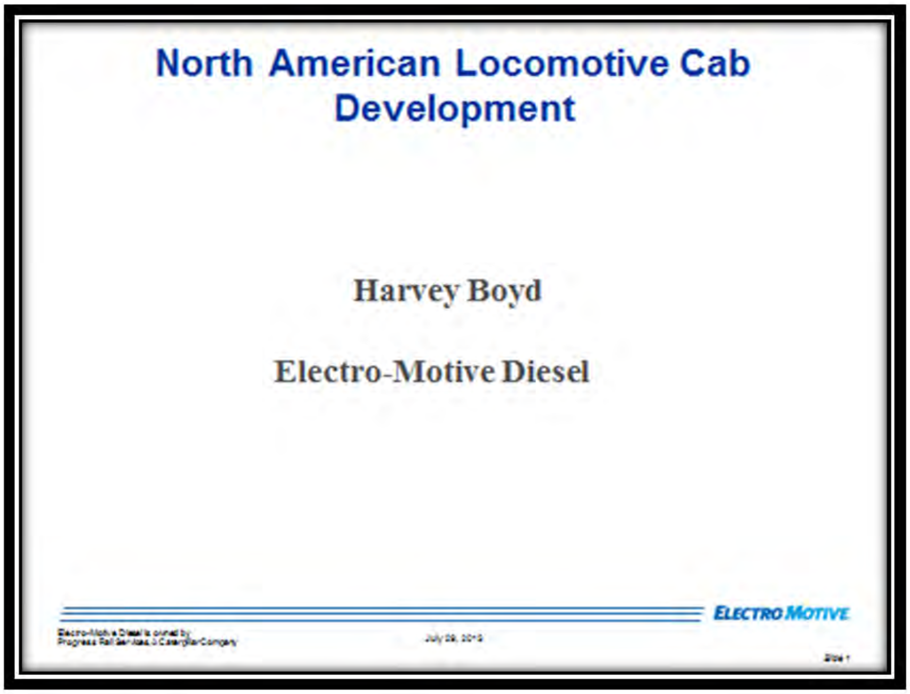
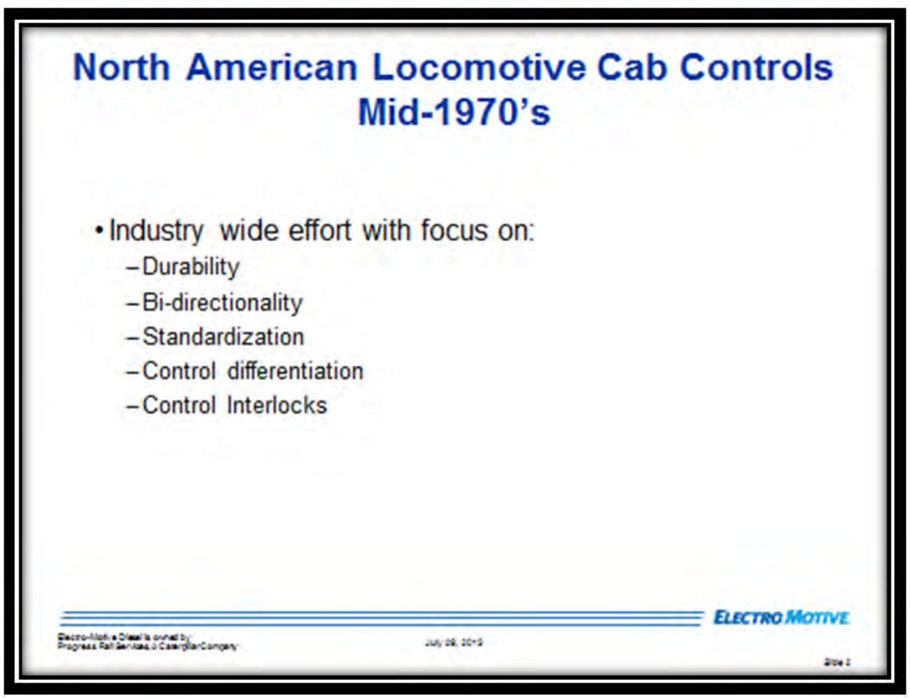
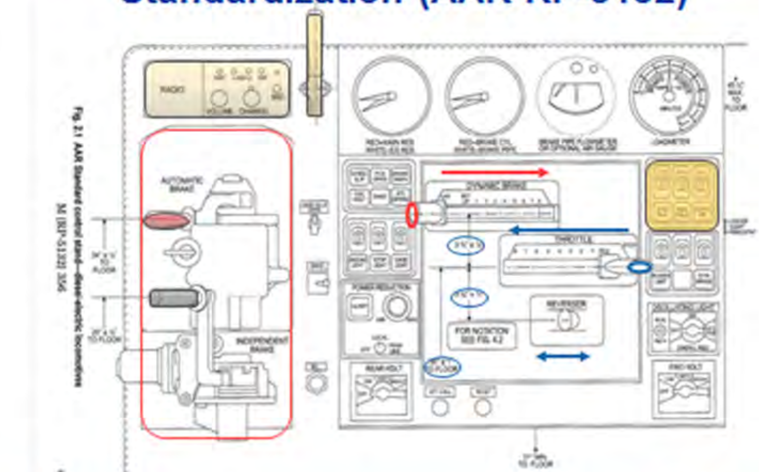
Mark Schwinn
Wikipedia
Lake Superior Railroad Museum – www.lsrm.org
and many others


The History of the Locomotive Cab
and Control Stand
THANK YOU
Further discussion and comments are welcome
Contact: dhm5@zips.uakron.edu
davemangold@hotmail.com
M 330-947-3685


North American Locomotive Cab Development
Harvey Boyd
Electro-Motive Diesel
ELECTRO MOTIVE


North American Locomotive Cab Controls Mid-1970's
• Industry wide effort with focus on:
– Durability
– Bi-directionality
– Standardization
– Control differentiation
– Control Interlocks
ELECTRO MOTIVE

North American Locomotive Cab Controls Standardization (AAR RP-5132)



ELECTRO MOTIVE

North American Locomotive Cab Mid-1970's

Other standard cab enhancements added

- Door closure bars
- Door hinge guards
- Doorway head bump pads
- Padded sun visors
- Rounding all convex edges
- External access to number board lights
- Windshield wiper motor cover

ELECTRO MOTIVE

AAR Bi-Directional Control Stand

Forward Operation

Reverse Operation

ELECTRO MOTIVE

Electro-Motive Diesel is owned by
Progress Rail Services, a Caterpillar Company

Late 1980s: The Push for a Comfort Cab

Requirements

- Office-like environment
- Work desk in place of control stand
- Primarily forward operation
- Quieter cab
- Soft ceiling
- Comfortable flooring
- Improved seating
- Improved toilet facilities
- Recessed add-on "black boxes"
- Air conditioning
- Improved heating
- Refrigerator

ELECTRO MOTIVE

Electro-Motive Diesel is owned by
Progress Rail Services, a Caterpillar Company

North American Comfort Cab

ELECTRO MOTIVE

Electro-Motive Diesel is owned by
Progress Rail Services, a Caterpillar Company

Slide 7

1990s: Enhanced Safety, Ergonomics and Efficiency

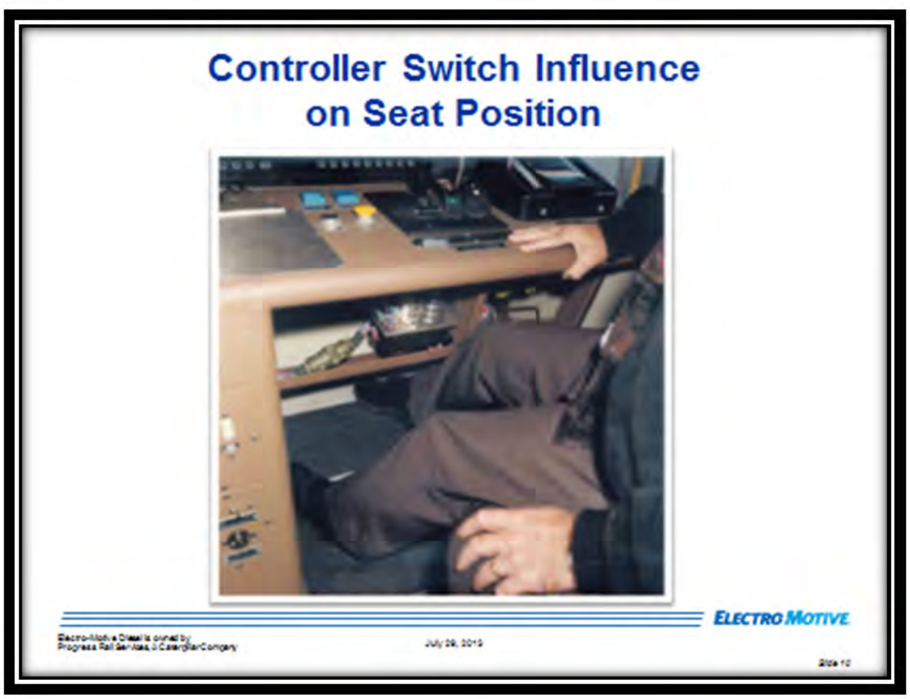
- Introduction of electronic display screens
- Changes to Engineer's workdesk for improved egress
- Controller tilted for improved operation
- Improved egress for Conductor
- Increased focus on ergonomics
- Enhanced role for Operators, involved in cab design process

ELECTRO MOTIVE

Electro-Motive Diesel is owned by
Progress Rail Services, a Caterpillar Company

Slide 8

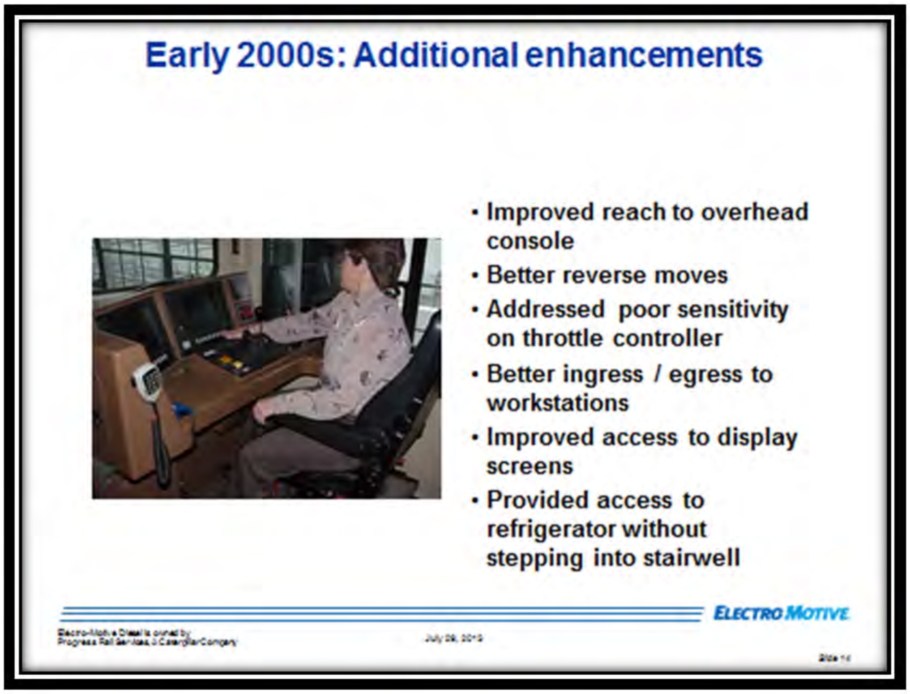

Improved Recess for Knee Clearance
ELECTRO MOTIVE


Controller Switch Influence
on Seat Position
ELECTRO MOTIVE

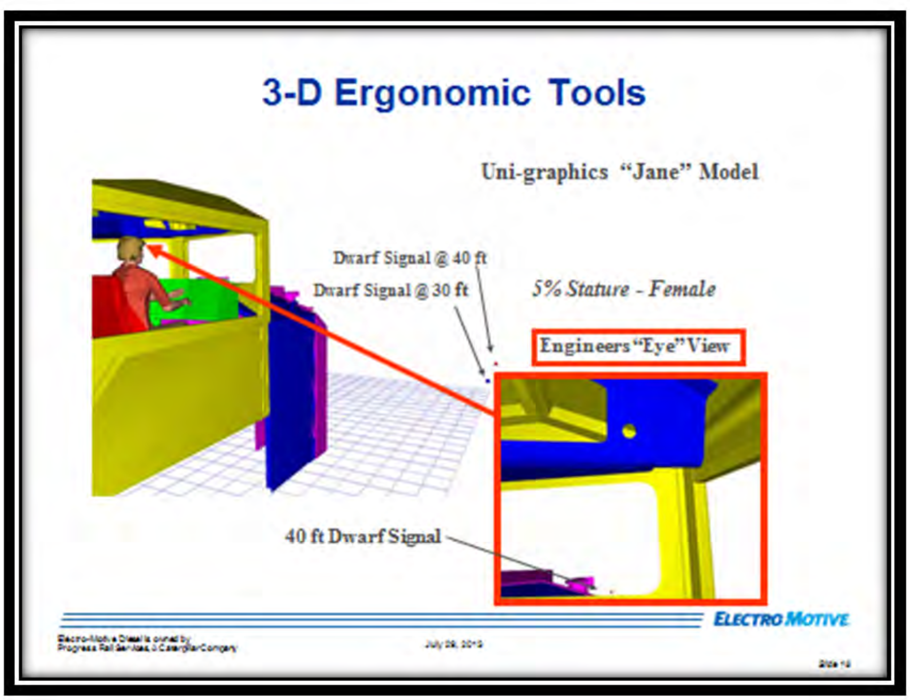

Improved Reach with Tilted Controller
ELECTRO MOTIVE

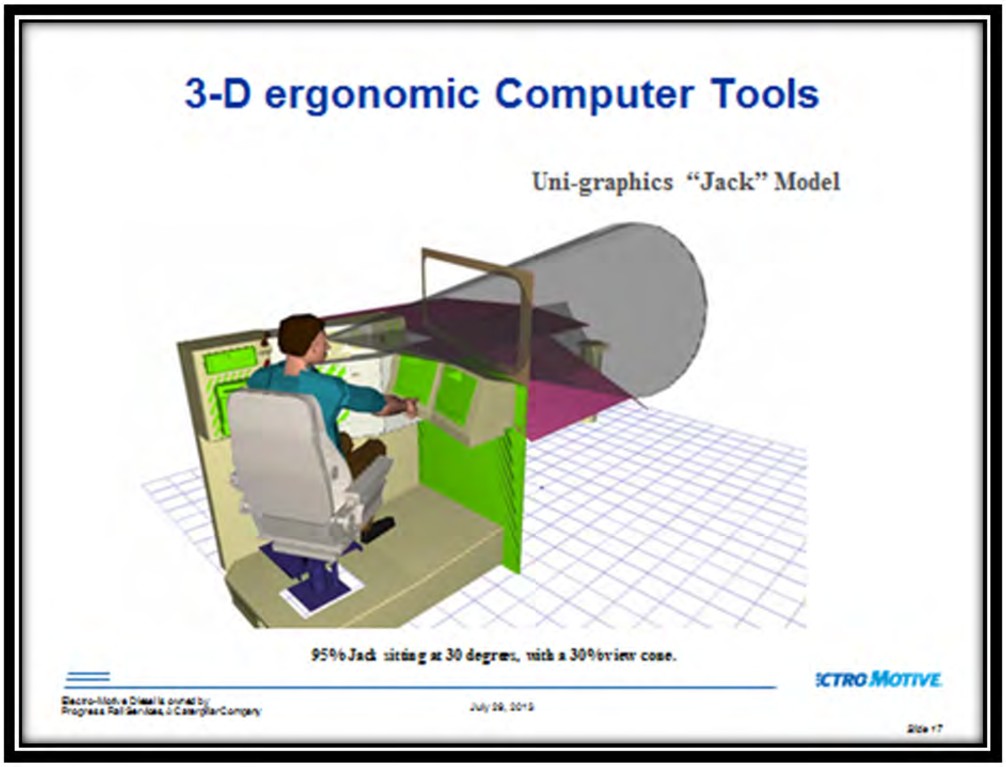

Conductor's Workdesk Designs
ELECTRO MOTIVE

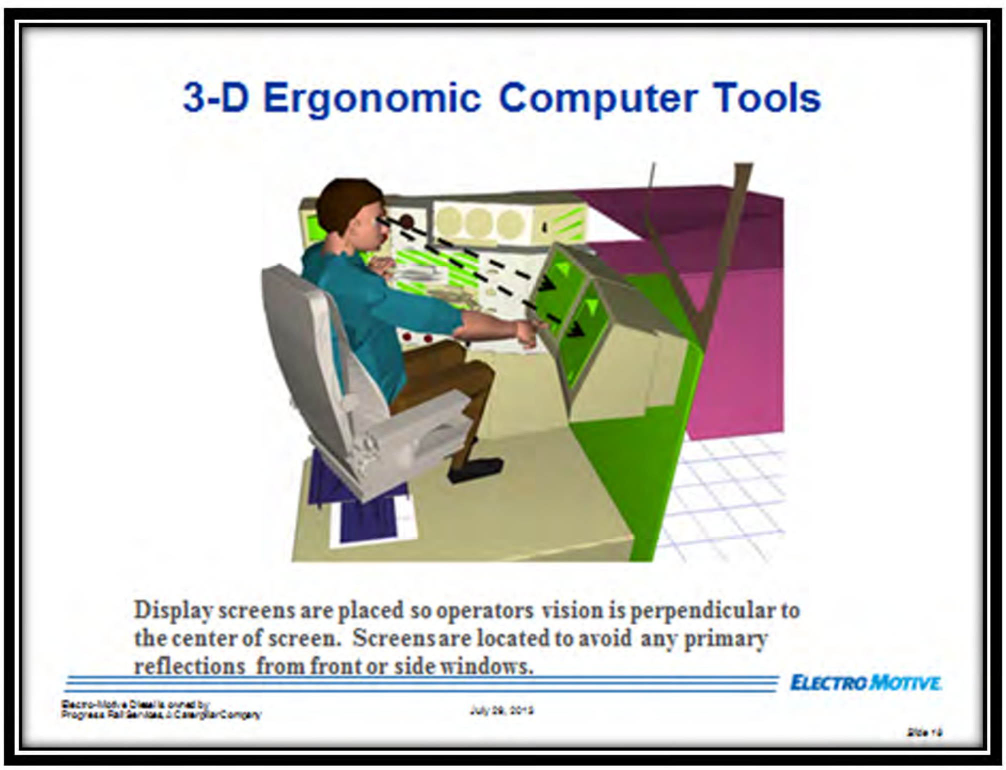

Conductors Workdesk Improved Egress
ELECTRO MOTIVE


Early 2000s: Additional enhancements
• Improved reach to overhead console
• Better reverse moves
• Addressed poor sensitivity on throttle controller
• Better ingress / egress to workstations
• Improved access to display screens
• Provided access to refrigerator without stepping into stairwell
ELECTRO MOTIVE


New Engineers Workstation Design
• Combined best features of the control stand and workdesk information screens in the front, with controls located on the side
ELECTRO MOTIVE


3-D Ergonomic Tools
Uni-graphics "Jane" Model
Dwarf Signal @ 40 ft
Dwarf Signal @ 30 ft
5% Stature - Female
Engineers "Eye" View
40 ft Dwarf Signal
ELECTRO MOTIVE


3-D ergonomic Computer Tools
Uni-graphics "Jack" Model
95% Jack sitting at 30 degrees, with a 30% view cone.
ELECTRO MOTIVE

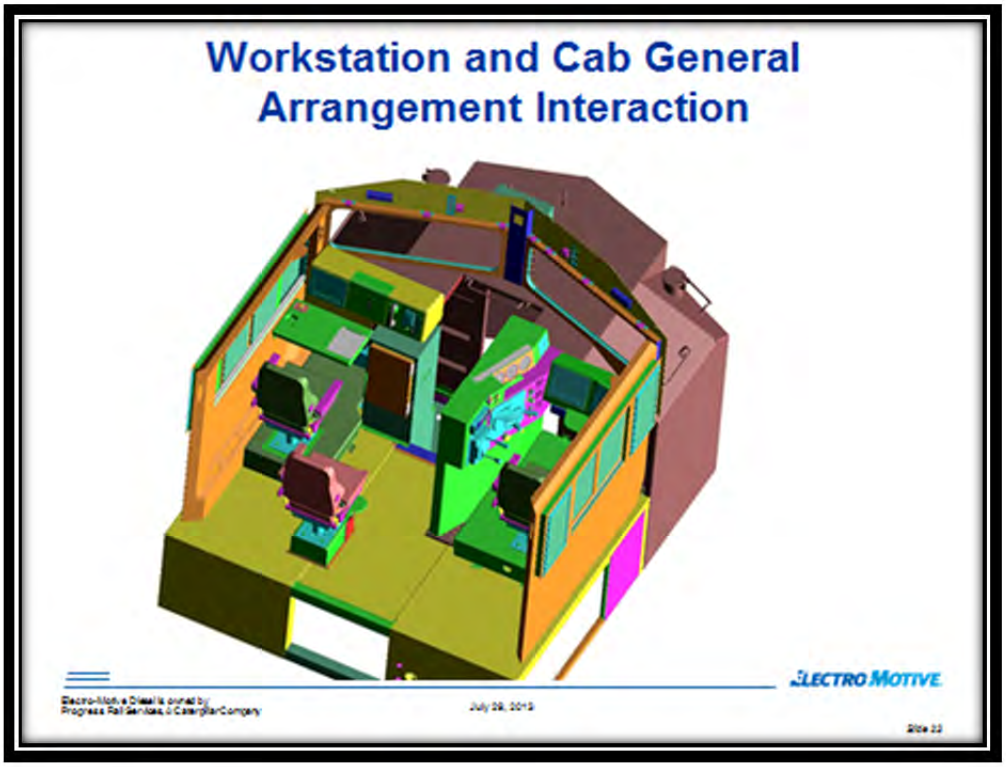

3-D Ergonomic Computer Tools
Display screens are placed so operators vision is perpendicular to the center of screen. Screens are located to avoid any primary reflections from front or side windows.
ELECTRO MOTIVE


New Engineers Workstation Design
UP 8711

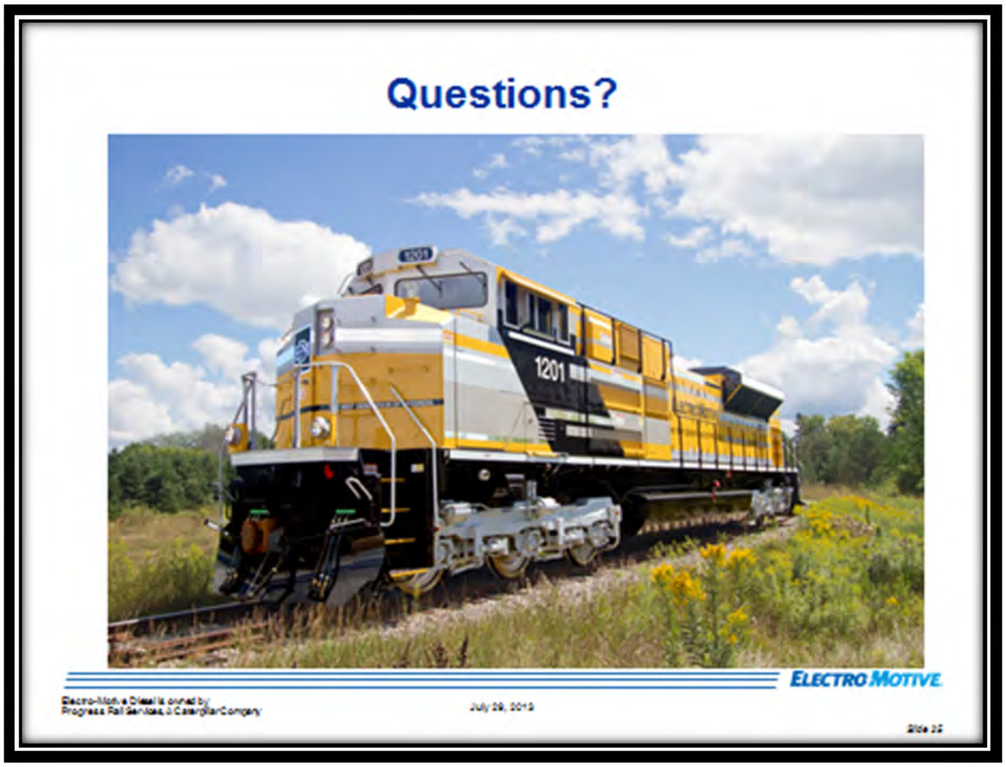

New Engineers Workstation Design
8751
ELECTRO MOTIVE


North American Locomotive Cab Controls Standardization
SAVE FUEL
ELECTRO MOTIVE
Electro-Motive Diesel is owned by Progress Rail Services, a Caterpillar Company


New Engineers Workstation Design
ELECTRO MOTIVE
Electro-Motive Diesel is owned by Progress Rail Services, a Caterpillar Company

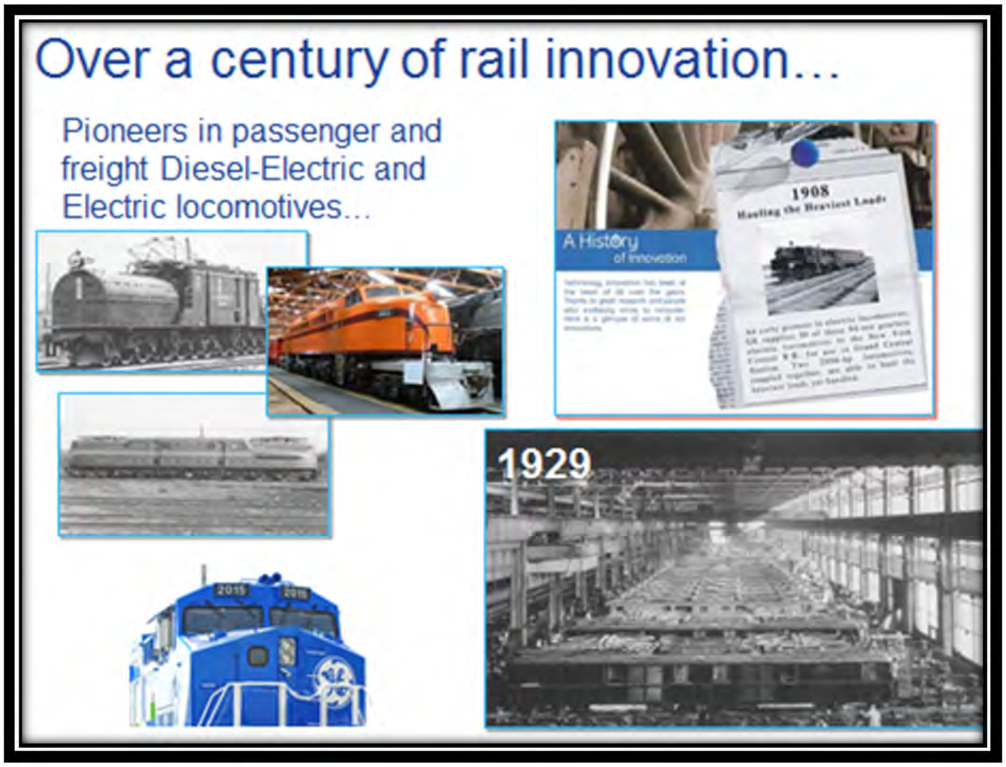

Workstation and Cab General Arrangement Interaction
ELECTRO MOTIVE


Improved Step Access
ELECTRO MOTIVE


Questions?
1201
ELECTRO MOTIVE
Electro-Motive Diesel is owned by
Progress Rail Services, a Caterpillar Company


Railroad Operational Safety Committee Meeting
Omaha, Nebraska
Steve Gerbracht
Manager, Proposal Engineering
July 2013


We are GE Transportation!
GE Transportation is a global technology leader and supplier to the railroad, mining, marine, stationary power, drilling and energy storage industries. Since its inception, GE Transportation has been at the forefront of many of transportation's most storied accomplishments.
Steve Gerbracht
• Manager, Proposal Engineering
• 13 years at GE
• Publications – 250+ articles in enthusiast/industry press
• Operator – GE test and validation since 2002


Over a century of rail innovation…
Pioneers in passenger and freight Diesel-Electric and Electric locomotives…
1908
Hauling the Heaviest Loads
A History of Innovation
1929


Heartbeat of the loco: vital organs
Communication/electronics
Engine
Cooling/radiator
2011
Controls/power management
Alternator
Traction motors
GE Privileged & Confidential

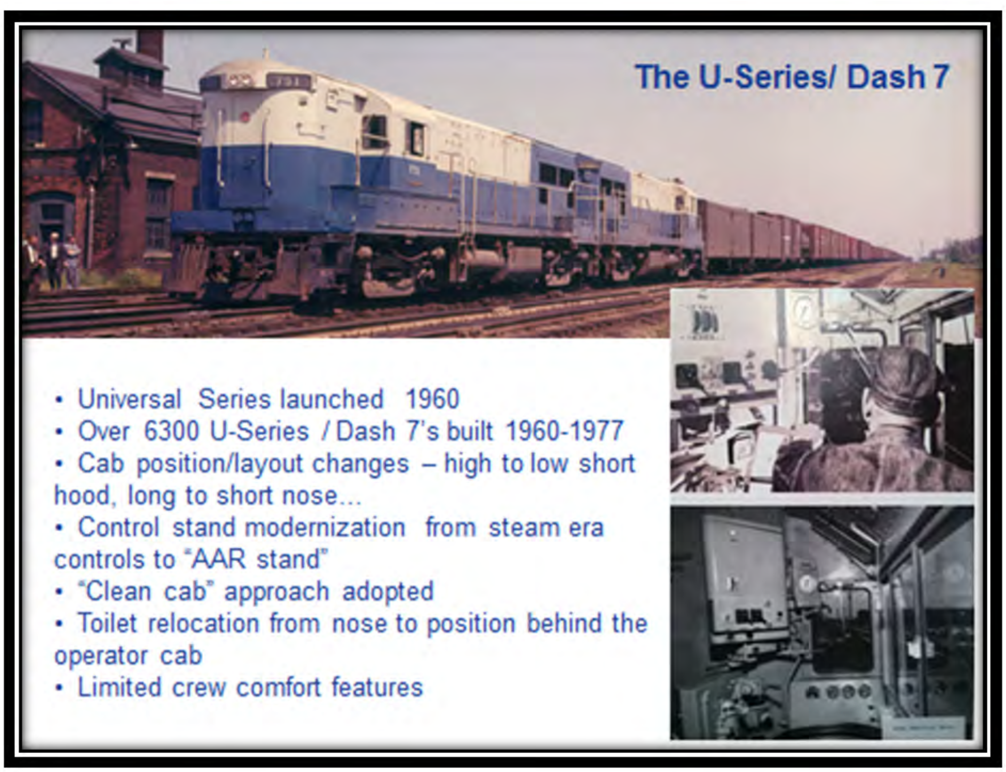
The radiator cab always gets attention…

But what about the operator cab?


The basics of operation are unchanged…
Dynamic Brake
Throttle
Reverser
Voice Radio
Air Brake
Automatic (Red)
Independent
(Black)
Horn
Sand
Sand
Bell


Why is the cab operating environment important?
• It's the office…thousands call it "home" daily
• Crew safety / ergonomics
• Train & operational safety
• Customer options
• Interoperability
• Operation
• Visibility
2005


GE "Standard Export Line" (SEL) Locomotive: 1955-1985
• Earliest units: GE design, Alco engine (seen left)
• Testing grounds for Cooper-Bessemer "FDL" (1950's)
• Led to "Standard Export Line" developed by early 1960's; thru 1980's
• Shovelnose widebody cabs led to more traditional narrow cabs/external walkways
• High short hood replaced by low hood
• Customer unique options / dual consoles


The U-Series/ Dash 7
• Universal Series launched 1960
• Over 6300 U-Series / Dash 7's built 1960-1977
• Cab position/layout changes – high to low short hood, long to short nose…
• Control stand modernization from steam era controls to "AAR stand"
• "Clean cab" approach adopted
• Toilet relocation from nose to position behind the operator cab
• Limited crew comfort features

The Dash 8

- Dash 8 line standardized main cab by late 80's
- Equipped with AAR control stand
- Equipped with nose-mounted toilet

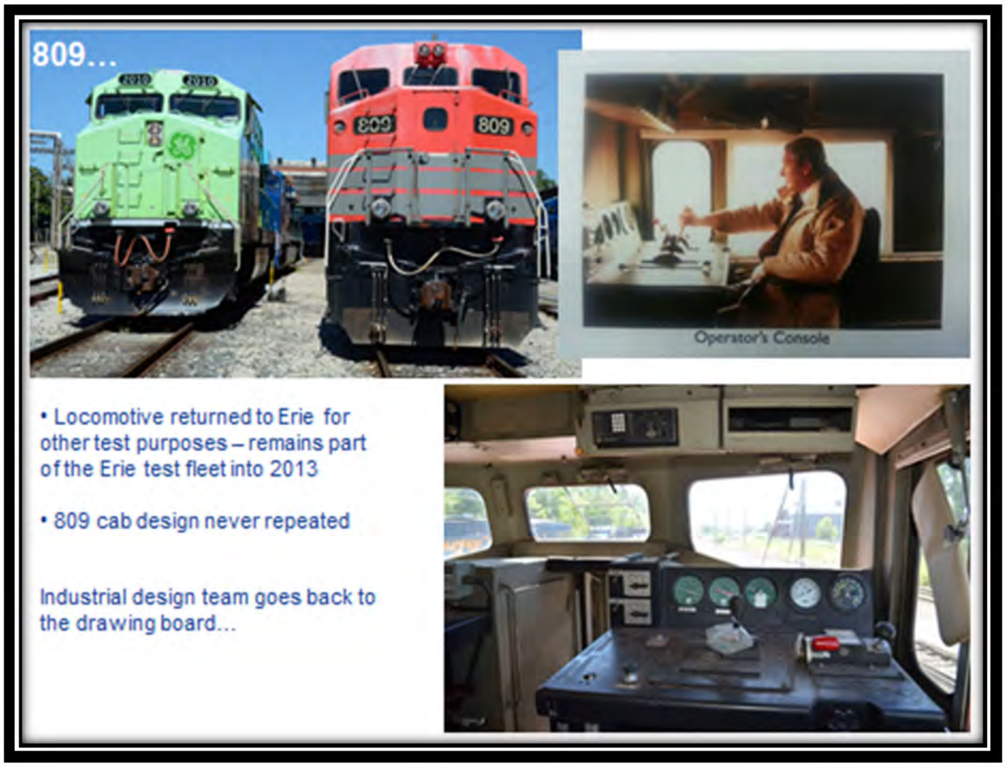
Just as GE approached standardization in the operator cab design...

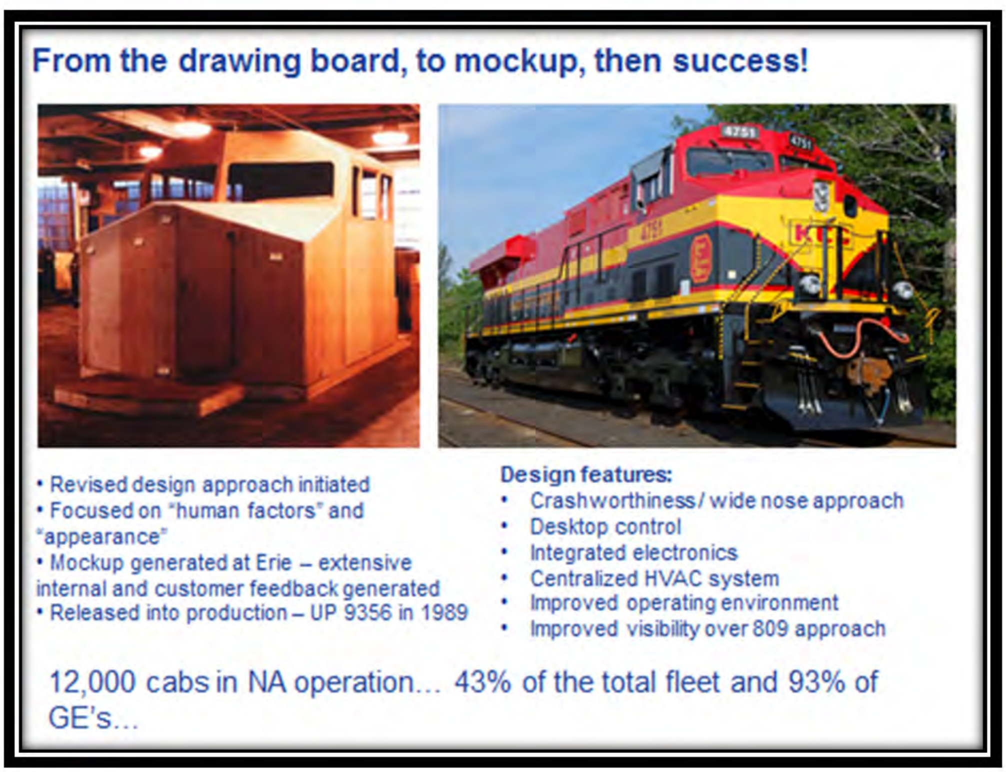
- GE receives order for CN Dash 8-40CM
- Implementation of "CN-style" safety cab and widebody loco (with hood taper)
- First modern jump into "widecab" features including desktop control
- Simultaneously, North American customers request a revised approach...

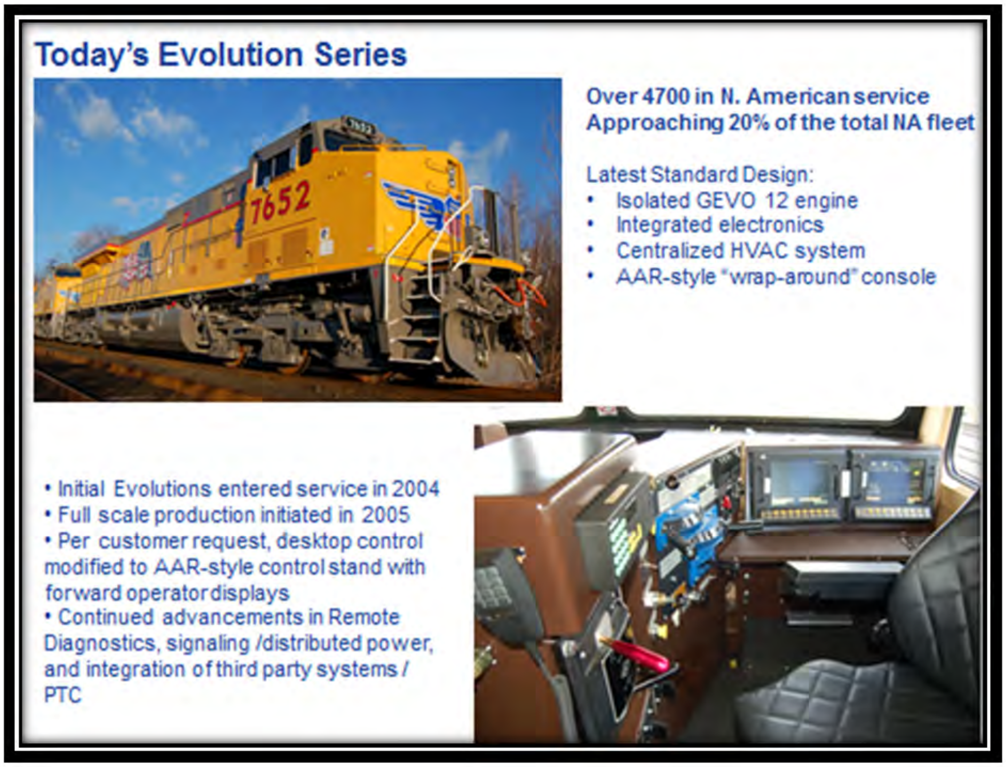
Enter the 809...

- GE initiates comfort cab design per customer request
- GE's initial concept implemented on GE Dash 8 808.
- Tested across North America (UP, Conrail) to solicit customer and operating crew feedback.
- Lots of feedback received...

"We learned a number of things in this cab design... It was obvious from the railroad's reaction that Engineering's quick minimum design change approach had many flaws, but showed that the general approach was right." - Jim Chapin

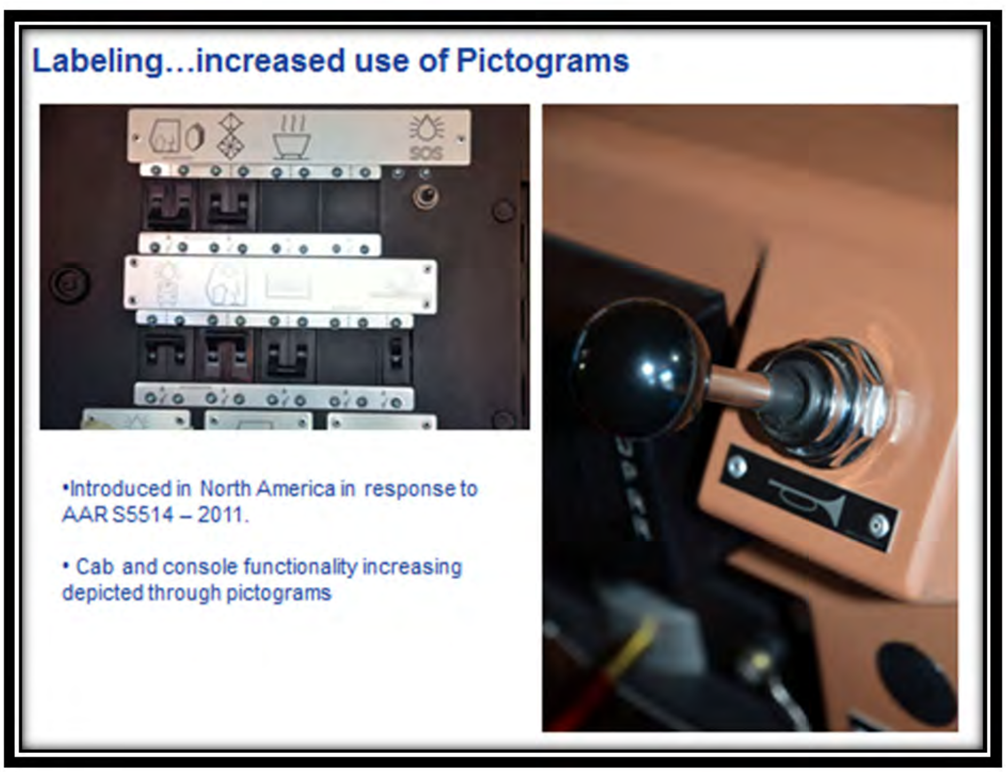

809...
Operator's Console
• Locomotive returned to Erie for other test purposes – remains part of the Erie test fleet into 2013
• 809 cab design never repeated
Industrial design team goes back to the drawing board...


From the drawing board, to mockup, then success!
• Revised design approach initiated
• Focused on "human factors" and "appearance"
• Mockup generated at Erie – extensive internal and customer feedback generated
• Released into production – UP 9356 in 1989
Design features:
• Crashworthiness / wide nose approach
• Desktop control
• Integrated electronics
• Centralized HVAC system
• Improved operating environment
• Improved visibility over 809 approach
12,000 cabs in NA operation... 43% of the total fleet and 93% of GE's...


