

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

DETAILS

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Technical Activities Division; Transportation Research Board; National Academies of Sciences, Engineering, and Medicine

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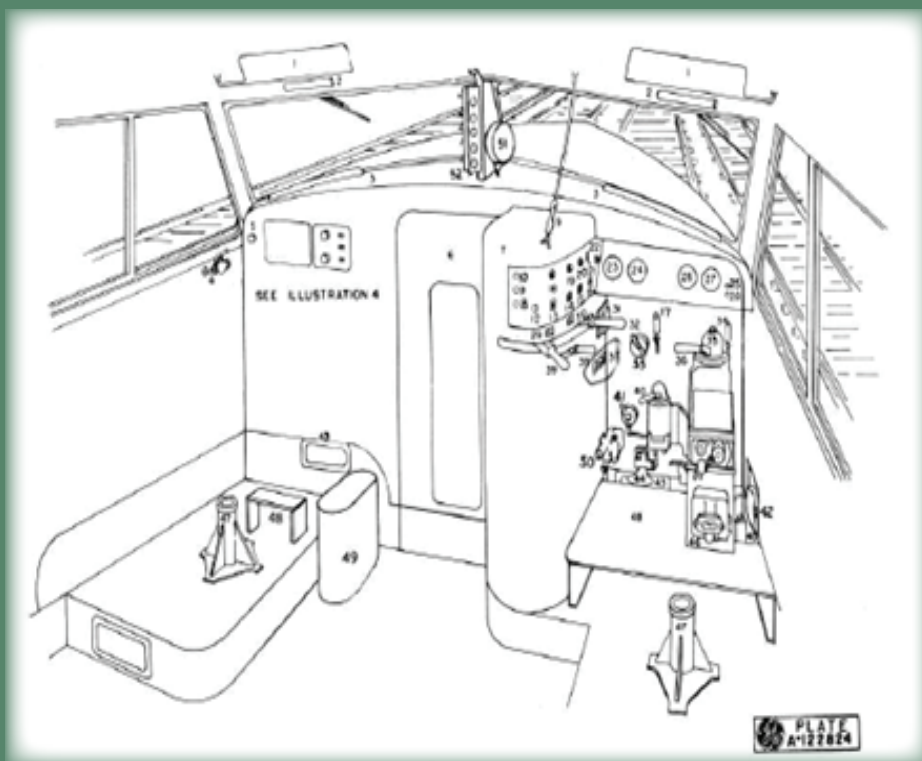
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The Future Locomotive

*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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The Future Locomotive

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

A Conference

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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

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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

PUBLISHER'S NOTE

The views expressed in this document by both the presenters and those of the individual participants are not to be construed as consensus views or findings of the conference participants. Furthermore, their views do not necessarily represent the views of all participants; the planning team; the sponsoring committees; TRB; or the National Academies of Sciences, Engineering, and Medicine. This e-circular has not been subjected to the formal TRB peer-review process.

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 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 participant 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 Kingdom 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; <i>Metroliner</i> 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.
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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.”

REFERENCES

1. Azevedo, R., and R. Bernard. A Meta-Analysis of the Effect of Feedback in Computer-Based Instruction. *Journal of Educational Computing Research*, Vol. 13, No. 2, 1995, pp. 109–125.
2. Johnson-Laird, P. N. *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness*, Cambridge University Press/Harvard University Press, Cambridge, Mass., 1983.

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 Voebel, 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 Kingdom 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

2:45–4:15 p.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
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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
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Jacquelyn 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
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Ann Mills
Rail Safety and Standards Board
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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, Massachusetts

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

Kathleen Voelbel
Massachusetts Institute of Technology
Cambridge, Massachusetts

James Udvardi
Union Pacific Railroad
Omaha, Nebraska

Tobin Zerfas
BNSF Railway
Overland Park, Kansas

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

APPENDIX C

Guest Speaker PowerPoint Presentations

Human Systems Integration

Nancy J. Cooke
Arizona State University
Chair, National Research Council,
Board on Human Systems Integration

TRB Railroad Operational Safety Committee (AR070) Mid-Year Meeting
July 30, 2013

Cooke's Background

Background

Education: Cognitive Psychology/Human Factors

- George Mason University, B.A.
- New Mexico State University, M.A., Ph.D.

Positions

- Rice University
- New Mexico State University
- Arizona State University &
- Cognitive Engineering Research Institute

Applied Experience:

- U.S Air Force, Navy, Army, NASA, NTSB, VA

Section Editor, *Human Factors*
USAF Scientific Advisory Board
National Research Council Board on Human Systems Integration

Relevant Research


Team Cognition in Military, Cyber, and Medical Applications


Communication Analysis

Sponsors

- Air Force Office of Scientific Research
- Air Force Research Laboratory
- Office of Naval Research
- Army Research Office
- Veteran's Administration

Metrics for Team Coordination and Collaboration



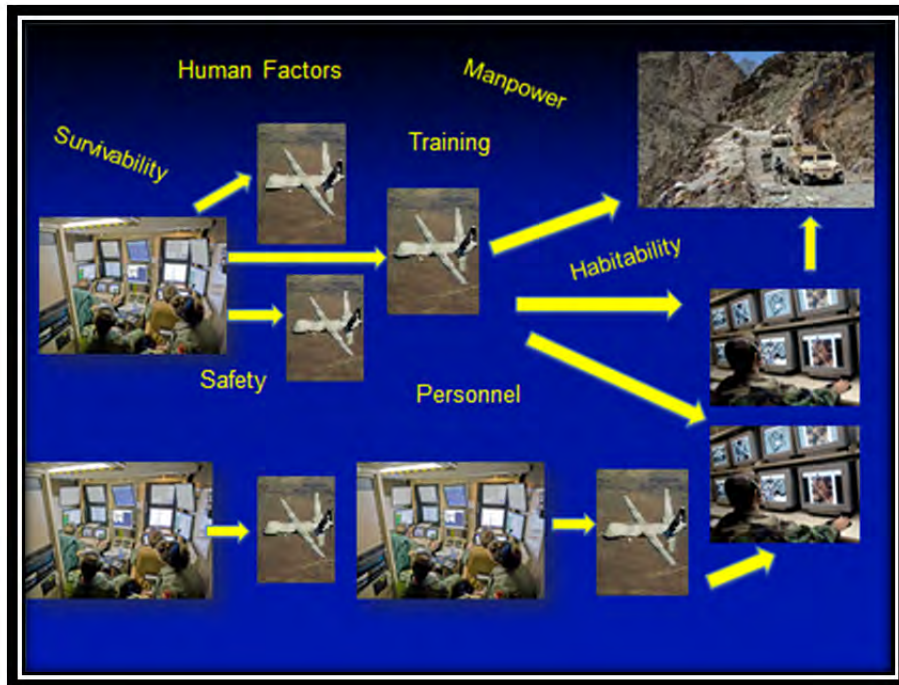
 

Overview

- 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




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



The slide features a blue background with yellow and white text. It includes several images: a yellow and white UAS in flight against a blue sky; a control room with multiple computer monitors; a laptop displaying a flight interface with a map; and a stick figure connected to a control panel by a cable.

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 slide features a blue background with yellow and white text. It includes three images: a long train on tracks at sunset; a view of railroad tracks stretching into the distance; and a close-up of a train engine.

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



The Breadth of HSI

Beyond Chairs and Stove Tops



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?




Which side of the rental car is the gas cap?




ATM that can only be reached by the tallest man in the world (8'5")




And how do I open it?



To go right or not?



Which way does it go?