Today's Evolution Series
7652
Over 4700 in N. American service
Approaching 20% of the total NA fleet
Latest Standard Design:
• Isolated GEVO 12 engine
• Integrated electronics
• Centralized HVAC system
• AAR-style "wrap-around" console
• Initial Evolutions entered service in 2004
• Full scale production initiated in 2005
• Per customer request, desktop control modified to AAR-style control stand with forward operator displays
• Continued advancements in Remote Diagnostics, signaling /distributed power, and integration of third party systems / PTC


What's Next?
Challenges and realities in 21st Century Operator cab design
8000


PTC and Third Party System Implementation
• PTC provisioning or install since 2011
• PTC provisioning varies per customer specification
• Significant challenges to standardize approach across all NA Class I's
• Differences remain in:
• Antennas
• Alcove equipment mounting
• Display locations
• Number of displays
• Nav Module location
• Off-board networking and communications systems
• Software variation
• Implementation timing
• Provisioning approach
Variation expected well past PTC implementation – may drive challenges in run-through operations and maintenance


Labeling…increased use of Pictograms
SOS
•Introduced in North America in response to AAR S5514 – 2011.
• Cab and console functionality increasing depicted through pictograms

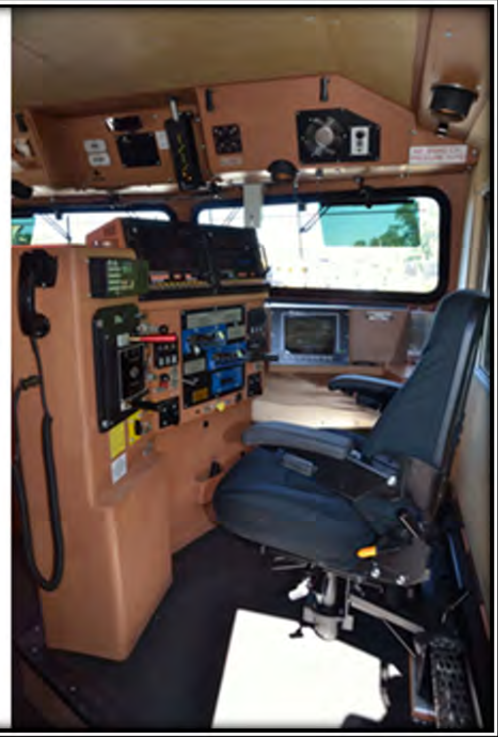
Customer Options

Despite the interoperability on NA fleets, significant operator cab option variation remains....

Today... seven NA Class I customers specify:

- Over 110 features with over 500 individual options in the main cab
- From consoles to switches to seats...

Continued design optimization to incorporate customer options while maintaining flexibility of build process



Crashworthiness

- FRA ammended S580 crash standards in 2006.
- Increased level of crashworthiness required for locomotives manufactured effective January 1, 2009.

- GE extensively redesigned the Evolution Series operator cab and platform.

Major changes include:

- Crash post size & height
- Greater integration of crash post into nose cab during assembly
- Thickness change in cab weldment
- Modification of front door
- Change in front door position based to safety analysis

Significant impact on mechanical design... critical to our overall approach toward crash and safety.

Over 2000 Evolutions in N. American operation.

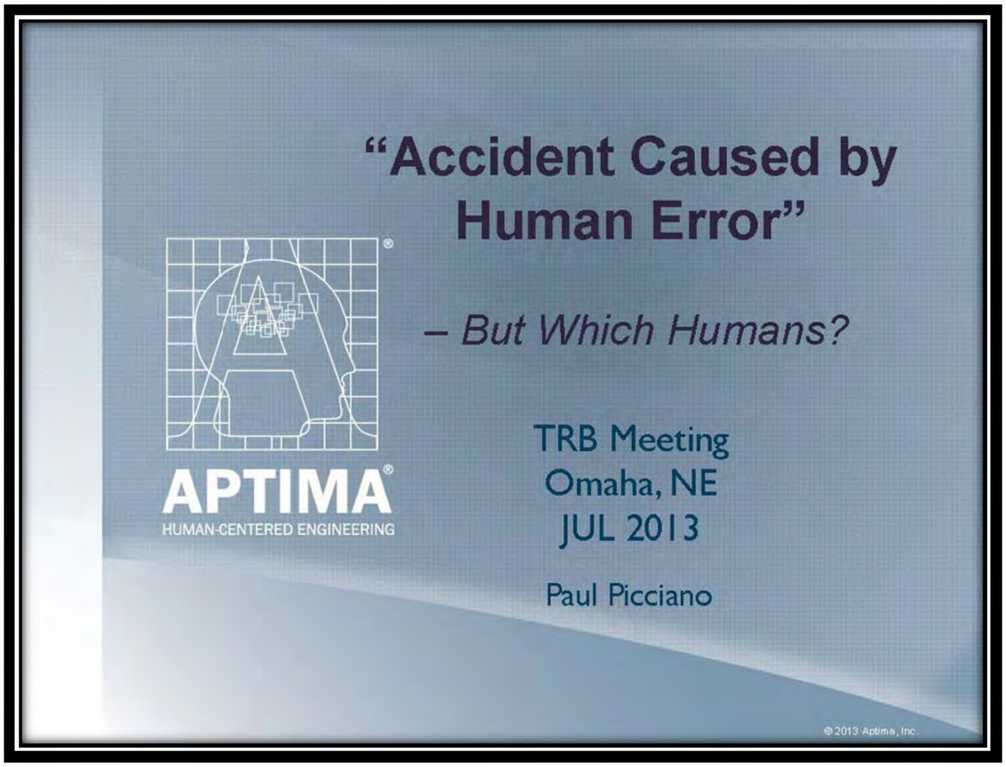

PowerHaul® Series locomotive
• $150 million investment over five years
• European Standards Compliant , 20-22 mt/axle
• Heavy Haul 6 axle AC Propulsion, +25% Haulage vs DC
• World Class Fuel Economy, 9-18% better than legacy UK fleets
• Delivering lower life-cycle costs
• Flexibility to comply with local regulations
• Expandability to meet future regulations
F=ma
PROJECT POWER


PowerHaul® Series locomotive


PowerHaul® Series locomotive -


Innovation will continue…
7259
EVOLUTION


Thank you…


"Accident Caused by Human Error"
– But Which Humans?
APTIMA
HUMAN-CENTERED ENGINEERING
TRB Meeting
Omaha, NE
JUL 2013
Paul Picciano
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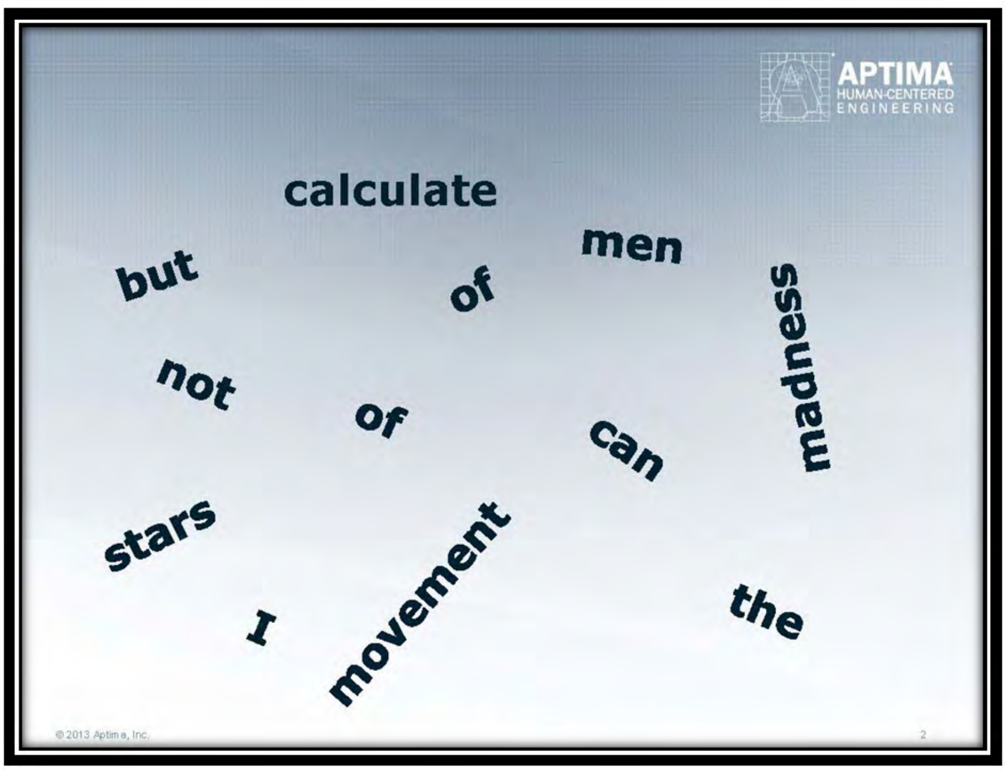
APTIMA
HUMAN-CENTERED ENGINEERING
calculate
men
but
of
madness
not
of
can
stars
movement
I
the
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2

APTIMA HUMAN-CENTERED ENGINEERING

Message in more digestible form

"I can calculate the movement of the stars but not the madness of men."

Newton - in response to South Sea bubble

 3

APTIMA HUMAN-CENTERED ENGINEERING

One View of the World

 4

Closer to Reality?

 5

System Design and Interaction

Trust

Can you predict how it will behave?

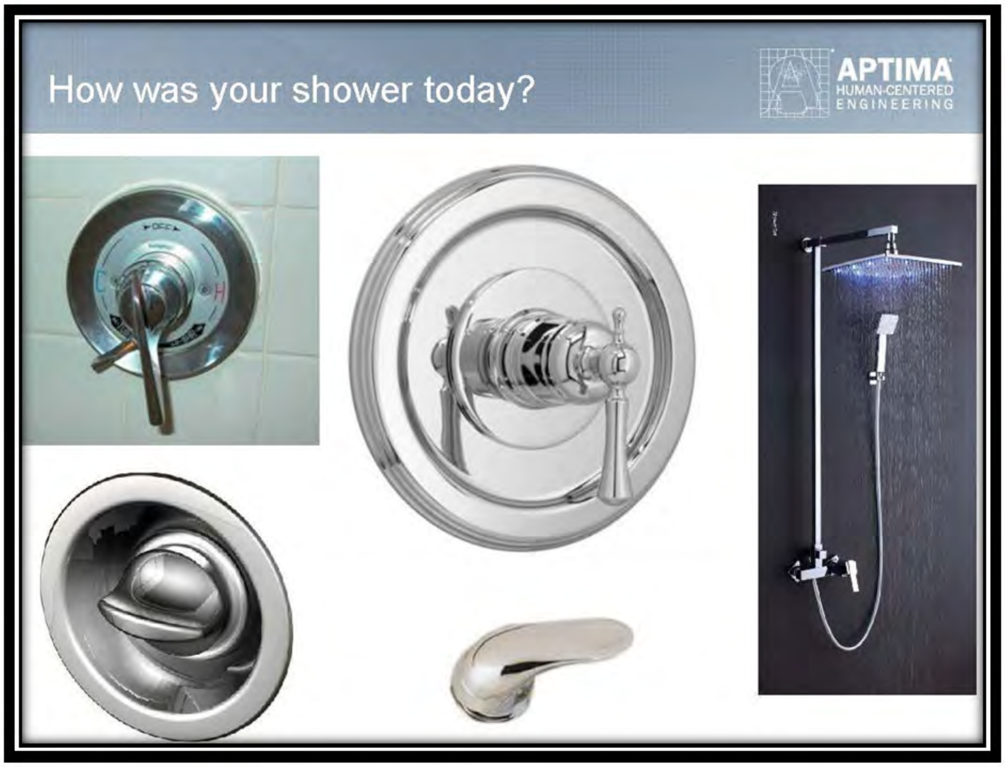
Transparency

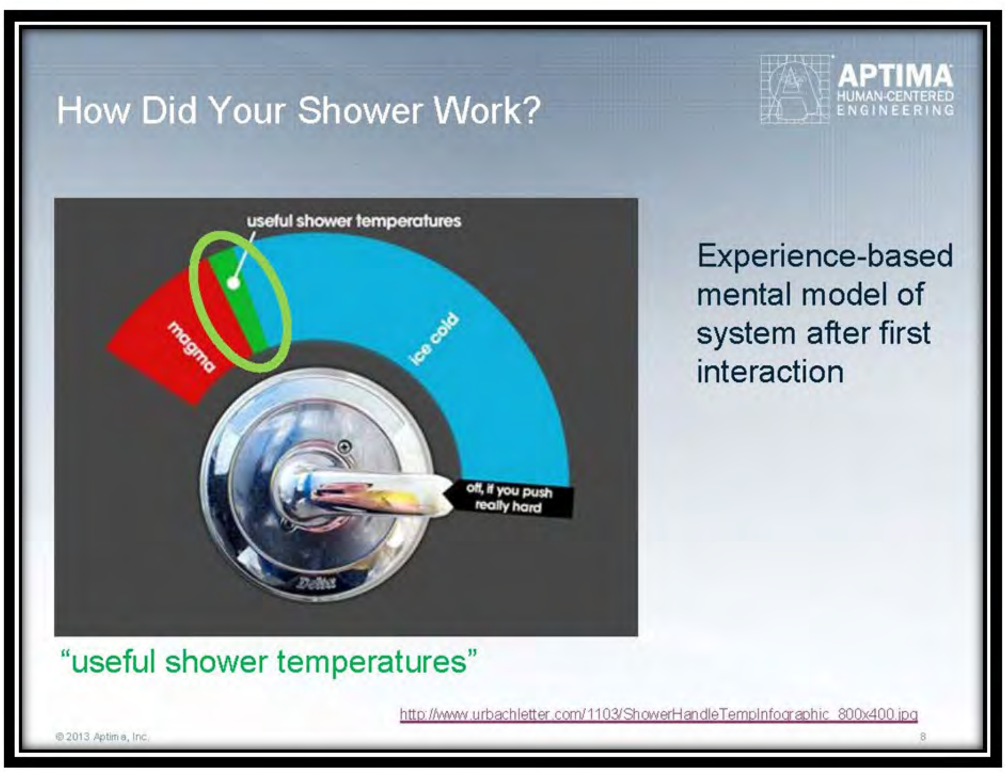
Can you see how the system works?

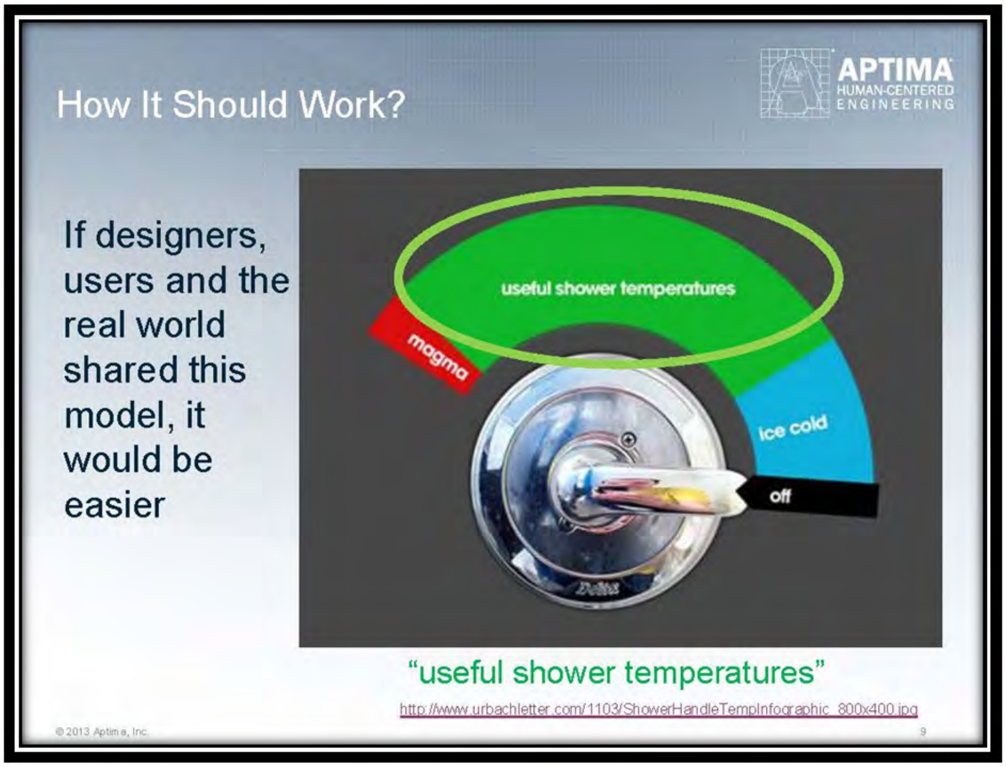
Feedback

Can you tell what it's doing now?

 6


How was your shower today?
APTIMA
HUMAN-CENTERED
ENGINEERING


How Did Your Shower Work?
APTIMA
HUMAN-CENTERED
ENGINEERING
useful shower temperatures
magma
ice cold
off, if you push really hard
Experience-based mental model of system after first interaction
“useful shower temperatures”
http://www.urbachletter.com/1103/ShowerHandleTempInfographic_800x400.jpg
© 2013 Aptima, Inc.
8


How It Should Work?
APTIMA
HUMAN-CENTERED ENGINEERING
If designers, users and the real world shared this model, it would be easier
useful shower temperatures
magma
ice cold
off
"useful shower temperatures"
http://www.urbachletter.com/1103/ShowerHandleTempInfographic_800x400.jpg
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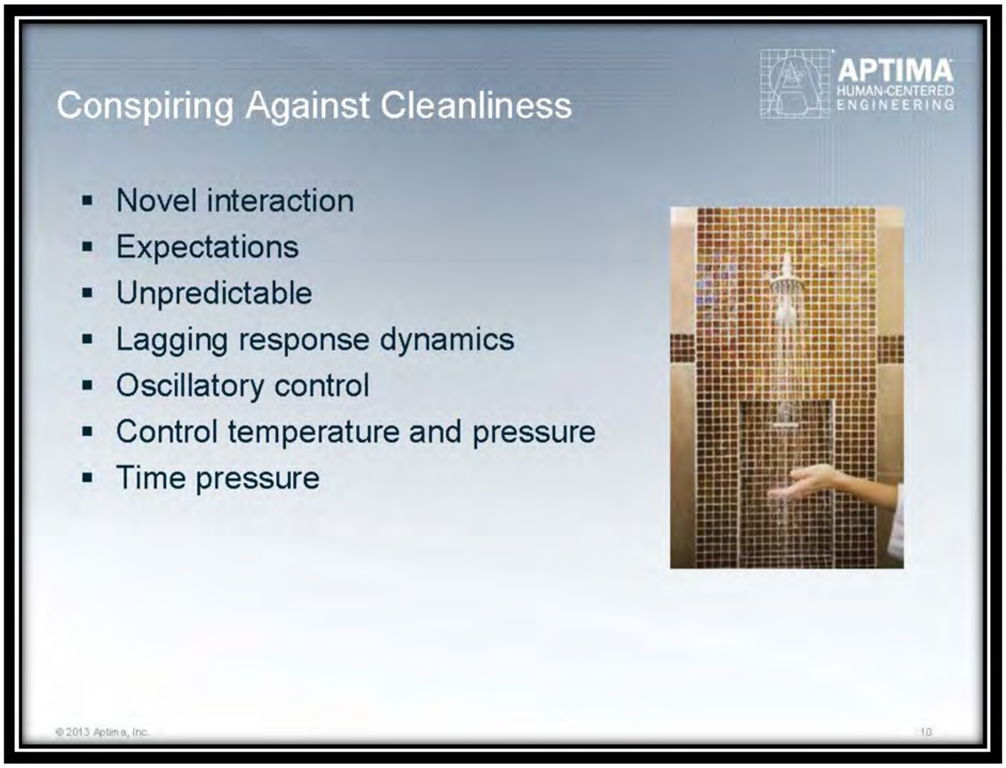
Conspiring Against Cleanliness
APTIMA
HUMAN-CENTERED ENGINEERING
▪ Novel interaction
▪ Expectations
▪ Unpredictable
▪ Lagging response dynamics
▪ Oscillatory control
▪ Control temperature and pressure
▪ Time pressure
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10

Examples:
System Design and Interaction

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Trust

Do you love your GPS?

Transparency

Can you see inside the core?

Feedback

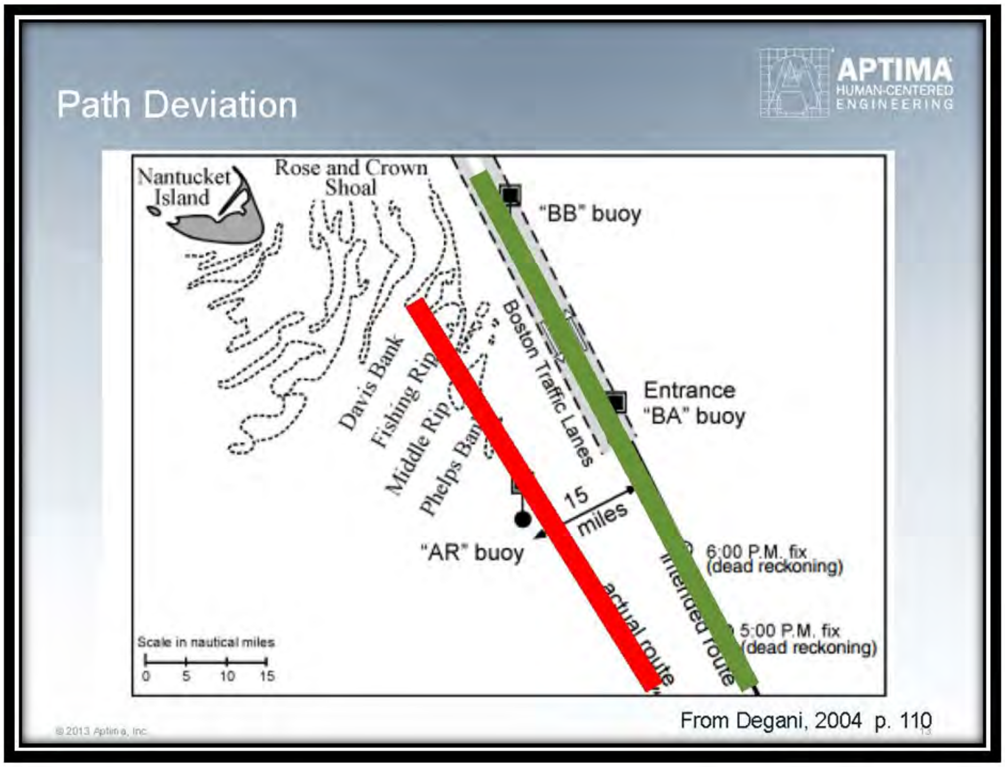
Can you confirm you're on the right track?

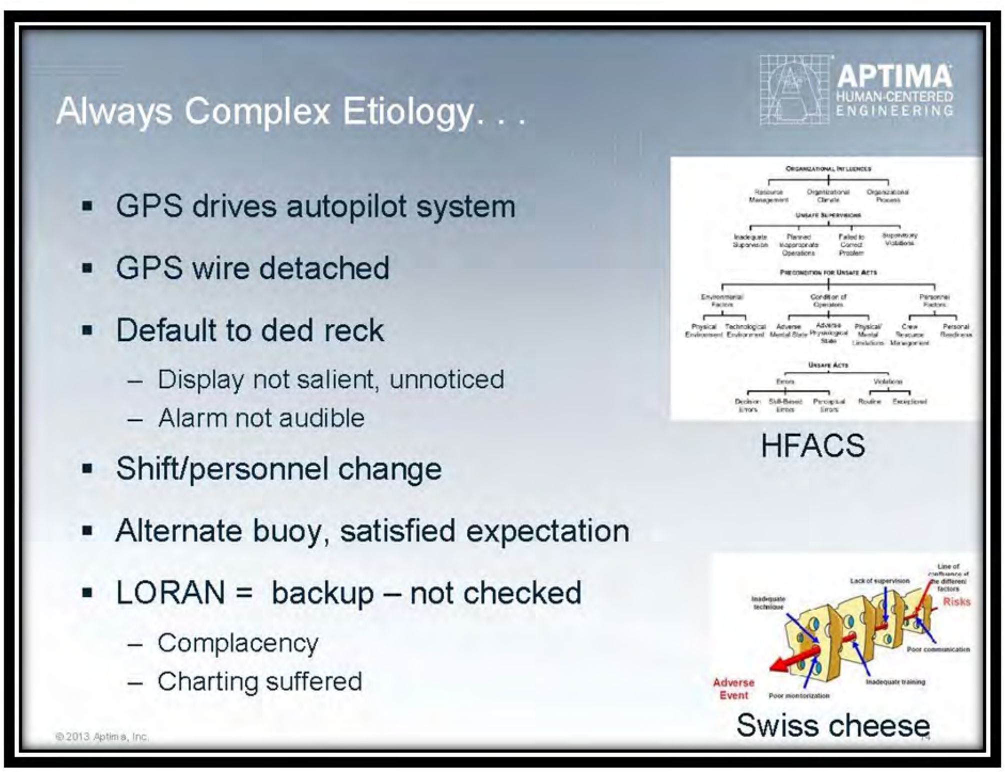
 11

TRUST The Royal Majesty, 1995

APTIMA
HUMAN-CENTERED ENGINEERING

 12


Path Deviation
APTIMA
HUMAN-CENTERED ENGINEERING
Nantucket Island
Rose and Crown Shoal
"BB" buoy
Davis Bank
Fishing Rip
Middle Rip
Phelps Bank
Boston Traffic Lanes
Entrance "BA" buoy
15 miles
"AR" buoy
6:00 P.M. fix (dead reckoning)
5:00 P.M. fix (dead reckoning)
actual route
intended route
Scale in nautical miles
0 5 10 15
From Degani, 2004 p. 110
© 2013 Aptima, Inc.


Always Complex Etiology. . .
APTIMA
HUMAN-CENTERED ENGINEERING
GPS drives autopilot system
GPS wire detached
Default to ded reck
– Display not salient, unnoticed
– Alarm not audible
Shift/personnel change
Alternate buoy, satisfied expectation
LORAN = backup – not checked
– Complacency
– Charting suffered
HFACS
Adverse Event
Risks
Swiss cheese
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GPS: Subtle Indication

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 15

NTSB Conclusions: Overreliance

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"[Numerous observations] should have **taken precedence over the automation** display on the central console and compelled the second officer to promptly use all available means to verify his position."

 16

TRANSPARENCY Three Mile Island, 1979

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What Happened at Three Mile Island ?

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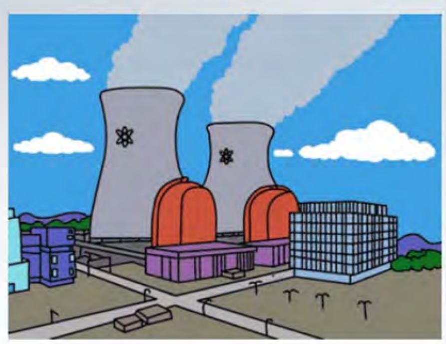
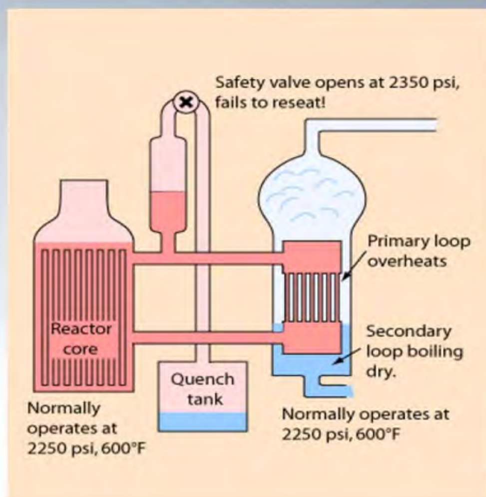
- Insufficient cooling in the core of Reactor 2
- Partial meltdown of the core
- Some radioactive gas escaped containment facility
- Reactor 2 destroyed

- Changes followed in:
  - Regulations
  - Design
  - Training



Relief Valve Believe Closed



No information revealing relief valve was stuck open

Sensor indicated closed

Personnel carried that assumption for hours

http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/tmi.html#oogleto:http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/imgnuk/tmi3.gif

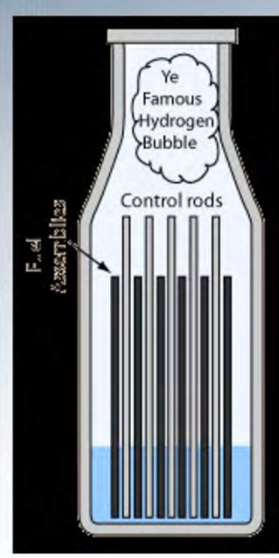
 19

Believed Core was Covered

Signal of water level inflated

Did not account for a bubble pushing water level indicator high

Leaving core uncovered



http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/tmi.html#oogleto:http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/imgnuk/tmi3.gif

 20


True System State Difficult to Assess
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HUMAN-CENTERED ENGINEERING
▪ Sensors measure proxy values
▪ "Avalanche" of Alerts
▪ Printer hours behind
▪ Information poorly organized
▪ Intensive search
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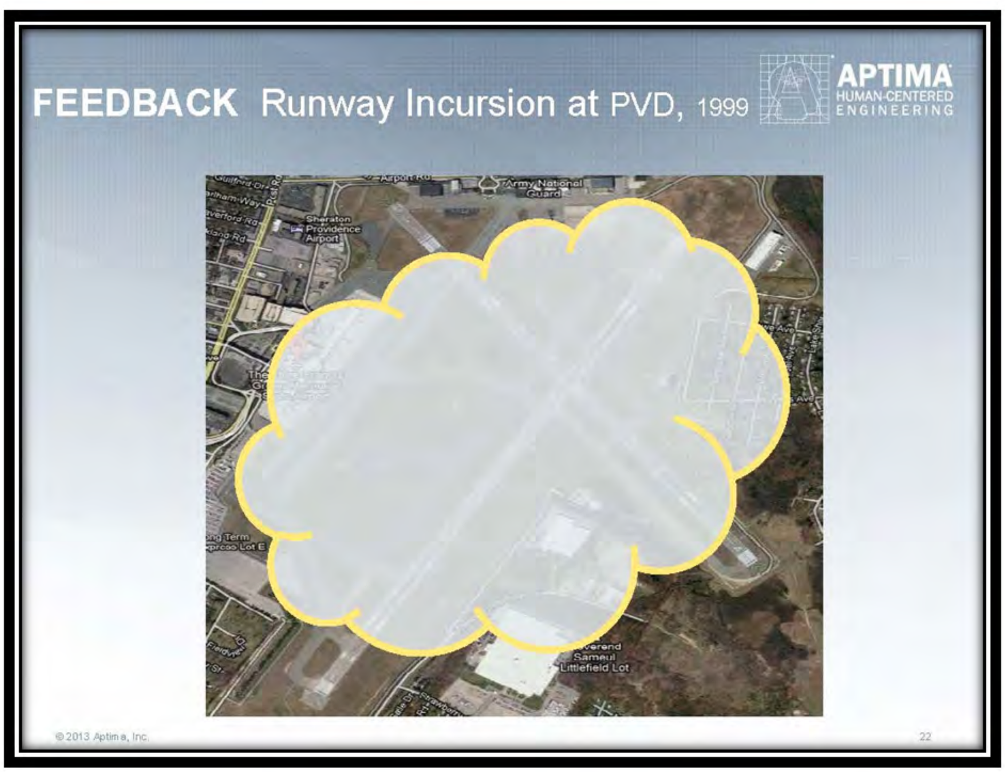
FEEDBACK Runway Incursion at PVD, 1999
APTIMA
HUMAN-CENTERED ENGINEERING
Sheraton Providence Airport
Army National Guard
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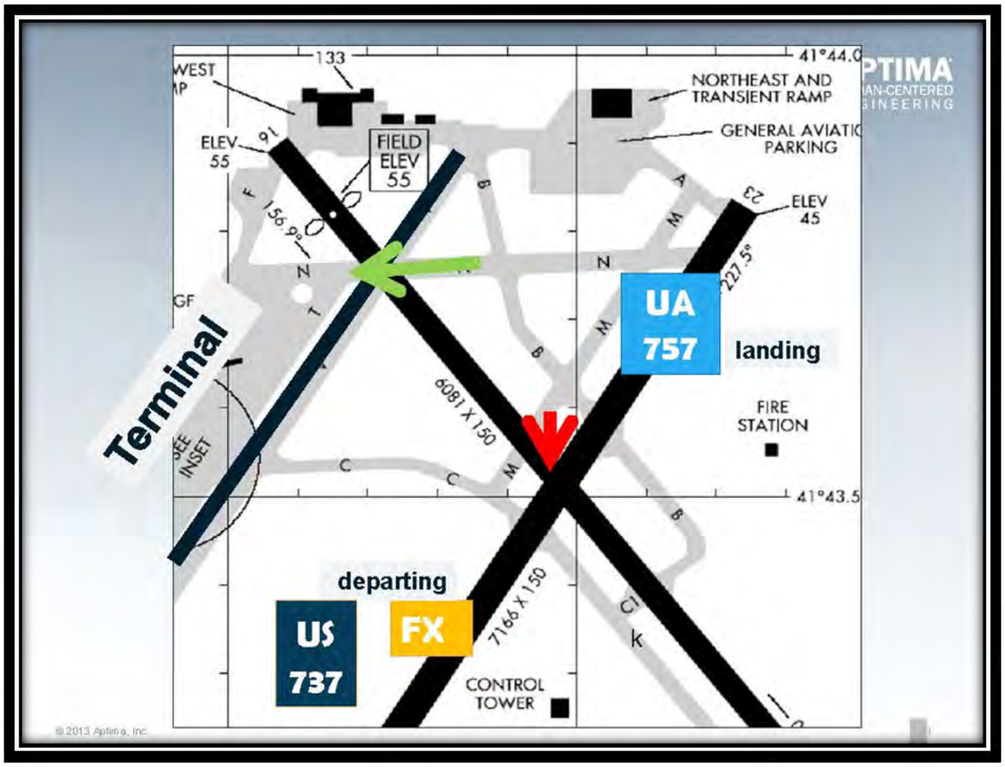
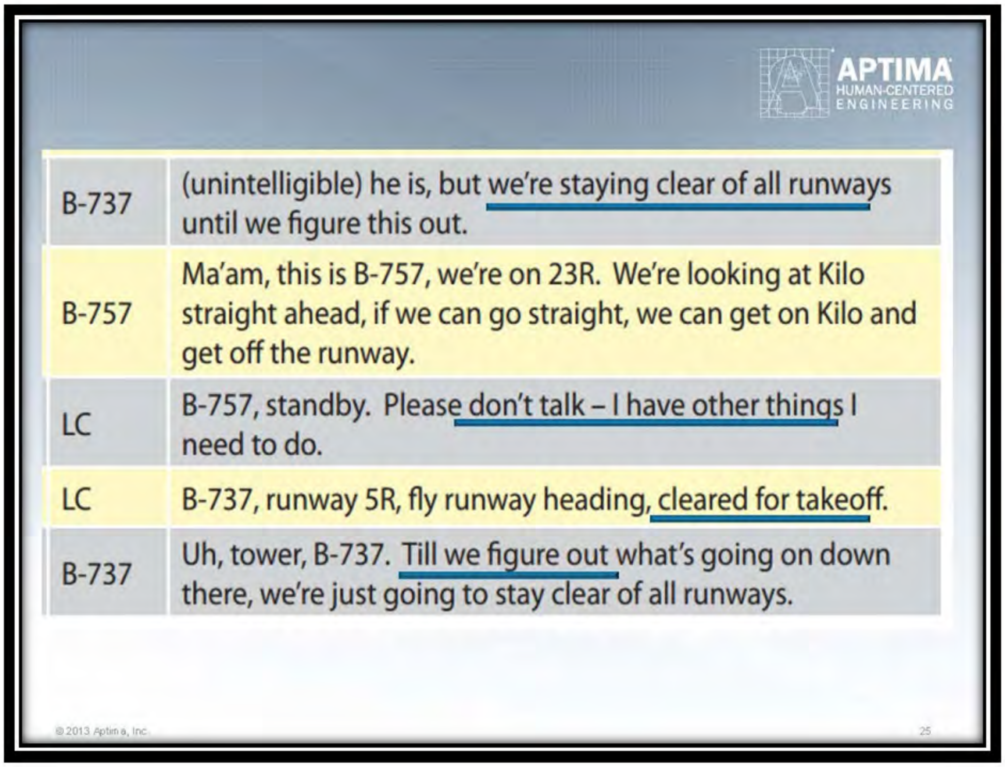


B-757	And, uh, B-757, we're approaching Kilo here, uh, um – somebody just took off.
LC	B-757, you shouldn't be anywhere near Kilo. Hold your position, please. Just stop.
B-757	Tower, this is B-757. We are currently on a runway. I'm looking out to the right with a Kilo, uh, we need to go on to the Kilo taxiway.
LC	B-757, you were supposed to taxi November and Tango. I need to know what runway you're on. I can't see anything from the tower.
B-757	Uh, ma'am, we are on 23R intersection of 16 and we did not connect on November. We are, we are by Kilo to our right and we just overshot Kilo. We did not see it.
LC	B-737, runway 5R, fly runway heading, cleared for takeoff.
B-757	Ma'am, I'm trying to advise you; we're on an active runway, B-757.
LC	23R is not an active runway; it's a taxiway when we're IFR or in the dark.


APTIMA
HUMAN-CENTERED ENGINEERING
B-737 | (unintelligible) he is, but we're staying clear of all runways until we figure this out.
B-757 | Ma'am, this is B-757, we're on 23R. We're looking at Kilo straight ahead, if we can go straight, we can get on Kilo and get off the runway.
LC | B-757, standby. Please don't talk – I have other things I need to do.
LC | B-737, runway 5R, fly runway heading, cleared for takeoff.
B-737 | Uh, tower, B-737. Till we figure out what's going on down there, we're just going to stay clear of all runways.
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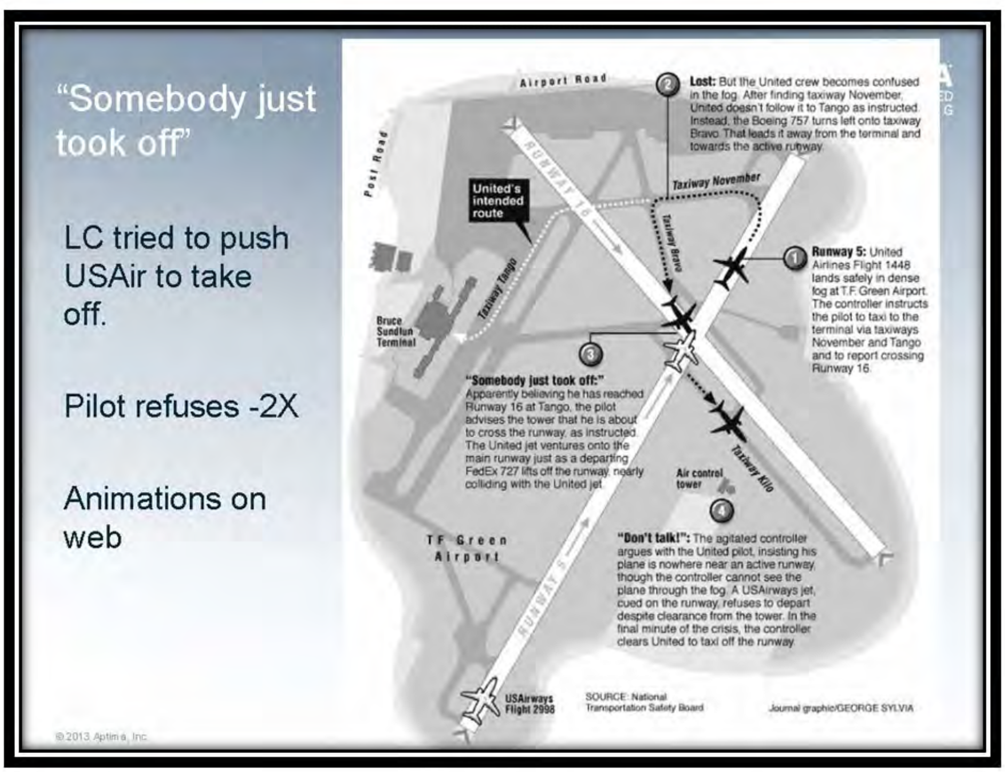
"Somebody just took off"
LC tried to push USAir to take off.
Pilot refuses -2X
Animations on web
Airport Road
Post Road
Runway 16
Runway 5
United's intended route
Taxiway Tango
Taxiway November
Taxiway Bravo
Taxiway Kilo
Bruce Sundlun Terminal
Air control tower
TF Green Airport
Lost: But the United crew becomes confused in the fog. After finding taxiway November, United doesn't follow it to Tango as instructed. Instead, the Boeing 757 turns left onto taxiway Bravo. That leads it away from the terminal and towards the active runway.
Runway 5: United Airlines Flight 1448 lands safely in dense fog at T.F. Green Airport. The controller instructs the pilot to taxi to the terminal via taxiways November and Tango and to report crossing Runway 16.
"Somebody just took off:" Apparently believing he has reached Runway 16 at Tango, the pilot advises the tower that he is about to cross the runway, as instructed. The United jet ventures onto the main runway just as a departing FedEx 727 lifts off the runway, nearly colliding with the United jet.
"Don't talk!": The agitated controller argues with the United pilot, insisting his plane is nowhere near an active runway, though the controller cannot see the plane through the fog. A USAirways jet, cued on the runway, refuses to depart despite clearance from the tower. In the final minute of the crisis, the controller clears United to taxi off the runway.
USAirways Flight 2998
SOURCE: National Transportation Safety Board
Journal graphic/GEORGE SYLVIA
© 2013 Aptima, Inc.


Thank You
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HUMAN-CENTERED ENGINEERING
ppicciano
@aptima.com
781 496 2407
Rubes By Leigh Rubin
rubescartoons.com
How masochists shower
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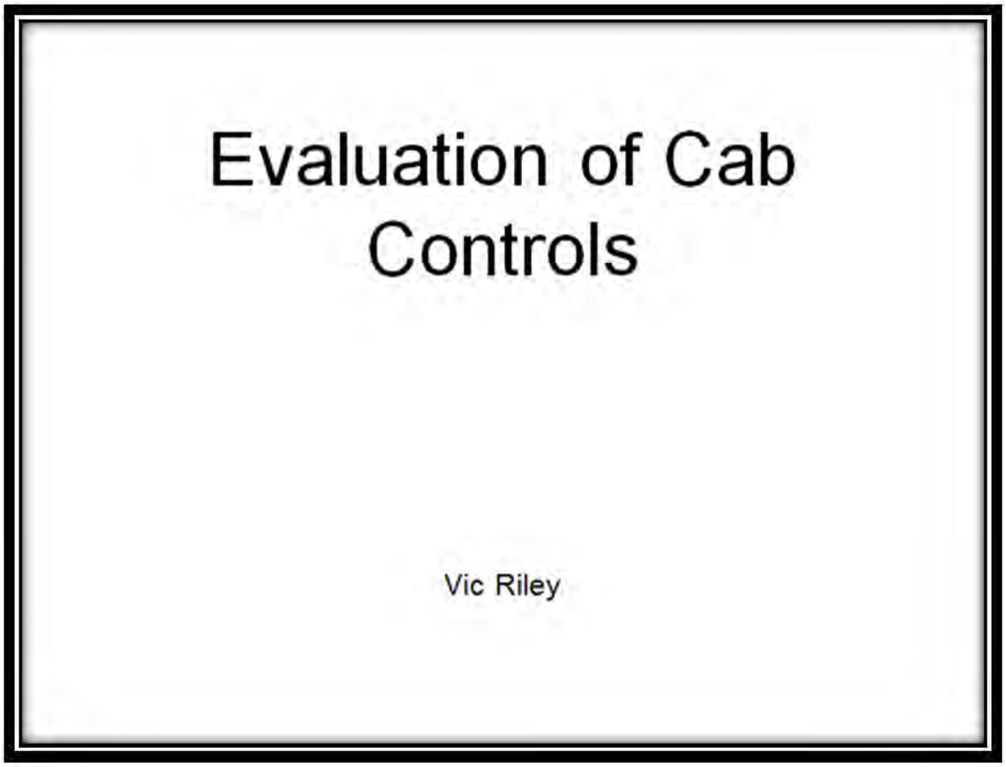
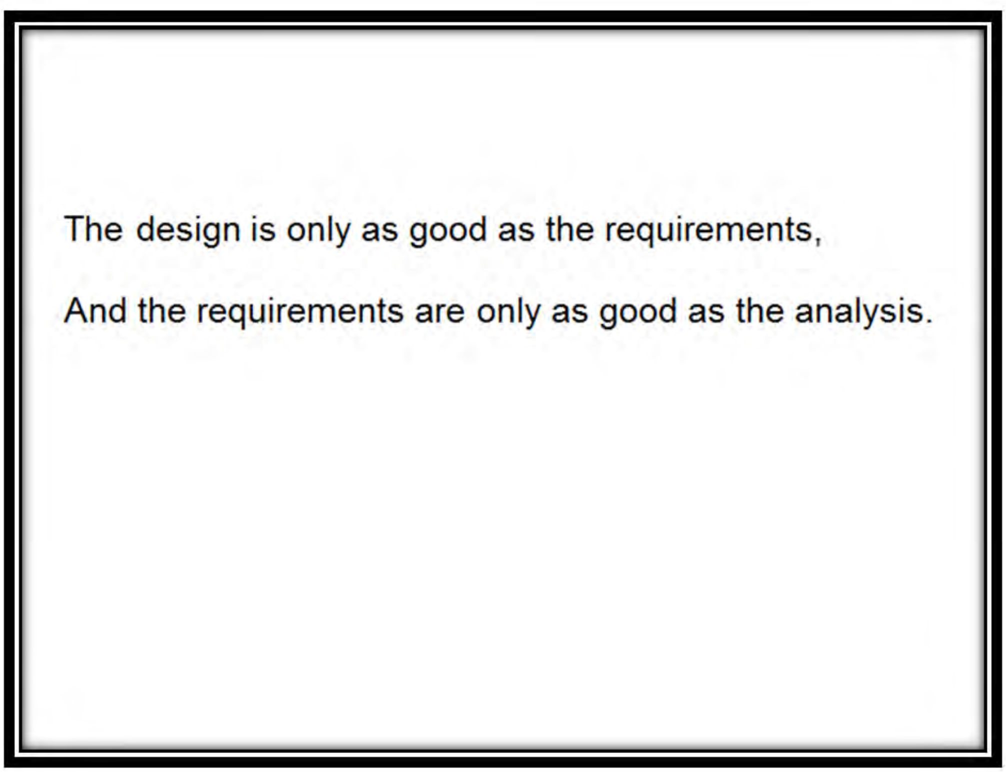
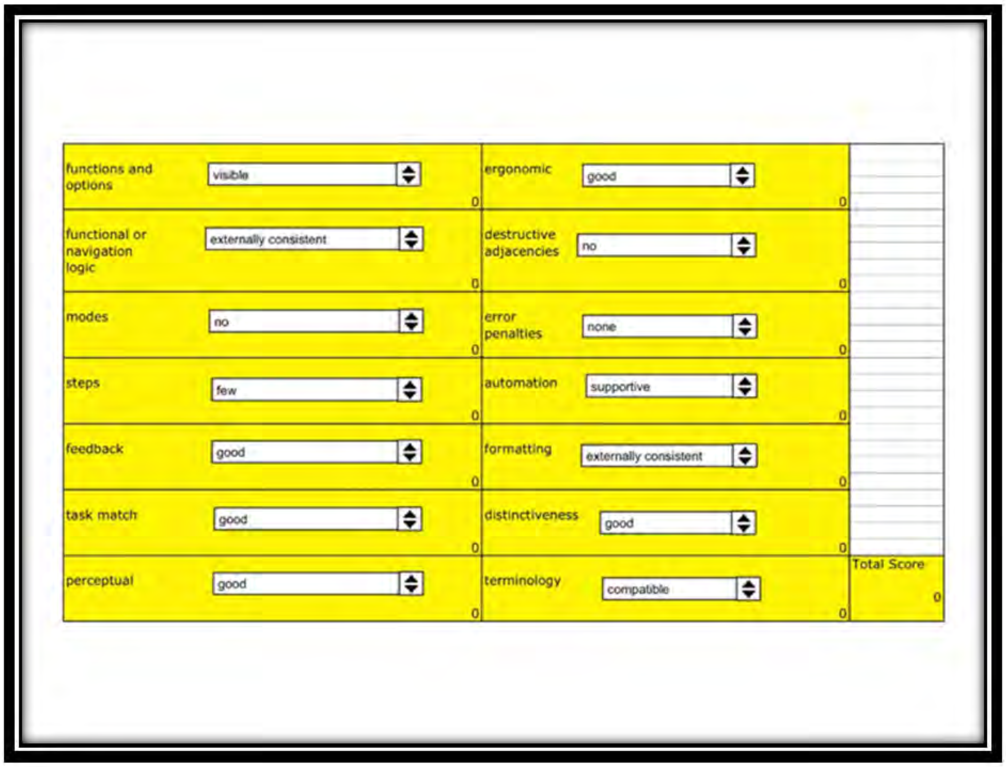
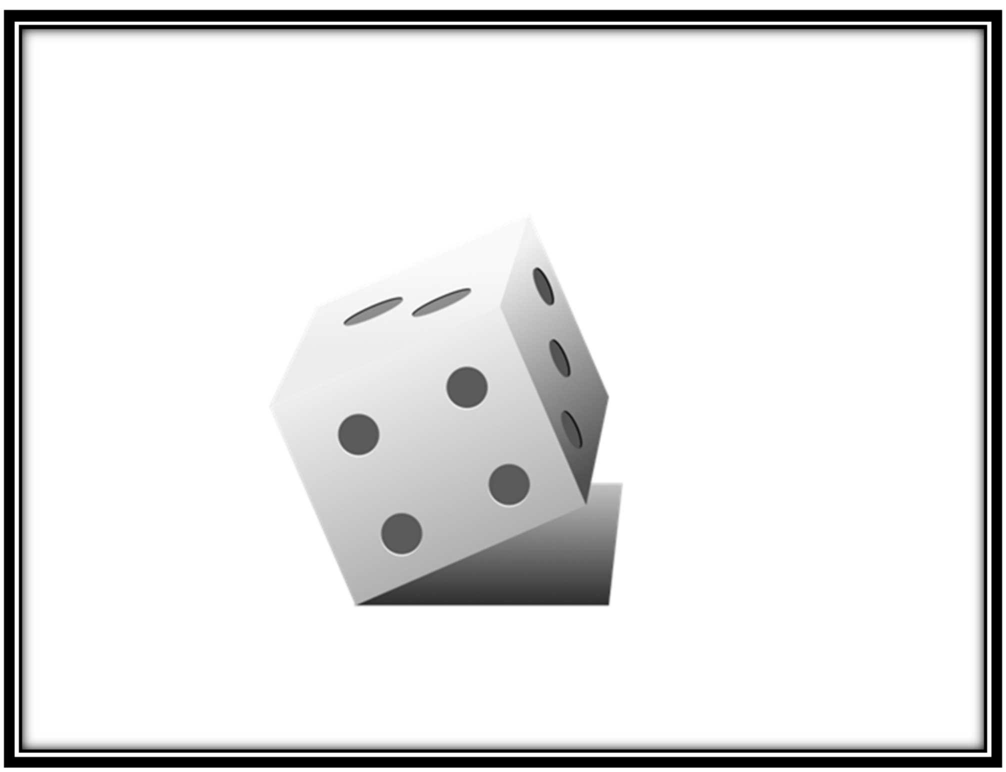

Evaluation of Cab Controls
Vic Riley

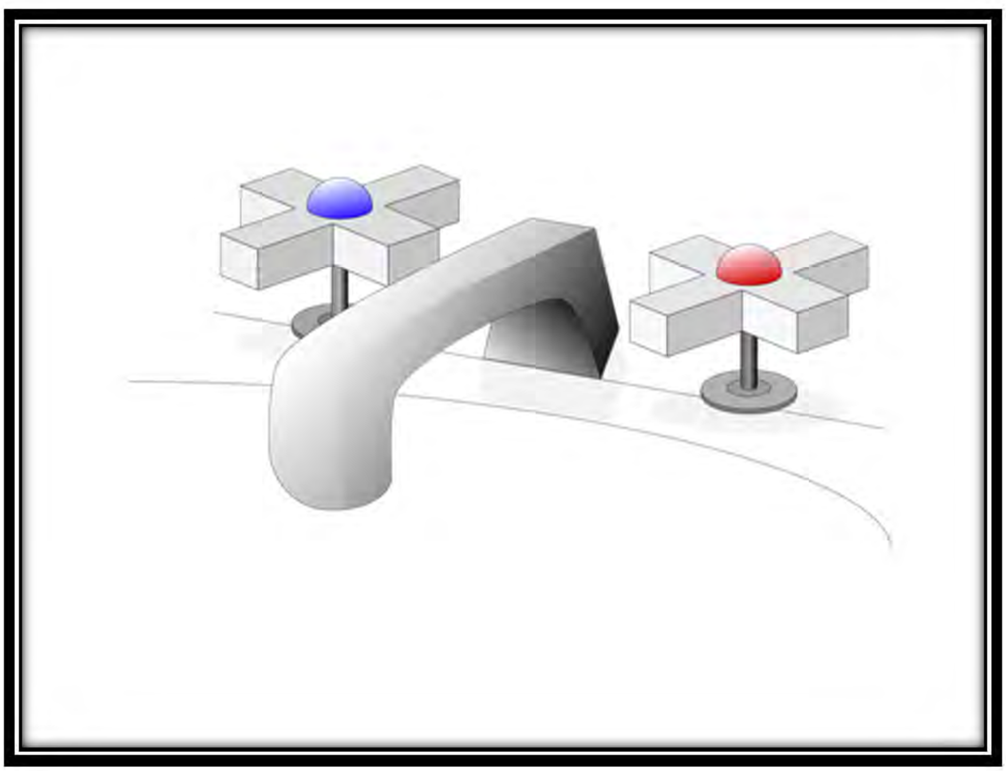

The design is only as good as the requirements,
And the requirements are only as good as the analysis.



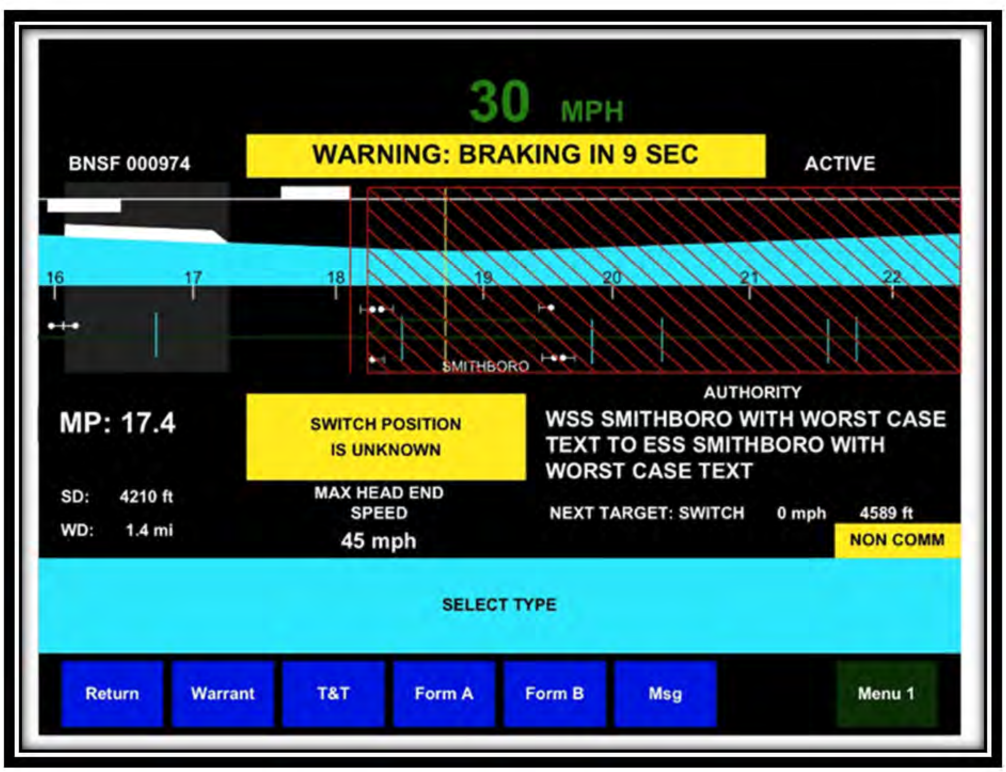
functions and options
visible
0
functional or navigation logic
externally consistent
0
modes
no
0
steps
few
0
feedback
good
0
task match
good
0
perceptual
good
0
ergonomic
good
0
destructive adjacencies
no
0
error penalties
none
0
automation
supportive
0
formatting
externally consistent
0
distinctiveness
good
0
terminology
compatible
0
Total Score
0




CISCO IP PHONE
14 10 05/16/05
23880
23880
Your current options
Redial
New Call
CFwdALL
more



The application of an expectation or habit from one design to a different design.



Screen Name	Page	key 1	key 2	key 3	key 4	key 5	key 6	key 7	key 8
main	2	DDA				acknowledge		init	menu 1
		go to new screen				acknowledge		activate function	open menu
representative	5	DDA							menu 1
		go to new screen							open menu
employee ID	T26	number	number	number	number	number	number	done	cancel
		scroll up	scroll up	scroll up	scroll up	scroll up	scroll up	done	cancel
initialization	13	DDA	proximity				departure test	init	menu 1
		go to new screen	go to new screen				activate function	activate function	open menu
initialization confirmation	15	yes							no
		yes							no
cut in/out cut out	21						consist	cut out	main
							go to new screen	activate function	go to home screen
cut in/out cut in	24						consist	cut in	main
							go to new screen	activate function	go to home screen
departure test	T33				fail test				
					no				
departure test	T34								exit
									back to prior screen
select location	T37				select location		consist	cut out	main
					go to new screen		go to new screen	activate function	go to home screen
location selection	T37	main 1	main 2	siding	clear track	cancel			
		activate function	activate function	activate function	activate function	cancel			
absolute signal	T126			access menu		received			
				open menu		yes			
absolute signal	T126	DDA	proximity	apply T&T		target prompt	depart test	init	menu 1
		go to new screen	go to new screen	go to new screen		go to new screen	activate function	activate function	open menu
DDA	37	return	warrant	T&T	form A	form B	msg		
		back to prior screen	go to new screen	go to new screen	go to new screen	go to new screen	go to new screen		
warrant	37	return	up arrow	down arrow	prev	next	accept/reject		all msg types
		back to prior screen	scroll up	scroll down	go to new screen	go to new screen	activate function		go to new screen
authority change	39					ok			
						acknowledge			
authority change	39					review			
						go to new screen			
warrant accept/rejec	39	quit		accept		reject			
		cancel		yes		no			
authority release	40	quit				release			
		cancel				activate function			
message view	44	return							all msg types
		back to prior screen							go to new screen

		FUNCTION KEY							
		1	2	3	4	5	6	7	8
1	main	DDA	0	0	0	acknowledge	0	init	menu 1
2	representative	DDA	0	0	0	0	0	0	menu 1
3	employee ID	number	number	number	number	number	number	done	cancel
4	initialization	DDA	proximity	0	0	0	departure test	init	menu 1
5	initialization	yes	0	0	0	0	0	0	no
6	cut in/out	0	0	0	0	0	consist	cut out	main
7	cut in/out	0	0	0	0	0	consist	cut in	main
8	departure test	0	0	0	fail test	0	0	0	0
9	departure test	0	0	0	0	0	0	0	exit
10	select location	0	0	0	select location	0	consist	cut out	main
11	location selection	main 1	main 2	siding	clear track	cancel	0	0	0
12	absolute signal	0	0	access menu	0	received	0	0	0
13	absolute signal	DDA	proximity	apply T&T	0	target prompt	depart test	init	menu 1
14	DDA	return	warrant	T&T	form A	form B	msg	0	0
15	warrant	return	up arrow	down arrow	prev	next	accept/reject	0	all msg types
16	authority change	0	0	0	0	ok	0	0	0
17	authority change	0	0	0	0	review	0	0	0
18	warrant accept/reject	quit	0	accept	0	reject	0	0	0
19	authority release	quit	0	0	0	release	0	0	0
20	message view	return	0	0	0	0	0	0	all msg types
21	end of authority	0	0	0	0	received	0	0	0
22	manual switch	0	0	0	0	acknowledge	0	0	0
23	switch position	0	0	main	siding	other	0	0	0
24	switch position	0	0	0	0	verified	0	0	0
25	end of authority	0	0	0	0	arrived	0	0	0
26	track and time 2	DDA	proximity	apply T&T	0	0	departure test	init	menu 1
27	speed test	0	0	0	0	speed test	consist	cut in	main
28	speed test	quit	0	0	down arrow	0	up arrow	0	0
29	work zone	0	0	access menu	0	received	0	0	0
30	work zone	DDA	proximity	0	0	target prompt	0	0	menu 1

Location

Shape

Size

Color

Action

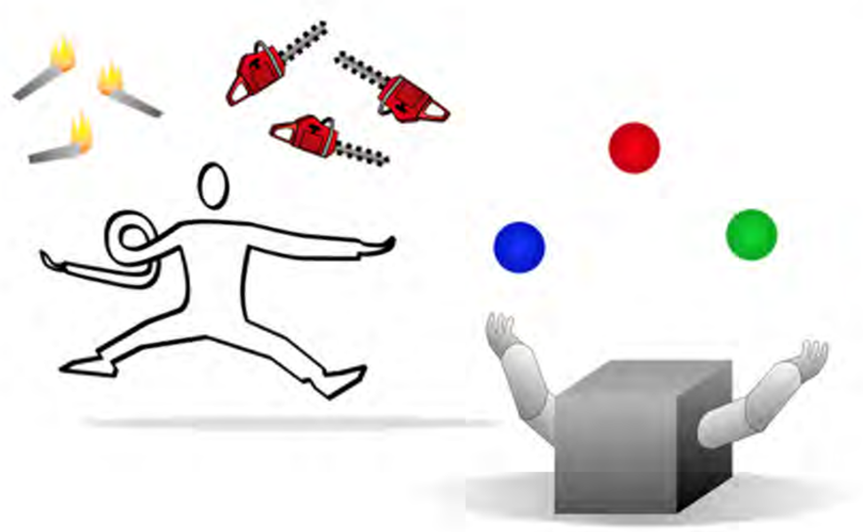
Consequences

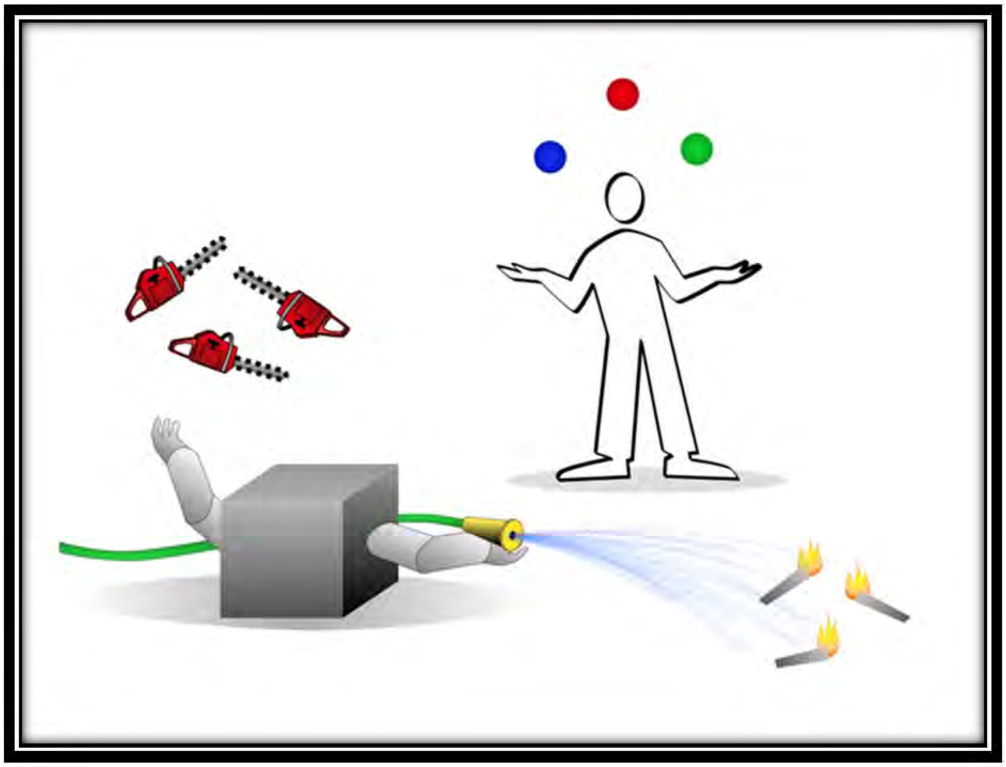
Feedback

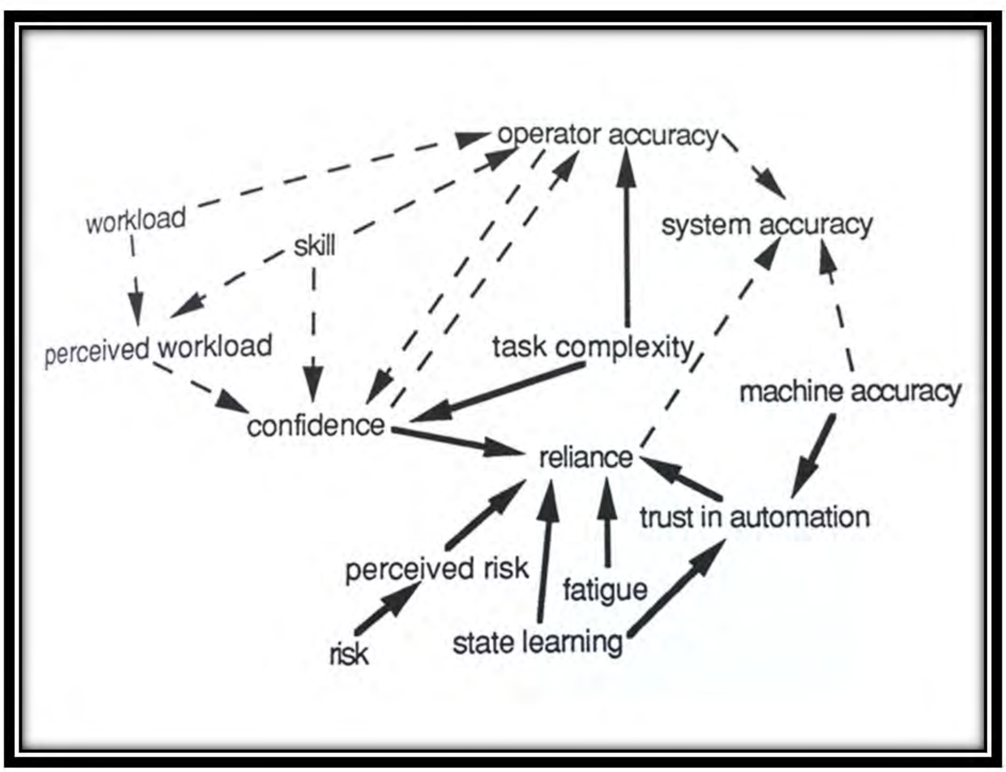
Recovery

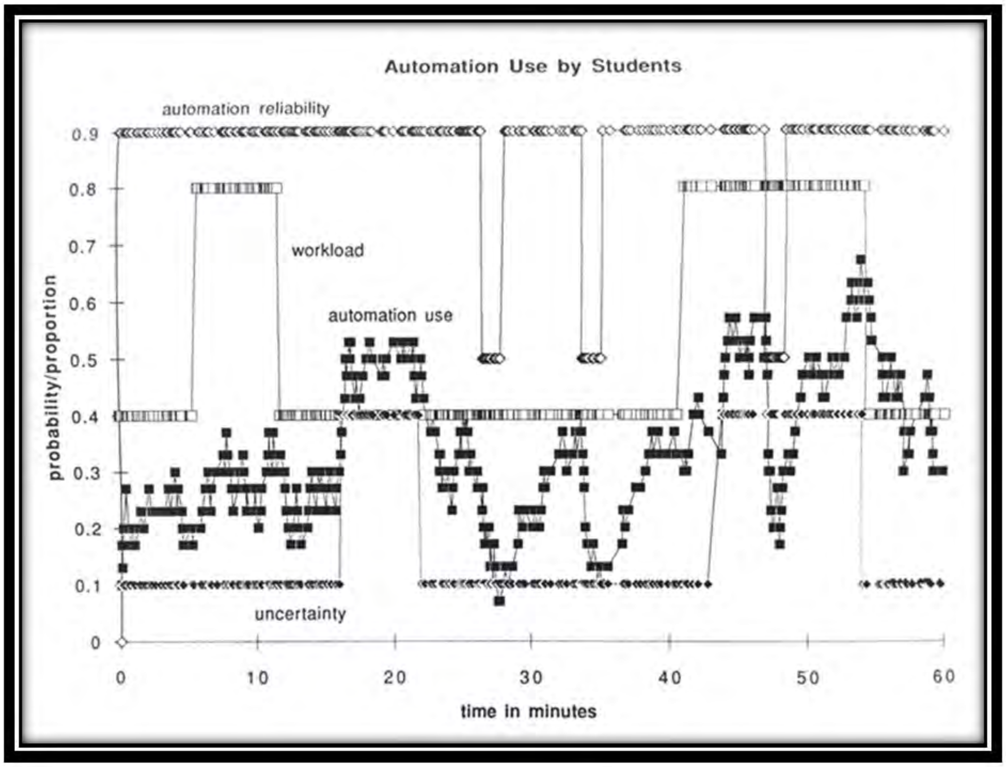
Automation and Workload

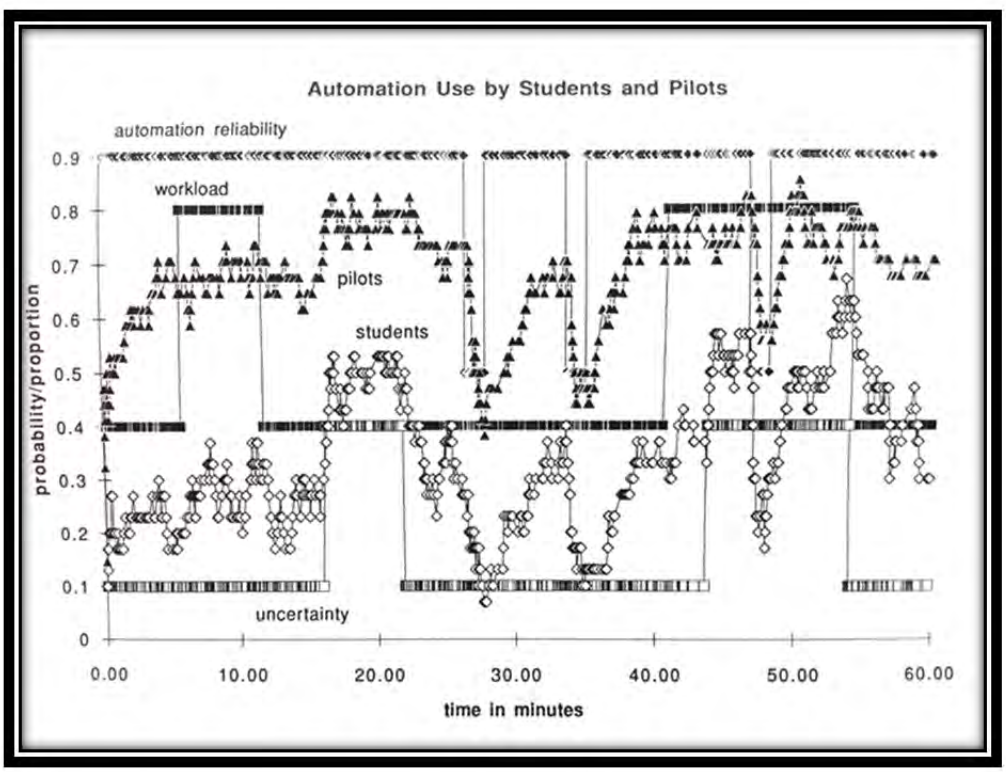
Vic Riley

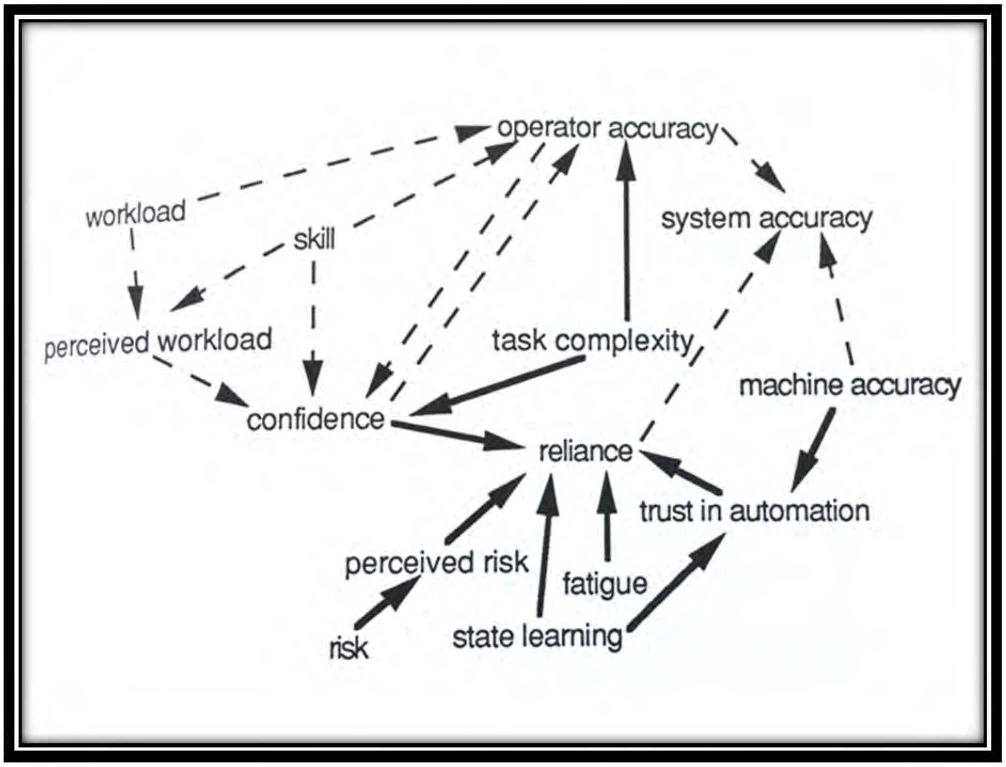


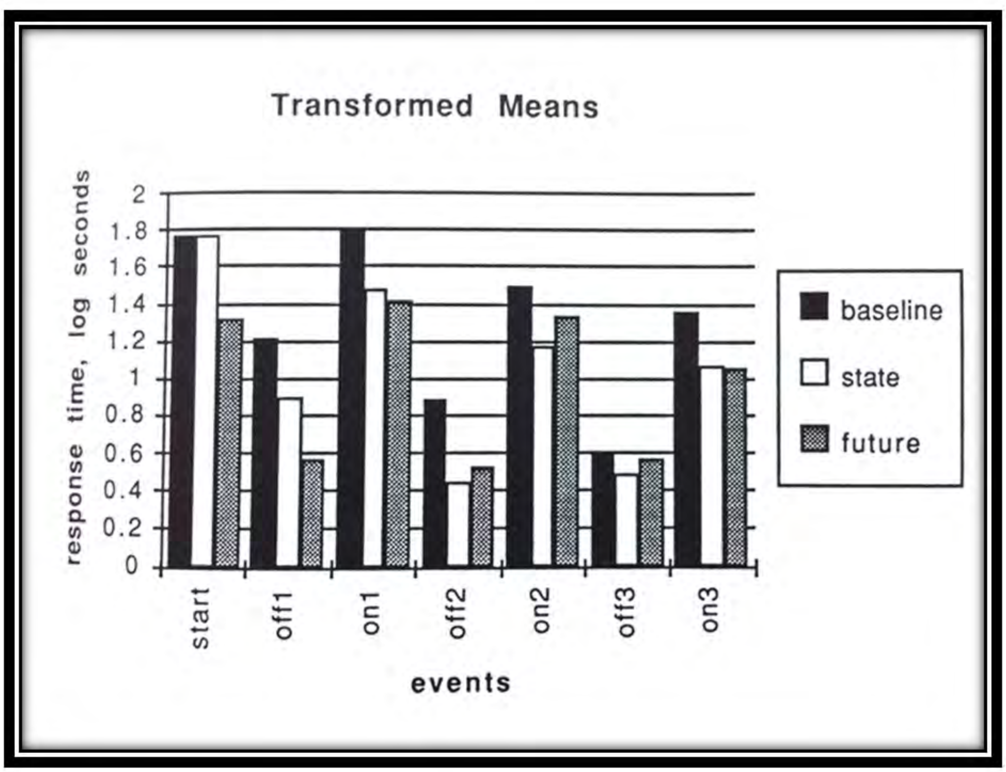


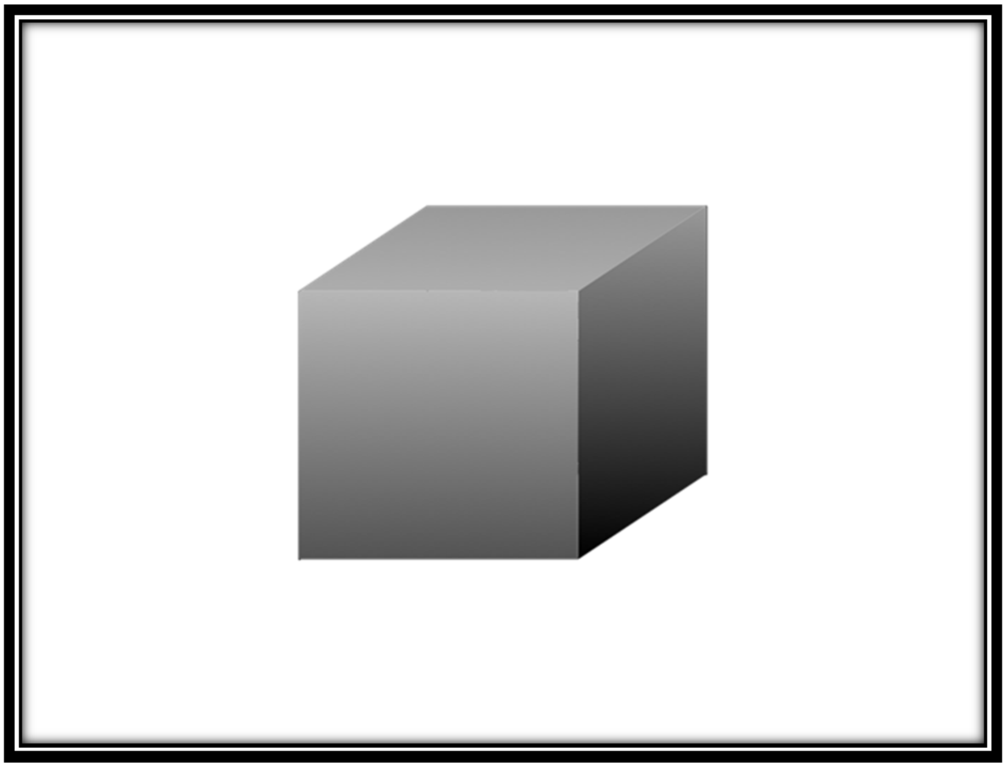

operator accuracy
workload
skill
system accuracy
perceived workload
task complexity
machine accuracy
confidence
reliance
trust in automation
perceived risk
fatigue
risk
state learning

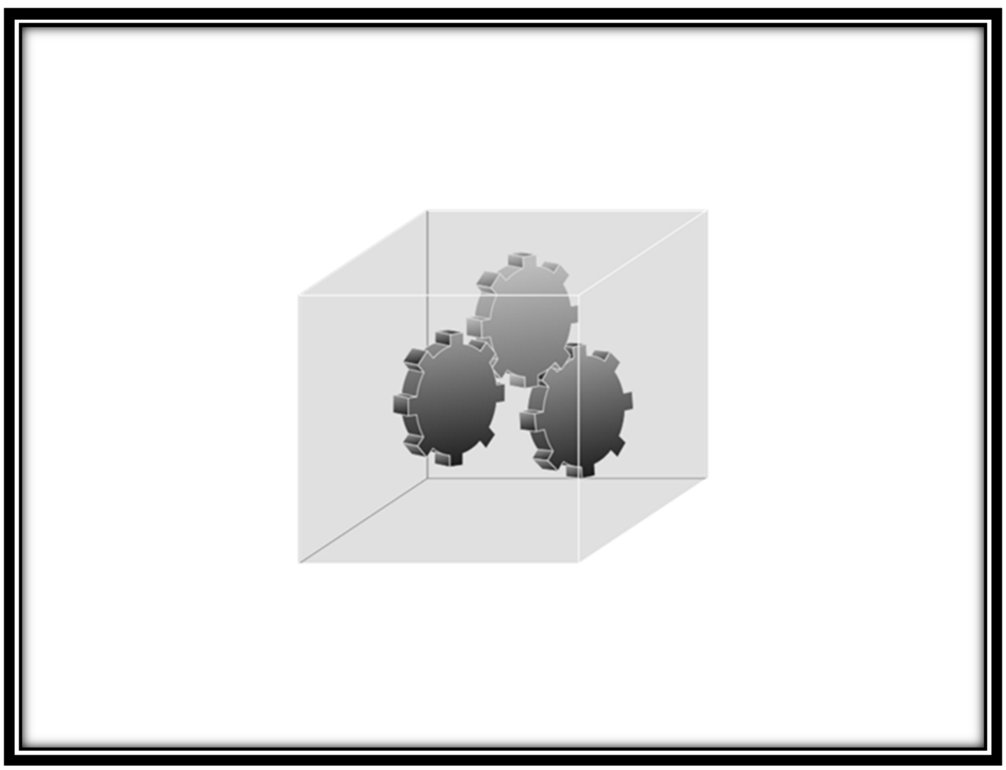

Automation Use by Students
automation reliability
workload
automation use
uncertainty
probability/proportion
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
time in minutes

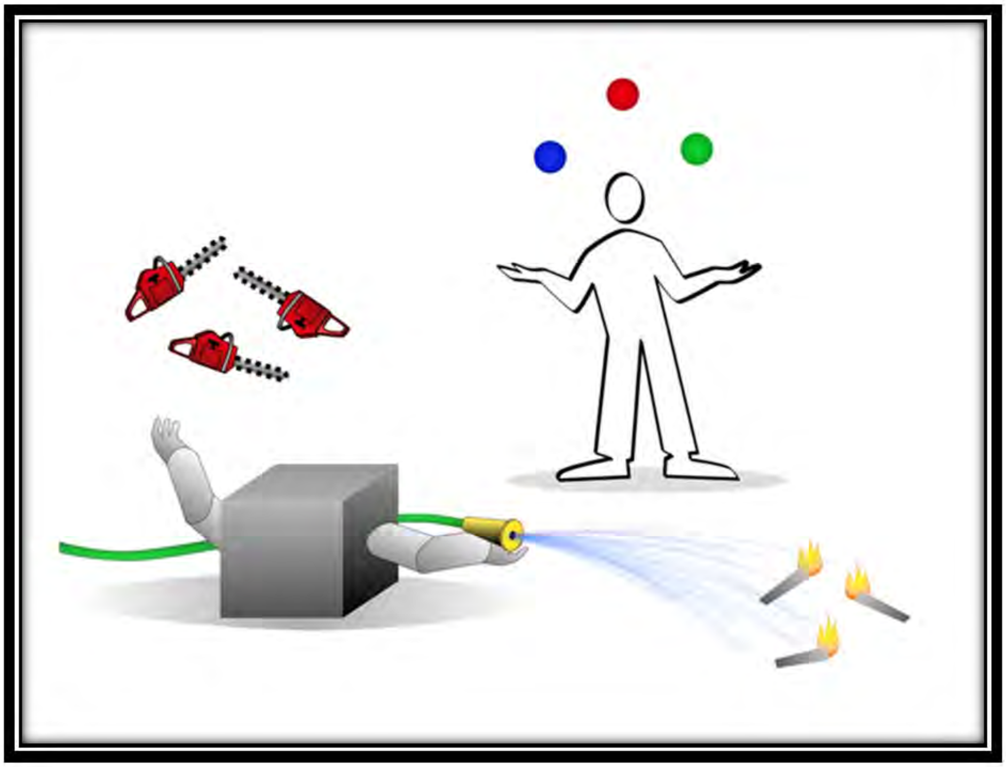

Automation Use by Students and Pilots
automation reliability
workload
pilots
students
uncertainty
probability/proportion
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.00
10.00
20.00
30.00
40.00
50.00
60.00
time in minutes


operator accuracy
workload
skill
system accuracy
perceived workload
task complexity
machine accuracy
confidence
reliance
trust in automation
perceived risk
fatigue
risk
state learning


Transformed Means
response time, log seconds
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
start
off1
on1
off2
on2
off3
on3
events
baseline
state
future

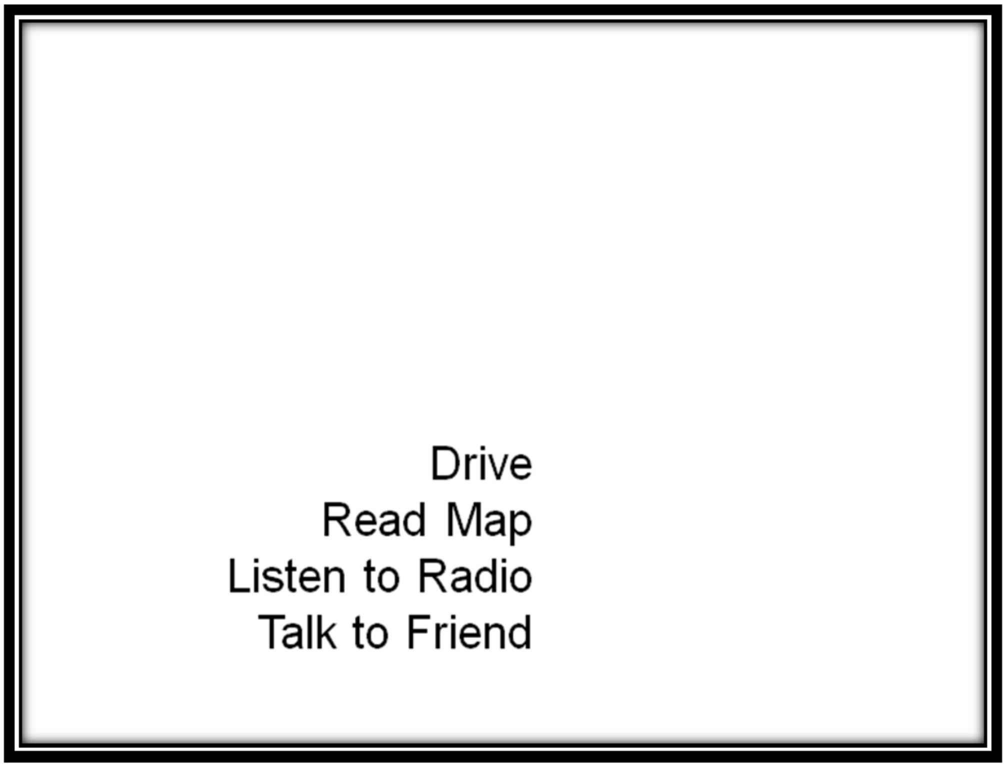


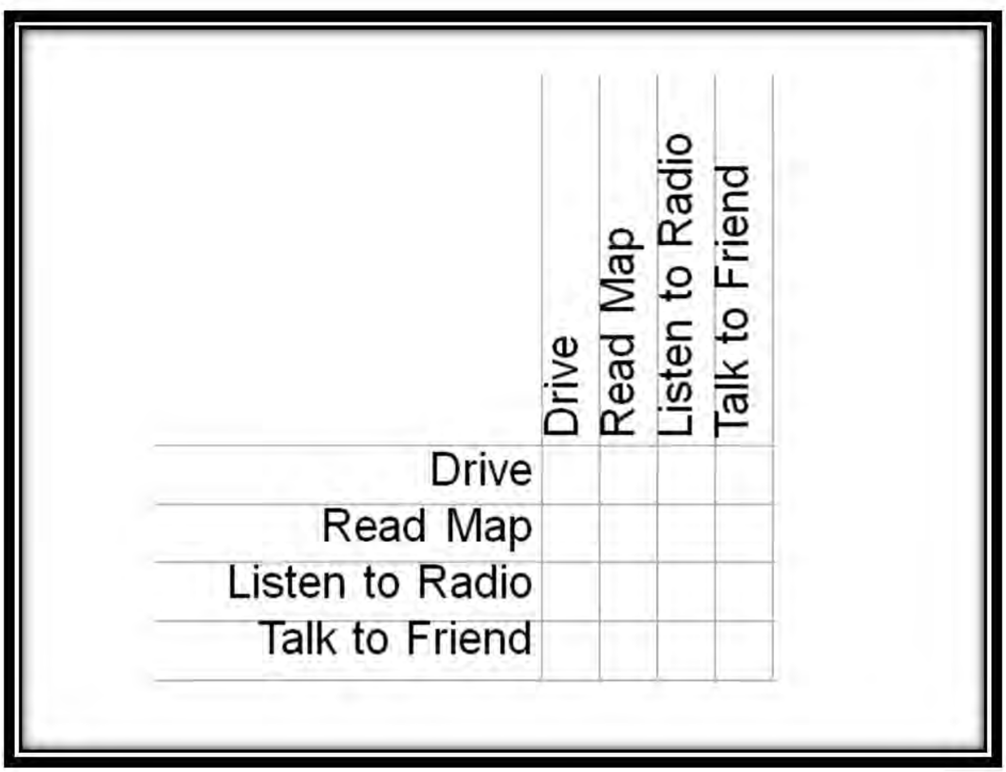




Time Required

Time Available


Drive
Read Map
Listen to Radio
Talk to Friend


Drive
Read Map
Listen to Radio
Talk to Friend
Drive
Read Map
Listen to Radio
Talk to Friend