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



#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











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

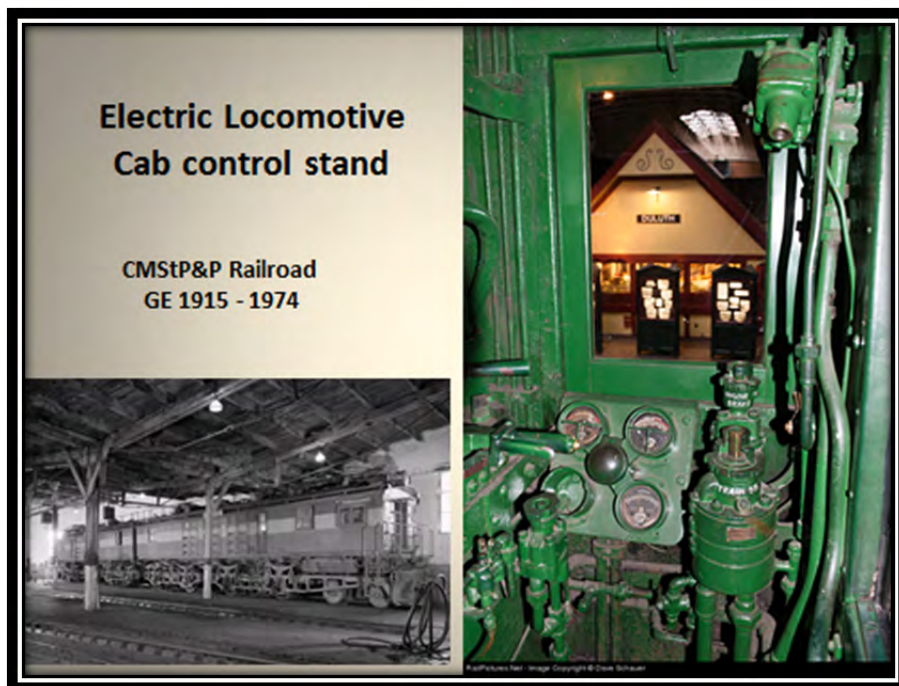
Nineteenth Century

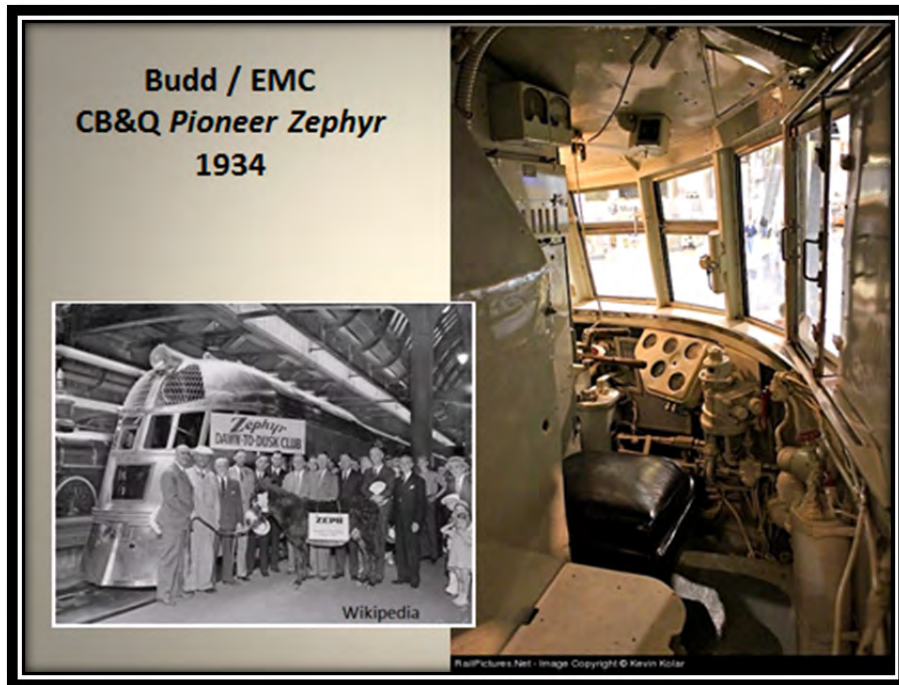
Early 1800s	Development of primitive locomotives without cabs
1831-	First locomotive cabs added to early locomotives
- Mid 1800s	Delivery of British locomotives and construction of early US built steam locomotives without cabs. Advancement in steam locomotive technology
Mid 1800s -	Locomotive refinements 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 - <i>Metroliner</i> 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 <i>ICE</i> train set from Germany
1998 -	Amtrak tests operation of <i>X2000</i> 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

<p>B&O – W. Norris & Co. - Lafayette horizontal boiler with no cab 1837 -</p> 	<p>SP - Baldwin - Cab-forward design 1909 - 1940s</p> 
--	---







**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.

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David Schauer

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David C. Warner



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Librarian, Thomas E. Hoffmann

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

**The History of the Locomotive Cab
and Control Stand**

THANK YOU

Further discussion and comments are welcome

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M 330-947-3685

North American Locomotive Cab Development

Harvey Boyd

Electro-Motive Diesel

ELECTRO MOTIVE

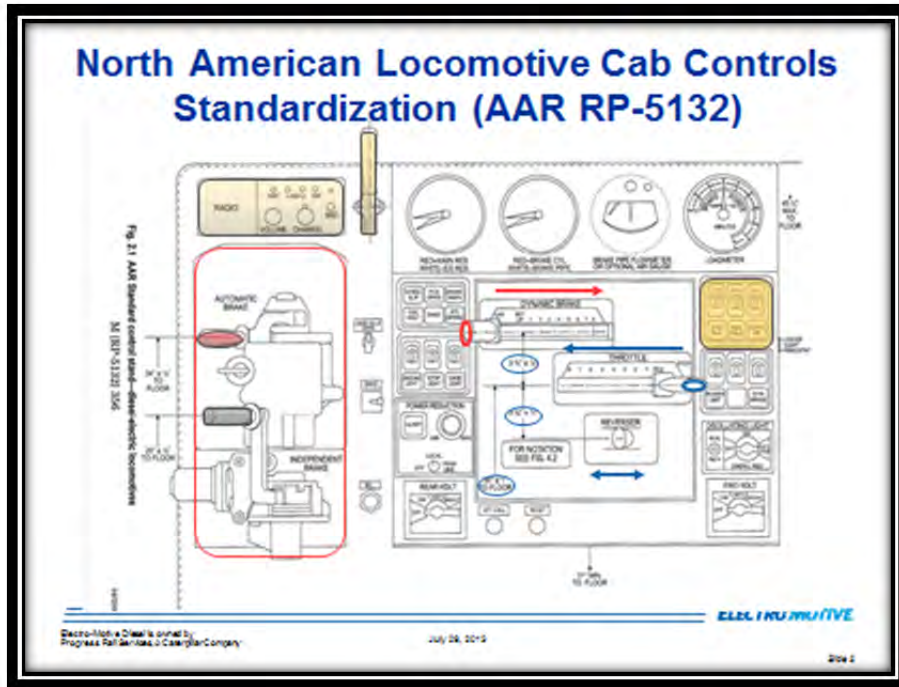
Electro-Motive Diesel is owned by
Progress Rail Services, a Caterpillar Company July 28, 2015 204 1

**North American Locomotive Cab Controls
Mid-1970's**

- Industry wide effort with focus on:
 - Durability
 - Bi-directionality
 - Standardization
 - Control differentiation
 - Control Interlocks

ELECTRO MOTIVE

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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

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AAR Bi-Directional Control Stand



Forward Operation Reverse Operation

ELECTRO MOTIVE

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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

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North American Comfort Cab




TOT. WT. 392,000
6328

ELECTRO MOTIVE

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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



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Improved Recess for Knee Clearance




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Slide 9

Controller Switch Influence on Seat Position



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ELECTRO MOTIVE

Slide 10

Improved Reach with Tilted Controller



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Conductor's Workdesk Designs



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Conductors Workdesk Improved Egress



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July 28, 2015 Slide 12

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

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July 28, 2015 Slide 14

New Engineers Workstation Design

- Combined best features of the control stand and workdesk information screens in the front, with controls located on the side



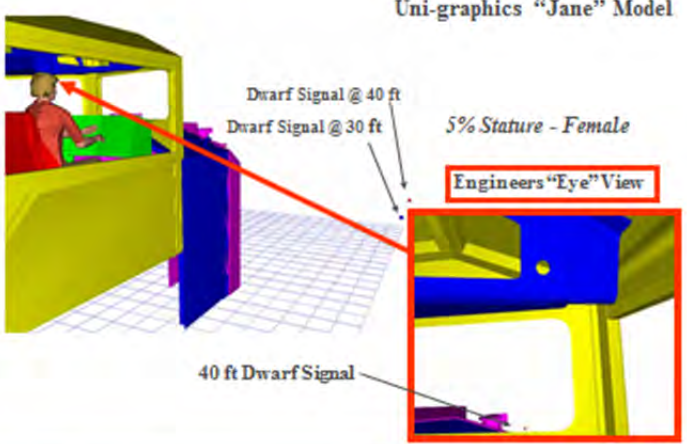
Electro-Motive Diesel is owned by Progress Rail Services, a Caterpillar Company July 28, 2012

ELECTRO MOTIVE

Slide 12

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

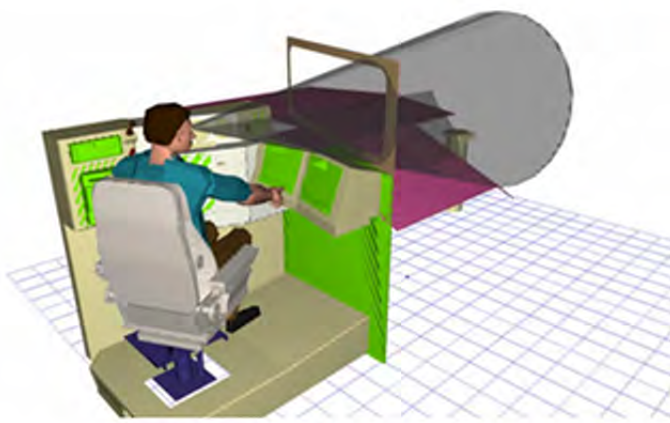
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ELECTRO MOTIVE

Slide 12

3-D ergonomic Computer Tools

Uni-graphics "Jack" Model

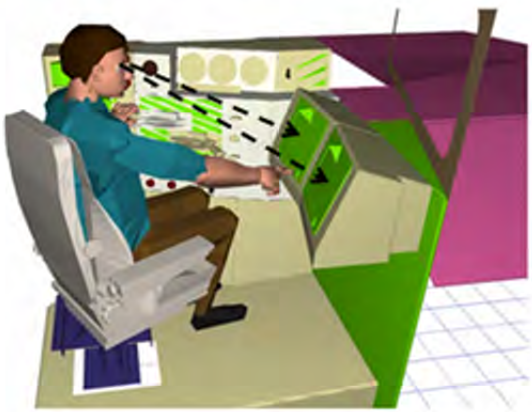


95% Jack sitting at 30 degrees, with a 30° view cone.