	Drive	Read Map	Listen to Radio	Talk to Friend
Drive			✓	
Read Map				
Listen to Radio				
Talk to Friend				

	Drive	Read Map	Listen to Radio	Talk to Friend
Drive		✗	✓	
Read Map				
Listen to Radio				
Talk to Friend				

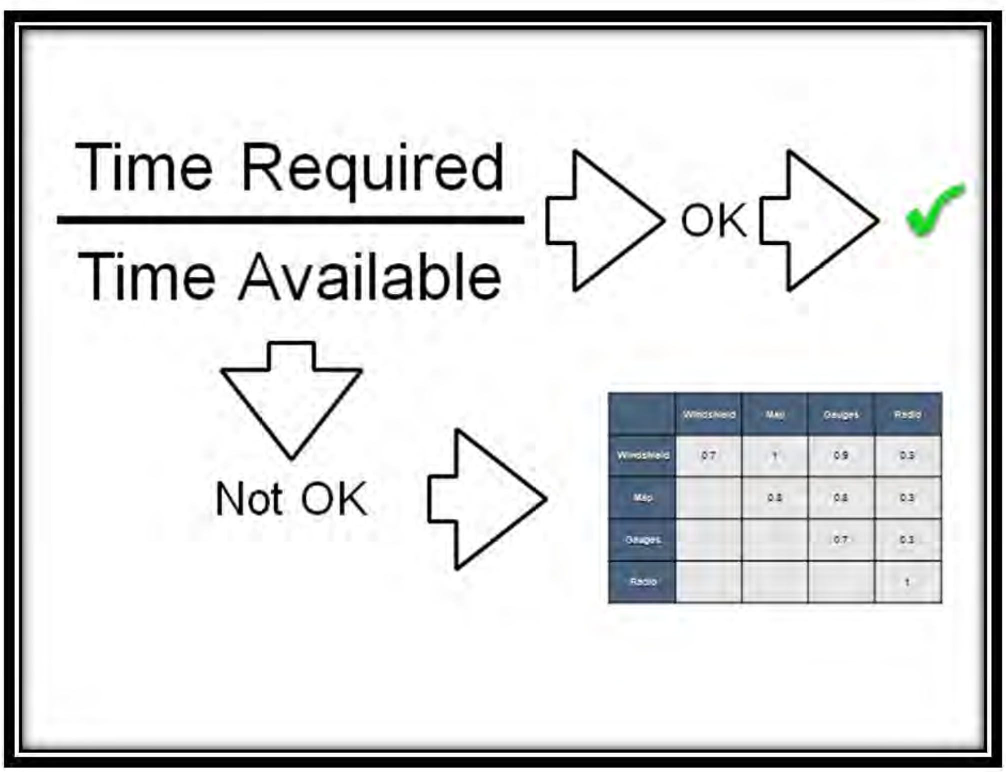
	Drive	Read Map	Listen to Radio	Talk to Friend
Drive		✗	✓	✓
Read Map				
Listen to Radio				
Talk to Friend				

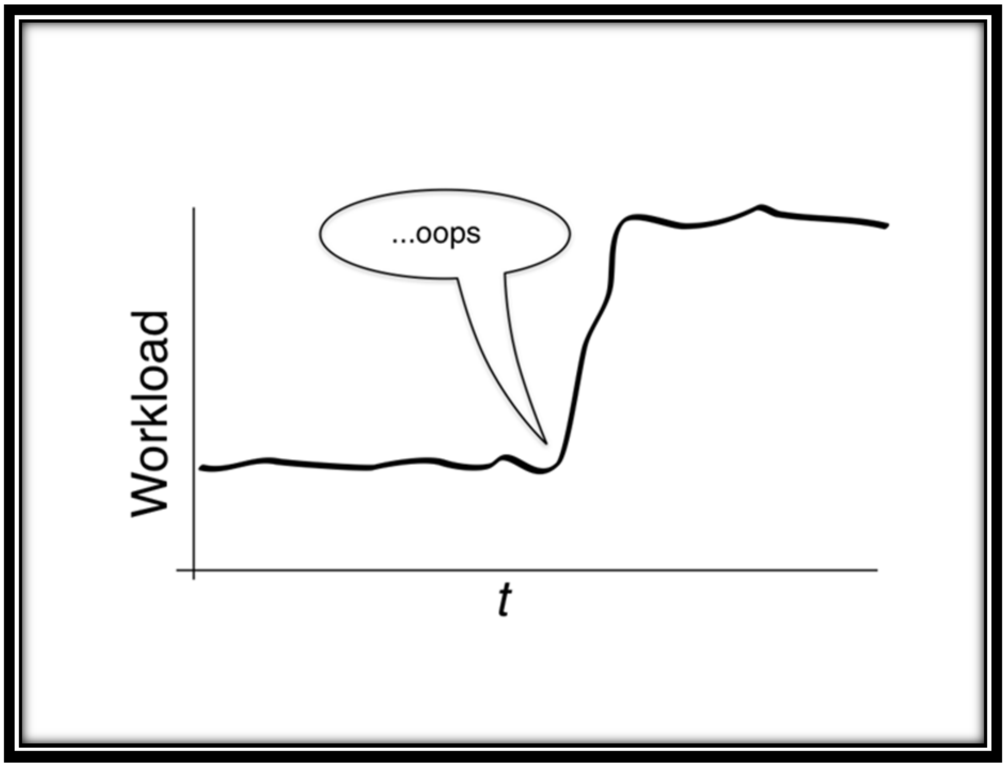
	Drive	Read Map	Listen to Radio	Talk to Friend
Drive		✗	✓	✓
Read Map				
Listen to Radio				✗
Talk to Friend				

	Drive	Read Map	Listen to Radio	Talk to Friend
Drive		✗	✓	✗
Read Map				
Listen to Radio				✗
Talk to Friend				

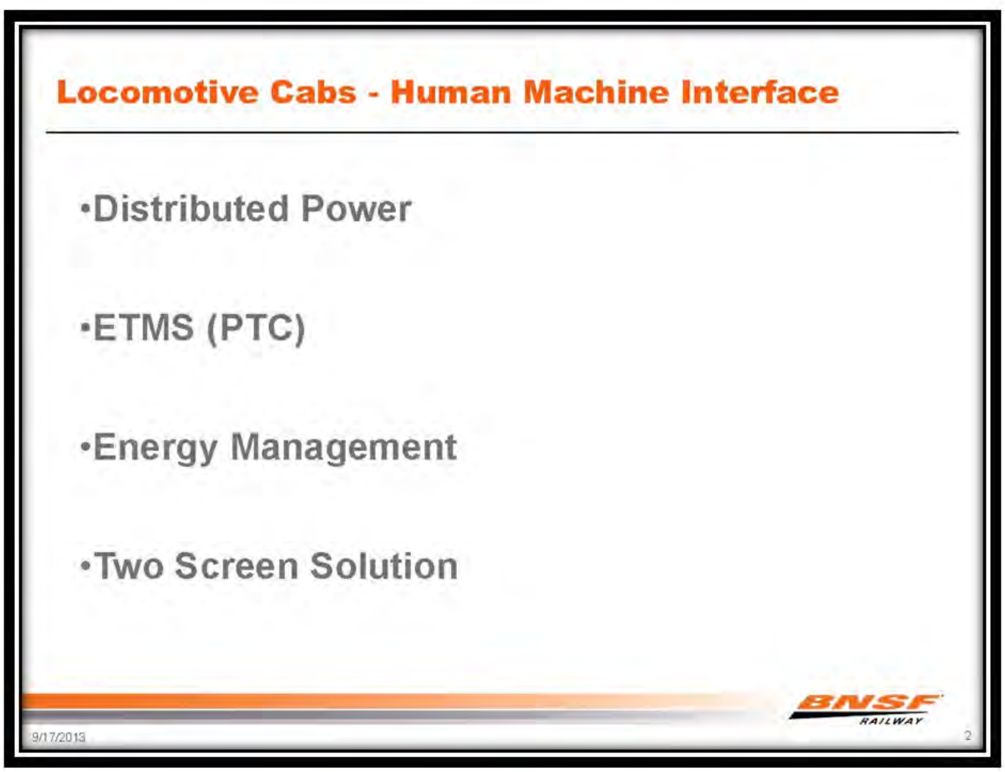
	Eyes	Ears	Speech	Right Hand	Left Hand	Right Foot	Left Foot	Cognitive
Eyes	.7-.9	.4-.6	.1-.3	.1-.3	.1-.3	.1-.3	.1-.3	.6-.8
Ears		.7-.9	.7-.9	.1-.3	.1-.3	.1-.3	.1-.3	.6-.8
Speech			1	.4-.6	.4-.6	.4-.6	.4-.6	.6-.8
Right Hand				1	0.8	0.8	0.8	.6-.8
Left Hand					1	0.8	0.8	.6-.8
Right Foot						1	0.8	.6-.8
Left Foot							1	.6-.8
Cognitive								.7-1

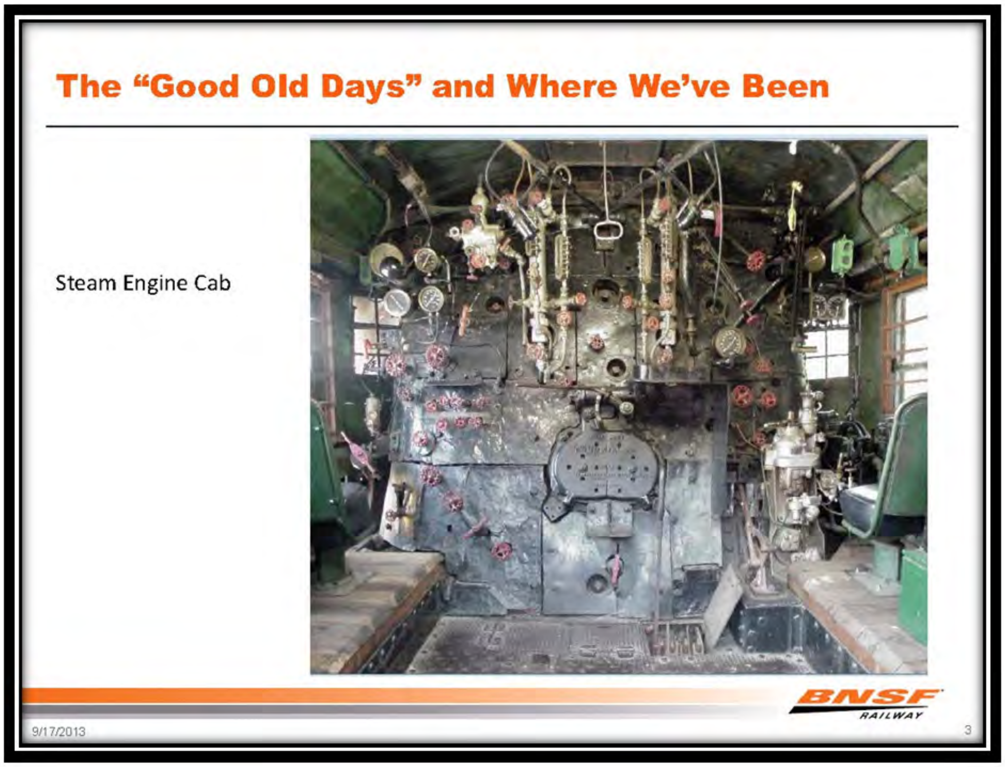
	Windshield	Map	Gauges	Radio
Windshield	0.7	1	0.9	0.3
Map		0.8	0.8	0.3
Gauges			0.7	0.3
Radio				1

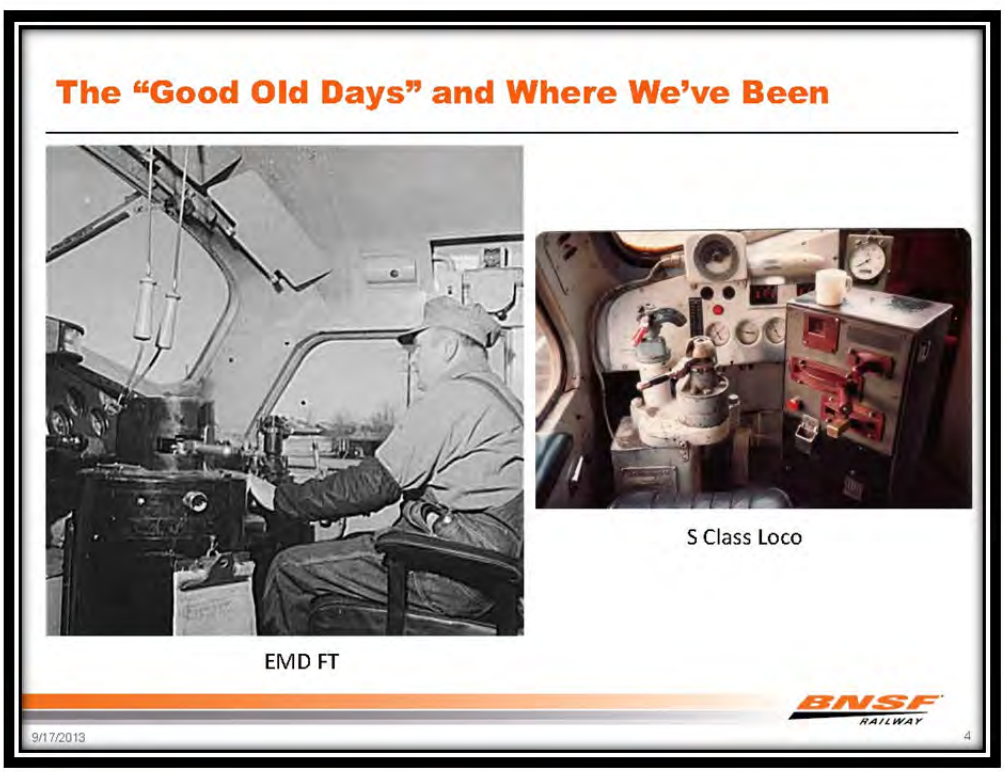



...oops
Workload
t


Distributed Power, ETMS and Energy Mgmt. Usage on BNSF Railway
Aaron Ratledge – Director Operating Practices
Omaha TRB Midyear Meeting – July 2013
BNSF RAILWAY
9/17/2013
1


Locomotive Cabs - Human Machine Interface
•Distributed Power
•ETMS (PTC)
•Energy Management
•Two Screen Solution
BNSF RAILWAY
9/17/2013
2


The "Good Old Days" and Where We've Been
Steam Engine Cab
BNSF RAILWAY
9/17/2013
3


The "Good Old Days" and Where We've Been
S Class Loco
EMD FT
BNSF RAILWAY
9/17/2013
4

The "Good Old Days" and Where We've Been

Early GP Locomotives

9/17/2013 5

Distributed Power

Locotrol II (RCE) – ATSF's U36C

'Master' and 'Receiver' Designated Locomotives

9/17/2013 6

Distributed Power

Early 90's DASH9

Before Locotrol III DP

Locotrol III - DASH9-44CW

- GE Harris Box
- Used as lead or DP remote

Locotrol III - DASH9-44CW

- System Module
- “Thumbwheel” and circuit breakers in nose of Locomotive

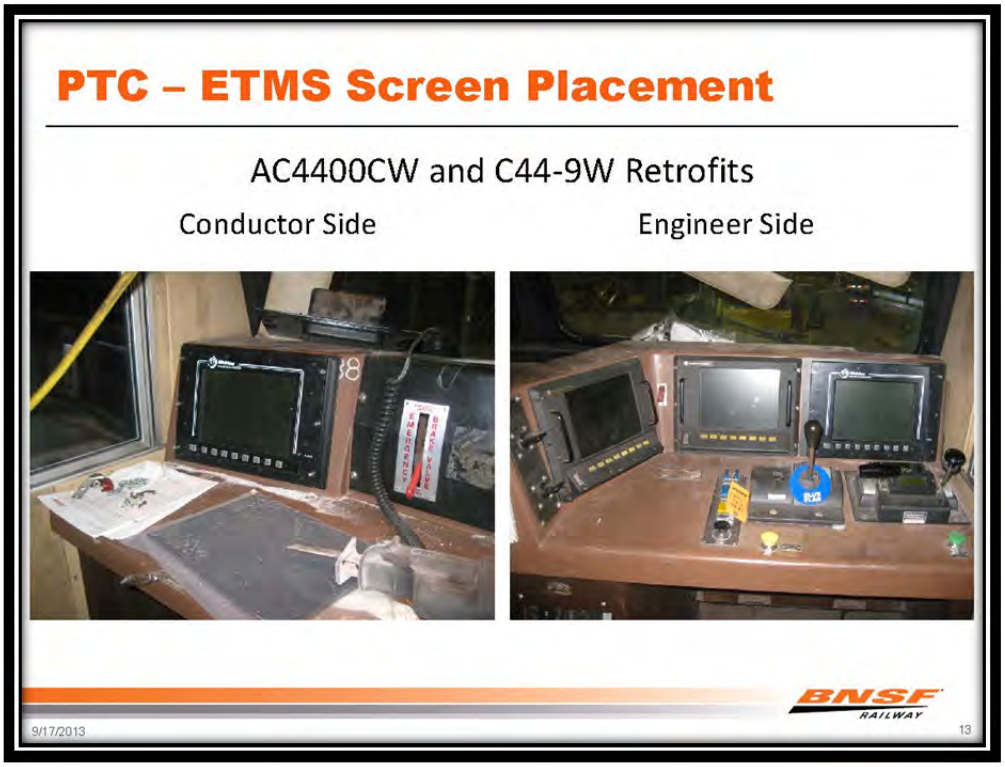
C44DASH9 – Integrated DP (IDP)

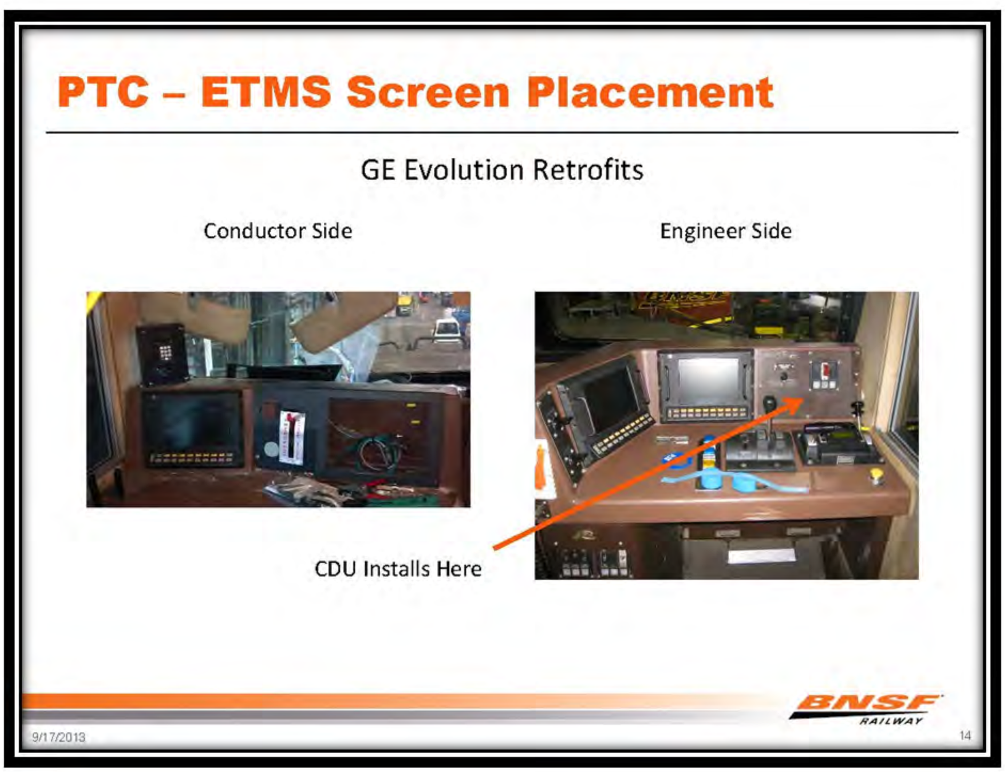
- GE HARRIS BOX Comes off control stand
- System Module ‘Integrated’ into IFC screen
- Engineer has choice for DP control on either screen

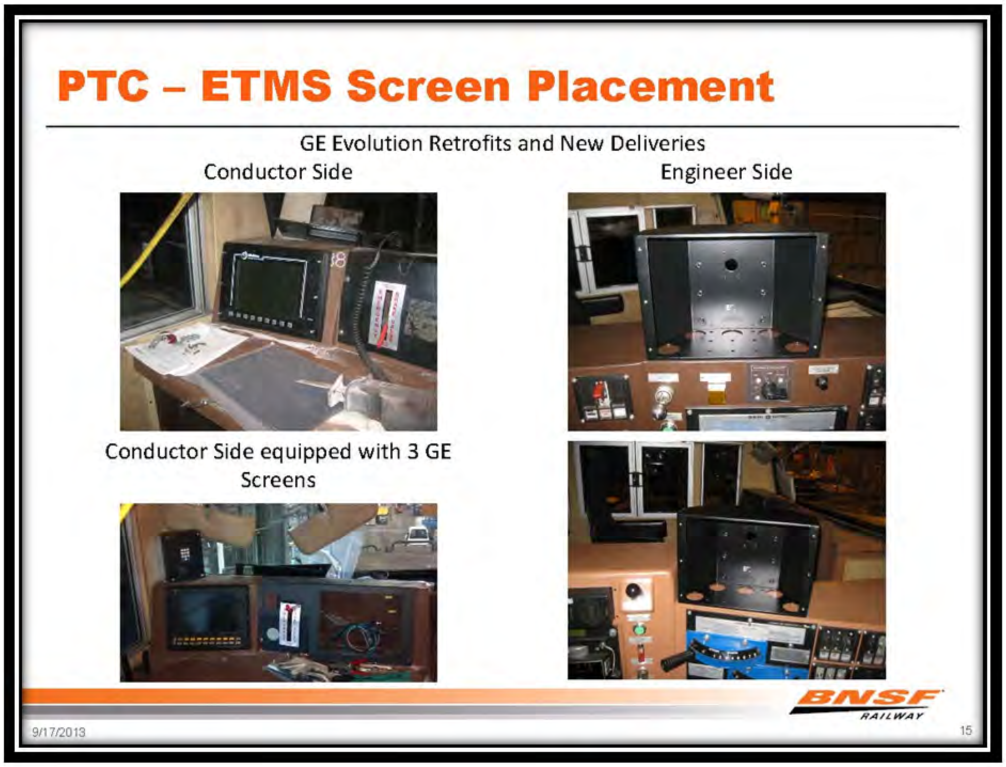
GE's ES44DC/AC – Integrated DP (IDP)

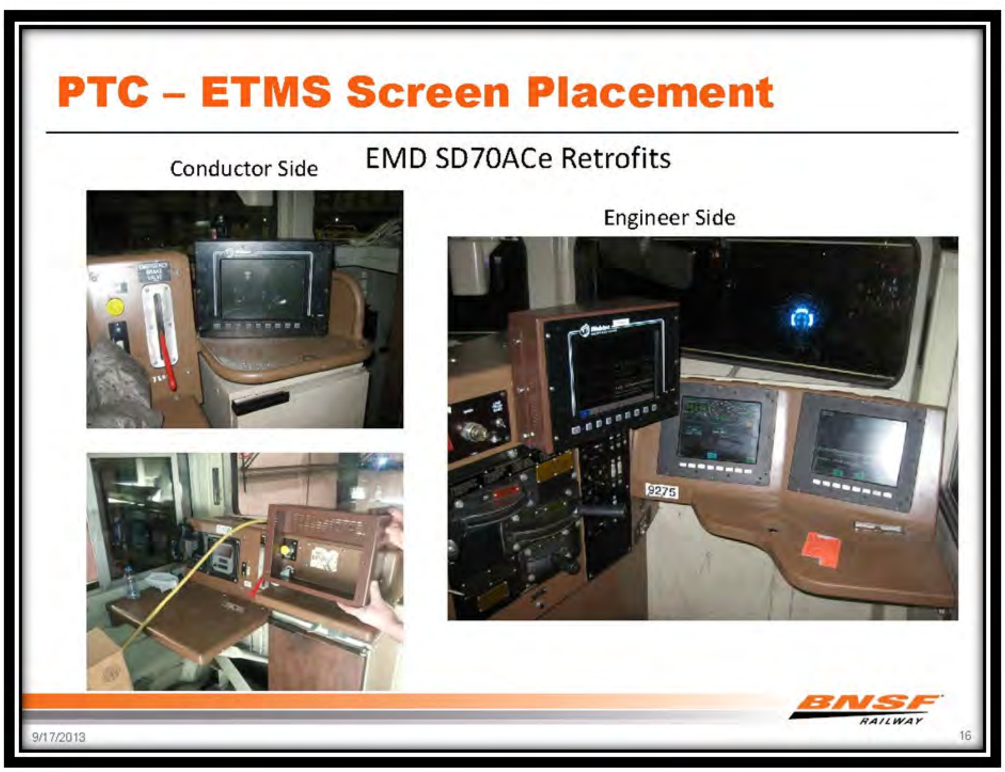
Engineer has choice:
- Right or left screen
- DP Control
- DP Combined

EMD's SD70ACe – Integrated DP (IDP)

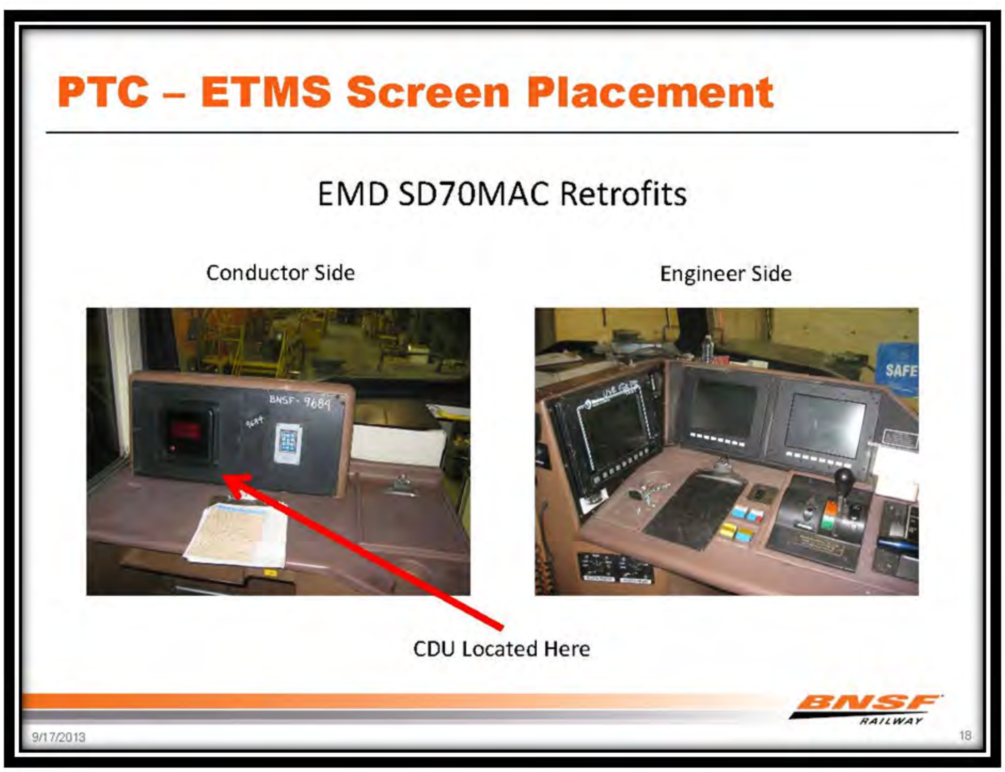

PTC – ETMS Screen Placement
AC4400CW and C44-9W Retrofits
Conductor Side
Engineer Side
BNSF RAILWAY
9/17/2013
13


PTC – ETMS Screen Placement
GE Evolution Retrofits
Conductor Side
Engineer Side
CDU Installs Here
BNSF RAILWAY
9/17/2013
14


PTC – ETMS Screen Placement
GE Evolution Retrofits and New Deliveries
Conductor Side
Engineer Side
Conductor Side equipped with 3 GE Screens
BNSF RAILWAY
9/17/2013
15


PTC – ETMS Screen Placement
Conductor Side
EMD SD70ACe Retrofits
Engineer Side
9275
BNSF RAILWAY
9/17/2013
16


PTC – ETMS Screen Placement
EMD SD70ACe New Delivery
VETMS
2012
BNSF RAILWAY
9/17/2013
17


PTC – ETMS Screen Placement
EMD SD70MAC Retrofits
Conductor Side
Engineer Side
CDU Located Here
BNSF RAILWAY
9/17/2013
18

PTC – ETMS Screen Placement

EMD SD60 Retrofits

BNSF RAILWAY

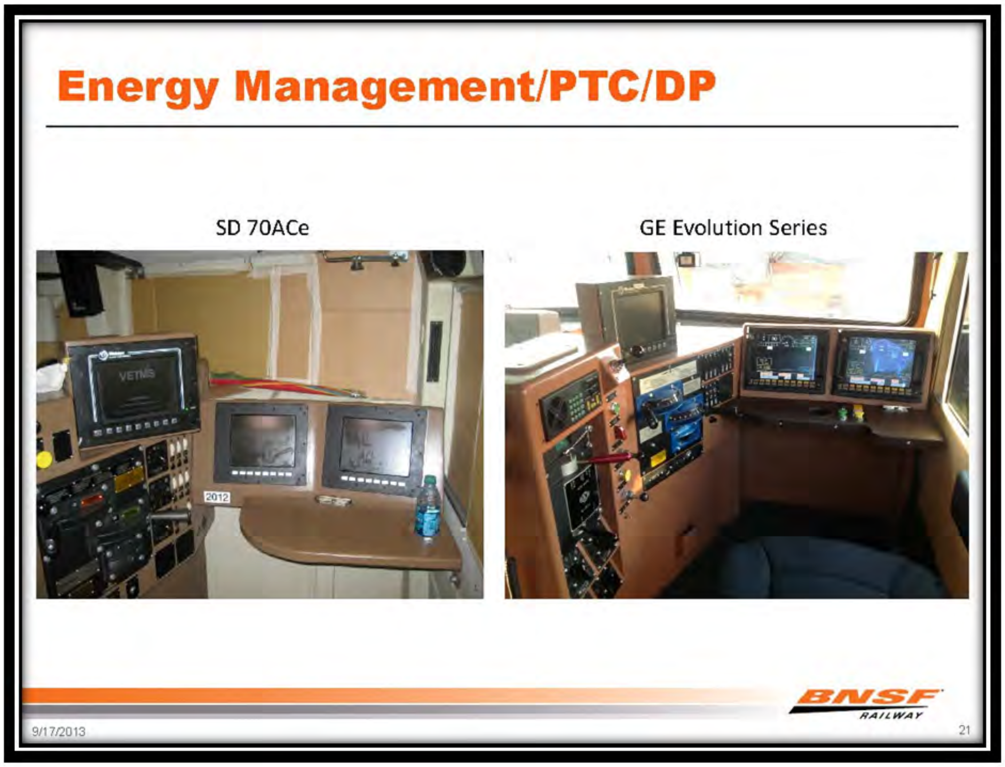
9/17/2013 19

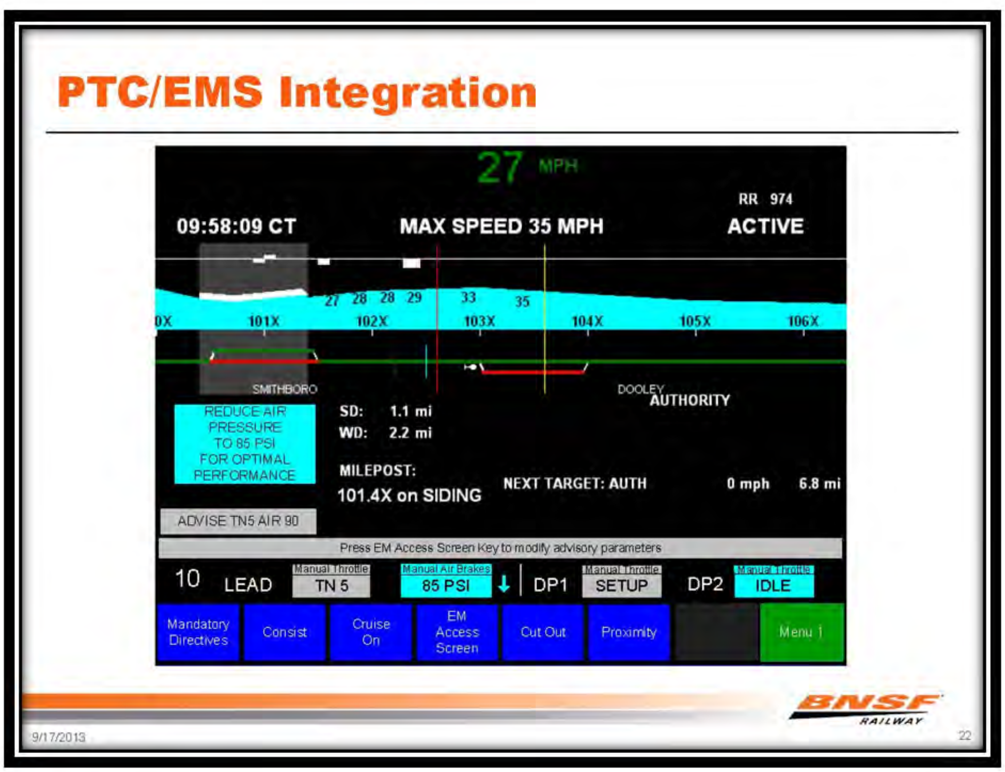
PTC – ETMS Screen Placement

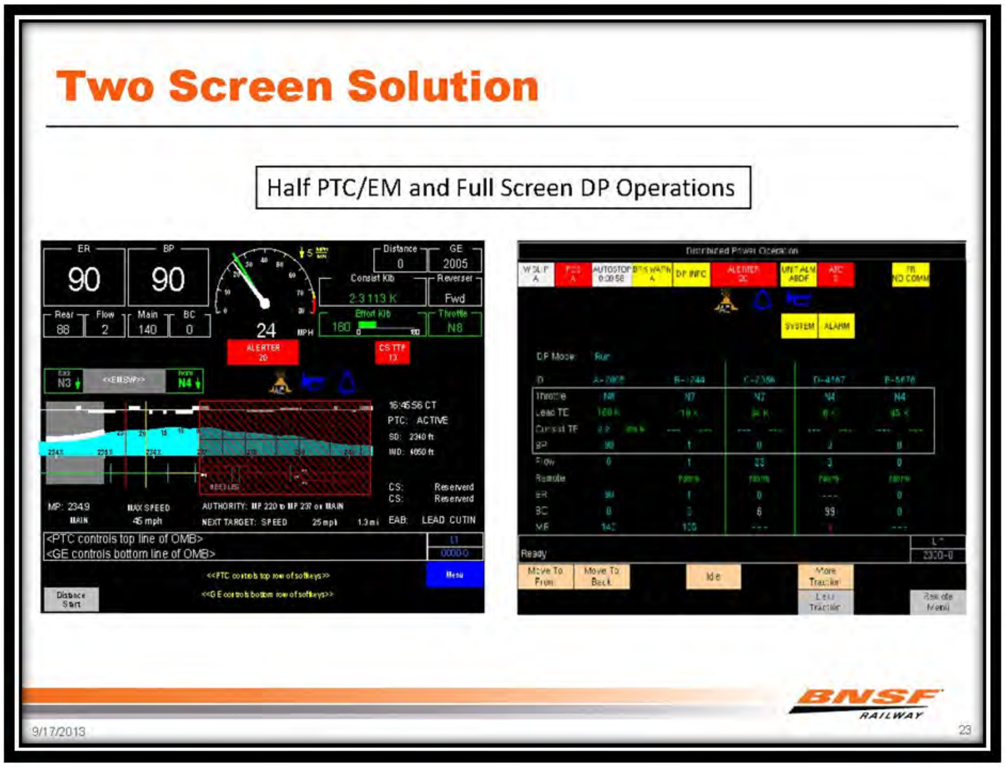
EMD Dash 2 Retrofits Conductor Side

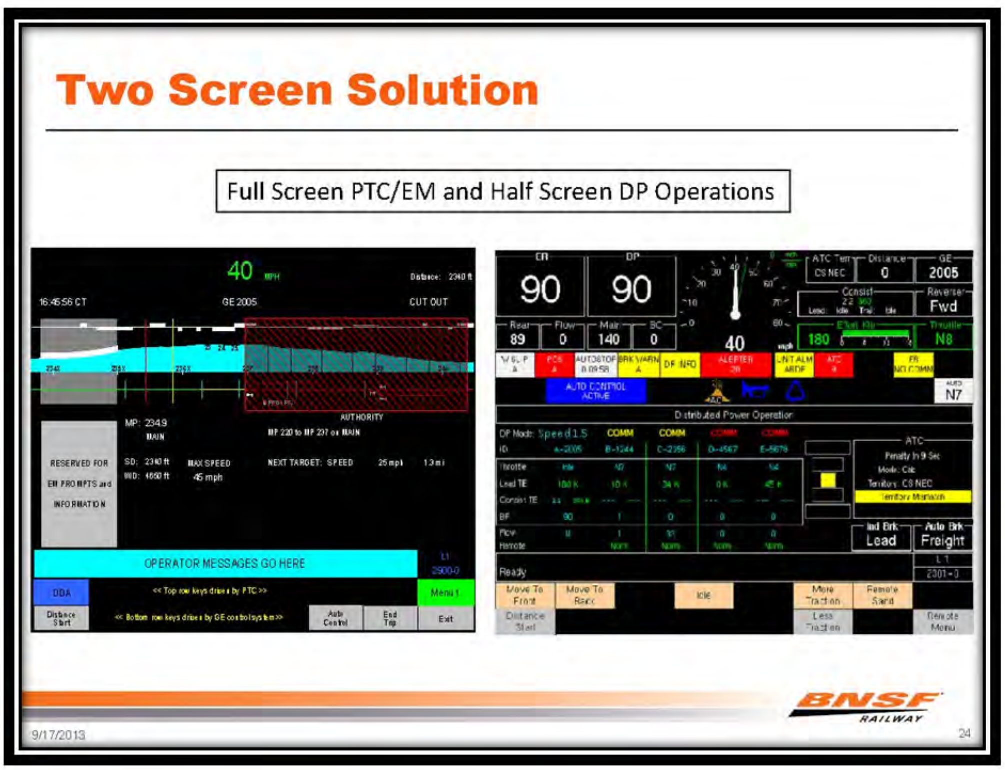
BNSF RAILWAY

9/17/2013 20


Energy Management/PTC/DP
SD 70ACe
GE Evolution Series
VETMS
2012
BNSF RAILWAY
9/17/2013
21


PTC/EMS Integration
27 MPH
RR 974
09:58:09 CT
MAX SPEED 35 MPH
ACTIVE
27 28 28 29 33 35
0X 101X 102X 103X 104X 105X 106X
SMITHBORO
DOOLEY
AUTHORITY
REDUCE AIR PRESSURE TO 85 PSI FOR OPTIMAL PERFORMANCE
SD: 1.1 mi
WD: 2.2 mi
MILEPOST:
101.4X on SIDING
NEXT TARGET: AUTH
0 mph
6.8 mi
ADVISE TN5 AIR 90
Press EM Access Screen Key to modify advisory parameters
10
LEAD
Manual Throttle
TN 5
Manual Air Brakes
85 PSI
DP1
Manual Throttle
SETUP
DP2
Manual Throttle
IDLE
Mandatory Directives
Consist
Cruise On
EM Access Screen
Cut Out
Proximity
Menu 1
BNSF RAILWAY
9/17/2013
22


Two Screen Solution
Half PTC/EM and Full Screen DP Operations
9/17/2013
23


Two Screen Solution
Full Screen PTC/EM and Half Screen DP Operations
9/17/2013
24


BNSF System Cab Committee
BNSF
RAILWAY
9/17/2013
25

Development and Evaluation of Locomotive Moving Map and Planning Displays

Kathleen Voelbel, Andrew M. Liu and Charles M. Oman

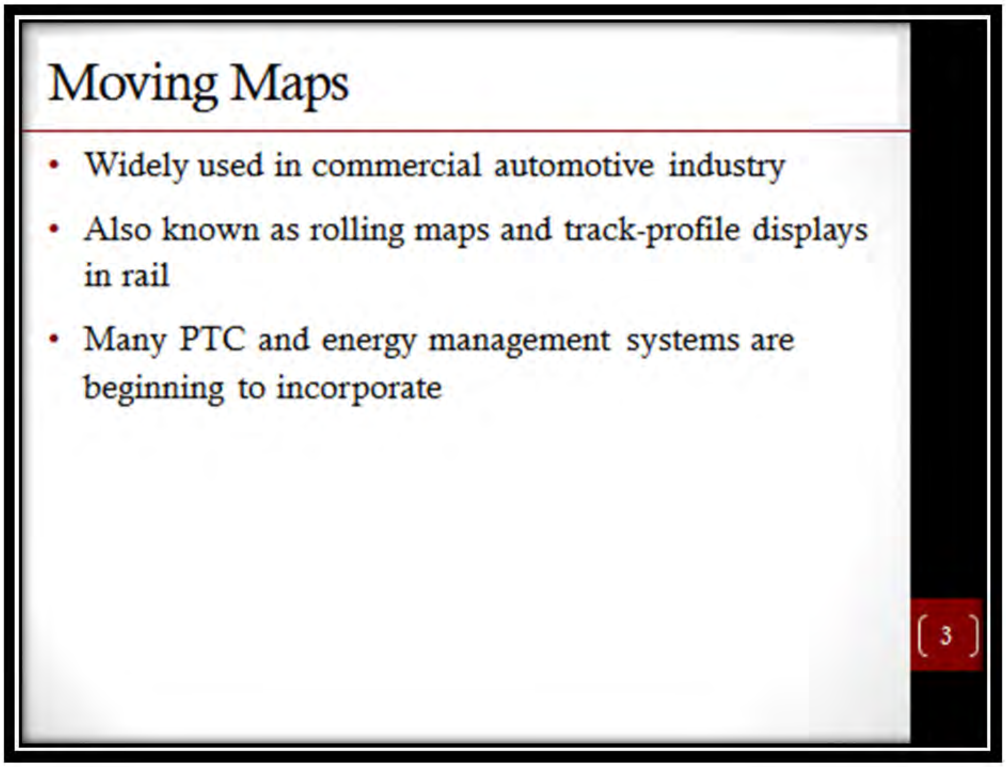
MIT Humans and Automation Laboratory (HAL)