Electro-Motive Diesel is owned by Progress Rail Services, a Caterpillar Company July 26, 2012 **ELECTRO MOTIVE** 202e 17

This slide illustrates a 3-D ergonomic model of a locomotive cab interior. A person is seated in a grey office-style chair, facing a control panel with various screens and buttons. A large, semi-transparent grey dome represents the view cone, extending from the operator's eye level. The background is a grid pattern. The text '95% Jack sitting at 30 degrees, with a 30° view cone.' is centered below the model. The Electro-Motive logo is in the bottom right corner.

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 Diesel is owned by Progress Rail Services, a Caterpillar Company July 26, 2012 **ELECTRO MOTIVE** 202e 18

This slide shows a similar 3-D ergonomic model of a locomotive cab interior. The person is seated in the same chair, but the control panel and screens are positioned differently. The text '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.' is centered below the model. The Electro-Motive logo is in the bottom right corner.



North American Locomotive Cab Controls Standardization



ELECTRO MOTIVE

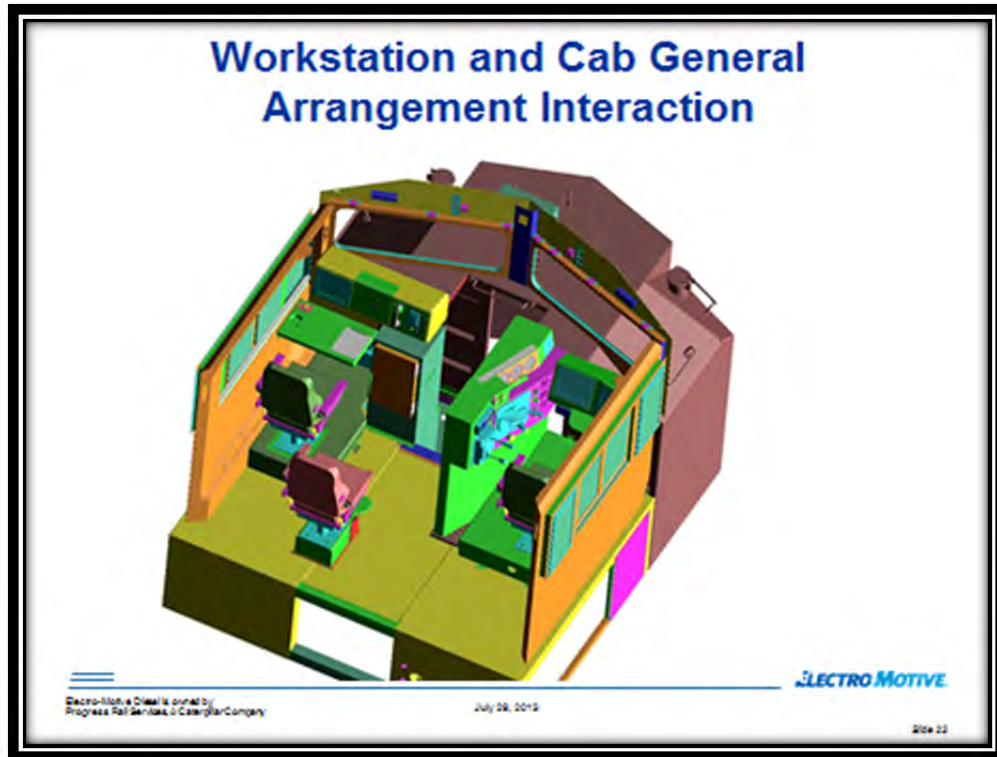
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New Engineers Workstation Design




ELECTRO MOTIVE

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Questions?



ELECTRO MOTIVE

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July 28, 2012

Slide 22



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

...innovating locomotives has been at the heart of GE over the years. Thanks to great research and several other solutions, many to improve what is a glacially slow process of innovation.

...the world's greatest freight locomotives. GE's 1908 4-6-2 steam locomotive, built for the Erie Railroad, was the first to haul the heaviest loads, per ton-mile.



1929



Heartbeat of the loco: vital organs

Communication/electronics



Engine



Cooling/radiator





Controls/power management



Alternator



Traction motors



GE Privileged & Confidential

The radiator cab always gets attention...



But what about the operator cab?






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...




- 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




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




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 1'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



- 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 amended 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 A.C 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



PowerHaul® Series locomotive







“Accident Caused by Human Error”
– But Which Humans?

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TRB Meeting
Omaha, NE
JUL 2013
Paul Picciano


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

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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*

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One View of the World





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Closer to Reality?




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System Design and Interaction



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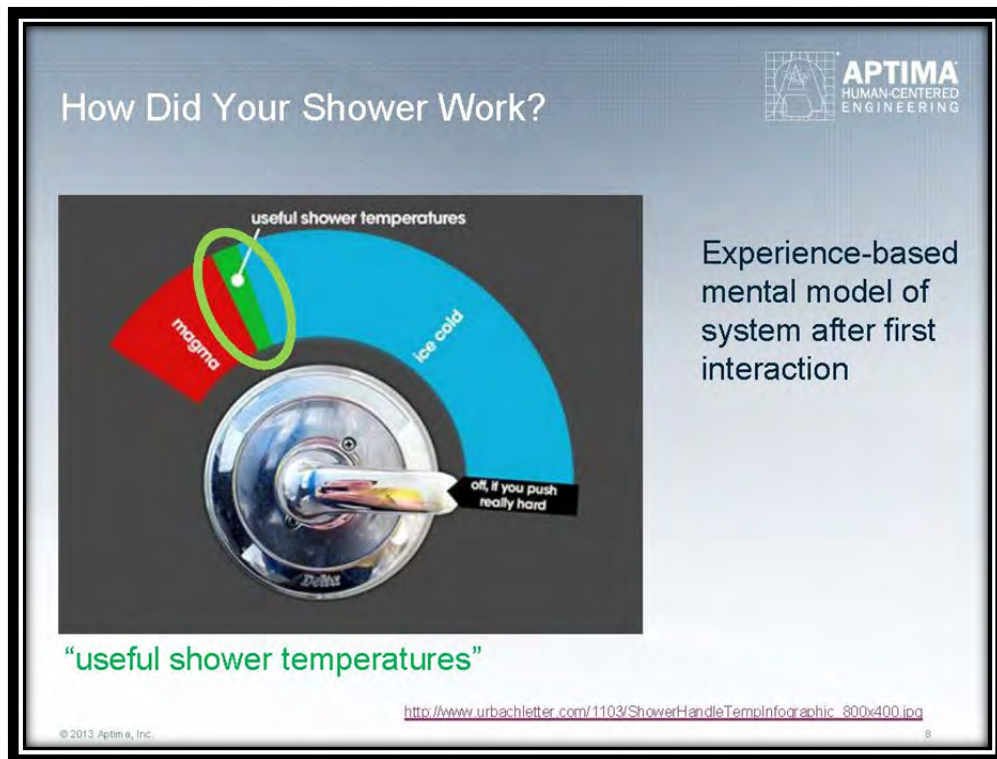
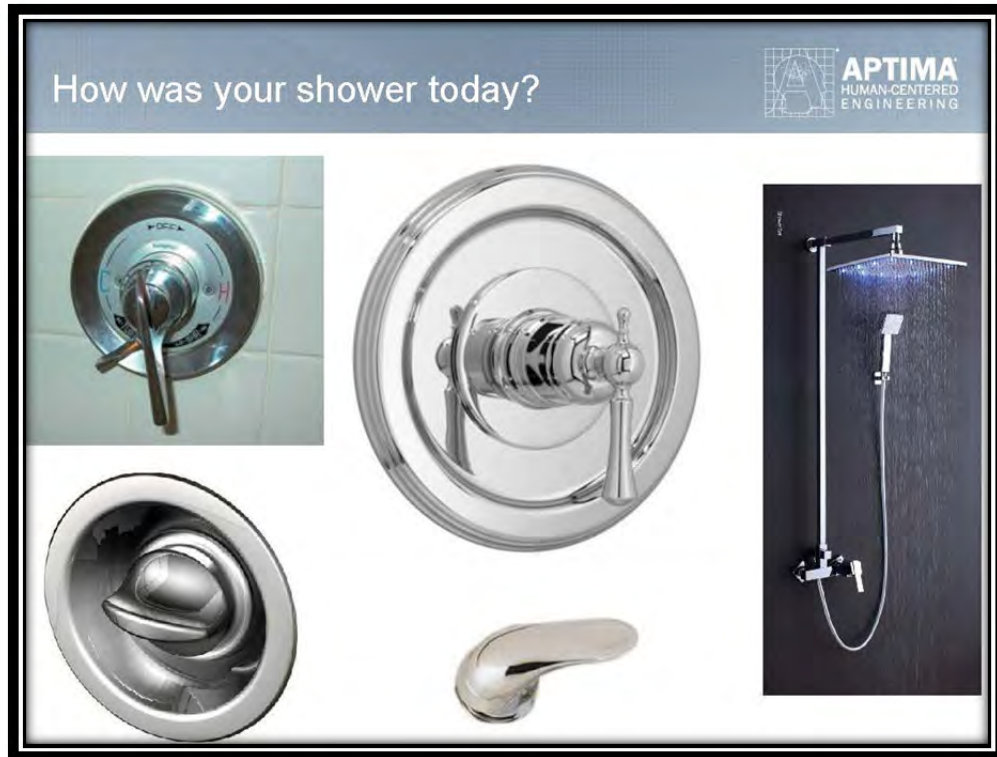
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Trust
Can you predict how it will behave?

Transparency
Can you see how the system works?


Feedback
Can you tell what it's doing now?

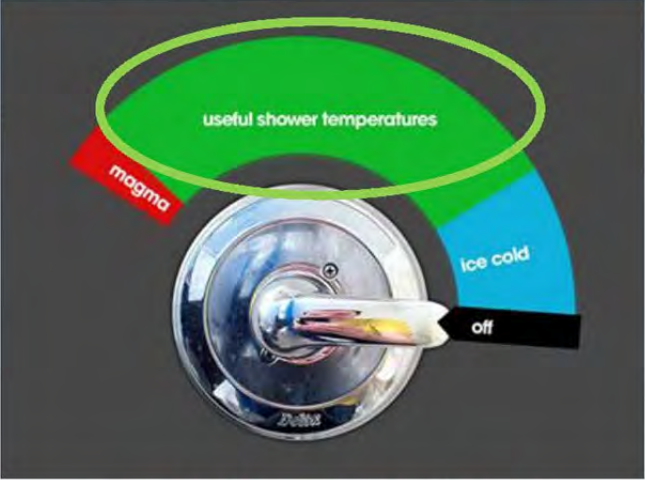
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How It Should Work?

If designers, users and the real world shared this model, it would be easier





“useful shower temperatures”


http://www.urbachletter.com/1103/ShowerHandleTempInfographic_800x400.jpg


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9

Conspiring Against Cleanliness

- 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





Trust
Do you love your GPS?

Transparency
Can you see inside the core?

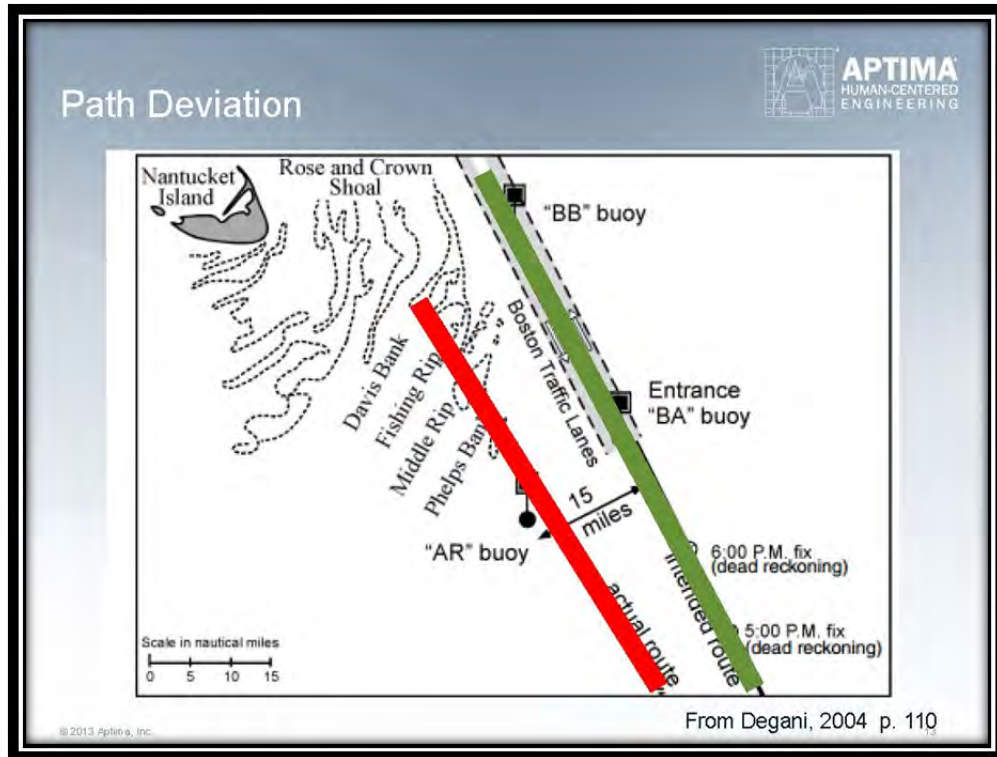
Feedback
Can you confirm you're on the right track?

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TRUST The Royal Majesty, 1995



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Always Complex Etiology. . .

- 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

Swiss cheese

GPS: Subtle Indication



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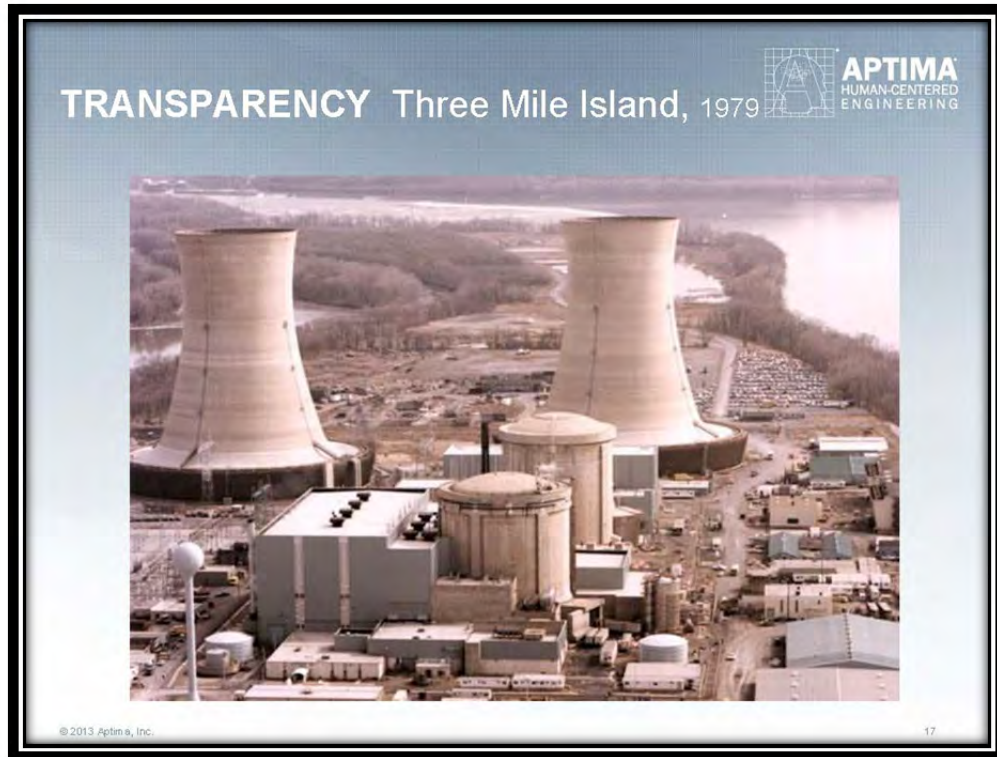
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NTSB Conclusions: Overreliance


“[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.”

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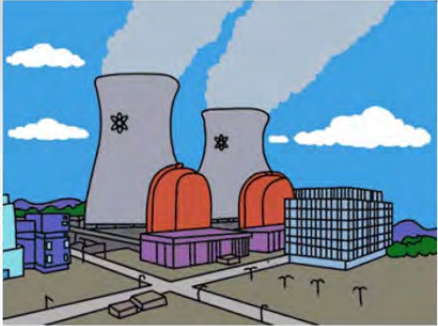
What Happened at Three Mile Island ?