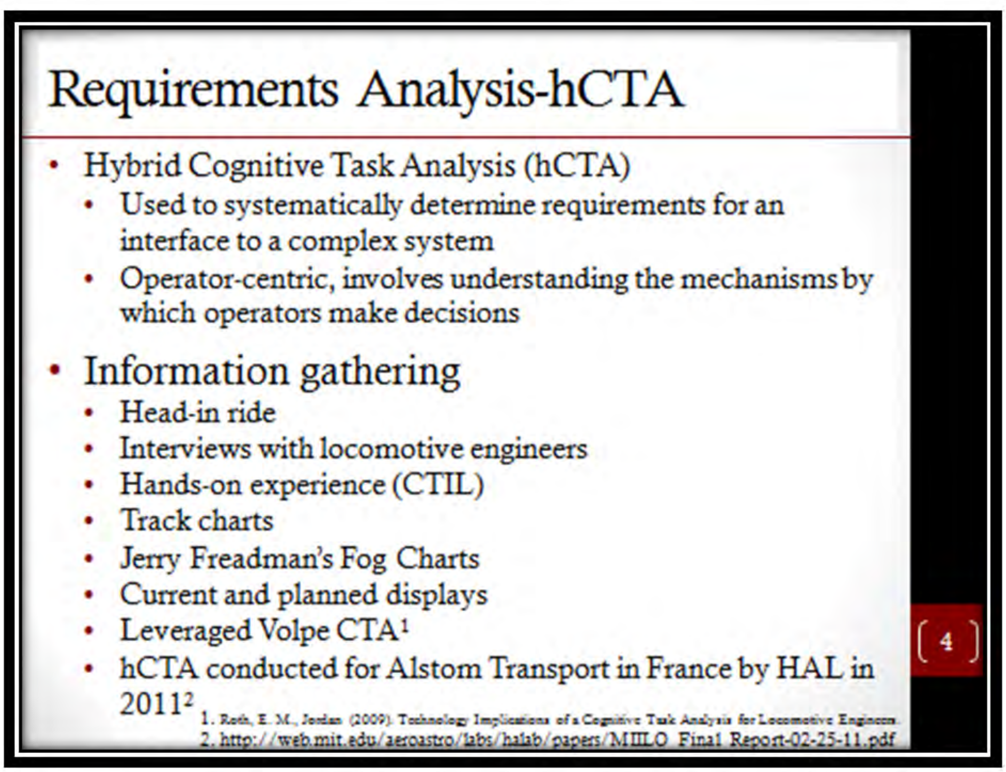
Research supported by FRA Contract DTFR53-11-C-00016

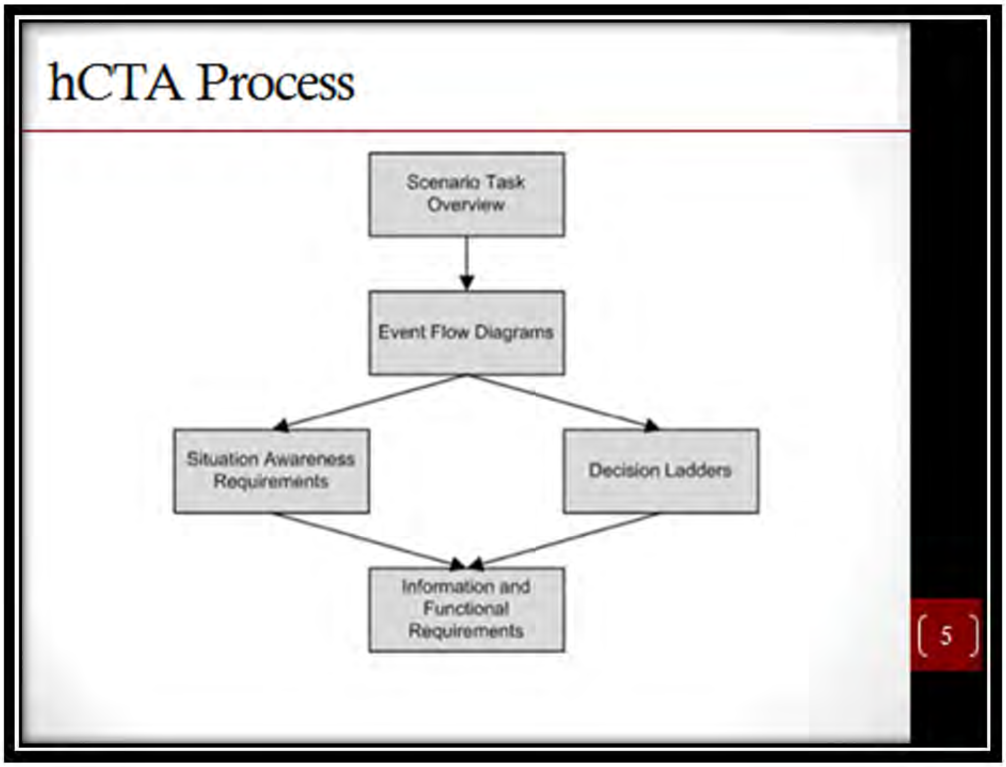
Agenda

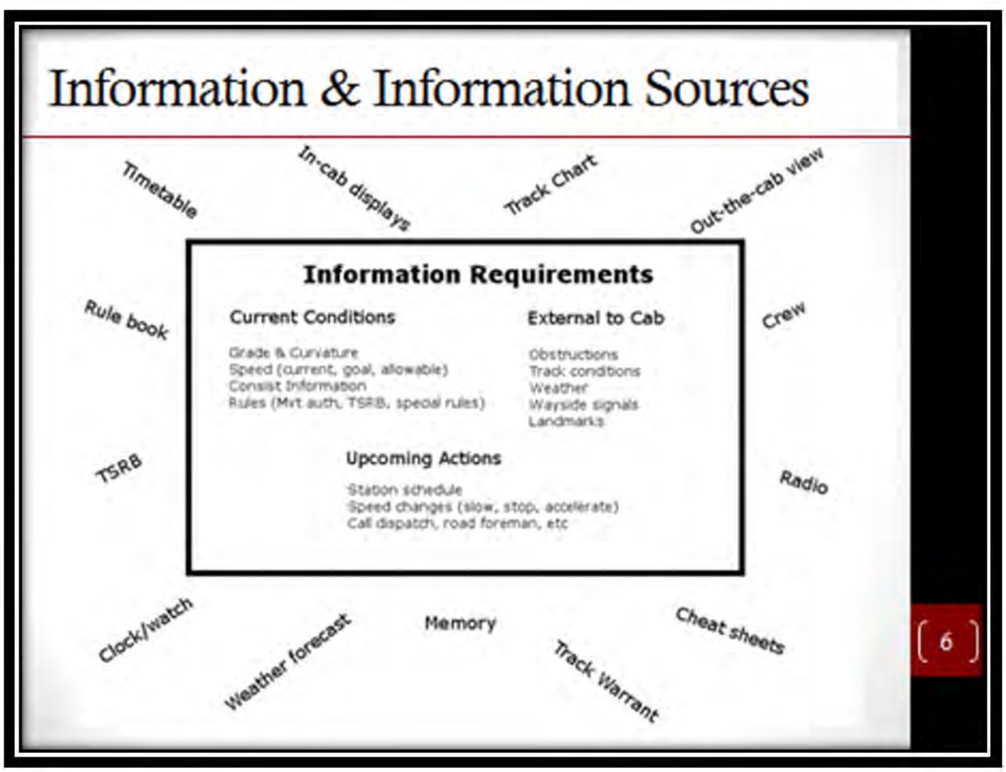
- Moving Maps
- Requirements Analysis (hCTA)
- Requirements to Design
- Evaluation

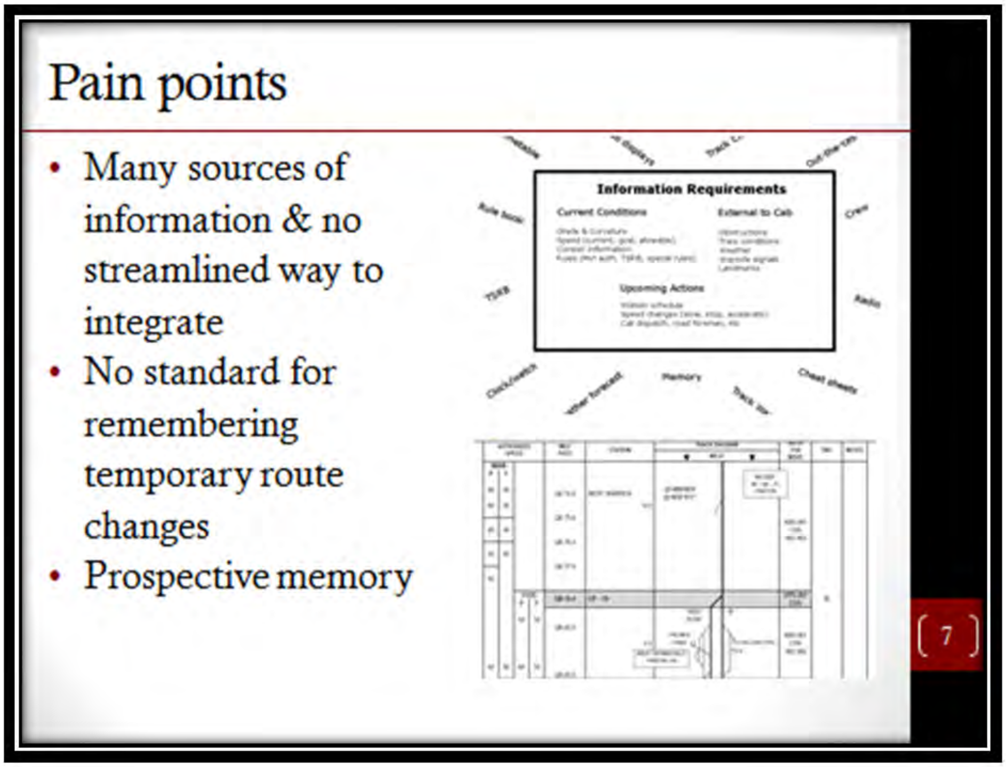
2

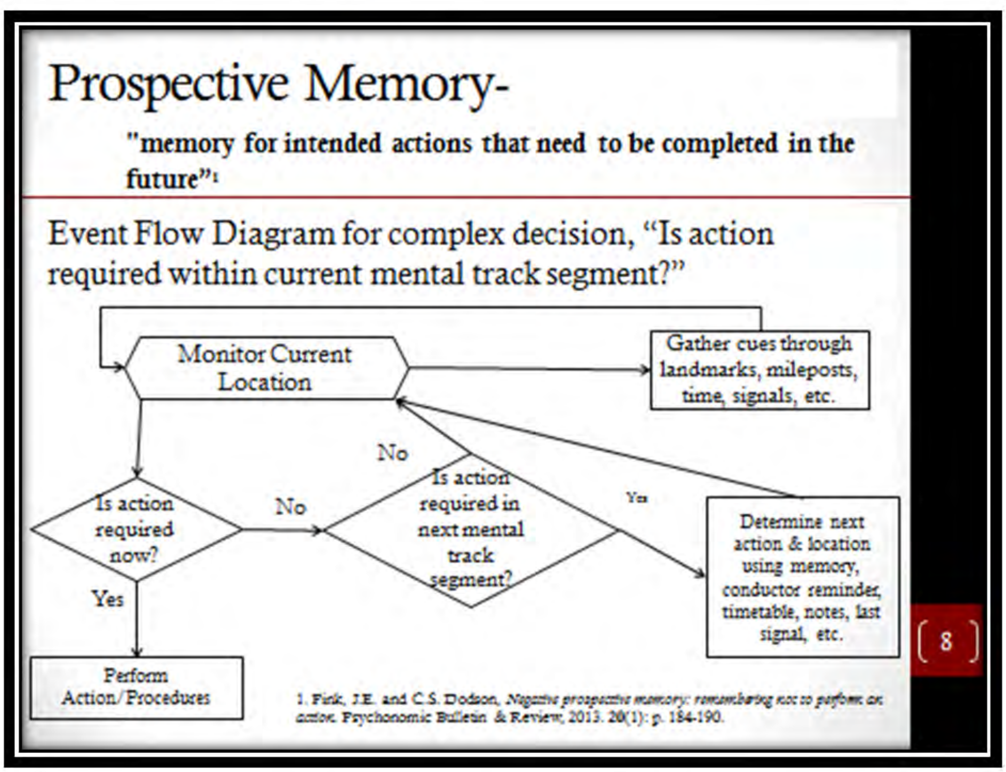

Moving Maps
Widely used in commercial automotive industry
Also known as rolling maps and track-profile displays in rail
Many PTC and energy management systems are beginning to incorporate
3

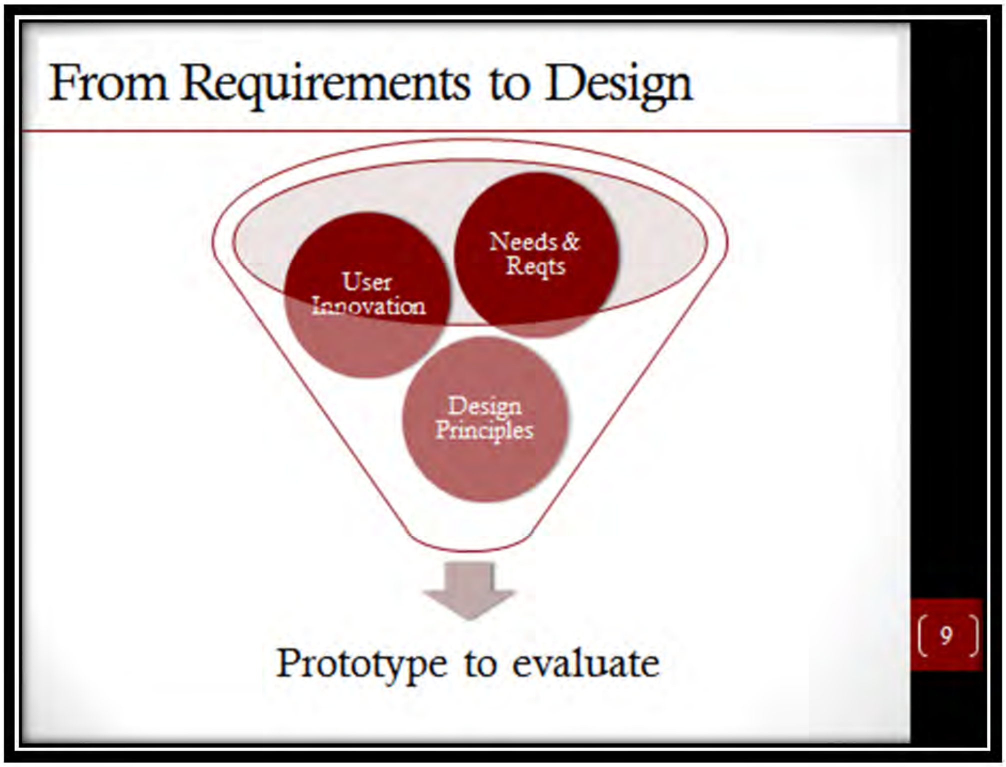

Requirements Analysis-hCTA
Hybrid Cognitive Task Analysis (hCTA)
Used to systematically determine requirements for an interface to a complex system
Operator-centric, involves understanding the mechanisms by which operators make decisions
Information gathering
Head-in ride
Interviews with locomotive engineers
Hands-on experience (CTIL)
Track charts
Jerry Freadman's Fog Charts
Current and planned displays
Leveraged Volpe CTA[1]
hCTA conducted for Alstom Transport in France by HAL in 2011[2]
1. Roth, E. M., Jordan (2009). Technology Implications of a Cognitive Task Analysis for Locomotive Engineers.
2. http://web.mit.edu/aeroastro/labs/halab/papers/MIILO_Final_Report-02-25-11.pdf
4

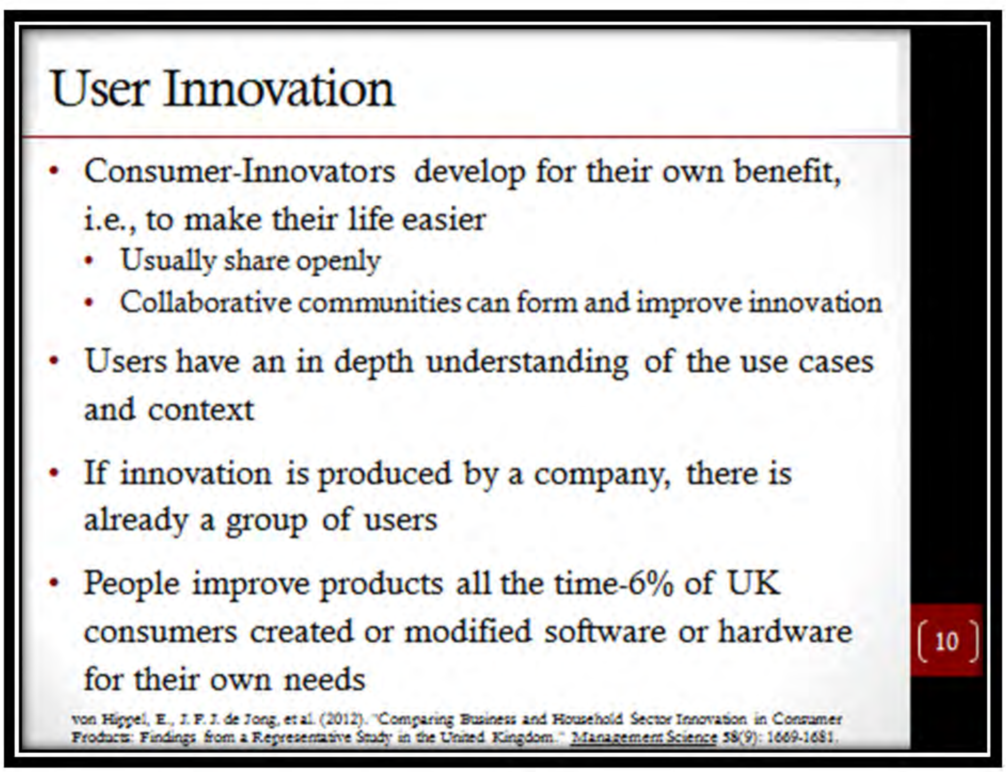

hCTA Process
Scenario Task Overview
Event Flow Diagrams
Situation Awareness Requirements
Decision Ladders
Information and Functional Requirements
5


Information & Information Sources
Timetable
In-cab displays
Track Chart
Out-the-cab view
Information Requirements
Current Conditions
Grade & Curvature
Speed (current, goal, allowable)
Consist Information
Rules (Mvt auth, TSRB, special rules)
External to Cab
Obstructions
Track conditions
Weather
Wayside signals
Landmarks
Upcoming Actions
Station schedule
Speed changes (slow, stop, accelerate)
Call dispatch, road foreman, etc
Rule book
Crew
TSRB
Radio
Clock/watch
Weather forecast
Memory
Track Warrant
Cheat sheets
6


Pain points
• Many sources of information & no streamlined way to integrate
• No standard for remembering temporary route changes
• Prospective memory
Information Requirements
Current Conditions
External to Cab
Upcoming Actions
Rule book
TSRB
Crew
Radio
Memory
Cheat sheets
7

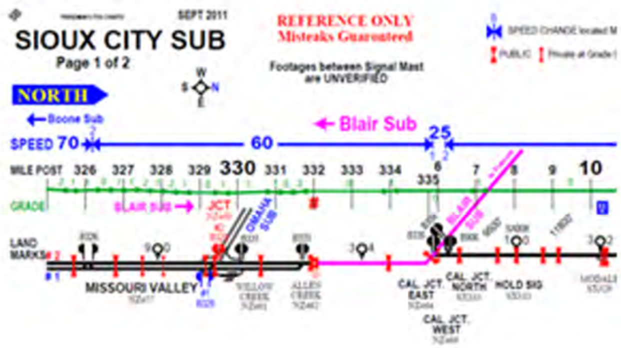

Prospective Memory-
"memory for intended actions that need to be completed in the future"1
Event Flow Diagram for complex decision, "Is action required within current mental track segment?"
Monitor Current Location
Gather cues through landmarks, mileposts, time, signals, etc.
Is action required now?
No
Is action required in next mental track segment?
No
Yes
Determine next action & location using memory, conductor reminder, timetable, notes, last signal, etc.
Yes
Perform Action/Procedures
1. Fink, J.E. and C.S. Dodson, Negative prospective memory: remembering not to perform an action. Psychonomic Bulletin & Review, 2013. 20(1): p. 184-190.
8


From Requirements to Design
Needs & Reqts
User Innovation
Design Principles
Prototype to evaluate
9


User Innovation
• Consumer-Innovators develop for their own benefit, i.e., to make their life easier
• Usually share openly
• Collaborative communities can form and improve innovation
• Users have an in depth understanding of the use cases and context
• If innovation is produced by a company, there is already a group of users
• People improve products all the time-6% of UK consumers created or modified software or hardware for their own needs
von Hippel, E., J. F. J. de Jong, et al. (2012). "Comparing Business and Household Sector Innovation in Consumer Products: Findings from a Representative Study in the United Kingdom." Management Science 58(9): 1669-1681.
10

What are current strategies?

- Cheat sheets, highlighters, sticky notes, writing on windscreen
- Jerry Freadman's Fog Charts



Fogchart.com

11

Design Principles

- Nielsen
  - Match between system and real world
  - Aesthetic and minimalist design
- Tog
  - Autonomy-keep users aware and informed
  - Human-interface objects-standard interactions and resulting behaviors
- Schneiderman
  - Usefulness-information and functions should be relevant to the user's task and context
  - Simplicity-eliminate unnecessary or irrelevant elements
  - Communication-clear and timely feedback of user's actions
  - Workload reduction-do not require user to remember information; allow recognition rather than recall

Nielsen, J., & Mack, R. L. (1994). Usability inspection methods / edited by Jakob Nielsen and Robert L. Mack. New York : John Wiley & Sons, c1994
Shneiderman, B., & Plaisant, C. (2010). Designing the user interface : strategies for effective human-computer interaction / Ben Shneiderman & Catherine Plaisant. Boston : Addison-Wesley, c2010

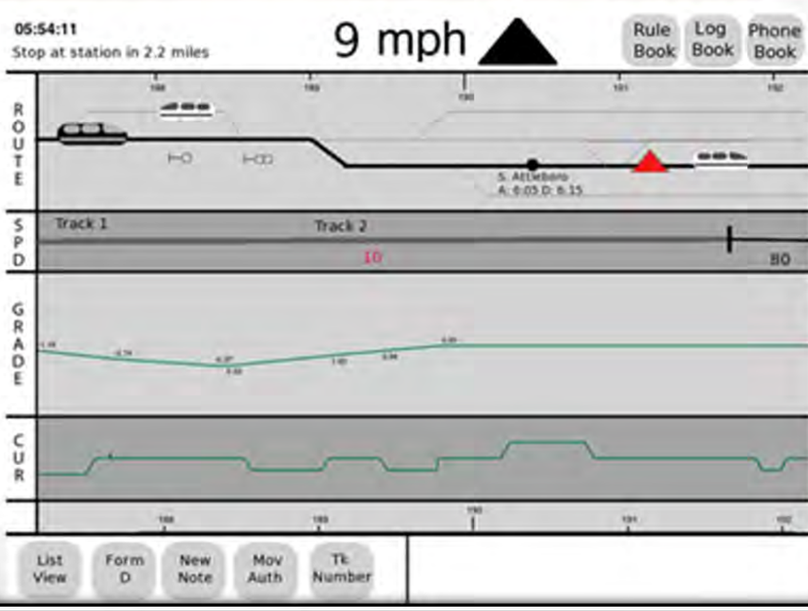
12

Design/Prototype Development

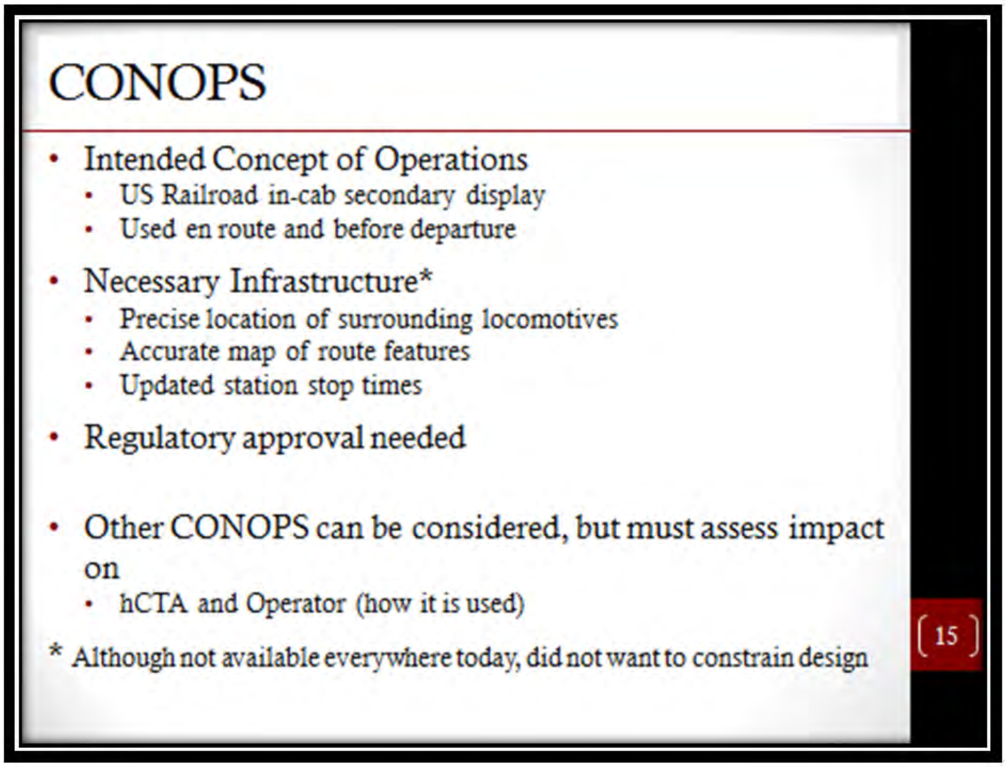
- Requirements highly dependent upon current location and upcoming information
- Moving map determined to be the best platform on which to display the Information Requirements
- Features include:
  - Pan across entire route
  - Zoom in/out for more detail
  - Visual display of upcoming track, adjacent tracks, speed, grade & curvature
  - Ability to add annotations
    - Track warrants
    - Speed restrictions
    - Men working
    - General/freeform notes
  - Reminders

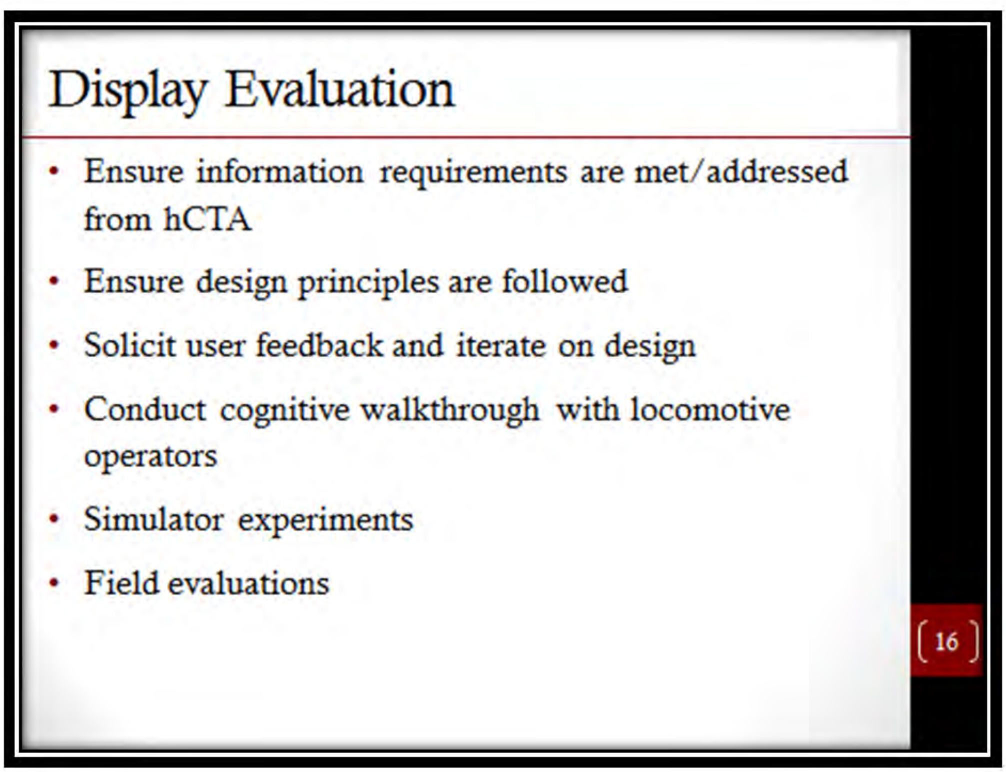
13

Interactive Moving Map Display

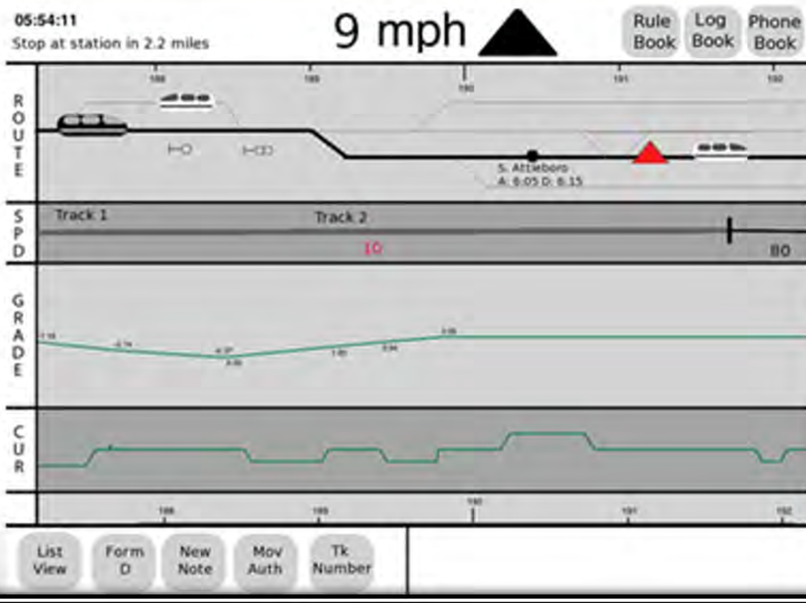


14


CONOPS
• Intended Concept of Operations
• US Railroad in-cab secondary display
• Used en route and before departure
• Necessary Infrastructure*
• Precise location of surrounding locomotives
• Accurate map of route features
• Updated station stop times
• Regulatory approval needed
• Other CONOPS can be considered, but must assess impact on
• hCTA and Operator (how it is used)
* Although not available everywhere today, did not want to constrain design
15


Display Evaluation
• Ensure information requirements are met/addressed from hCTA
• Ensure design principles are followed
• Solicit user feedback and iterate on design
• Conduct cognitive walkthrough with locomotive operators
• Simulator experiments
• Field evaluations
16

Screen Shot of Prototype Display



17

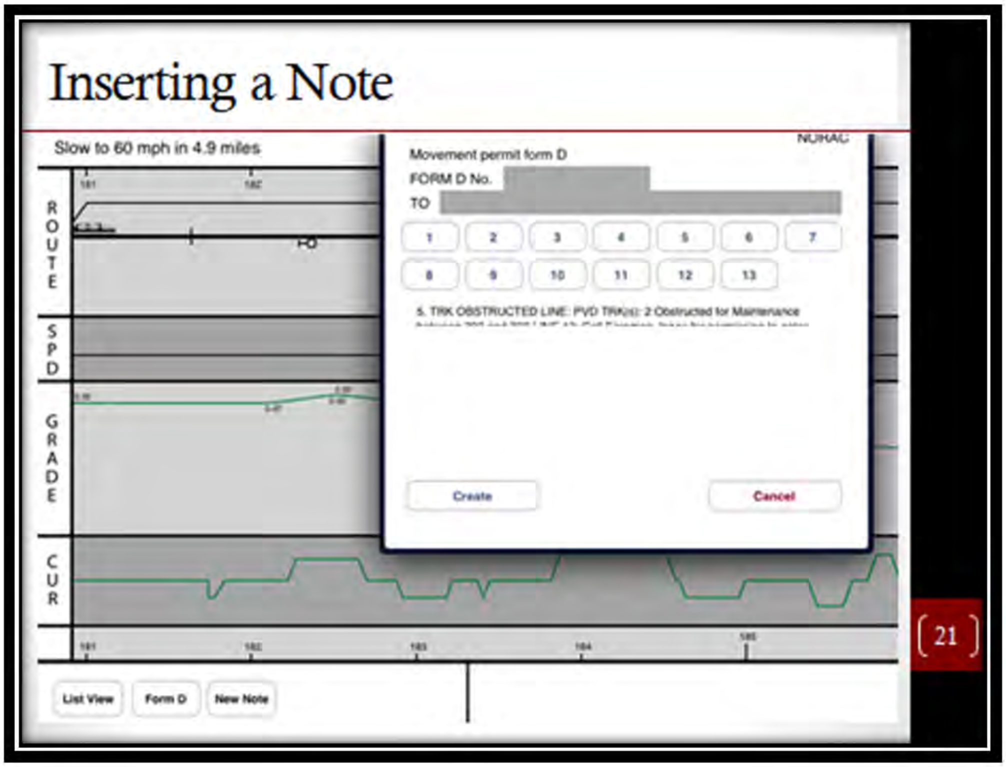
Future Work

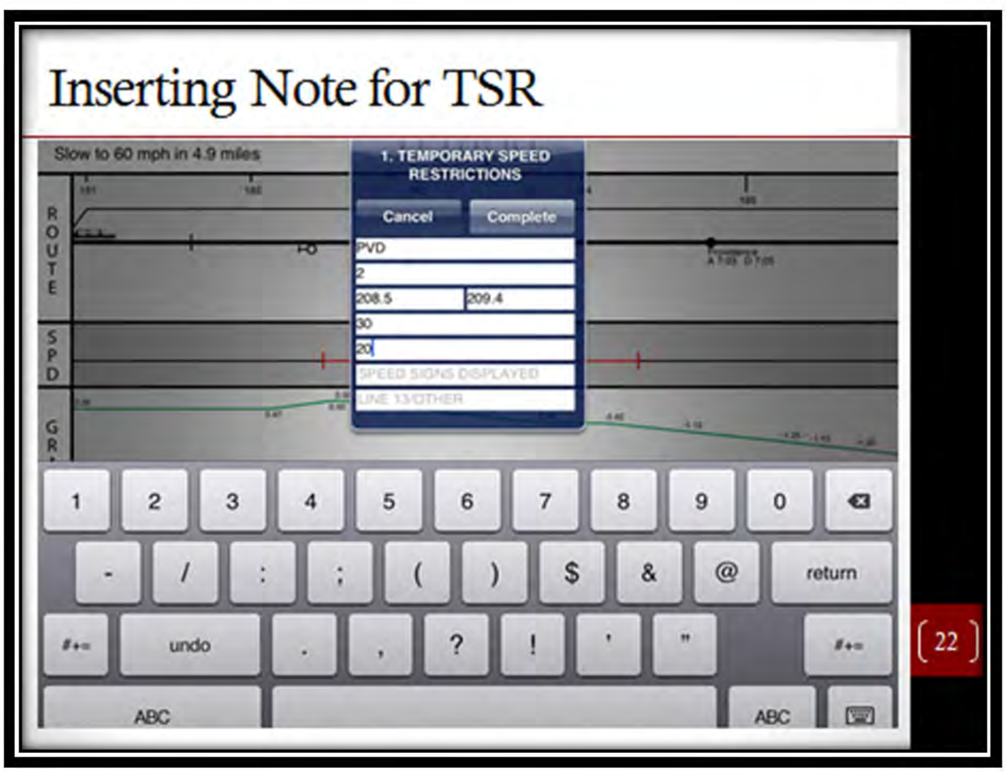
- Cognitive Walkthrough/Usability Study
  - Evaluate ease of use and collect data on user experience
- CTIL Experiment with current display
  - Does the ability for a locomotive engineer to view and interact with a detailed map aid in his/her ability to <u>respond correctly to changes in the normal route</u> over the current standard (i.e., relying on memory, viewing multiple displays and using paper notes)?

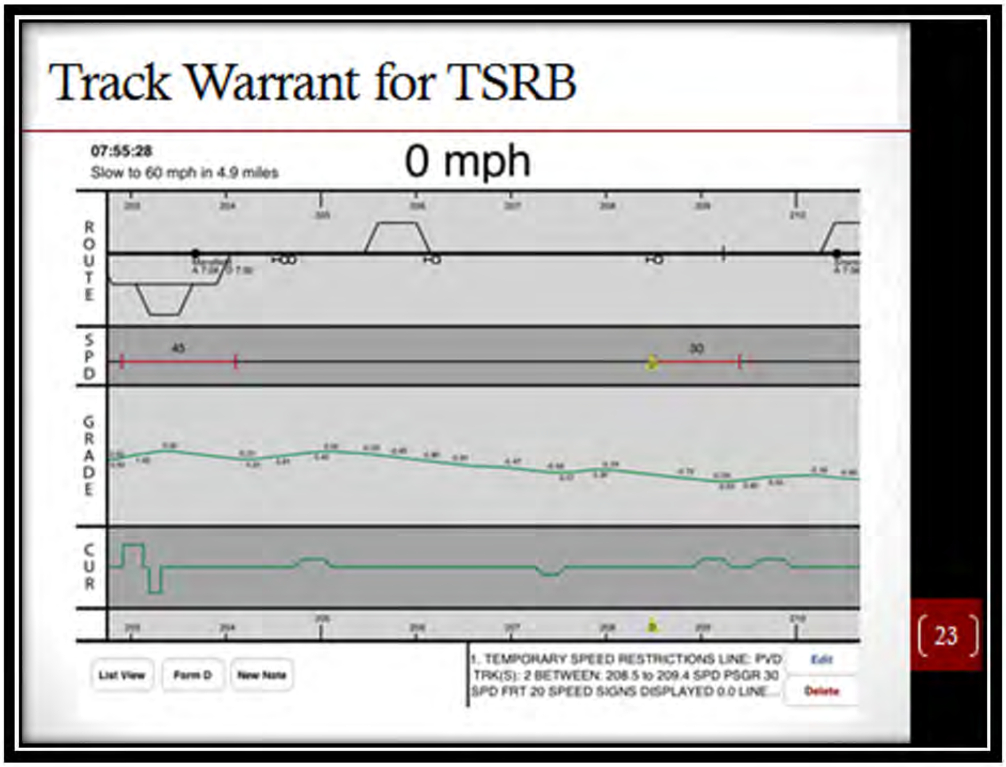
18

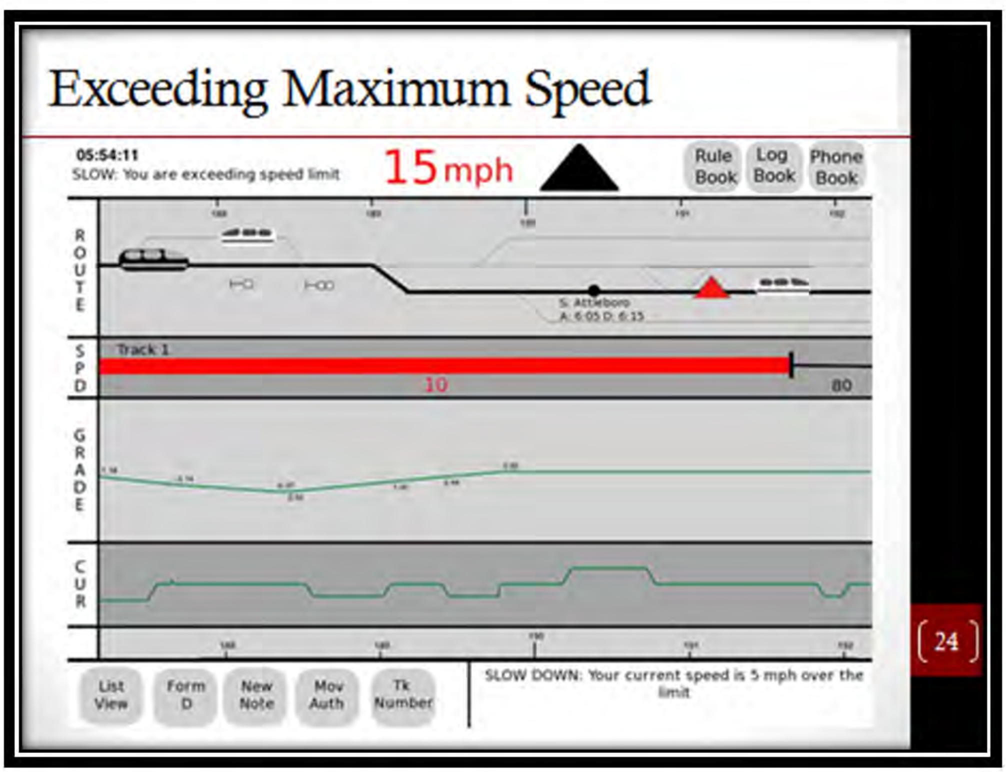

Follow-up
• You are welcome to interact with the display-I will have the iPad with me during the conference
• Contact info:
• Kathleen Voelbel
• kv@mit.edu
19