- 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:

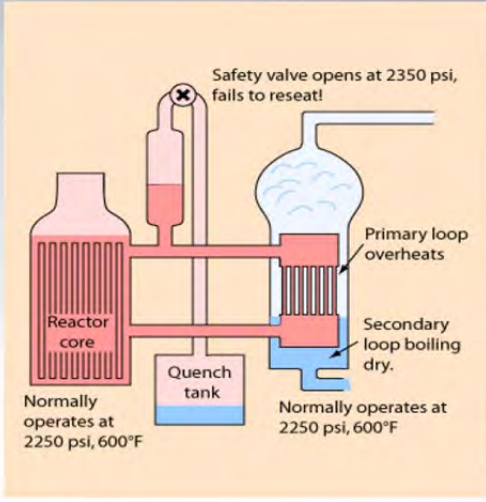
- Regulations
- Design
- Training



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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#oooleto> <http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/imanuk/tmi3.gif>

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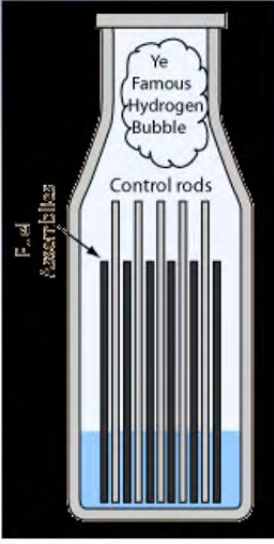
Believed Core was Covered



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#oooleto> <http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/imanuk/tmi3.gif>

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True System State Difficult to Assess





- Sensors measure proxy values
- “Avalanche” of Alerts
- Printer hours behind
- Information poorly organized
- Intensive search



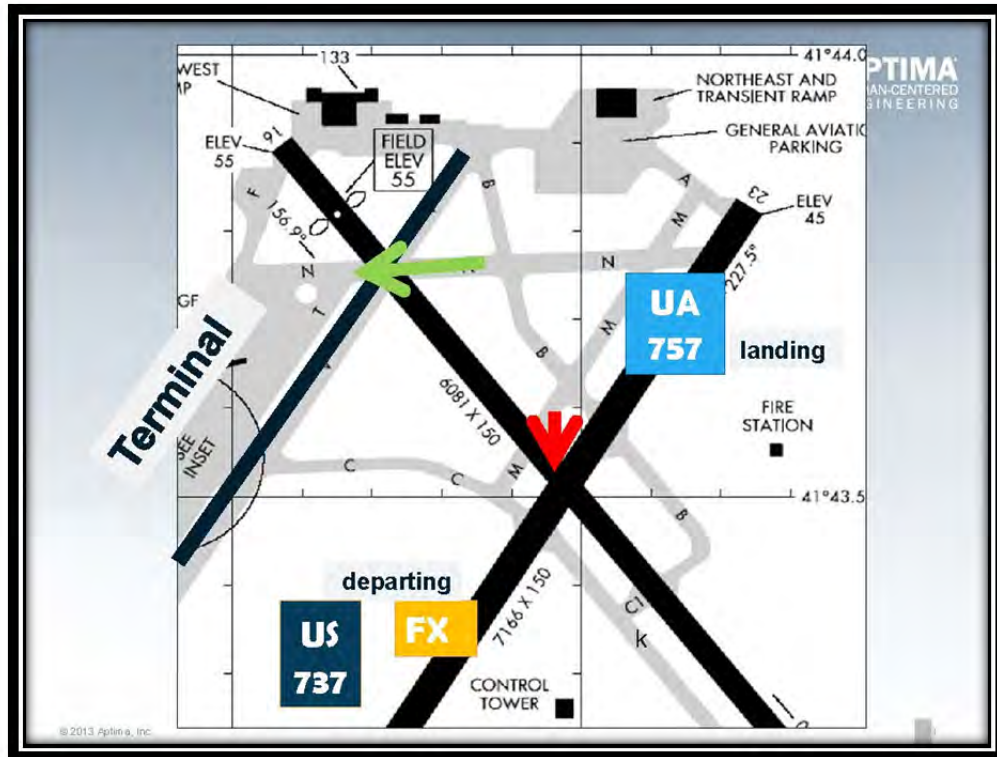
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FEEDBACK Runway Incursion at PVD, 1999




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22



B-757	And, uh, B-757, we're approaching Kilo here, uh, um – <u>somebody just took off.</u>
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 <u>currently on a runway.</u> 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. <u>I can't see anything from the tower.</u>
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, <u>cleared for takeoff.</u>
B-757	Ma'am, I'm trying to advise you; <u>we're on an active runway,</u> B-757.
LC	<u>23R is not an active runway;</u> it's a taxiway when we're IFR or in the dark.



B-737	(unintelligible) he is, but <u>we're staying clear of all runways until we figure this out.</u>
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 <u>don't talk – I have other things I need to do.</u>
LC	B-737, runway 5R, fly runway heading, <u>cleared for takeoff.</u>
B-737	Uh, tower, B-737. <u>Till we figure out what's going on down there, we're just going to stay clear of all runways.</u>

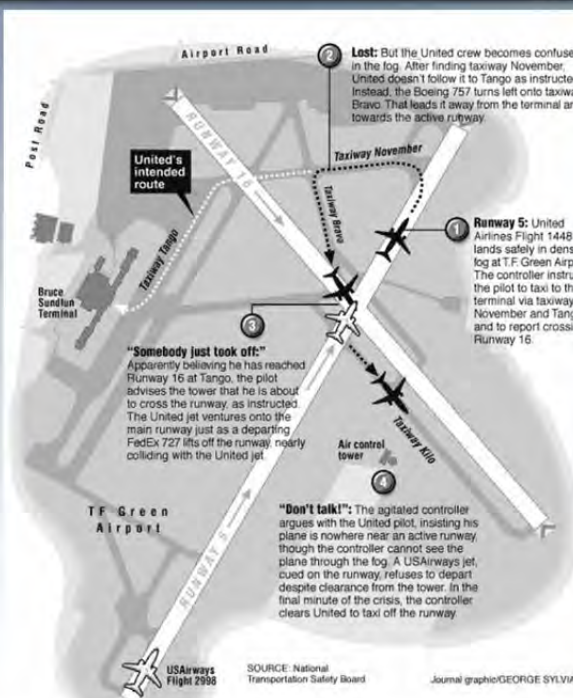
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“Somebody just took off”

LC tried to push USAir to take off.

Pilot refuses -2X

Animations on web



1 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.

2 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.

3 “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.

4 “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.

SOURCE: National Transportation Safety Board. Journal graphic/GEORGE SYLVA

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Thank You

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Rubes By Leigh Rubin
rubescartoons.com

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How masochists shower

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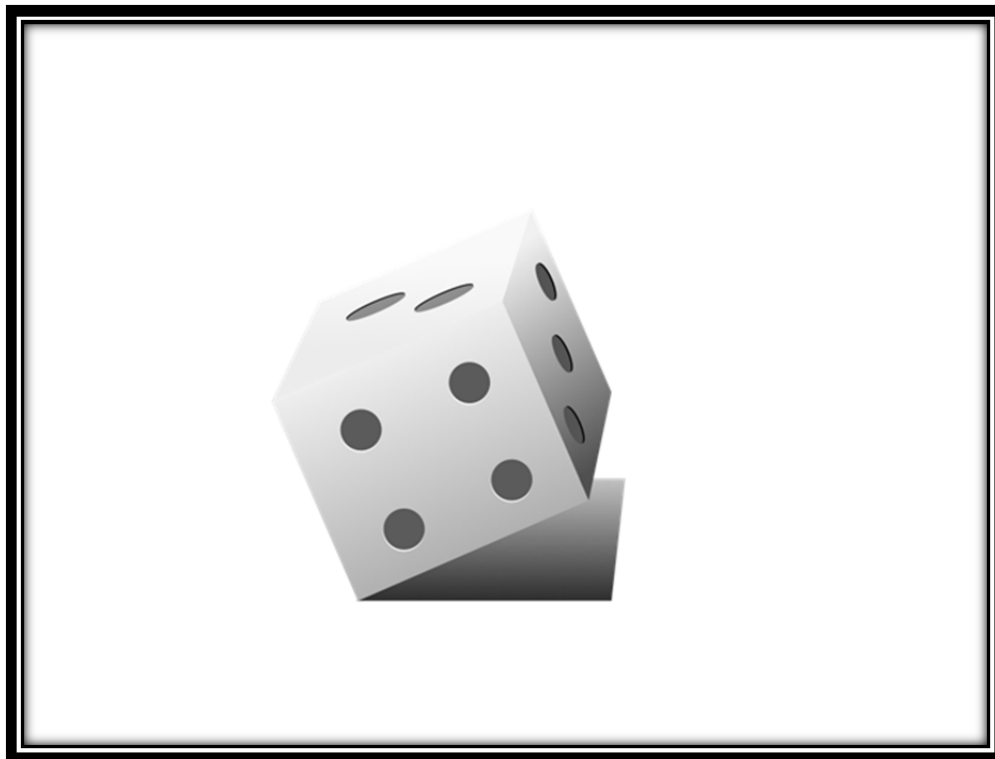
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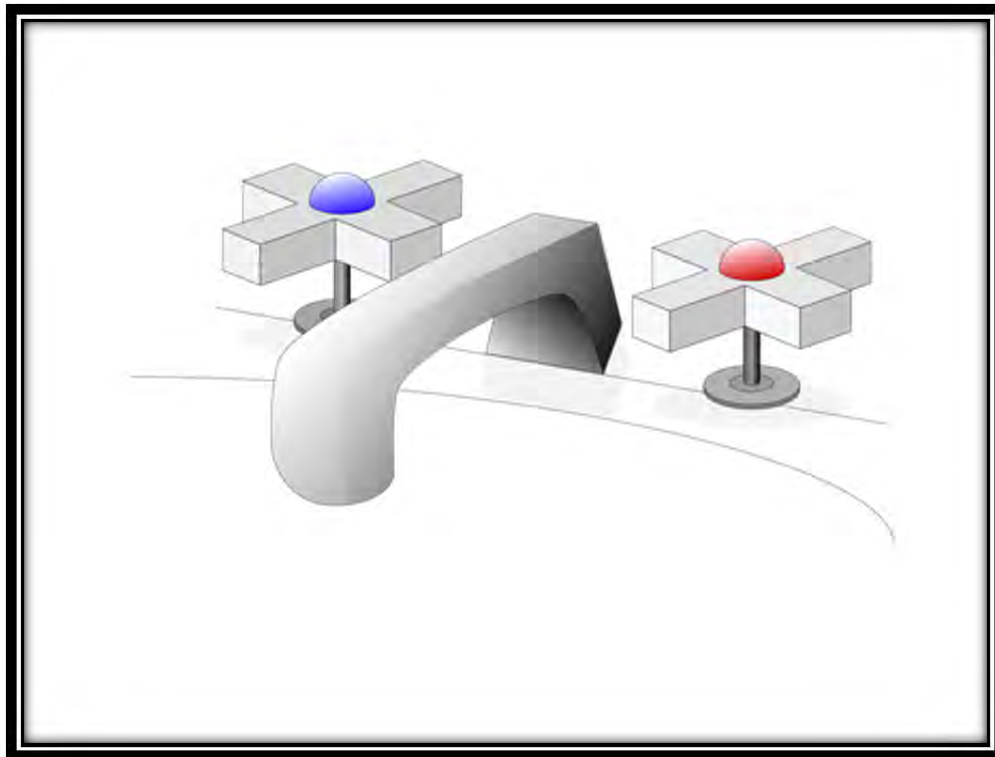
Evaluation of Cab Controls

Vic Riley

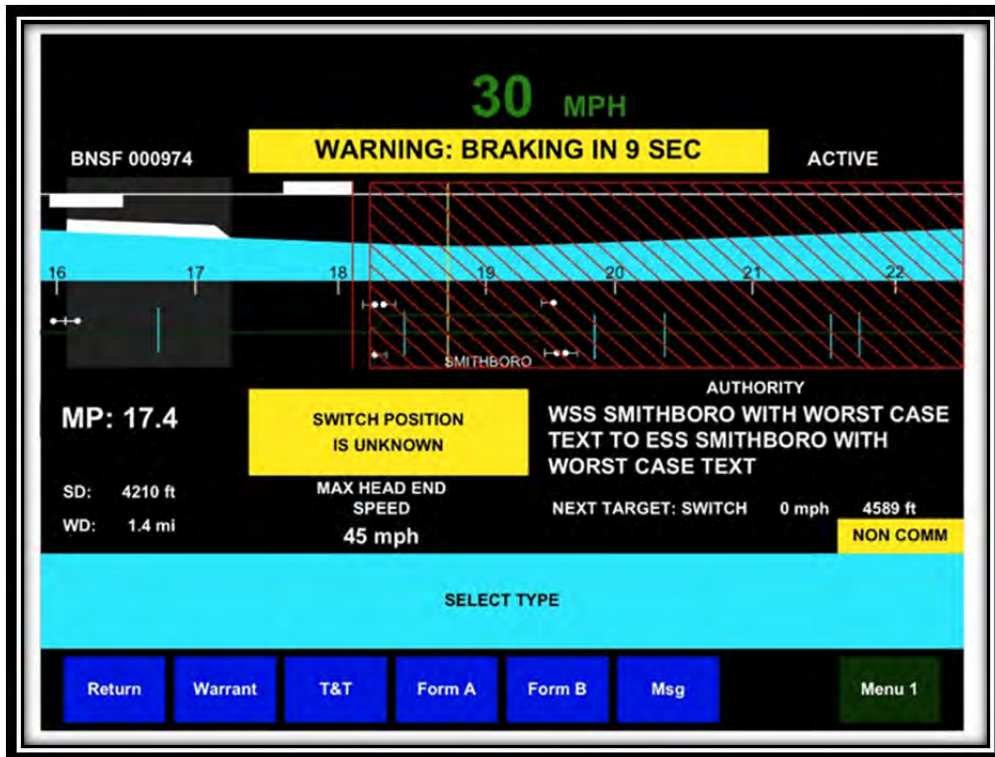
The design is only as good as the requirements,
And the requirements are only as good as the analysis.

functions and options	<input type="text" value="visible"/>	ergonomic	<input type="text" value="good"/>	0
functional or navigation logic	<input type="text" value="externally consistent"/>	destructive adjacencies	<input type="text" value="no"/>	0
modes	<input type="text" value="no"/>	error penalties	<input type="text" value="none"/>	0
steps	<input type="text" value="few"/>	automation	<input type="text" value="supportive"/>	0
feedback	<input type="text" value="good"/>	formatting	<input type="text" value="externally consistent"/>	0
task match	<input type="text" value="good"/>	distinctiveness	<input type="text" value="good"/>	0
perceptual	<input type="text" value="good"/>	terminology	<input type="text" value="compatible"/>	0
Total Score				0



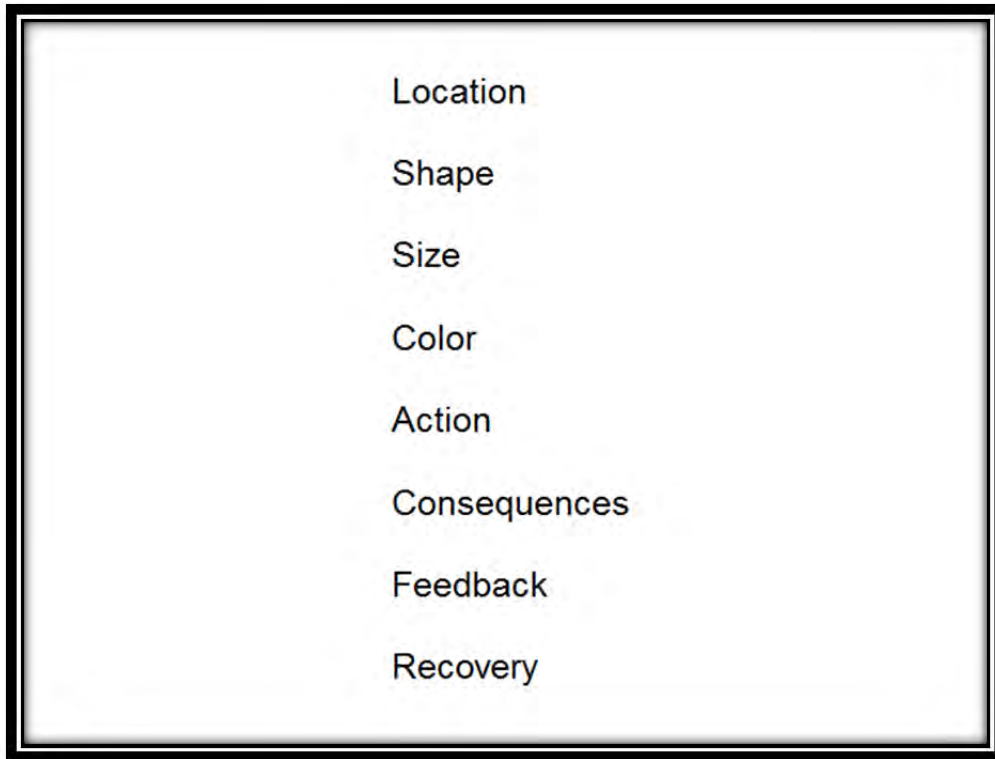


The application of an expectation or habit from one design to a different design.