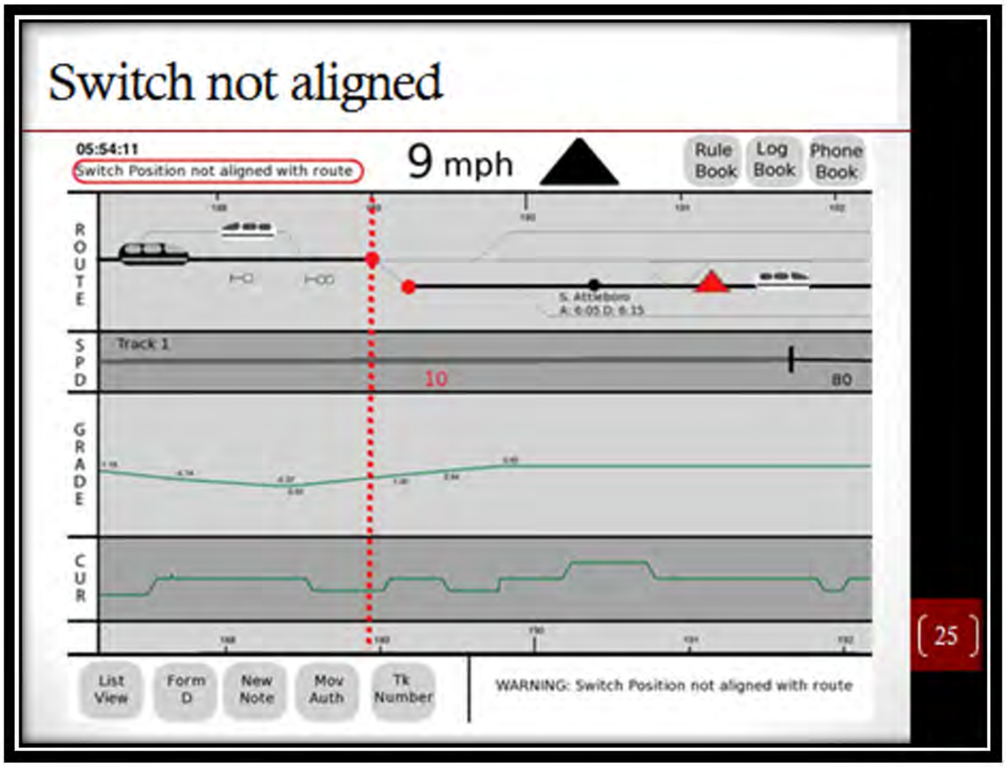

Back up

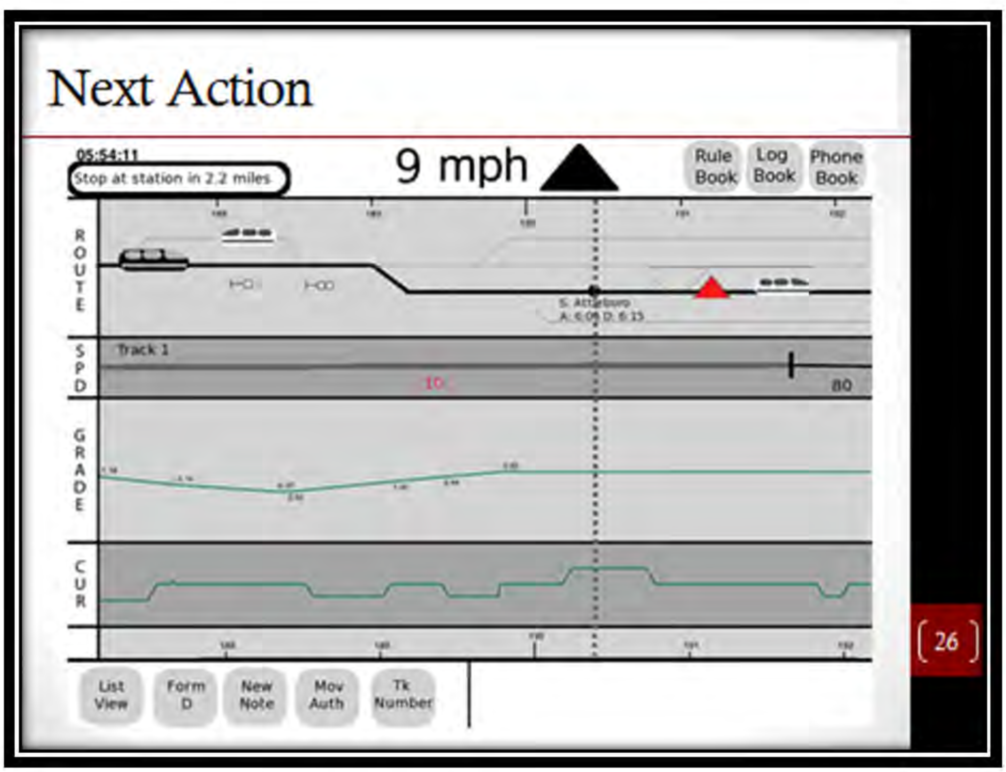

Inserting a Note
Slow to 60 mph in 4.9 miles
ROUTE
SPD
GRADE
CUR
Movement permit form D
FORM D No.
TO
1 2 3 4 5 6 7
8 9 10 11 12 13
5. TRK OBSTRUCTED LINE: PVD TRK(s): 2 Obstructed for Maintenance
Create
Cancel
List View
Form D
New Note
21

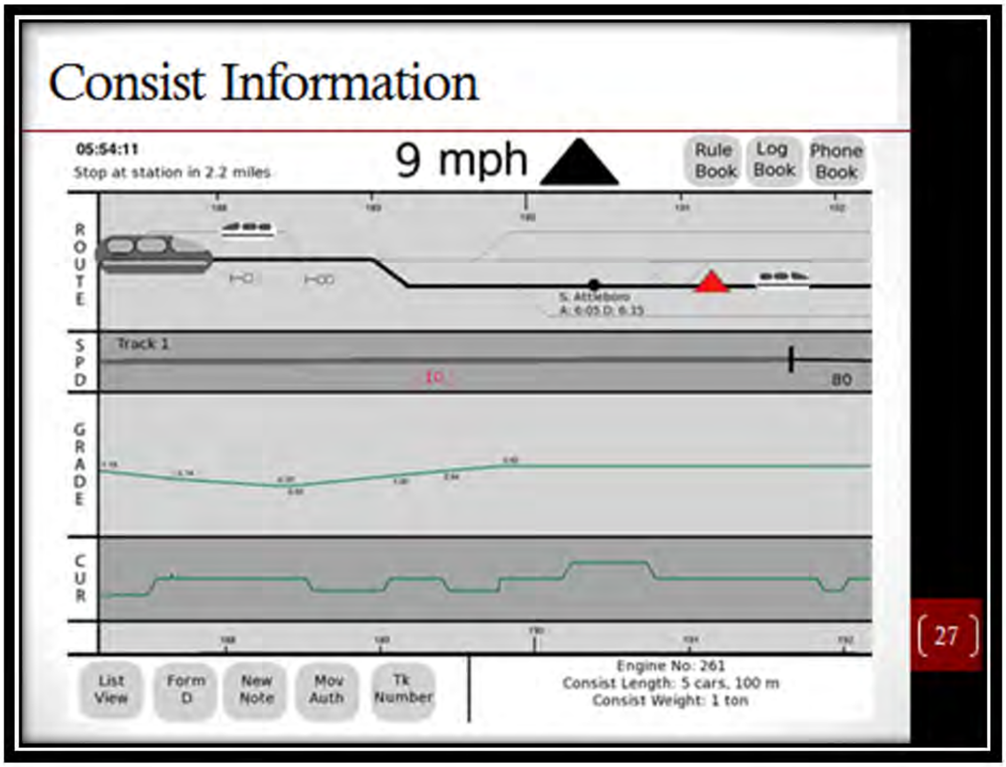

Inserting Note for TSR
Slow to 60 mph in 4.9 miles
ROUTE
SPD
1. TEMPORARY SPEED RESTRICTIONS
Cancel
Complete
PVD
2
208.5
209.4
30
20
SPEED SIGNS DISPLAYED
LINE 13/OTHER
1 2 3 4 5 6 7 8 9 0
- / : ; ( ) $ & @ return
#+= undo . , ? ! ' " #+=
ABC ABC
22

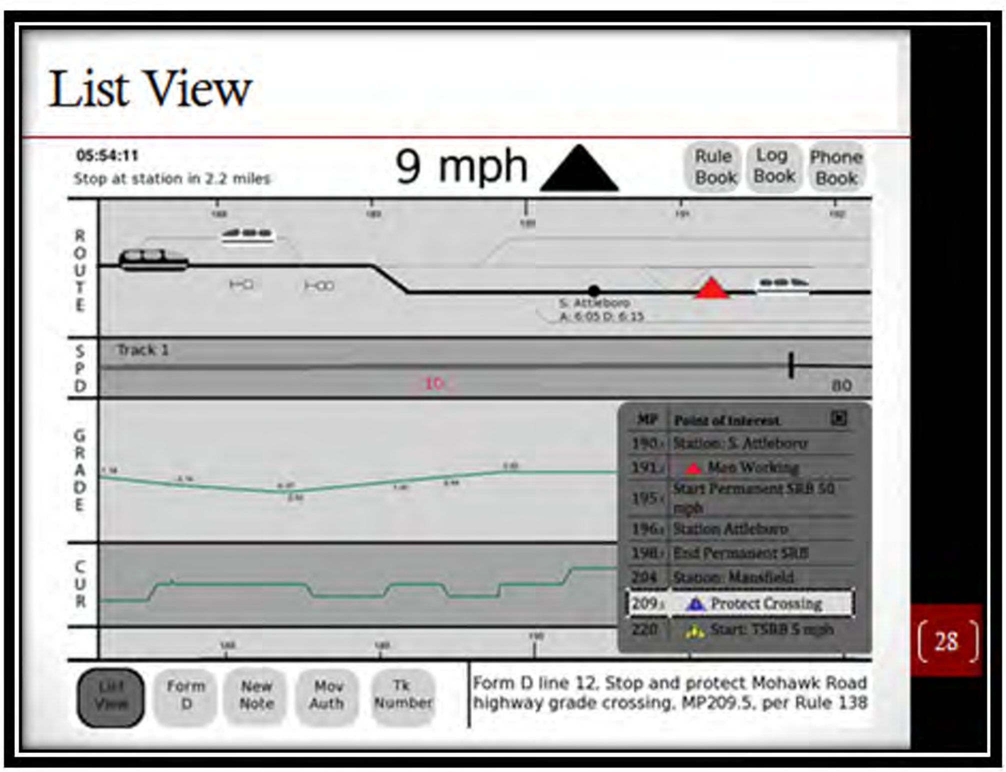

Track Warrant for TSRB
07:55:28
Slow to 60 mph in 4.9 miles
0 mph
ROUTE
SPD
45
30
GRADE
CUR
List View
Form D
New Note
1. TEMPORARY SPEED RESTRICTIONS LINE: PVD TRK(S): 2 BETWEEN: 208.5 to 209.4 SPD PSGR 30 SPD FRT 20 SPEED SIGNS DISPLAYED 0.0 LINE...
Edit
Delete
23

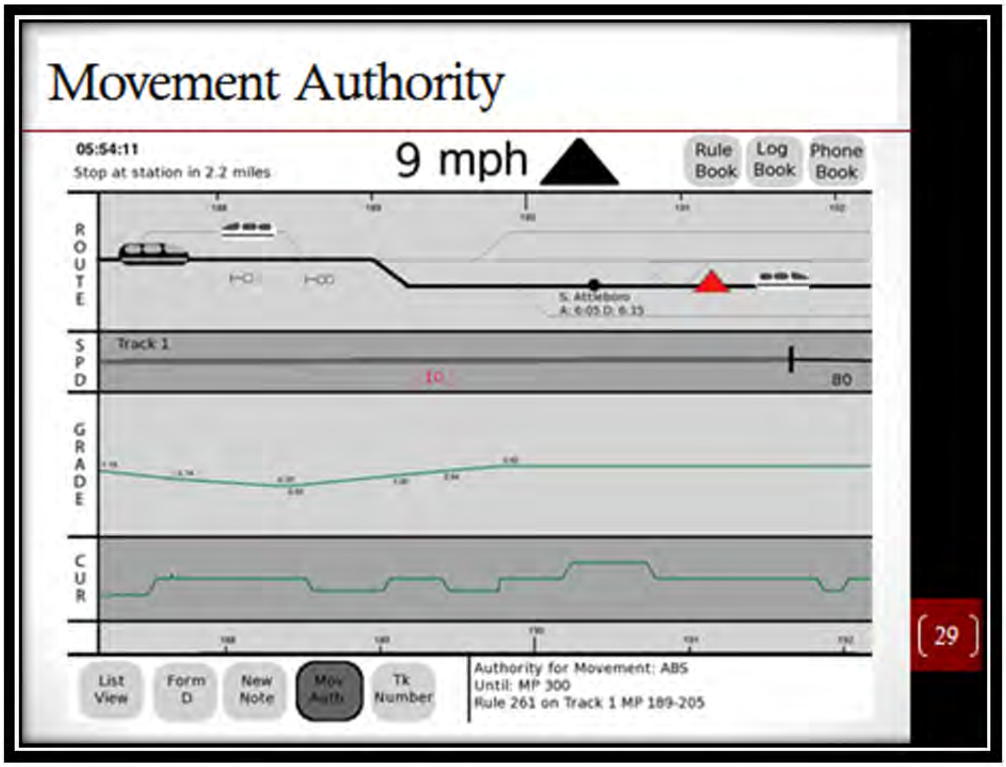

Exceeding Maximum Speed
05:54:11
SLOW: You are exceeding speed limit
15 mph
Rule Book
Log Book
Phone Book
ROUTE
S. Attleboro
A: 6:05 D: 6:15
SPD
Track 1
10
80
GRADE
CUR
List View
Form D
New Note
Mov Auth
Tk Number
SLOW DOWN: Your current speed is 5 mph over the limit
24

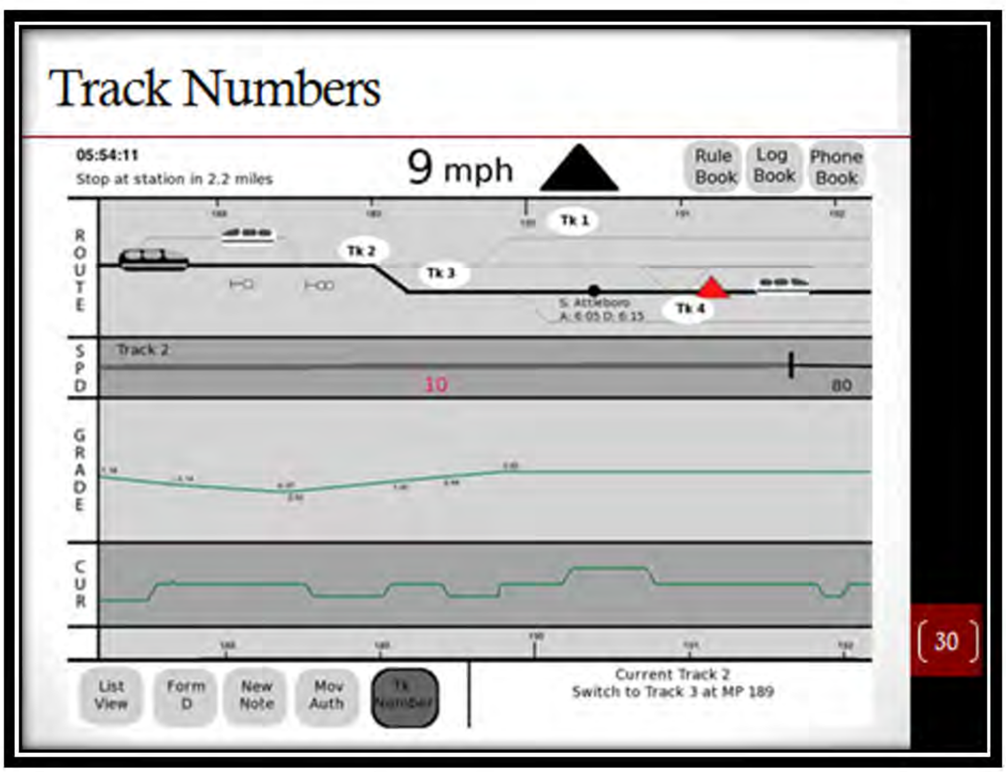

Switch not aligned
05:54:11
Switch Position not aligned with route
9 mph
Rule Book
Log Book
Phone Book
ROUTE
S. Attleboro
A: 6:05 D: 6:15
SPD
Track 1
10
80
GRADE
CUR
List View
Form D
New Note
Mov Auth
Tk Number
WARNING: Switch Position not aligned with route
25

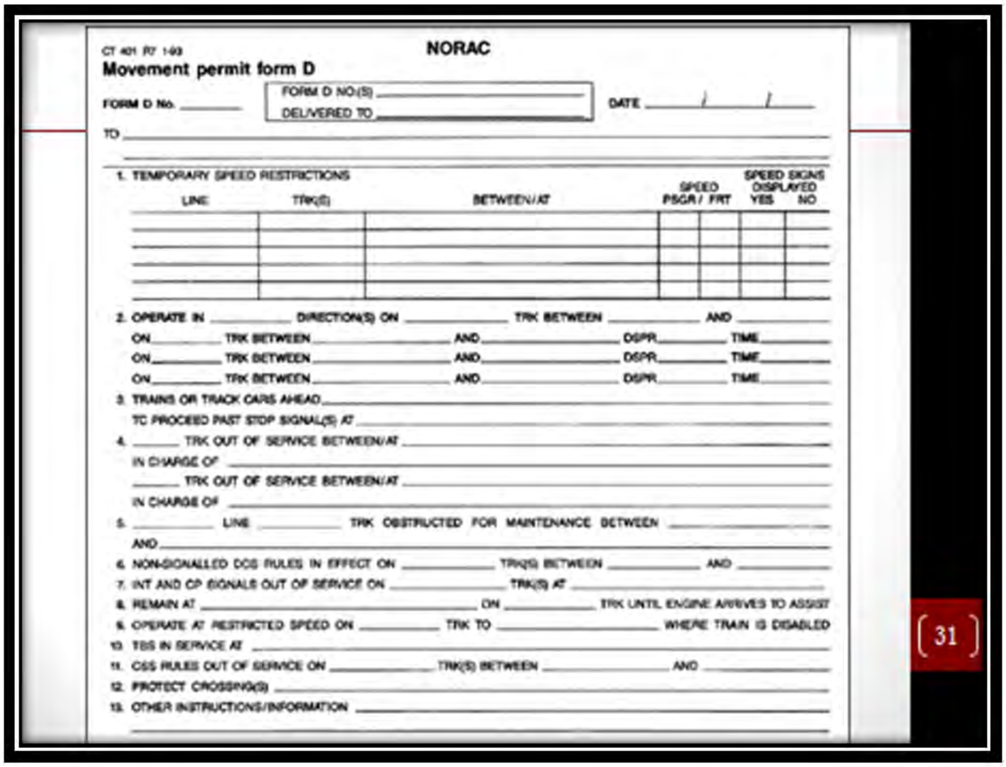

Next Action
05:54:11
Stop at station in 2.2 miles
9 mph
Rule Book
Log Book
Phone Book
ROUTE
S. Attleboro
A: 6:05 D: 6:15
SPD
Track 1
10
80
GRADE
CUR
List View
Form D
New Note
Mov Auth
Tk Number
26


Consist Information
05:54:11
Stop at station in 2.2 miles
9 mph
Rule Book
Log Book
Phone Book
ROUTE
S. Attleboro
A: 6:05 D: 6:15
SPD
Track 1
10
80
GRADE
CUR
List View
Form D
New Note
Mov Auth
Tk Number
Engine No: 261
Consist Length: 5 cars, 100 m
Consist Weight: 1 ton
27


List View
05:54:11
Stop at station in 2.2 miles
9 mph
Rule Book
Log Book
Phone Book
ROUTE
S. Attleboro
A: 6:05 D: 6:15
SPD
Track 1
10
80
GRADE
CUR
MP
Point of Interest
190 Station: S. Attleboro
191 Men Working
195 Start Permanent SRB 50 mph
196 Station Attleboro
198 End Permanent SRB
204 Station: Mansfield
209 Protect Crossing
220 Start: TSRB 5 mph
List View
Form D
New Note
Mov Auth
Tk Number
Form D line 12, Stop and protect Mohawk Road highway grade crossing, MP209.5, per Rule 138
28


Movement Authority
05:54:11
Stop at station in 2.2 miles
9 mph
Rule Book
Log Book
Phone Book
ROUTE
S. Attleboro
A: 6:05 D: 6:15
SPD
Track 1
10
80
GRADE
CUR
List View
Form D
New Note
Mov Auth
Tk Number
Authority for Movement: ABS
Until: MP 300
Rule 261 on Track 1 MP 189-205
29


Track Numbers
05:54:11
Stop at station in 2.2 miles
9 mph
Rule Book
Log Book
Phone Book
Tk 1
Tk 2
Tk 3
Tk 4
ROUTE
S. Attleboro
A: 6:05 D: 6:15
SPD
Track 2
10
80
GRADE
CUR
List View
Form D
New Note
Mov Auth
Tk Number
Current Track 2
Switch to Track 3 at MP 189
30



CT 401 R7 1-93

NORAC

Movement permit form D

FORM D No. ______ FORM D NO.(S) ______ DELIVERED TO ______ DATE ___/___/___

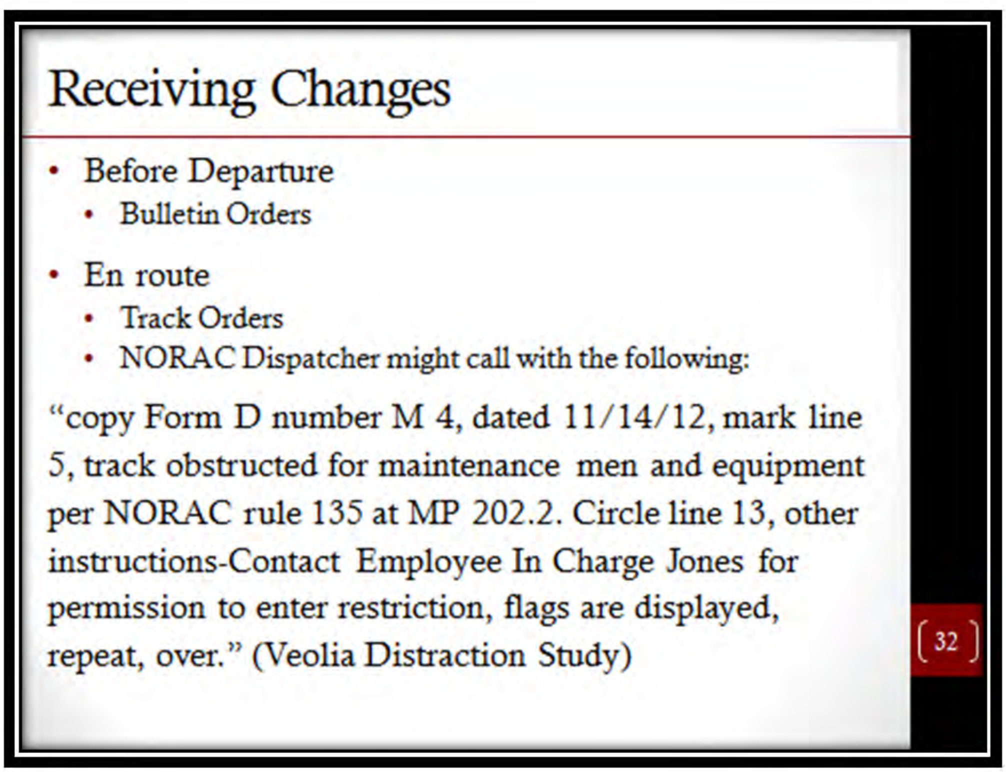
TO ______

1. TEMPORARY SPEED RESTRICTIONS

LINE	TRK(S)	BETWEEN/AT	SPEED PSGR /	SPEED FRT	SPEED SIGNS DISPLAYED YES	SPEED SIGNS DISPLAYED NO

2. OPERATE IN ______ DIRECTION(S) ON ______ TRK BETWEEN ______ AND ______
ON ______ TRK BETWEEN ______ AND ______ DSPR ______ TIME ______
ON ______ TRK BETWEEN ______ AND ______ DSPR ______ TIME ______
ON ______ TRK BETWEEN ______ AND ______ DSPR ______ TIME ______
3. TRAINS OR TRACK CARS AHEAD ______
TO PROCEED PAST STOP SIGNAL(S) AT ______
4. ______ TRK OUT OF SERVICE BETWEEN/AT ______
IN CHARGE OF ______
______ TRK OUT OF SERVICE BETWEEN/AT ______
IN CHARGE OF ______
5. ______ LINE ______ TRK OBSTRUCTED FOR MAINTENANCE BETWEEN ______
AND ______
6. NON-SIGNALLED DCS RULES IN EFFECT ON ______ TRK(S) BETWEEN ______ AND ______
7. INT AND CP SIGNALS OUT OF SERVICE ON ______ TRK(S) AT ______
8. REMAIN AT ______ ON ______ TRK UNTIL ENGINE ARRIVES TO ASSIST
9. OPERATE AT RESTRICTED SPEED ON ______ TRK TO ______ WHERE TRAIN IS DISABLED
10. TBS IN SERVICE AT ______
11. CSS RULES OUT OF SERVICE ON ______ TRK(S) BETWEEN ______ AND ______
12. PROTECT CROSSING(S) ______
13. OTHER INSTRUCTIONS/INFORMATION ______

31



Locomotive Alerter Technology Assessment

Charles M. Oman
Man Vehicle Laboratory, Department of Aeronautics and Astronautics
Massachusetts Institute of Technology
Cambridge, MA 02139 USA

TRB Railroad Operational Safety Committee (AR070) Mid-Year Themed Meeting
The Future Locomotive:
How to Manage What You Have Today With A View to the Future
Union Pacific Center, Omaha, Nebraska, July 30-31, 2013

Supported by DOT/FRA Contracts DTFR53-11-C-00016 and PR79-3389
Conclusions are those of author, not DOT/ FRA.

Massachusetts Institute of Technology

Man Vehicle Laboratory

Deadman Limitations

- Long used in Europe, and in US passenger locomotives, subways, streetcars, lawnmowers, snow throwers... .
- Simple type: Spring loaded pedal or throttle handle, lever or ring
  - If handle or pedal is released, power is cut and brake is applied after short delay.
  - However: drivers may slump on pedal and do not always relax in early phases of sleep.
- Three position, timed release pedal.
  - Driver holds pedal in intermediate position. Audible alarm every minute. Driver must release and depress to reset position within 3 sec or penalty braking is activated.
    - AKA: Driver's Safety Device in UK or Veille Automatique de Contôle à Maintien d'Appui (VACMA) in France.
    - "it is a matter of pride amongst drivers that they can time the need to reset within a few seconds without causing an alarm." (UK Railway Techweb)
- Continuously holding handle or pedal is fatiguing, and changing seat position is difficult.

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Alerter basics

EMD SD70 cab console with software alerter. Timer reset button circled.

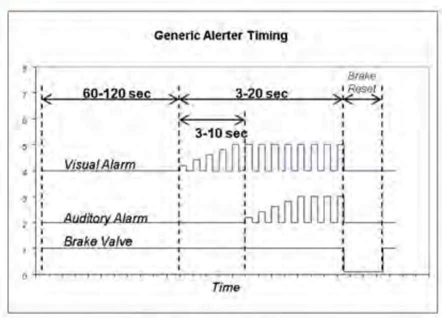
EMD F40 cab retrofit with Train Sentry III visual alert above forward view

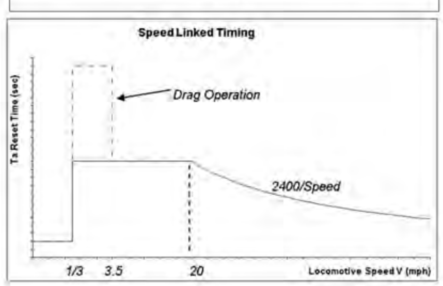
- Detect operator inattention, sleepiness or incapacity without sustained physical effort.
- 60-120 sec countdown timer
- Button/lever for manual pre-emptive reset on console or stand, usually near horn or bell.
- After timeout, visual and horn alarms activate, usually successively.
- If no manual reset after alarm sequence, penalty brake and power down are initiated.
- In older equipment, visual display location varies.
- Timer duration and alarm durations were specified by customer.

Massachusetts Institute of Technology

Alerter reset logic

- Time based: alert triggered every 60-120 sec if no counter reset. At 20 mph, consist travels 3500 feet. At 50 mph, almost 2 miles. >> typical stop signal overlap distance.
- Speed/distance linked timer (Westinghouse, 1961): at speeds over 20-25 mph, timer resets based on distance counter (e.g. 3500 ft).
- Activity linked timer (General Signal, 1966): any use of throttle, brakes, horn, bell, etc. also resets the timer. Reduces nuisance visual alarms.
- Drag operation switch: Timer set to 240 sec for drag operations < 3 mph. (Train Sentry III, 1989)
- Rollaway protection: preset first cycle to 10 sec when first moving off.
- Penalty brake reset time: time needed to reset brakes before moving again.





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Accidents and regulations

- 1983-1991 – Fatigue related US rail accidents, including:
  - Sullivan IN, Wiggins Valley CO, Thompsontown PA, Sugar Valley GA
- NTSB investigates, and repeatedly recommends that FRA:
  - Require alerters in all US freight and passenger locomotives.
  - Develop improved alerters that cannot be "reflexively reset".
- 1997 - FRA decides not to invest in improved alerter development since Positive Train Separation (e.g. PTC) technologies will obviate need and market is small.
- 1999 FRA modifies 49 CFR 239 to require alerters on all US _passenger_ trains outside cab signaled or PTS territory.
  - All freight locomotives and passenger locomotives with deadman devices built before 2003 remained exempt.
  - Promote "continuous, active attentiveness" by monitoring "select" (unspecified) operator control activities.
  - Speed linking not required.
  - Mandated audible and visual alarms, and manual preemptive reset. Timing up to operating railroad.
- Class I railroads begin to install alerters in most locomotives, and initiate fatigue management programs.

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Recent Regulatory Changes

AAR Manual of Standards and Recommended Practices
Railway Electronics
LOCOMOTIVE ALERTER REQUIREMENTS
Standard
S-5513
Adopted: November 2007

- 2007 AAR Locomotive Alerter Requirements.
  - Requires speed and activity linked alerter in all road freight locomotives built > 2009.
  - Timer reset by any of 8 activities: throttle, dynamic/automatic/independent brake, horn, bell, sander, softkeys
  - Flashing visual alert beneath speed display on operating console. 10 sec audio alert ramp in. (AAR MSRP S-591 for Operating Display)
  - Time to penalty brake numeric countdown, appearing with visual alert.
  - 120 sec timer below 20 mph, 3500 feet above 20 mph. Inop below 4 mph.
- 1997-2008 Delia KS, Kelso WA , Macdona TX, Anding MS, Chatsworth CA accidents
- 2008 - Congressional RSIA mandates interoperable PTC by 2015.
- 2012 - FRA requires speed linked, activity based alerters in both passenger and freight locomotives operating > 25 mph.
  - Detect 3 or more of 6 actions: throttle, dynamic/automatic/independent brake, horn and bell.
  - Visual alert >5 sec before audio.
  - Speed linking required. Alert delay 3500 feet +/- No requirements for low speed features.
  - Provide manual reset capability

  Requires a pre-departure penalty braking system test.

Department of Transportation
Federal Railroad Administration
49 CFR Parts 229 and 238
Locomotive Safety Standards; Final Rule

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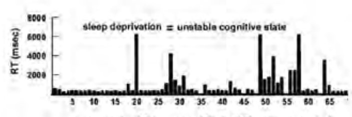
How to improve current alerters ?

- FRA and AAR regulations are permissive, leaving room for improvements.
- Provide redundant visual alert displays, and adjust for ambient light.
- Be sure visual alert period long enough (> 5 sec) so busy operator has time to notice it. Make audio alert warble ramp from slow to fast.
- Install redundant control microswitches on major controls, so they function reliably. Monitor more activities (e.g. radio, touchscreen displays).
- Alerters can be a nuisance – audio alarm rate can be 30-40/hr. But alerters have low no response (i.e. false alarm) rate – only several dozen penalty brake applications occur per year in US due to inattentiveness.
- Problem sensitivity and selectivity – alerter can be slapped off by distracted (e.g. texting) driver or reflexly reset by drowsy one.
- Pre-emptive resetting feature encourages automatic operator resetting of alerter button, or throttle "notching". Modify alerter logic to reduce operator automaticity (Haworth, 06).
    - Make pre-alarm timer interval more variable.
    - If operator pre-emptively resets timer before visual alert, lock out manual timer reset prior to visual alert on next cycle.
    - Do not initially flash visual alert - so operator must remember to look for it.
- Consider alerter a job aid. Allow operator to shorten pre alert timer cycle, or lock out pre-emptive reset.

MIT Massachusetts Institute of Technology

Laboratory tests

- Response time to simple visual stimuli has scientific construct validity for assessment of mildly impaired drowsiness and cognitive function under laboratory conditions (e.g. 10 min PVT, Dinges 1985; Lim 2010). However, PVT is subject's only task, and test requires 3-10 min.



- Response time to secondary task visual stimuli are frequently used to assess mental workload due to primary visual tasks and are also sensitive to fatigue in driving (Lisper, 1986) and robotics (Lowenthal, 2012) tasks. However such secondary tasks are themselves distracting, and testing also requires minutes.
- Measuring sustained eye closures (e.g. Perclos; Wierwille, 1984) or reduced eyelid reopening speed (Johns, 2005) currently appear to be the reliable non EEG methods for detecting microsleep. The challenge is to build systems which can do this reliably under operational conditions.

MIT Massachusetts Institute of Technology

VigilanceTechnology

- FRA, ITSRR and RSSB initiate reviews of alerters and vigilance/drowsiness technologies: Quintec, 2002; Halcrow Pacific, 2006; Monash, 2006, ITSRR, 2006, DOT Volpe 2006, 2009.
  - Many SPaD accidents likely due to distraction, rather than fatigue. Need data on fatigue prevalence.
  - A distracted (e.g. texting) driver can simply slap off an alerter.
  - Image based percolos detectors (e.g. CoPilot) and machine vision based head pose and gaze position detectors (e.g. Facelab) are being developed for cars and trucks.
  - Some are incorporated in optional automotive fatigue detectors by e.g. Mercedes, Saab, Nissan, Toyota. Some also detect eye closure (e.g. perclos). However:
    - Most limit head pose or anthropometric operational envelope, require calibration, don't work with glasses, and have problems with stray reflections. Some require user calibration.
    - Gaze and eye closure estimates are noisy. Little data on correct/incorrect detection rate under operational conditions in auto and rail applications.

External & sunlight artifacts Dong et al 2011

(a) (b) (c) (d)

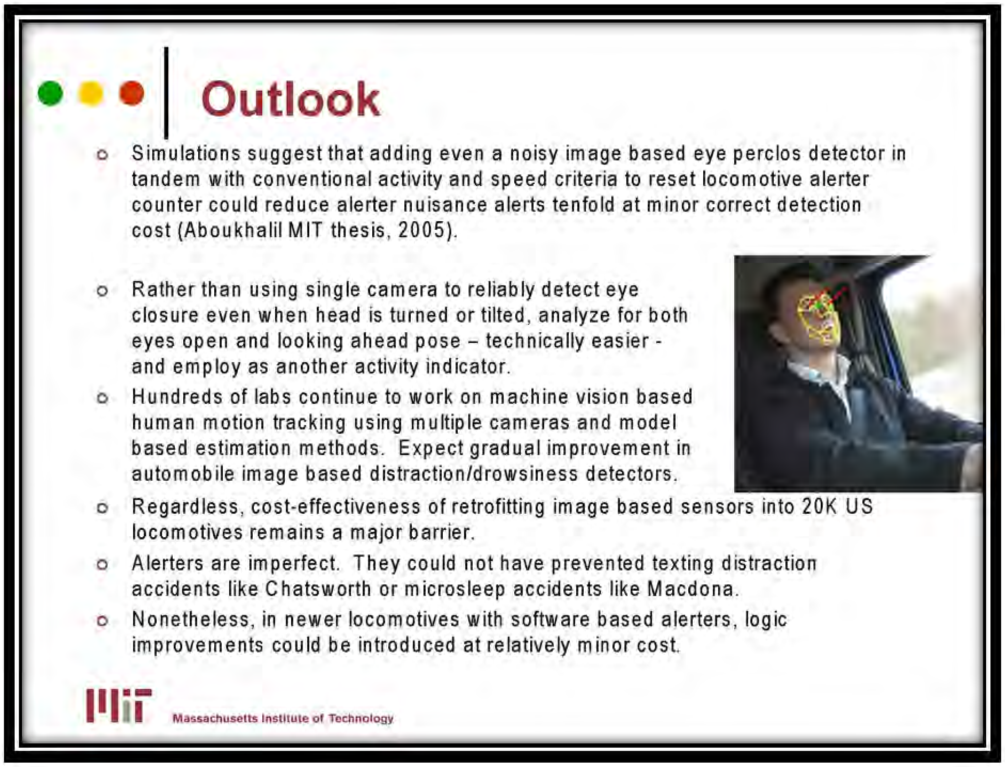
Massachusetts Institute of Technology

Macdona, TX (2004)

- NTSB Railroad Accident Report RAR-06/03
- 2 freight train collision @ 5:30AM; at-fault train was equipped with an alerter.
  - At-fault train did not stop to allow other train to fully enter siding.
  - NTSB report noted the engineer "... remained sufficiently alert to make train control inputs yet was unaware to respond to vitally important signal indications... ."
  - Evidence suggested engineer drifted in and out of micro-sleep, while exhibiting inappropriate control activity in between episodes.
  - Conductor was probably fully asleep and alarms were not sufficient to rouse him.
- Narcoleptics, who exhibit frequent microsleep episodes, often display "Automatic Behavior Syndrome (ABS)" which typically involve the continuation of an activity that does not require extensive skill, e.g. automobile driving
  - Amnesia is a common characteristic of microsleep. "What did I do ?"
  - Notion of time is "completely annihilated"

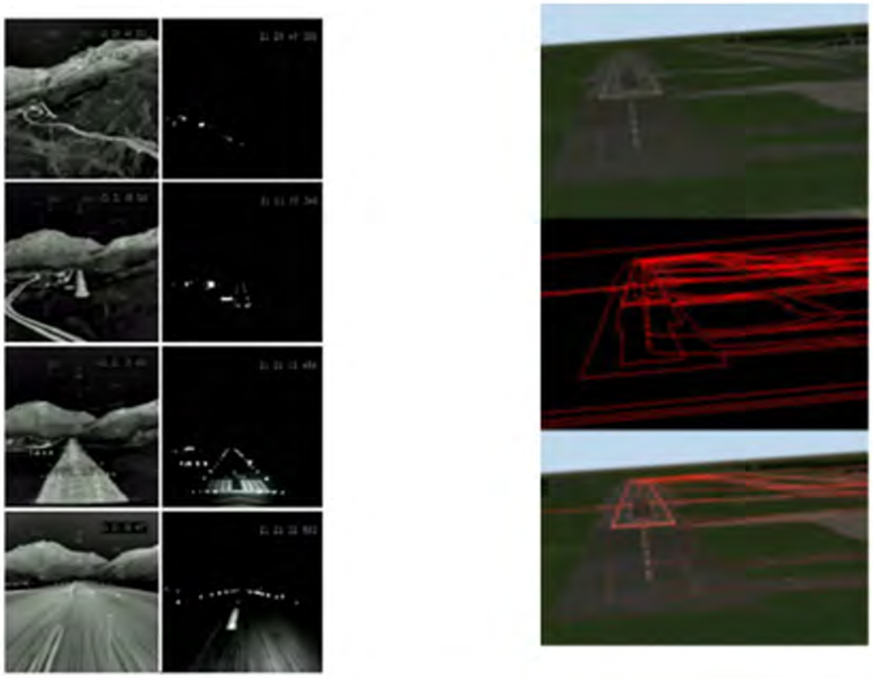
10

Massachusetts Institute of Technology

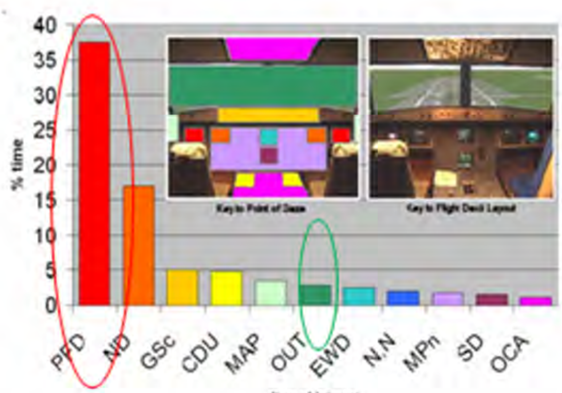

Outlook
Simulations suggest that adding even a noisy image based eye perclos detector in tandem with conventional activity and speed criteria to reset locomotive alerter counter could reduce alerter nuisance alerts tenfold at minor correct detection cost (Aboukhalil MIT thesis, 2005).
Rather than using single camera to reliably detect eye closure even when head is turned or tilted, analyze for both eyes open and looking ahead pose – technically easier - and employ as another activity indicator.
Hundreds of labs continue to work on machine vision based human motion tracking using multiple cameras and model based estimation methods. Expect gradual improvement in automobile image based distraction/drowsiness detectors.
Regardless, cost-effectiveness of retrofitting image based sensors into 20K US locomotives remains a major barrier.
Alerters are imperfect. They could not have prevented texting distraction accidents like Chatsworth or microsleep accidents like Macdona.
Nonetheless, in newer locomotives with software based alerters, logic improvements could be introduced at relatively minor cost.
Massachusetts Institute of Technology


RSSB
FEASIBILITY OF HEAD UP DISPLAYS
IN DRIVING CABS
Dr Ann Mills
RSSB, UK
BAE SYSTEMS


What is a Head Up Display?
RSSB
1960s Military Aircraft
1970s Commercial Aircraft
1980s Automotive



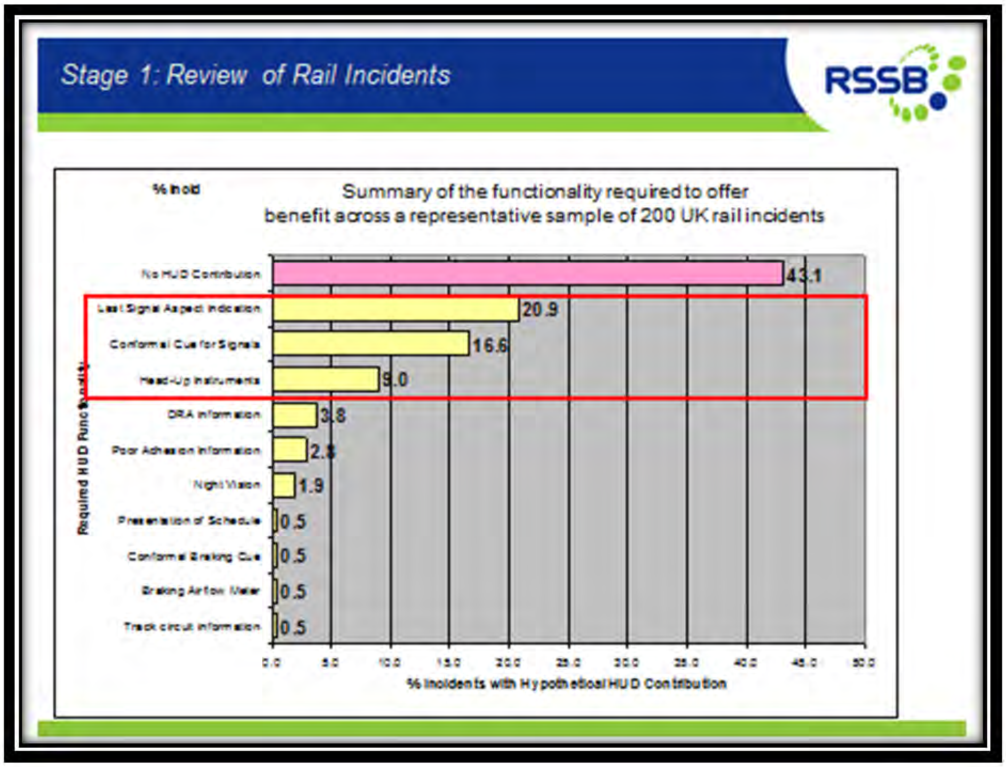
The benefits



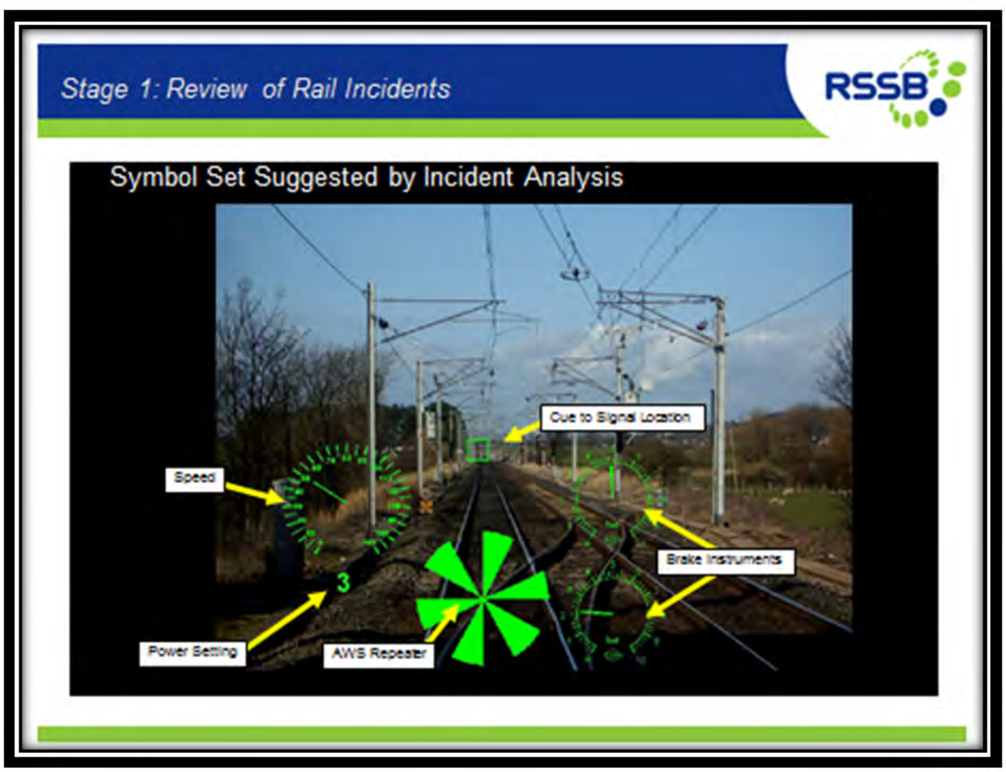
- Increased safety
- Enhanced efficiency & accuracy and reliability