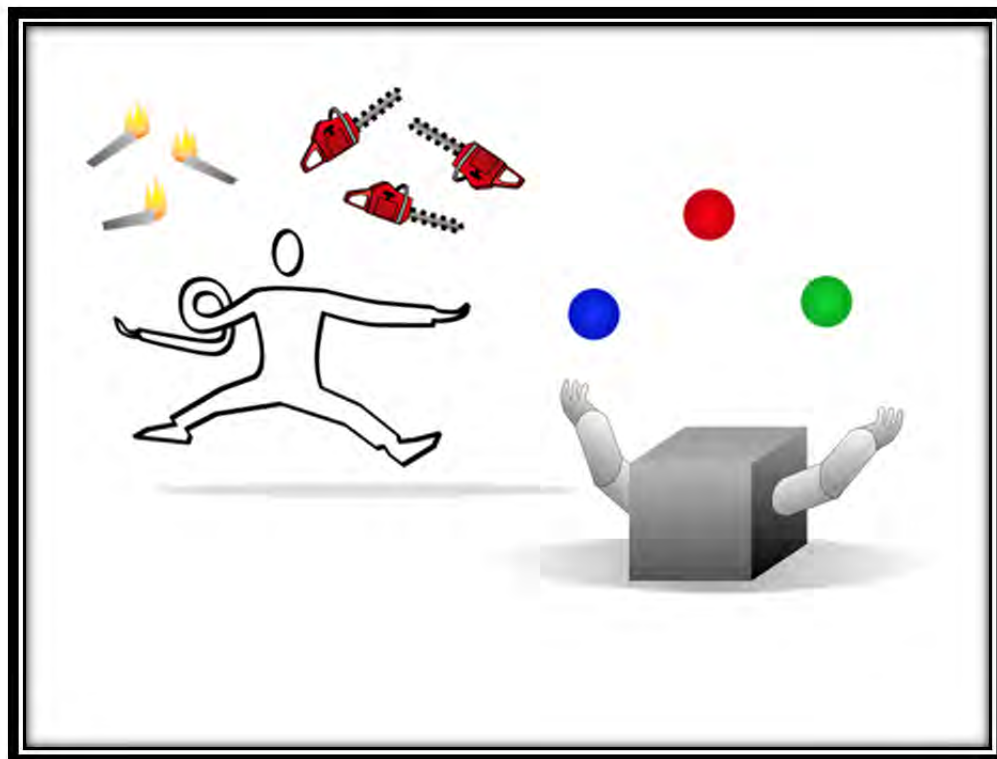
Screen Name	Page	key 1	key 2	key 3	key 4	key 5	key 6	key 7	key 8
main	2	DDA				acknowledge		init	menu 1
representative	3	go to new screen				acknowledge		activate function	open menu
employee ID	126	number	number	number	number	number	number	done	cancel
initialization	13	DDA	proximity				departure test	init	menu 1
initialization	15	yes							no
configuration	21						consist	cut out	main
cut in/out	24						go to new screen	activate function	go to home screen
cut in/out	24						consist	cut in	main
departure test	133				fail test				
departure test	134				yes				exit
select location	137				select location		consist	cut out	main
location selection	137	main 1	main 2	siding	clear track	cancel	go to new screen	activate function	go to home screen
absolute signal	1126				access menu				received
absolute signal	1126	DDA	proximity	apply T&T		target prompt	depart test	init	menu 1
DDA	37	return	warrant	T&T	form A	form B	msg		
warrant	37	back to prior screen	up arrow	down arrow	prev	next	accept/reject		all msg types
authority change	39								
authority change	39					ok			
warrant accept/reject	39	quit		accept		reject			
authority release	40	quit		yes		release			
message view	44	return							all msg types
		back to prior screen							go to new screen

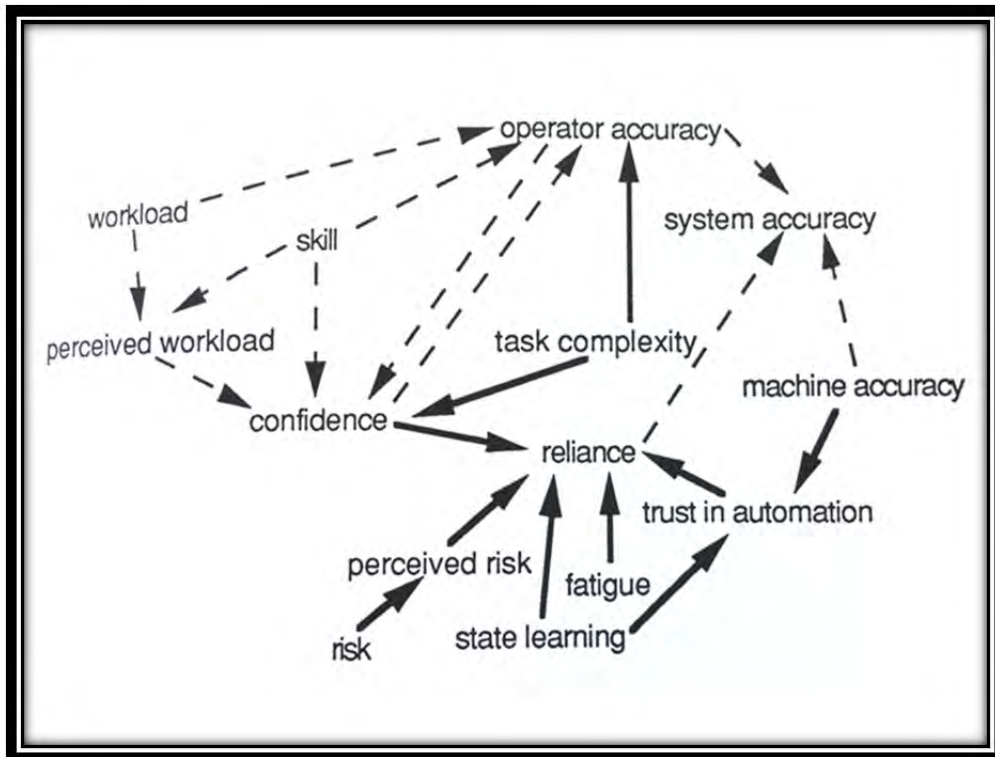
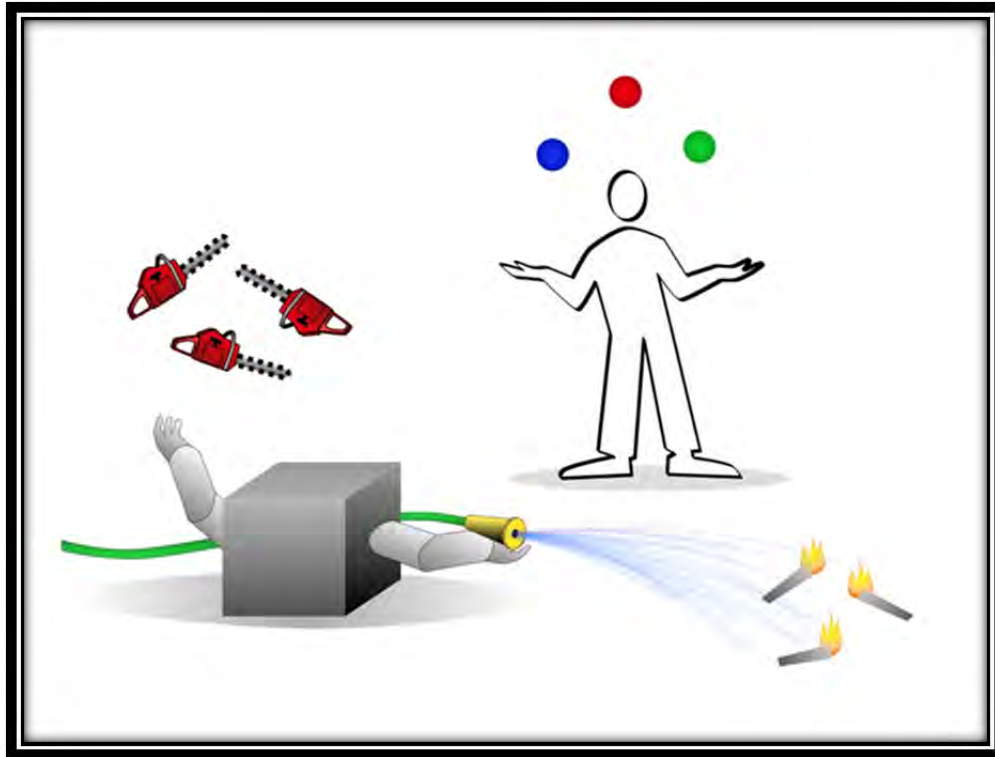
	FUNCTION KEY							
	1	2	3	4	5	6	7	8
1 main	DDA	0	0	0	acknowledge	0	init	menu 1
2 representative	DDA	0	0	0	0	0	0	menu 1
3 employee ID	number	number	number	number	number	number	done	cancel
4 initialization	DDA	proximity	0	0	0	departure test	init	menu 1
5 initialization	yes	0	0	0	0	0	0	no
6 cut in/out	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