The rail context
RSSB

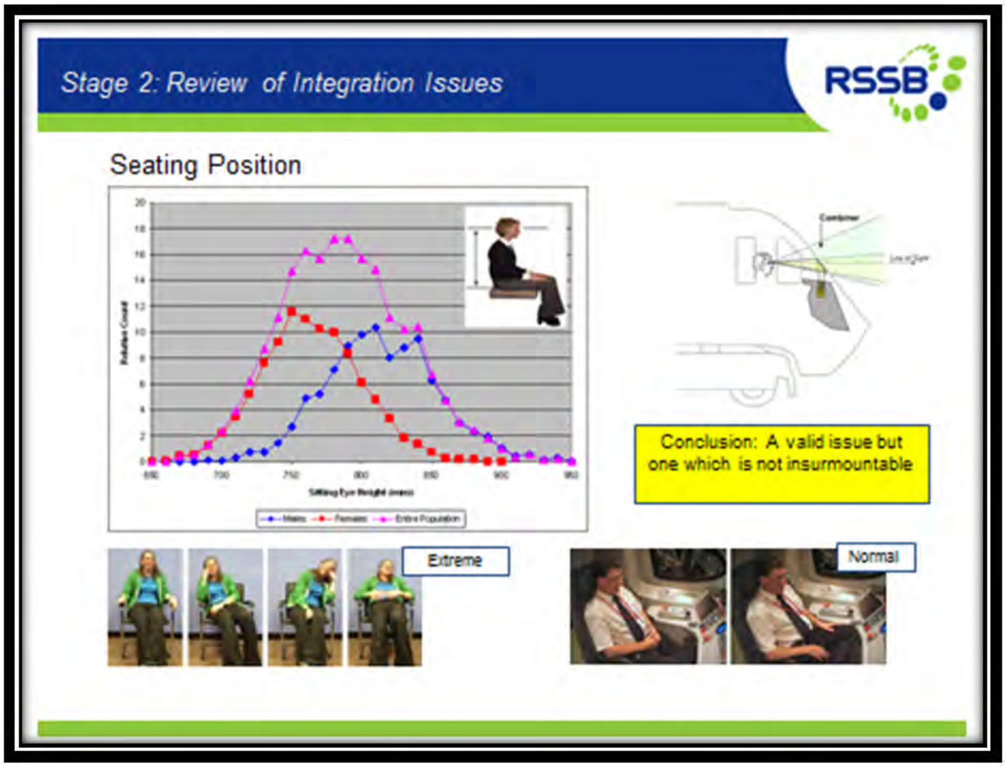

Research
RSSB
Stage 1) Assessment of Potential Safety Benefit
Review of Rail Incidents
Stage 2) Review of Integration Issues for the Rail Environment
Engineering Review
Stage 3) Assessment of Potential Benefits from Driver's Perspective
Simulator Study

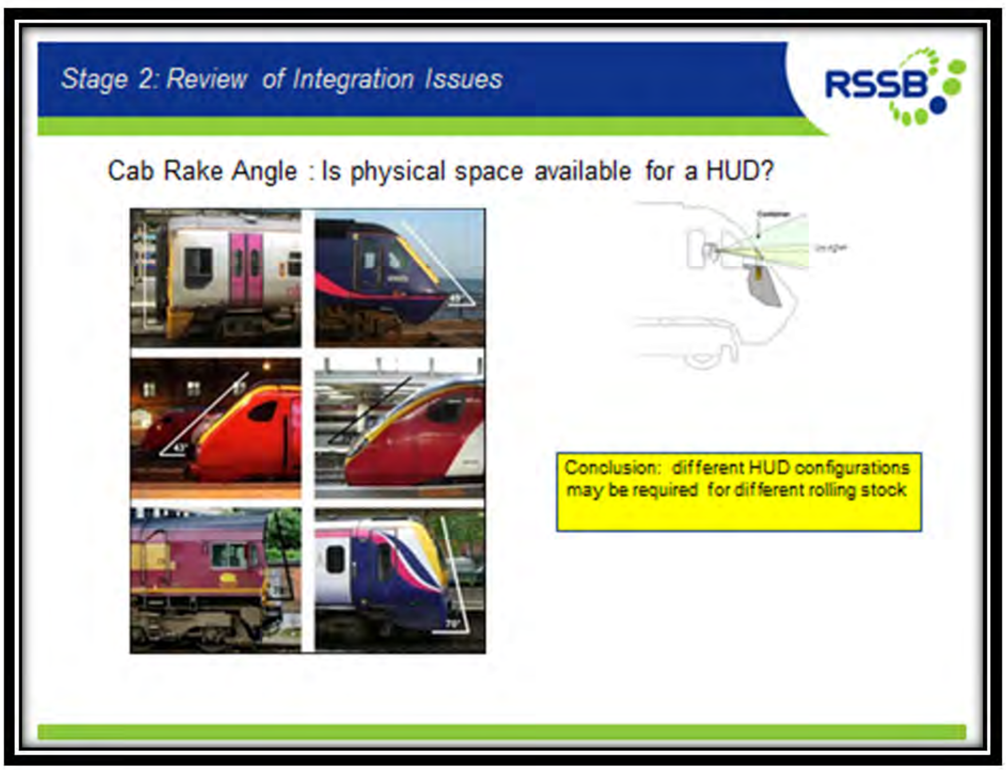


Stage 1: Review of Rail Incidents
RSSB
Summary of the functionality required to offer benefit across a representative sample of 200 UK rail incidents
No HUD Contribution
Last Signal Aspect Indication
Conformal Cue for Signals
Head-Up Instruments
DRA Information
Poor Adhesion Information
Night Vision
Presentation of Schedule
Conformal Braking Cue
Braking Airflow Meter
Track circuit information
43.1
20.9
16.6
9.0
3.8
2.8
1.9
0.5
0.5
0.5
0.5
0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0 45.0 50.0
% Incidents with Hypothetical HUD Contribution
Required HUD Functionality



Stage 1: Review of Rail Incidents
RSSB
Symbol Set Suggested by Incident Analysis
Cue to Signal Location
Speed
Brake Instruments
Power Setting
AWS Repeater
3


Stage 2: Review of Integration Issues
RSSB
Seating Position
Conclusion: A valid issue but one which is not insurmountable
Extreme
Normal


Stage 2: Review of Integration Issues
RSSB
Cab Rake Angle : Is physical space available for a HUD?
Conclusion: different HUD configurations may be required for different rolling stock


Stage 3: Simulator Assessment
RSSB
Based on Class 390 'Pendolino'
Located at BAE SYSTEMS in Bristol

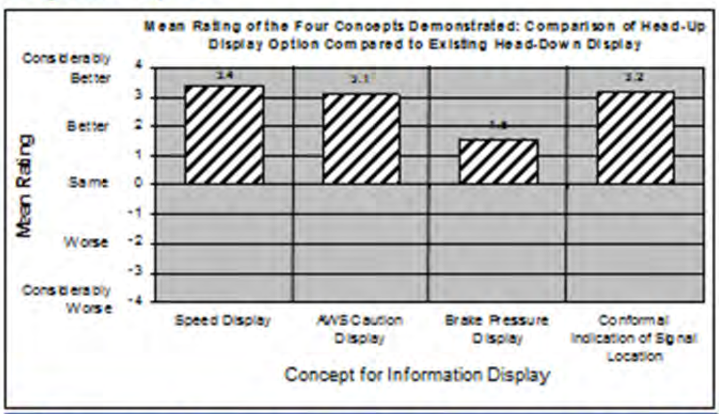

Stage 3: Simulator Assessment
RSSB
Trials Simulator
• Full driving controls
• AWS
• Driver's vigilance system
• Train management system
• Full experimenter station
• Integral touch-screen
• Workload assessment tools
• ERTMS & TVM 400
• Head Up display

Stage 3: Simulator Assessment

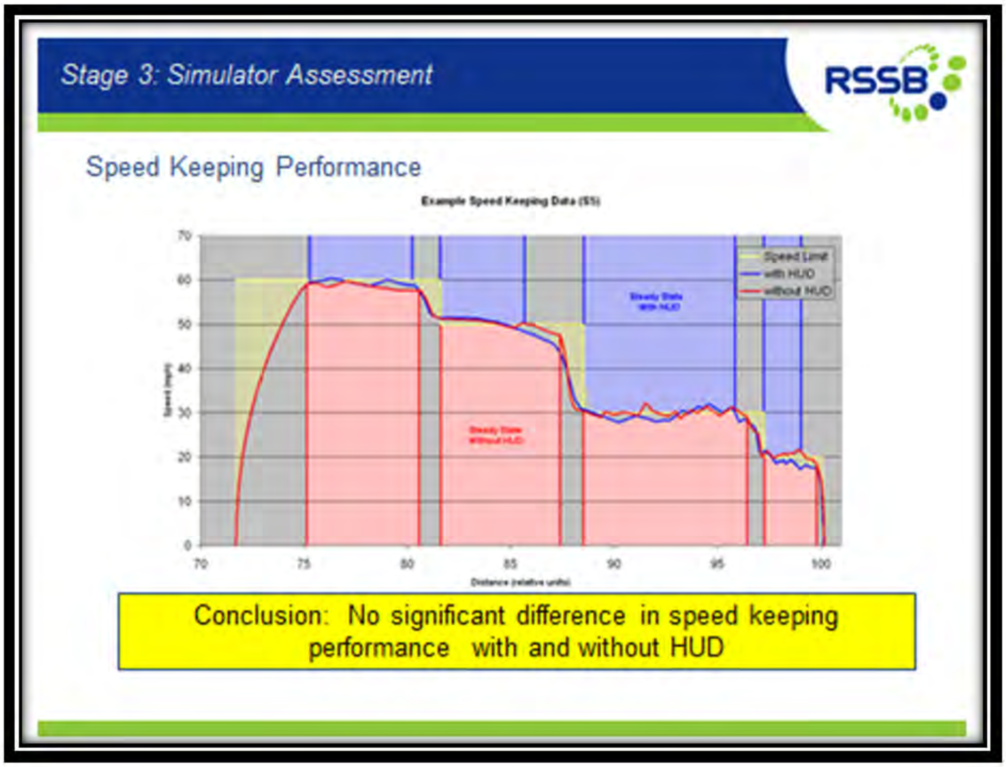
Assessments
- Overall value of head-up presentation of information
- Assessment of potential value of conformal symbology
- Impact of HUD on speed keeping
- Impact of HUD on workload

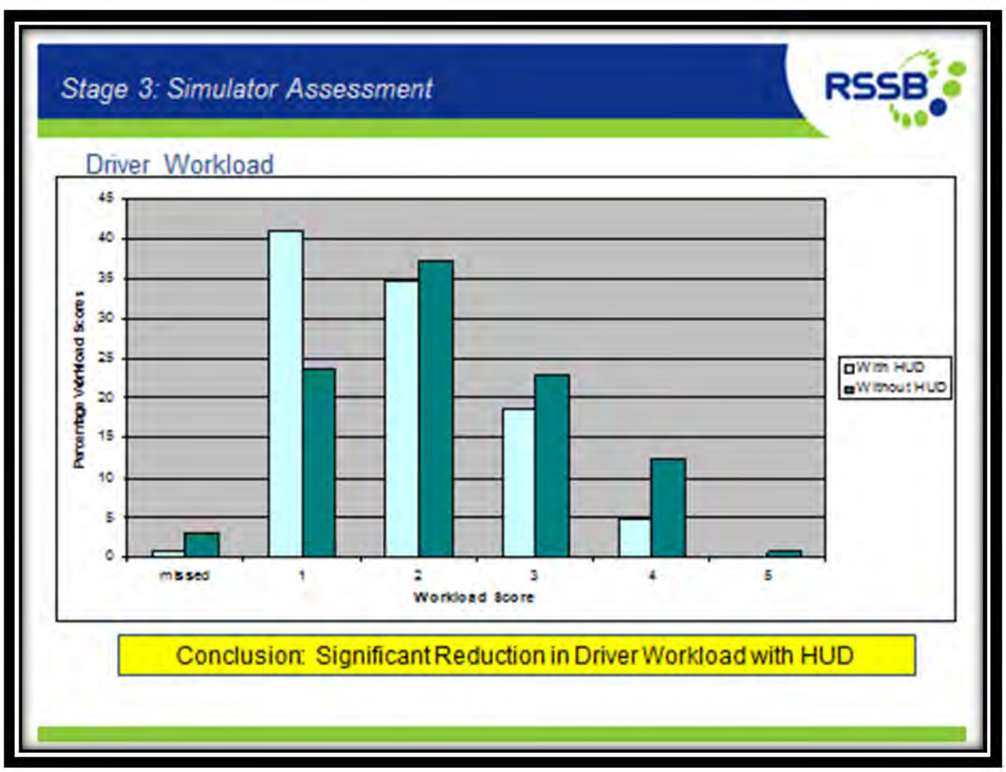
Stage 3: Simulator Assessment

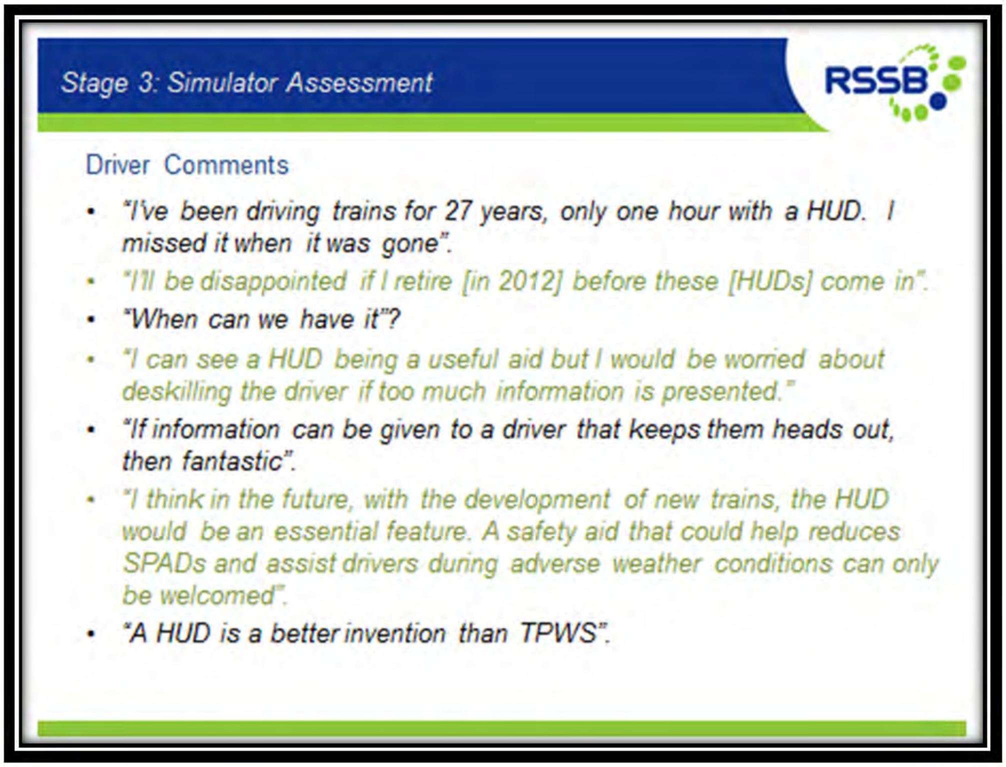
Driver Subjective Opinion

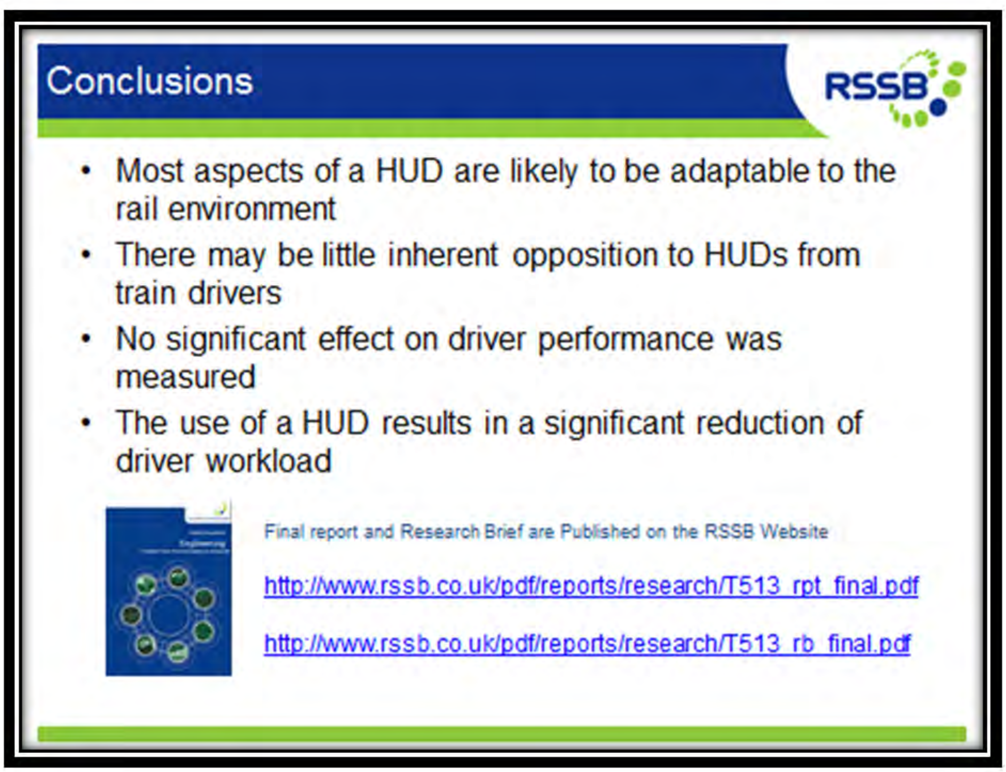


Conclusion: Drivers are supportive of the capability of a HUD, particularly for speed, AWS and signal information display

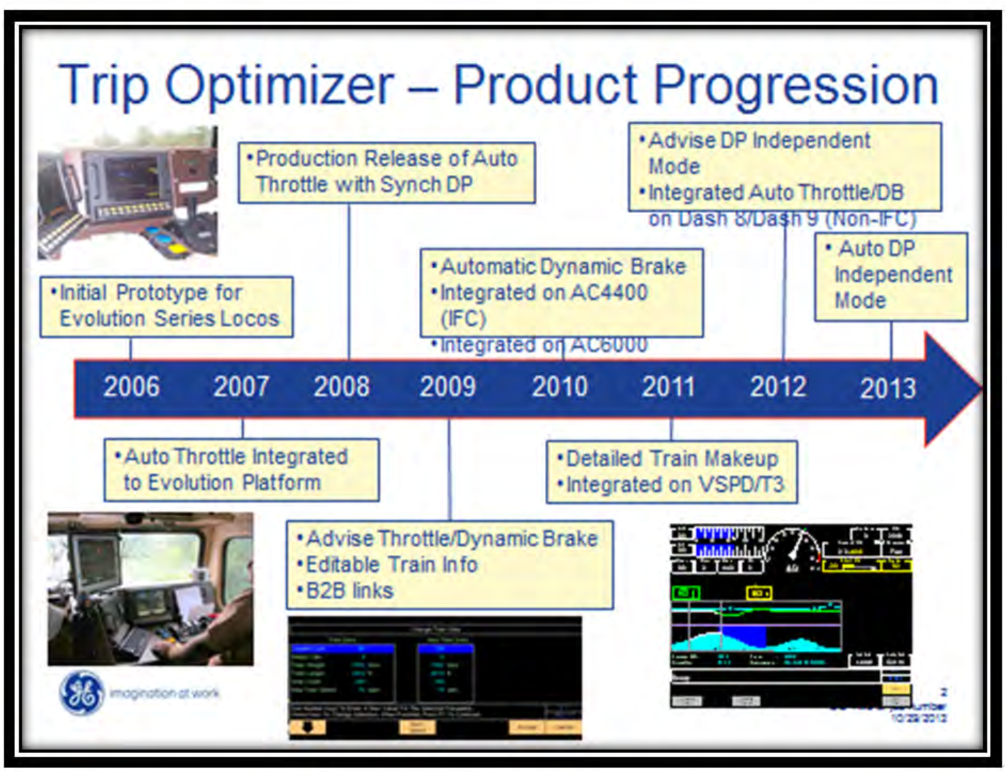

Stage 3: Simulator Assessment
RSSB
Speed Keeping Performance
Example Speed Keeping Data (S5)
Speed Limit
with HUD
without HUD
Steady State
with HUD
Steady State
Without HUD
Distance (relative units)
70
60
50
40
30
20
10
0
70
75
80
85
90
95
100
Conclusion: No significant difference in speed keeping performance with and without HUD


Stage 3: Simulator Assessment
RSSB
Driver Workload
Percentage Workload Scores
45
40
35
30
25
20
15
10
5
0
missed
1
2
3
4
5
Workload Score
With HUD
Without HUD
Conclusion: Significant Reduction in Driver Workload with HUD


Stage 3: Simulator Assessment
RSSB
Driver Comments
• "I've been driving trains for 27 years, only one hour with a HUD. I missed it when it was gone".
• "I'll be disappointed if I retire [in 2012] before these [HUDs] come in".
• "When can we have it"?
• "I can see a HUD being a useful aid but I would be worried about deskilling the driver if too much information is presented."
• "If information can be given to a driver that keeps them heads out, then fantastic".
• "I think in the future, with the development of new trains, the HUD would be an essential feature. A safety aid that could help reduces SPADs and assist drivers during adverse weather conditions can only be welcomed".
• "A HUD is a better invention than TPWS".


Conclusions
RSSB
• Most aspects of a HUD are likely to be adaptable to the rail environment
• There may be little inherent opposition to HUDs from train drivers
• No significant effect on driver performance was measured
• The use of a HUD results in a significant reduction of driver workload
Final report and Research Brief are Published on the RSSB Website
http://www.rssb.co.uk/pdf/reports/research/T513_rpt_final.pdf
http://www.rssb.co.uk/pdf/reports/research/T513_rb_final.pdf


Evolution of Energy Management
Advisement and Automatic Systems


Trip Optimizer – Product Progression
•Initial Prototype for Evolution Series Locos
•Production Release of Auto Throttle with Synch DP
•Automatic Dynamic Brake
•Integrated on AC4400 (IFC)
•Integrated on AC6000
•Advise DP Independent Mode
•Integrated Auto Throttle/DB on Dash 8/Dash 9 (Non-IFC)
• Auto DP Independent Mode
2006
2007
2008
2009
2010
2011
2012
2013
•Auto Throttle Integrated to Evolution Platform
•Advise Throttle/Dynamic Brake
•Editable Train Info
•B2B links
•Detailed Train Makeup
•Integrated on VSPD/T3
imagination at work

Energy Management

- Hardware and software solution to provide optimal speed profile over a route for most fuel efficient "Trip" possible
- Non-vital system using automatic throttle and dynamic brake control
- Train operator responsible for safe train operation at all times – must still maintain full vigilance and situational awareness at all times
- Manual control obtained at any time through a variety of methods
- User interfaces through HMI in Lead controlling locomotive

Energy Management: Auto Throttle

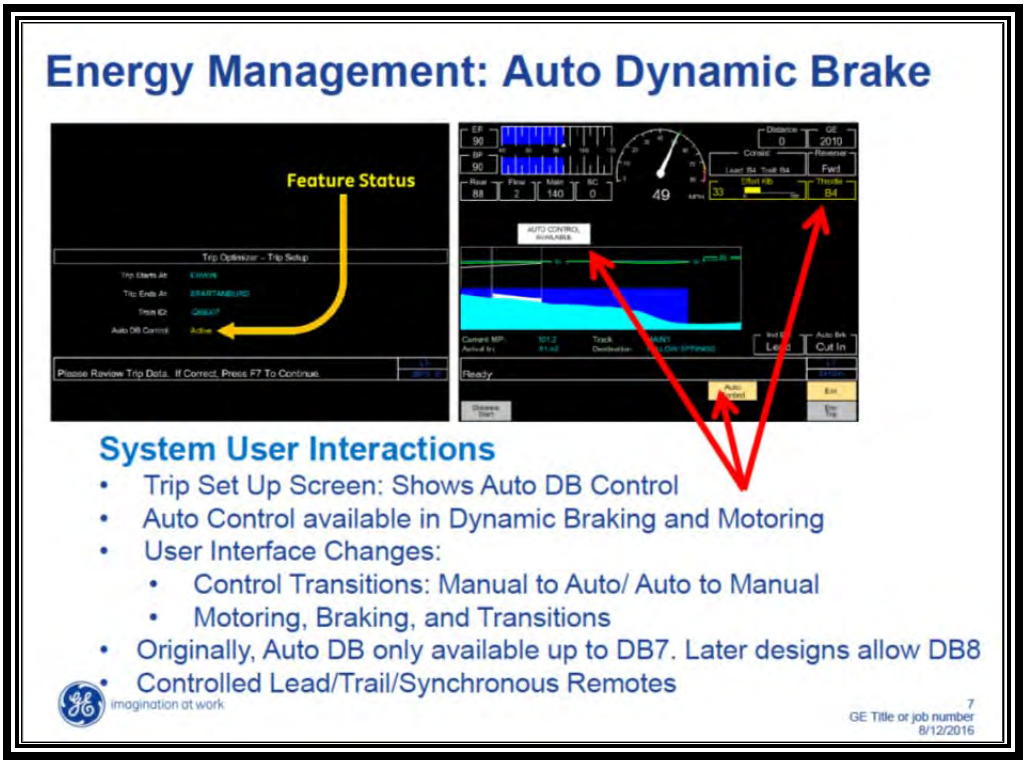
Original Interface

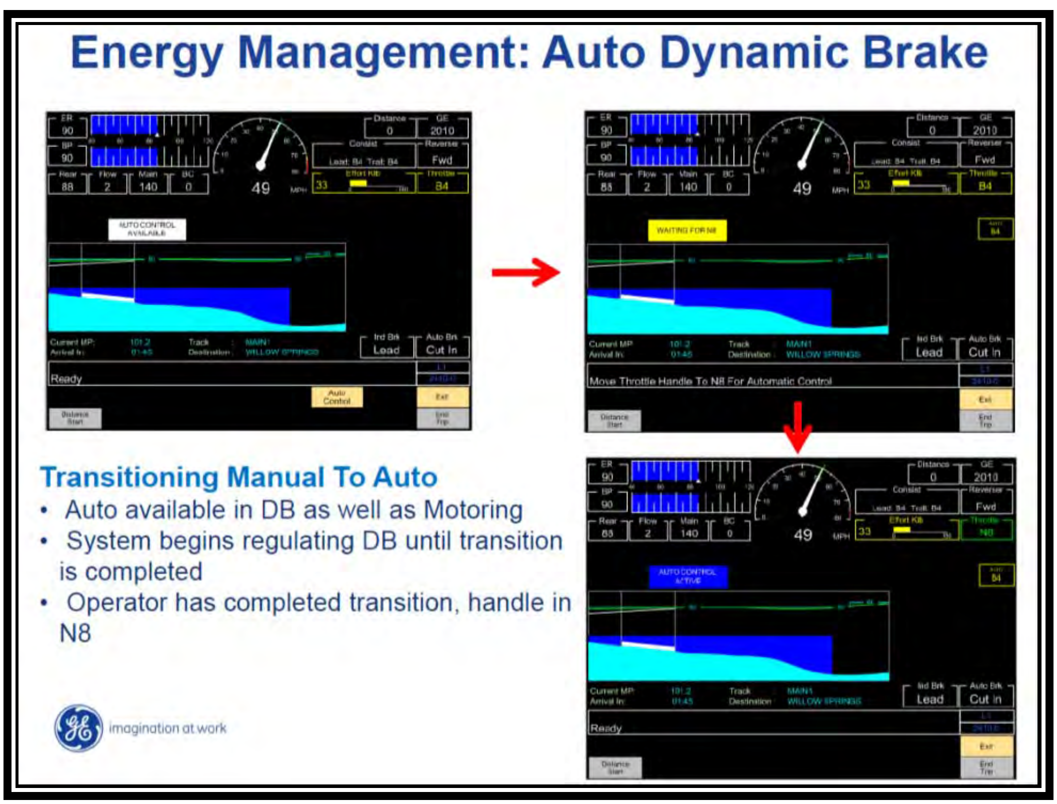
- Brown used to represent ground (blue used today)
- Yellow Zone for slow orders (now removed)
- Actual speed line was Magenta, Train was blue (both now white)
- Extraneous text "Speed" and "Terrain" (now removed)
- Auto Throttle Box white (now either yellow or green with Auto DB to match coloring or notch box)

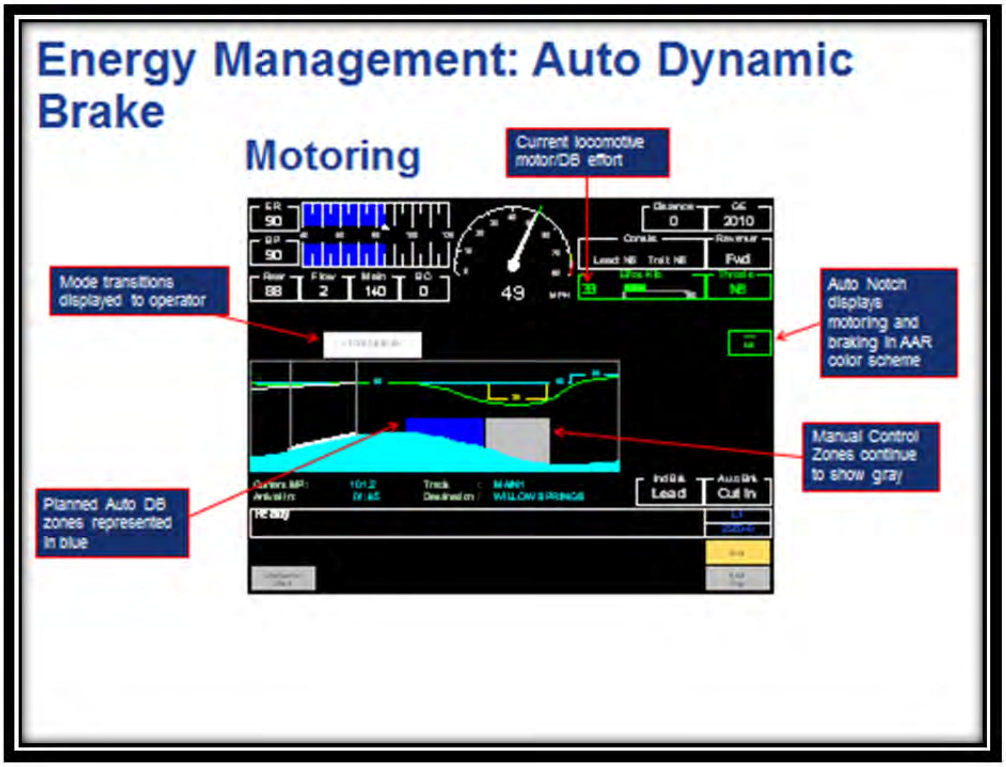
Energy Management: Advisement

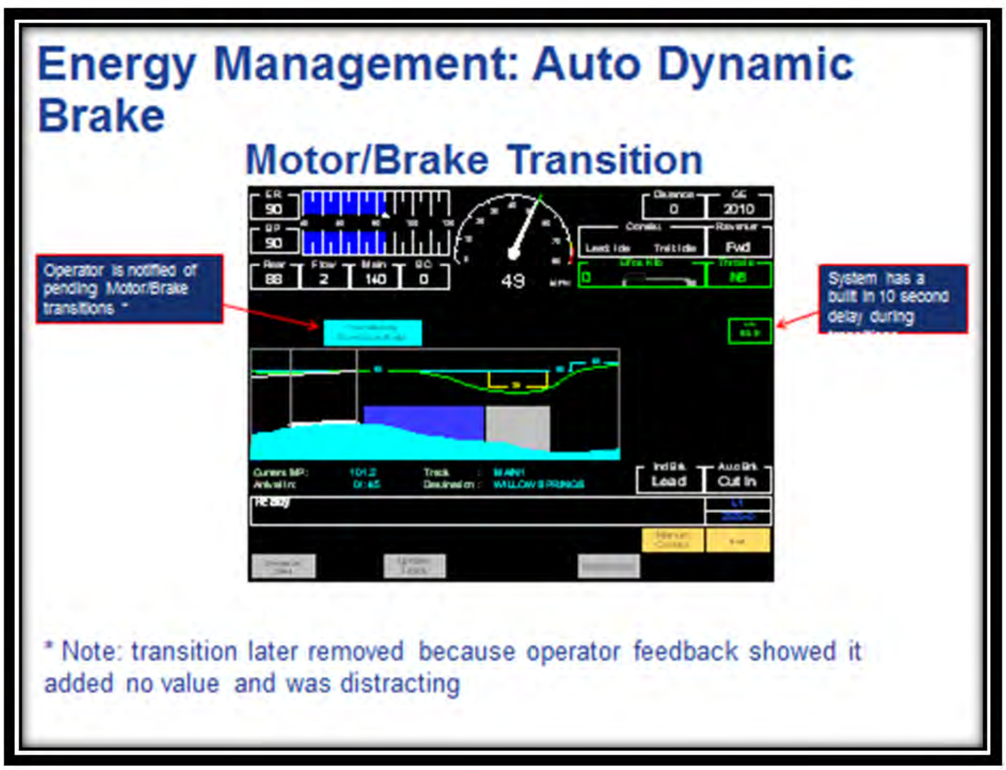
- Prompts operator to control train speed via simple visual prompts on the display. Arrow indicates if the next prompt will be a higher (↑) or lower (↓) command
- Open loop control

Automatic Dynamic Braking


Energy Management: Auto Dynamic Brake
Feature Status
System User Interactions
• Trip Set Up Screen: Shows Auto DB Control
• Auto Control available in Dynamic Braking and Motoring
• User Interface Changes:
• Control Transitions: Manual to Auto/ Auto to Manual
• Motoring, Braking, and Transitions
• Originally, Auto DB only available up to DB7. Later designs allow DB8
• Controlled Lead/Trail/Synchronous Remotes
imagination at work
7
GE Title or job number
8/12/2016

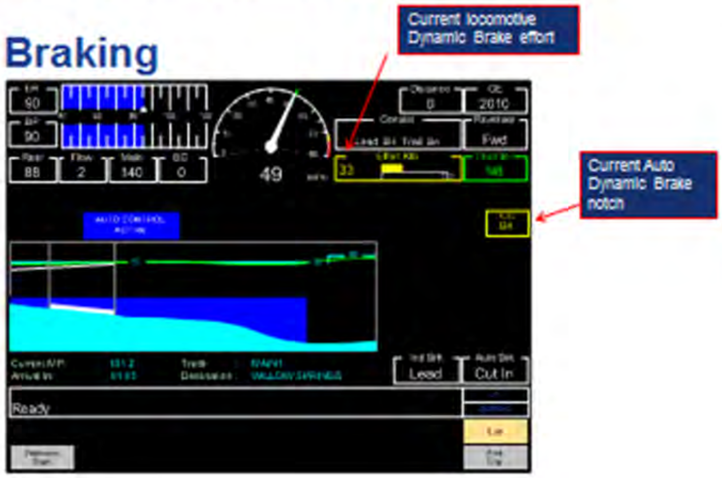

Energy Management: Auto Dynamic Brake
Transitioning Manual To Auto
• Auto available in DB as well as Motoring
• System begins regulating DB until transition is completed
• Operator has completed transition, handle in N8
imagination at work


Energy Management: Auto Dynamic Brake
Motoring
Current locomotive motor/DB effort
Mode transitions displayed to operator
Auto Notch displays motoring and braking in AAR color scheme
Manual Control Zones continue to show gray
Planned Auto DB zones represented in blue
49
Fwd
Lead
Cut In

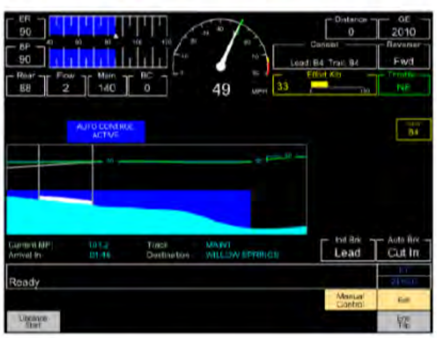

Energy Management: Auto Dynamic Brake
Motor/Brake Transition
Operator is notified of pending Motor/Brake transitions *
System has a built in 10 second delay during
49
Fwd
Lead
Cut In
* Note: transition later removed because operator feedback showed it added no value and was distracting

Energy Management: Auto Dynamic Brake

Braking

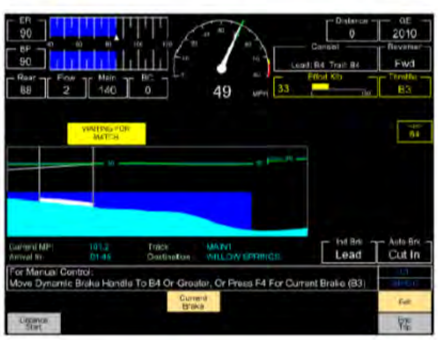


Energy Management: Auto Dynamic Brake



Auto To Manual: Transition Initiation

- Operator may make an air brake application
- Operator may move the Master Controller out of N8
- Operator may press the Manual Control key



Auto To Manual: Transition Completion

- Operator is instructed on actions needed to complete the transition
- Preferred method of completing transition is matching throttle
- System will maintain Dynamic Brake

Energy Management: Independent DP

Independent DP **Advise**

- Notch Prompts on Main Operator Screen
- End of Train remote Consist Only
- Limit back group notch changes to minimize operator work load

Automatic Independent DP

- Command status on DP operation screen
- Mid train remotes and two remote consists
- Algorithms consistent with train handling needs

imagination at work

13
GE Title or job number
10/29/2013

Automatic Independent Mode

imagination at work

14
GE Title or job number
10/29/2013

Energy Management: Auto Independent

User Interface Changes

➢ Trip Set Up Screen: Shows Auto Ind Control

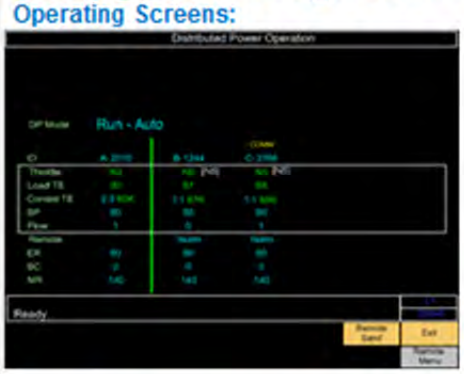
imagination at work

GE Proprietary & Confidential Material

15
GE Title or job number
10/29/2013

Energy Management: Auto Independent

Operating Screens:



Auto Independent Control DP screen changes

- DP Mode indicates Run – Auto
- Fence is up, indicating independent control mode; Fence after lead consist
- Remote consist commanded notch is shown in brackets next to notch status
- Softkeys that control fence position and back group power levels are hidden

Rolling Map Screen:

Removed blue braking zone box

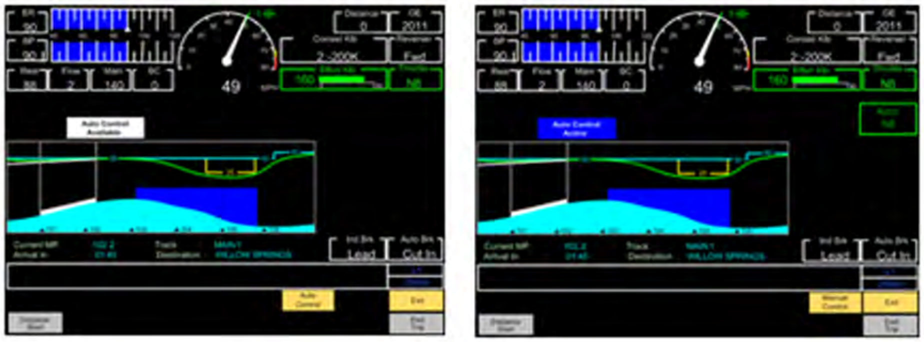
Consist Indicator (Grey Line) on Train

Process for engaging and disengaging from Auto Mode remains the same

16
GE Title or job number
10/29/2013

Energy Management: Auto Independent

Rolling Map Screens – Transitioning into Automatic Control



- When transitioning from manual to auto and vice versa system will maintain current operating mode (i.e. synchronous or independent)
- When a transition from auto to manual occurs, matching of throttle is based on lead consist notch at the time of transition

imagination at work

17
GE Title or job number
10/29/2013

GE Proprietary & Confidential Material

Air Brake Advisement

imagination at work

18
GE Title or job number
10/29/2013

Energy Management: Air Brake Advisement

Air Brake Advisement for speed control while in automatic operation

Advisement of air applications up to a 15 psi reduction

Using available data (train speed and dynamics) to plan and advise air brake applications

Control adjusts advisement based on performance and estimations

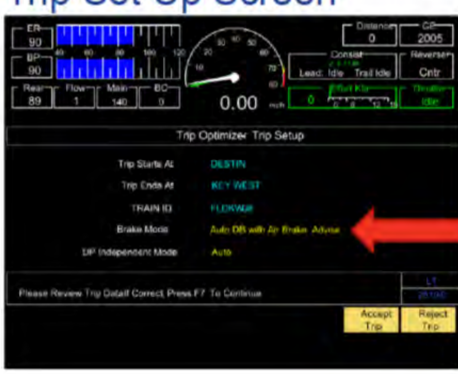
Design Still in Progress – Targeting initial launch 2013

imagination at work

GE Title or job number

Energy Management: Air Brake Advisement

Trip Set Up Screen



Rolling Map

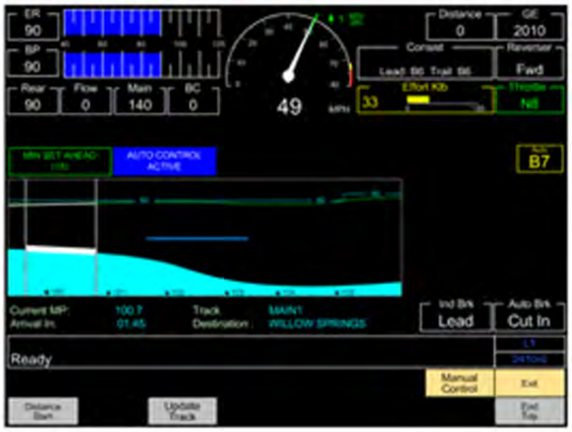
Planned air brake zones indicated by blue lines - lines update dynamically real-time

Eliminated blue dynamic braking zones

imagination at work

20
GE Title or job number
8/12/2016

Energy Management: Air Brake Advisement

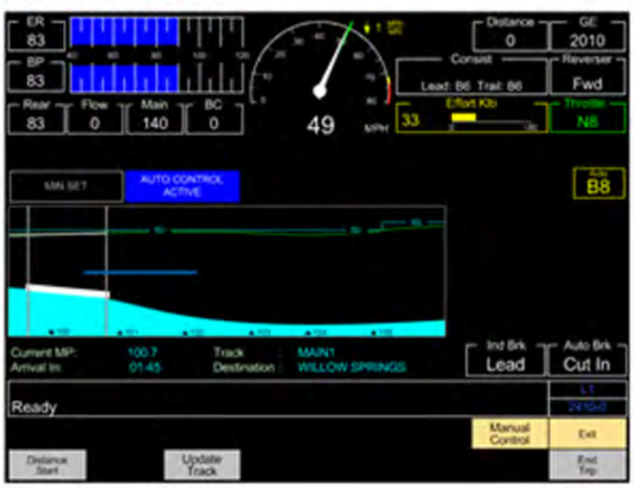


- System prompts for air application with a 15 second countdown timer
- Designed for the engineer to apply at the end of the 15 seconds
- Prompts transitions to a flashing state and tone sounds at the end of the 15 seconds
- Additional 15 second countdown follows for the engineer to complete action
- Transition to manual occurs if action is not performed

imagination at work

21
GE Title or job number
10/29/2012

Energy Management: Air Brake Advisement

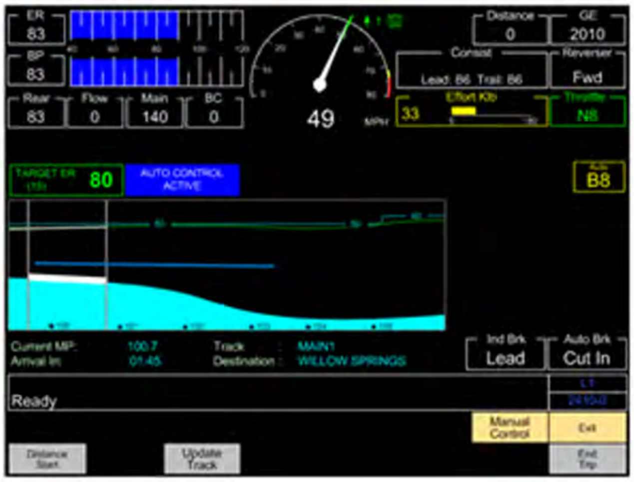


- Prompt grays out once engineer has taken action
- System designed to accommodate engineer making the prompted application or more/less

imagination at work

22
GE Title or job number
10/29/2012

Energy Management: Air Brake Advisement

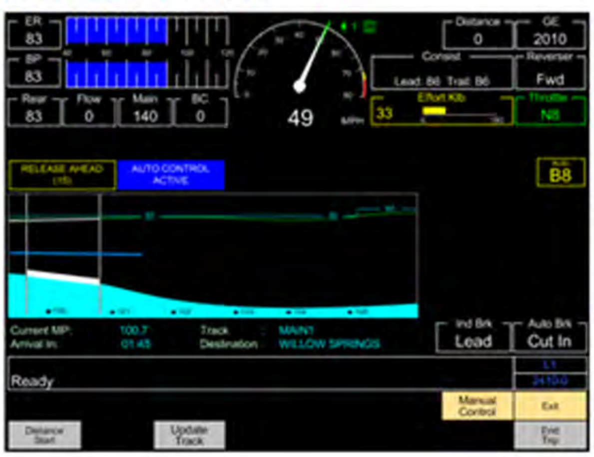


- Prompt for a split reduction or an initial 10lb reduction
- Prompt grays out once action has been taken by the engineer

imagination at work

23
GE Title or job number
10/29/2013

Energy Management: Air Brake Advisement



- System prompts for release with a 15 second countdown timer
- Designed for the engineer to apply at the end of the 15 seconds
- Prompts transitions to a flashing state and tone sounds at the end of the 15 seconds
- Additional 15 second countdown follows for the engineer to complete action
- Transition to manual occurs if action is not performed

imagination at work

24
GE Title or job number
10/29/2013

RSSB

Designing future systems with the end user in mind: The European perspective

Anita Scott
Senior Human Factors Specialist, RSSB

Projects

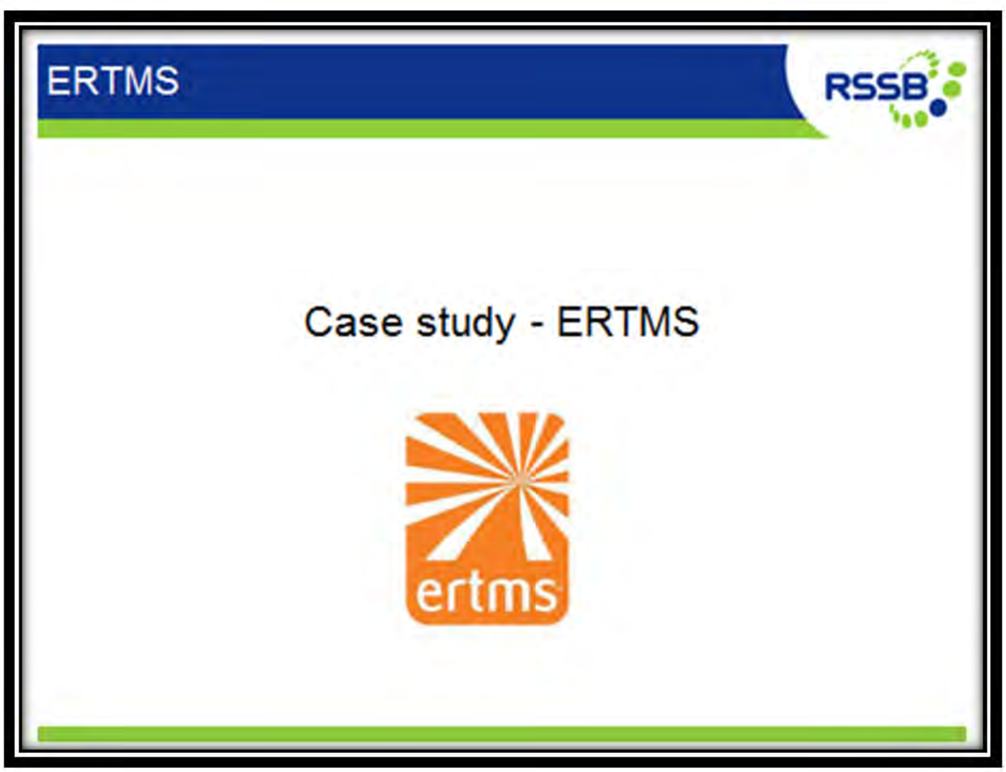
RSSB

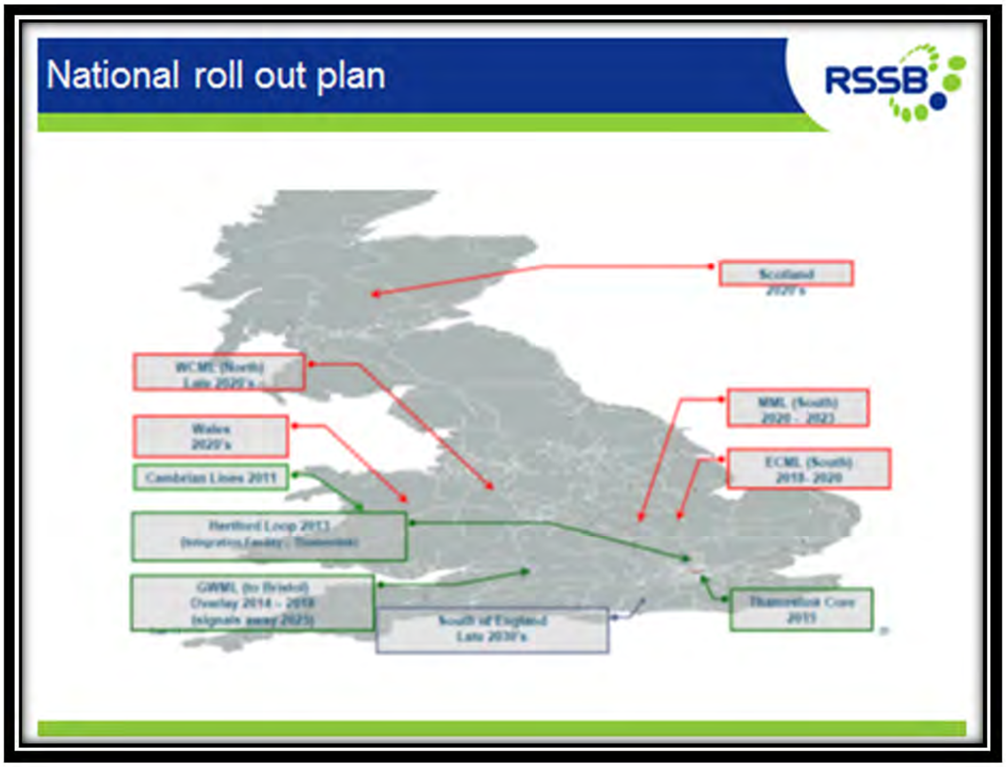
- How to manage what you have today with a view to the future
- Examples of projects
  - Integrating existing train protection systems with automatic train protection systems using the same interface
  - Integrating energy saving systems into the drivers cab
  - Metrication of our imperial railway (miles and chains!)

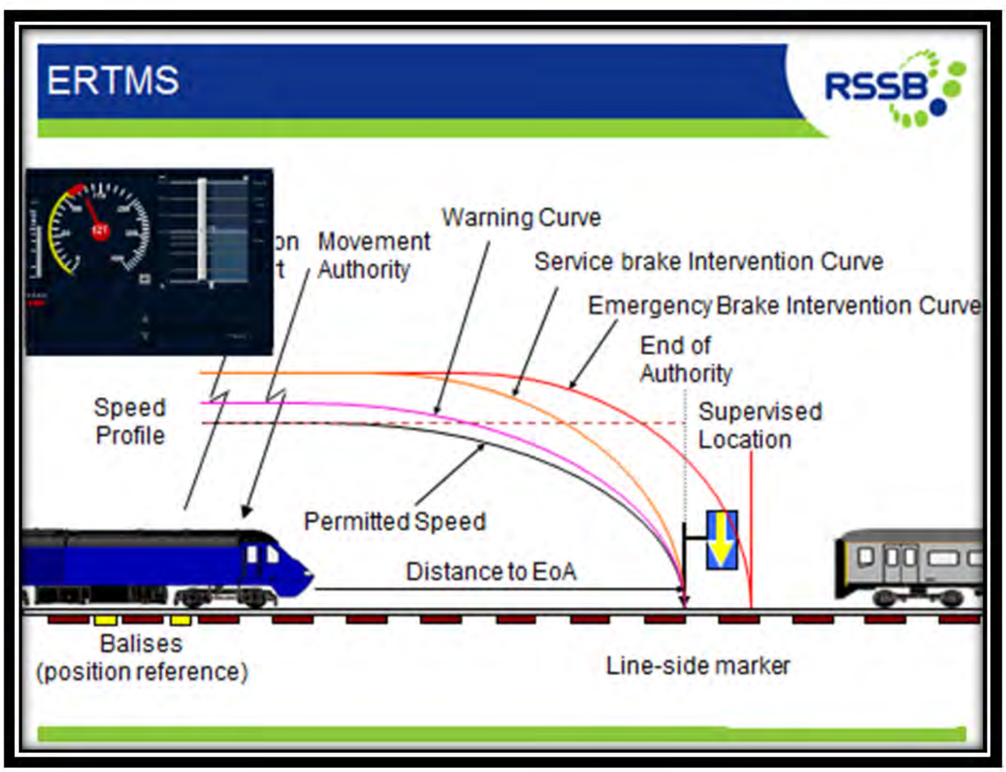
Knorr Bremse – Driver advisory system

Imperial and metric speedometer


HF Integration
RSSB
• To successfully integrate you must consider:
– Operability of equipment
– Physical design of equipment
– Functional safety and system security
– Staffing and training development
– Procedures and staff organisation
– Integrating human factors into system development


ERTMS
RSSB
Case study - ERTMS
ertms


National roll out plan
RSSB
Scotland
2020's
WCML (North)
Late 2020's
Wales
2020's
Cambrian Lines 2011
Hertford Loop 2013
GWML (to Bristol)
Overlay 2014 - 2018
(signals away 2025)
South of England
Late 2030's
MML (South)
ECML (South)
2018- 2020
Thameslink Core


ERTMS
RSSB
Warning Curve
Movement
Authority
Service brake Intervention Curve
Emergency Brake Intervention Curve
End of
Authority
Speed
Profile
Supervised
Location
Permitted Speed
Distance to EoA
Balises
(position reference)
Line-side marker


Operability – Integrating with legacy systems
RSSB
• Converting a hardware interface to a touch screen
Existing hardware train protection system interfaces
TEMPORARY ISOLATION/ FAULT
TRAIN STOP OVERRIDE
BRAKE RELEASE
Possible solution: Existing train protection system interface when integrated into ETCS DMI touchscreen


Physical design
RSSB
97303
Most important and frequently used equipment:
• Within reach
• Within visual field
Anthropometry

Functional safety & system security

RSSB

- Data entry before departure
  - Preference for automated loading of data, then
  - Preference for preconfigured to manual input
  - If manual could have errors in eg, train category, max train speed, train length etc. which impacts train supervision and may result in overspeed and SPAD
- Working groups in GB and Belgium looking at the issue and potential mitigations

Staffing and training and development

RSSB

Training simulator in Spain

- Most European Countries implementing ERTMS have a test site or a new line to ease introduction and learning
- GB will have fitted and unfitted trains and retro fitting of equipment to existing trains
- Require an industry strategy for the training of existing and new people to operate in an ETCS environment
- Simulator – familiarising drivers in low risk environment

Spain – training experience

RSSB

- 3 days training per driver per ETCS DMI supplier
- Since ERTMS was introduced, training has increased by 500%
- ETCS training is simulator practice and practical handling
- Training emphasis is on rare/ failure scenarios

Procedures and staff organisation

RSSB

- Speed restriction management
  - Improvement - direct implementation of speed restriction by signaller
  - No need to go on track to erect speed signs
  - For Cambrian Lines, conversions needed for imperial to metric data for locations of speed restrictions – error potential
  - During migration – mix of fitted and unfitted trains – still require old method

The old way

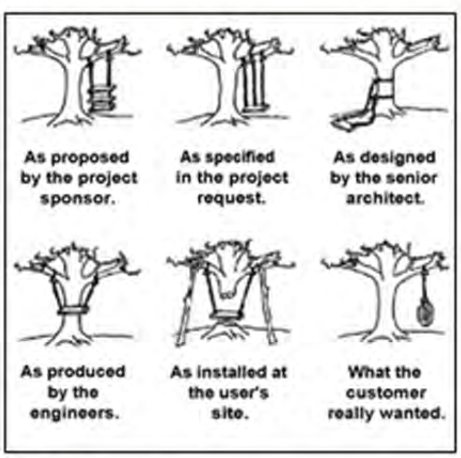
Integrating HF into system development

RSSB

- Systems engineering approach
- Integration of HF requirements into requirements database
- Operations Concept for ERTMS
- Follow-on detailed HF work for 'gaps' in the concept

Key message

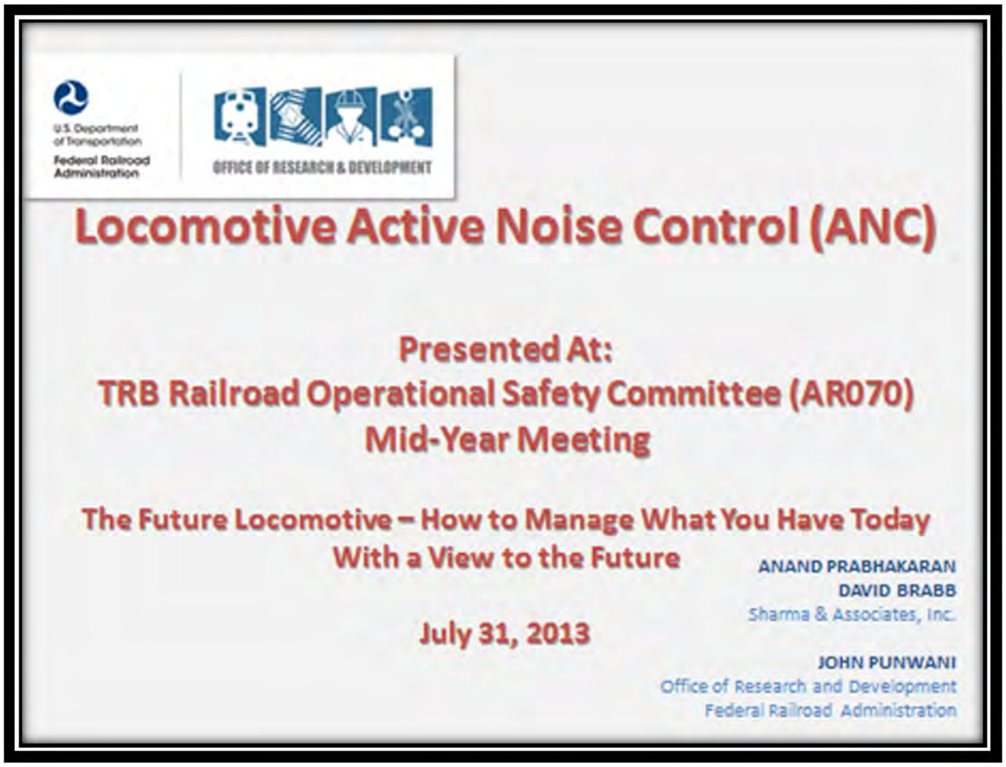
RSSB

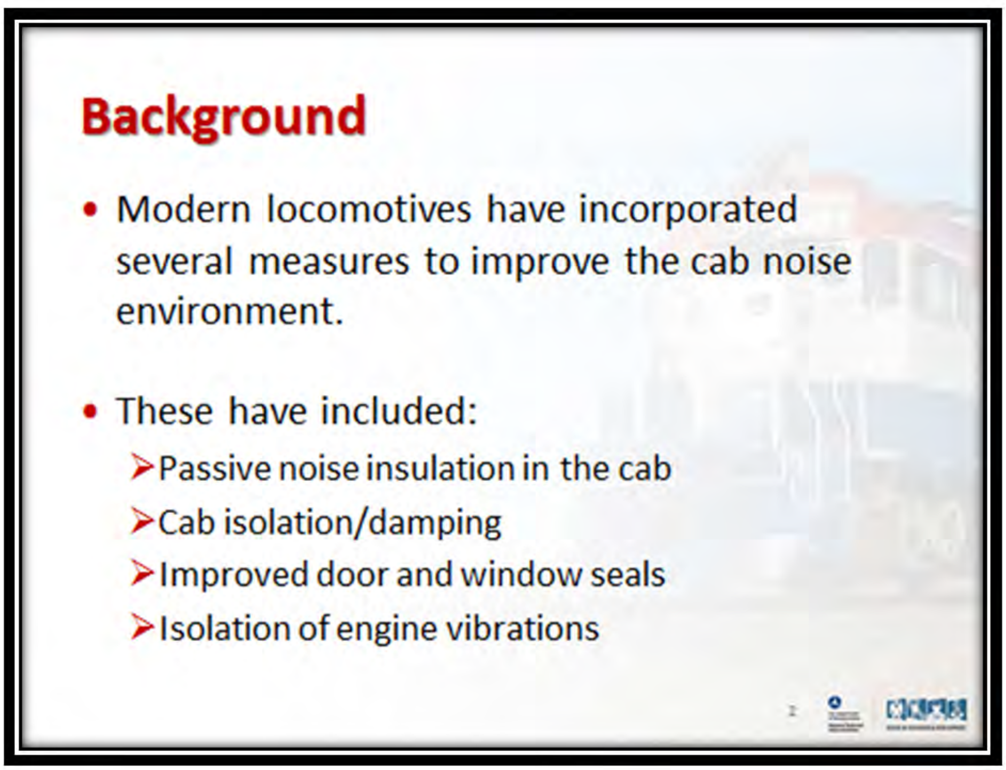


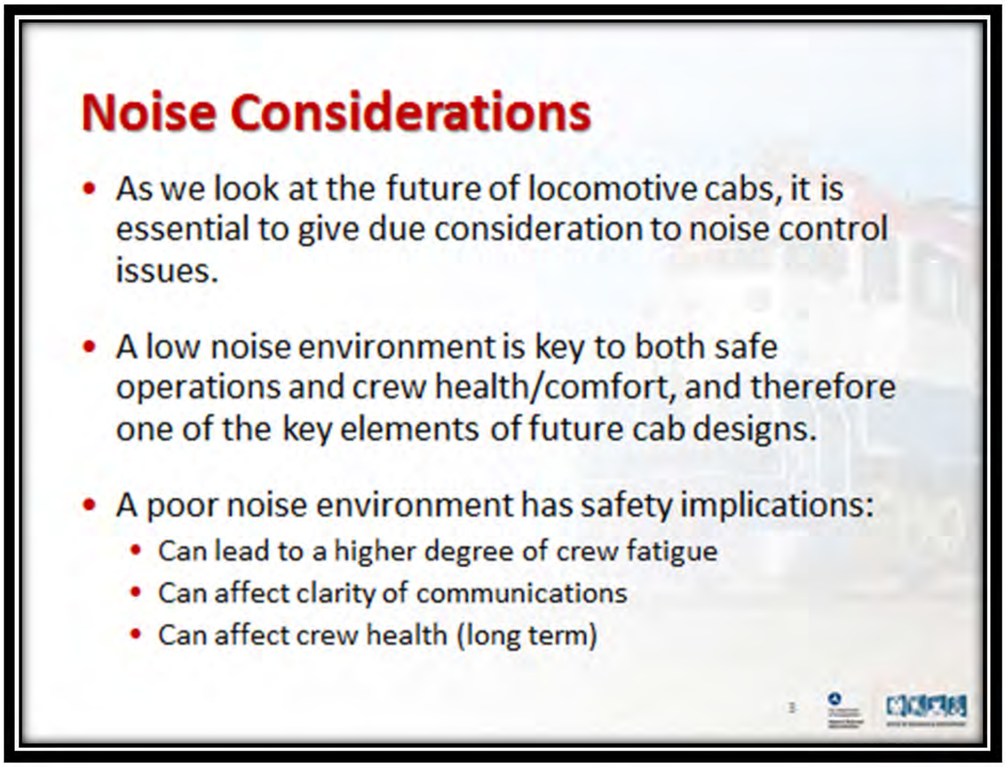
'Tree Swing'

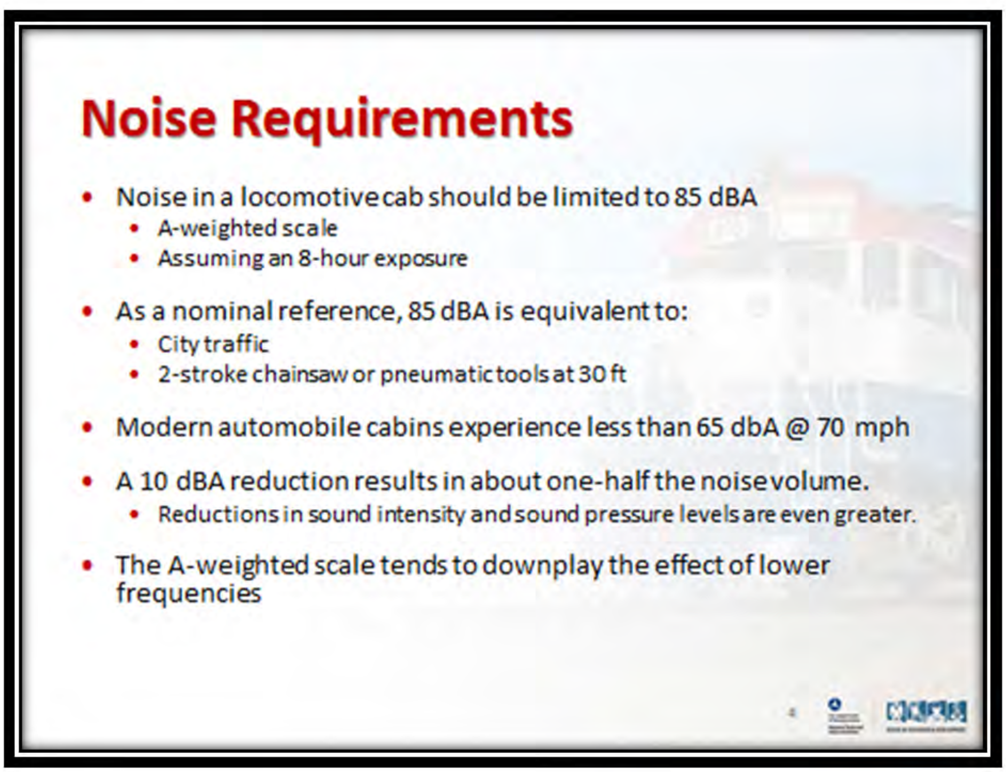
- Who is the customer?
- The end user
- The train driver, signaller, track maintainer…


RSSB
Any Questions?
anita.scott@rssb.co.uk


U.S. Department of Transportation
Federal Railroad Administration
OFFICE OF RESEARCH & DEVELOPMENT
Locomotive Active Noise Control (ANC)
Presented At:
TRB Railroad Operational Safety Committee (AR070)
Mid-Year Meeting
The Future Locomotive – How to Manage What You Have Today
With a View to the Future
July 31, 2013
ANAND PRABHAKARAN
DAVID BRABB
Sharma & Associates, Inc.
JOHN PUNWANI
Office of Research and Development
Federal Railroad Administration


Background
• Modern locomotives have incorporated several measures to improve the cab noise environment.
• These have included:
➢Passive noise insulation in the cab
➢Cab isolation/damping
➢Improved door and window seals
➢Isolation of engine vibrations
2


Noise Considerations
As we look at the future of locomotive cabs, it is essential to give due consideration to noise control issues.
A low noise environment is key to both safe operations and crew health/comfort, and therefore one of the key elements of future cab designs.
A poor noise environment has safety implications:
Can lead to a higher degree of crew fatigue
Can affect clarity of communications
Can affect crew health (long term)


Noise Requirements
Noise in a locomotive cab should be limited to 85 dBA
A-weighted scale
Assuming an 8-hour exposure
As a nominal reference, 85 dBA is equivalent to:
City traffic
2-stroke chainsaw or pneumatic tools at 30 ft
Modern automobile cabins experience less than 65 dbA @ 70 mph
A 10 dBA reduction results in about one-half the noise volume.
Reductions in sound intensity and sound pressure levels are even greater.
The A-weighted scale tends to downplay the effect of lower frequencies

Locomotive Cab Noise

- Sources
  - Prime-mover (Engine) operation
  - Wind noise
  - Structural noise (from long hood components)
  - Structural noise (from track input)
  - Short term noise (horns, whistles, etc.)
- Character
  - Significant low frequency content
  - Engine noise is tonal

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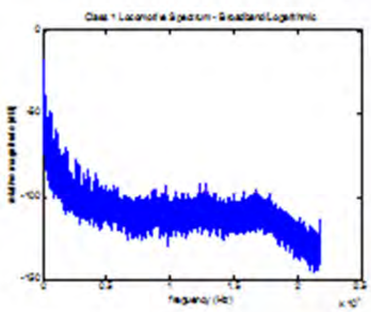
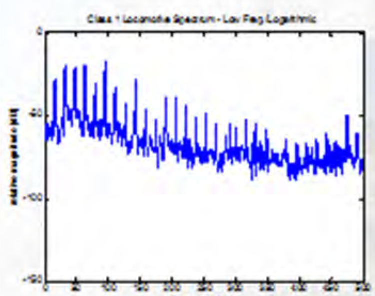
Example of Locomotive Sound

- Low frequency content is most dominant of all sound energy
- Low frequency content is tonal in nature





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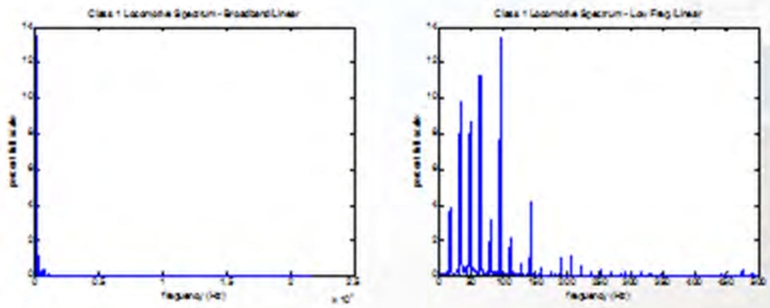
Example – Loco Sound - Linear

- Identical data from earlier spectrum plot with linear y-axis
- Low frequency zoom-in shows intense LF tonal content



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ANC Project Description

- The Office of Research & Development (RDV) of the FRA is exploring potential solutions for improving the noise environment in locomotive cabs, particularly, the low frequency content.
- Among others, the FRA has funded a research effort to evaluate 'in-cab', a locomotive noise cancellation/reduction (ANC) system.
- The underlying technology has been successfully implemented in several non-railroad applications.
  - The intent of this research effort is to evaluate the applicability & effectiveness in a locomotive cab.
- Mr. John Punwani is the Contracting Office's Representative (COR) of the FRA in charge of the project.

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What is ANC?

- Active control can be differentiated from passive control in that active control uses energy to destroy the energy present in a disturbance.
- Passive controllers merely dissipate energy by converting it into heat.
- Adaptive control can be differentiated from fixed control in that an adaptive controller continually "redesigns" itself to meet the instantaneous needs of a situation.
- Fixed controllers do the same thing, over and over, regardless of what noise is present.
  - The non-stationary tonal nature of locomotive noise makes the use of fixed ANC methods, such as active headphones, less productive.

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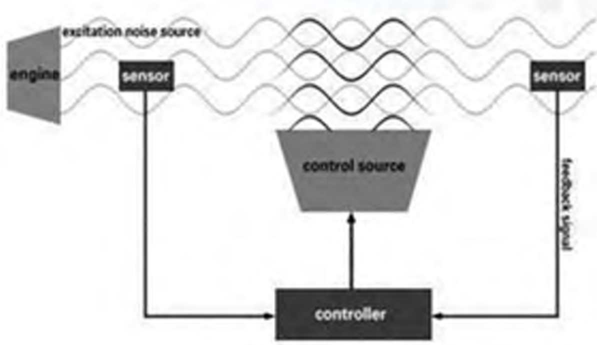
ANC – Why use it?

- There is LF tonal energy present that is difficult to practically address through passive treatment



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ANC General Description

- TechnoFirst® QuietCab™ adaptive, active noise cancellation or control (ANC) system reduces the low frequency noises generated by locomotive prime-movers without requiring the use of personal protection equipment worn on the head.

- Non-contact cabin quieting allows users to hear audible alarms and in-cab communications with less difficulty or interference.

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ANC - How it works

- The system uses sensors mounted on the headliner of the locomotive cab to measure the noise content in the cab.
- A tap into the engine's tachometer allows for tachometer readings while the locomotive is cycled from idle to notch 1 through notch 8. This information is used to correlate engine speed with noise.
- A digital signal processor-based active noise control unit with internal amplification calculates the counteracting noise sequence that will destructively interfere with the noise that is present during each locomotive throttle-notch position.
- The unit delivers this sequence using a precision speaker system that is mounted inside the cab.

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Project Scope

- The system was installed and tested on two locomotives
  - An older EMD built GP-40 unit @ TTCI
  - A newer GE built ES44AC unit @ a North American Railroad
- The evaluations @ TTCI were conducted at test track conditions, whereas the RR evaluations were conducted in revenue service
- In each case, baseline noise data and locomotive cab dimensions were used to customize the installation

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Test Locomotive @ TTCI

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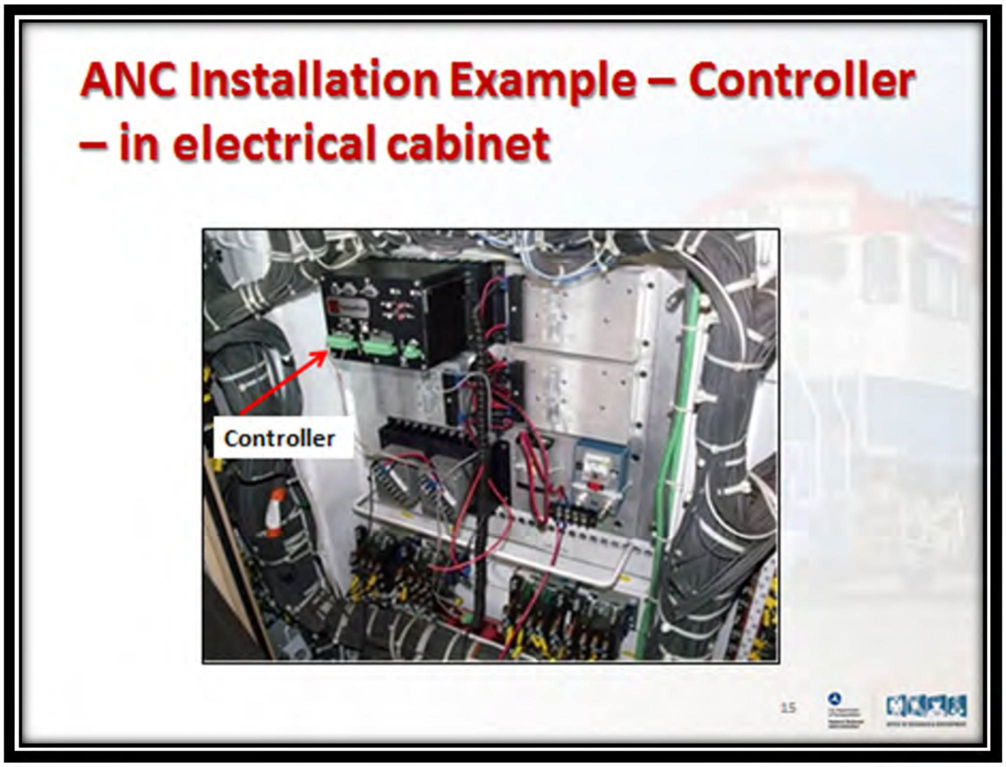
ANC Installation Example – Controller – in electrical cabinet
Controller
15


ANC Install – Microphone & On/Off Switch – above Engineer side window
On/Off switch
Microphone
16

ANC – Installation – Speakers above windshield

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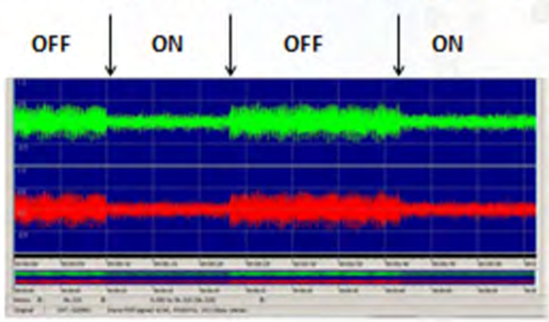
ANC – Test Results Example

- EMD GP-40 - ANC On/Off Noise Comparison, Engineer's Side, Notch 8, Left ear - green, Right ear - red:



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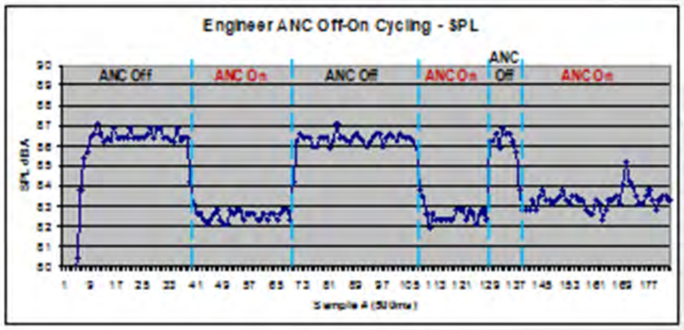
ANC – Test Results Example

- EMD GP-40 – dBA Comparison, Engineer’s Side, Notch 8.



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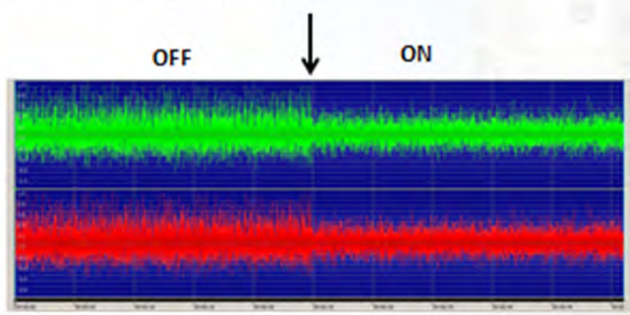
ANC – Test Results Example

- GE ES44AC - ANC On/Off Noise Comparison, Conductor Side, Notch 6:



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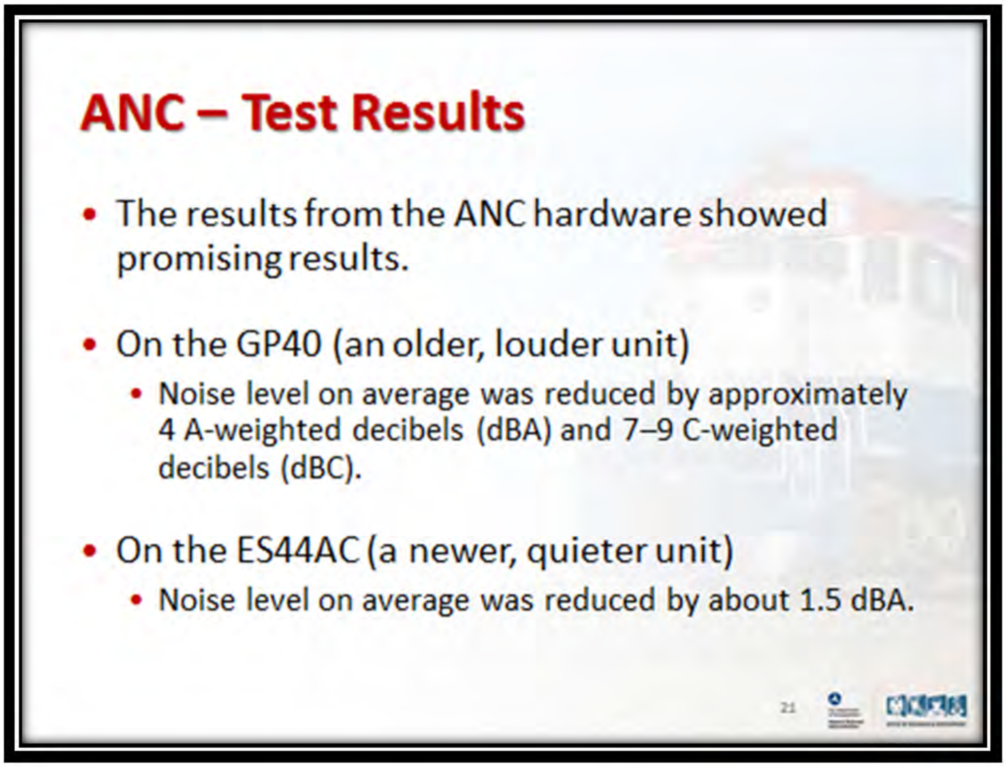
ANC – Test Results
• The results from the ANC hardware showed promising results.
• On the GP40 (an older, louder unit)
• Noise level on average was reduced by approximately 4 A-weighted decibels (dBA) and 7–9 C-weighted decibels (dBC).
• On the ES44AC (a newer, quieter unit)
• Noise level on average was reduced by about 1.5 dBA.
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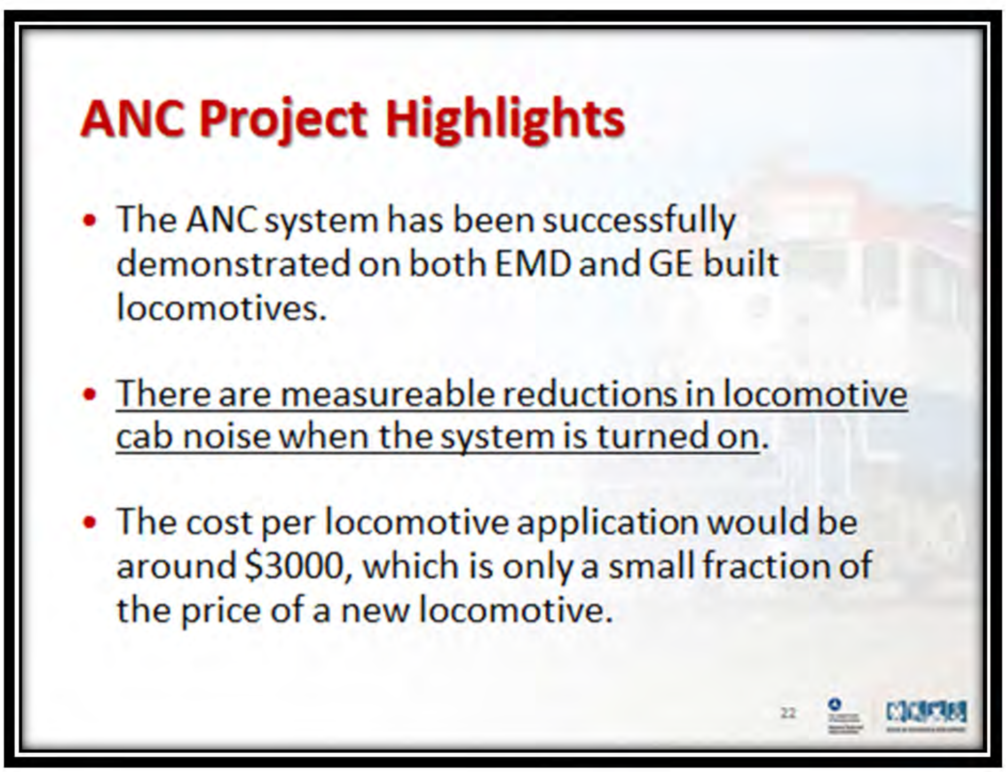
ANC Project Highlights
• The ANC system has been successfully demonstrated on both EMD and GE built locomotives.
• There are measureable reductions in locomotive cab noise when the system is turned on.
• The cost per locomotive application would be around $3000, which is only a small fraction of the price of a new locomotive.
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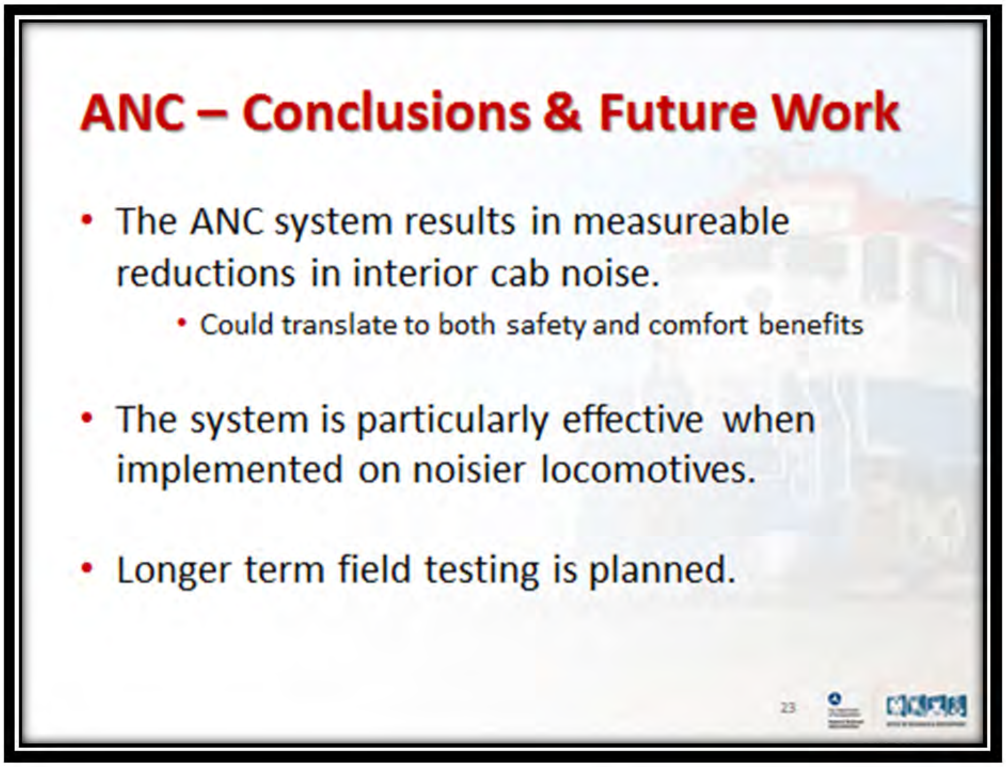
ANC – Conclusions & Future Work
• The ANC system results in measureable reductions in interior cab noise.
• Could translate to both safety and comfort benefits
• The system is particularly effective when implemented on noisier locomotives.
• Longer term field testing is planned.
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• David Brabb
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