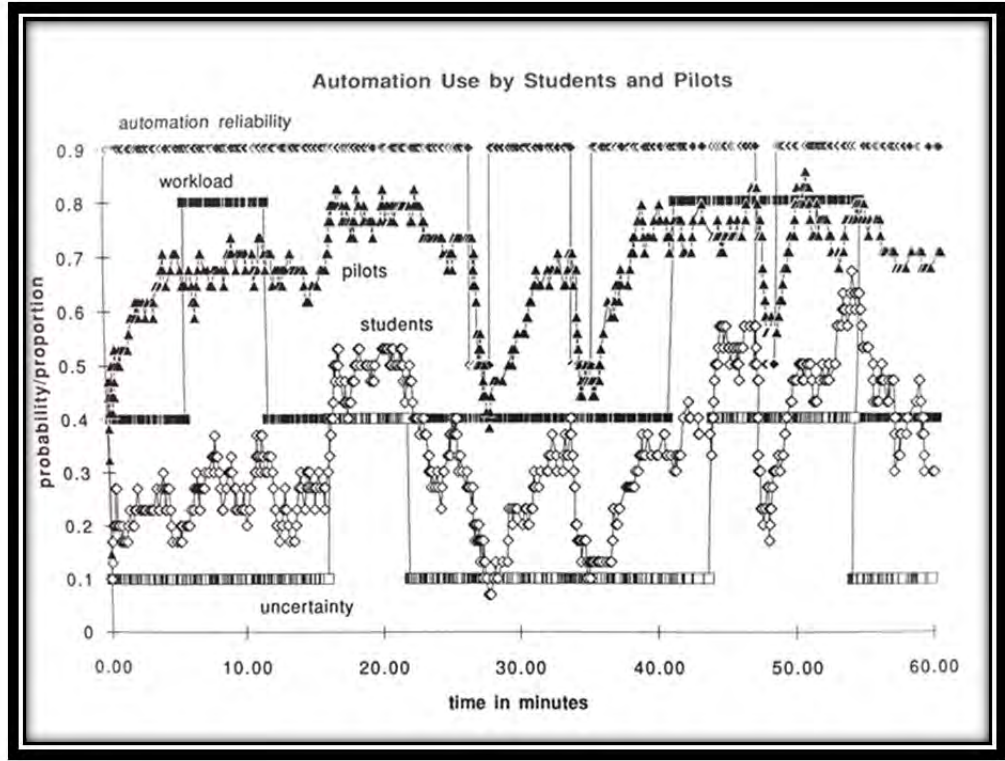
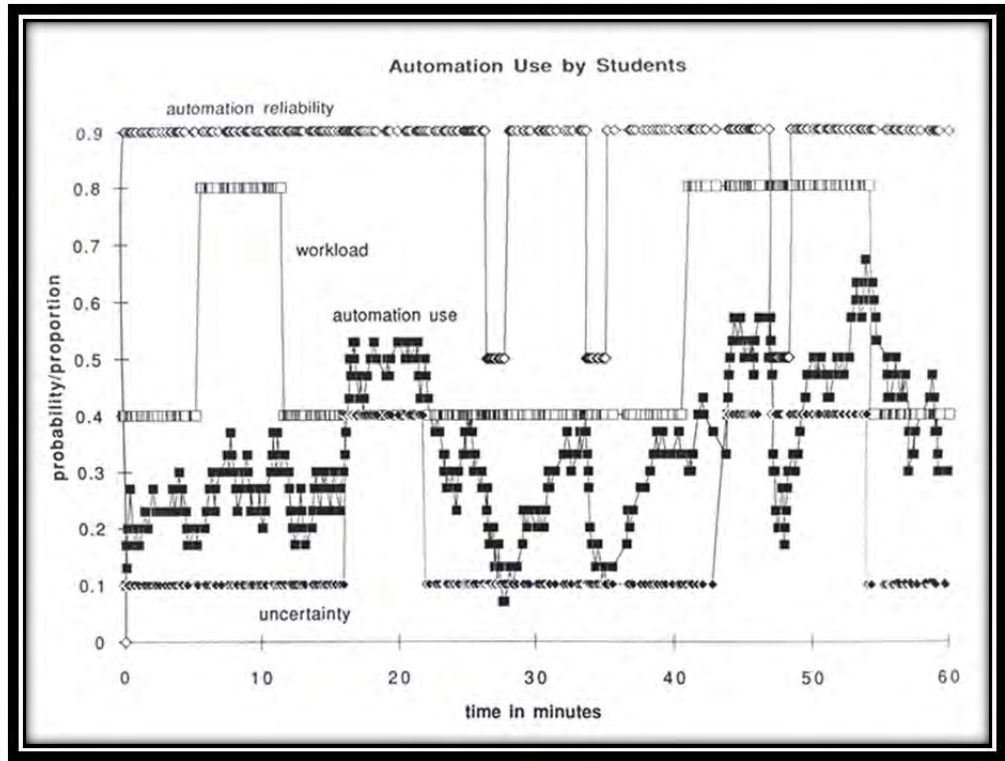


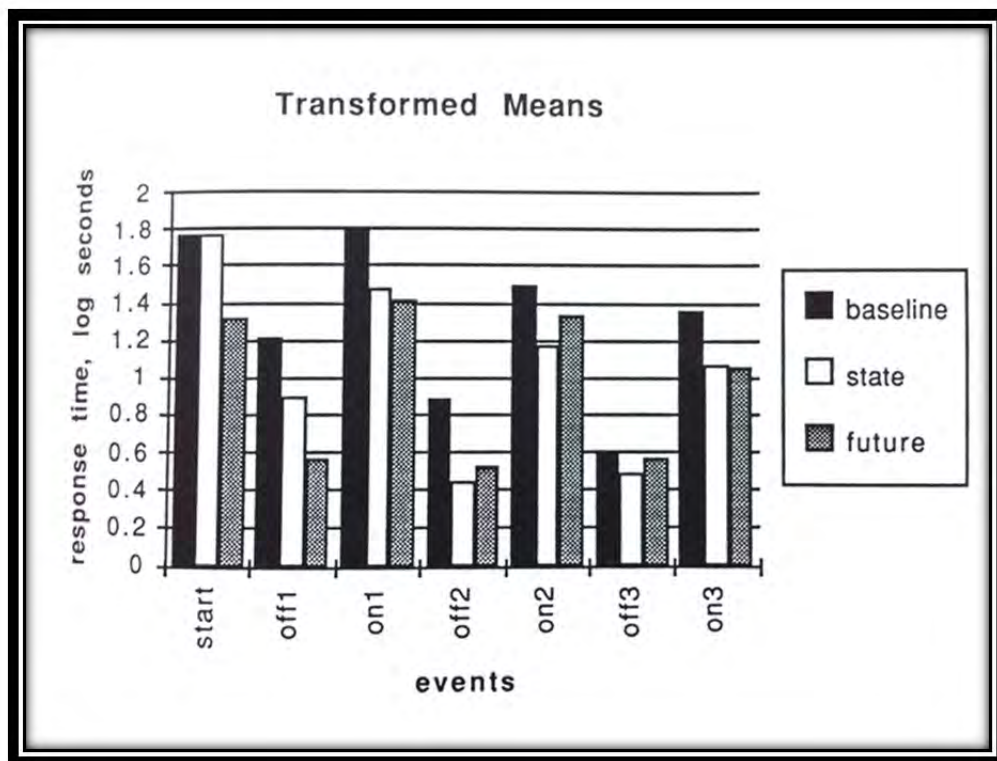
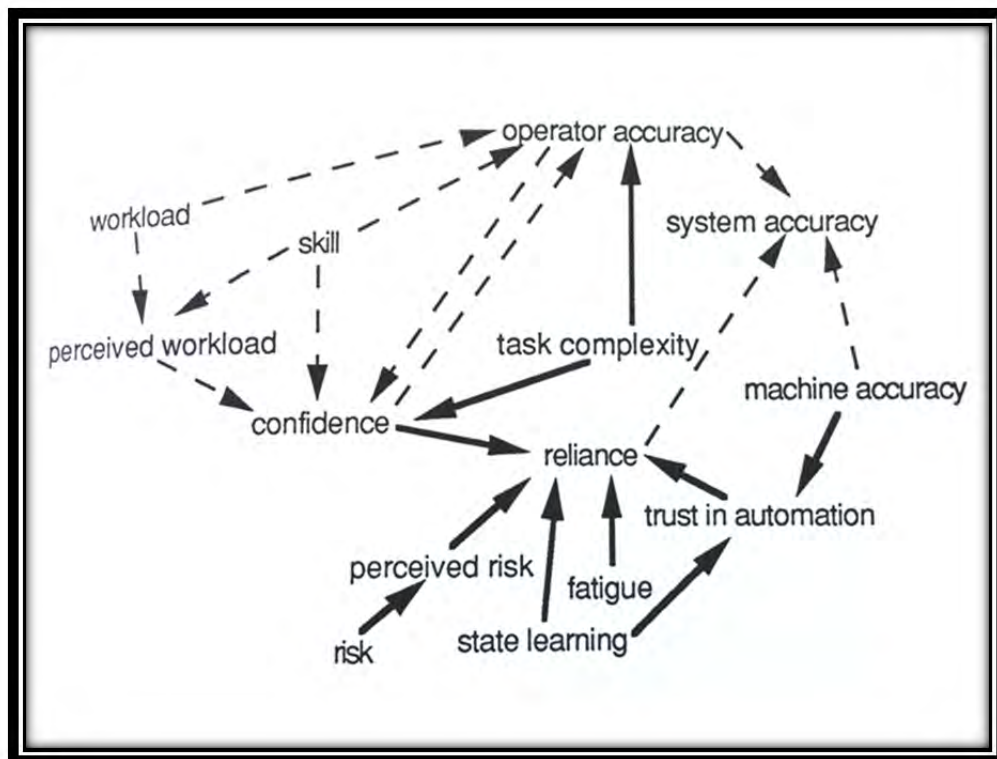
Automation and Workload

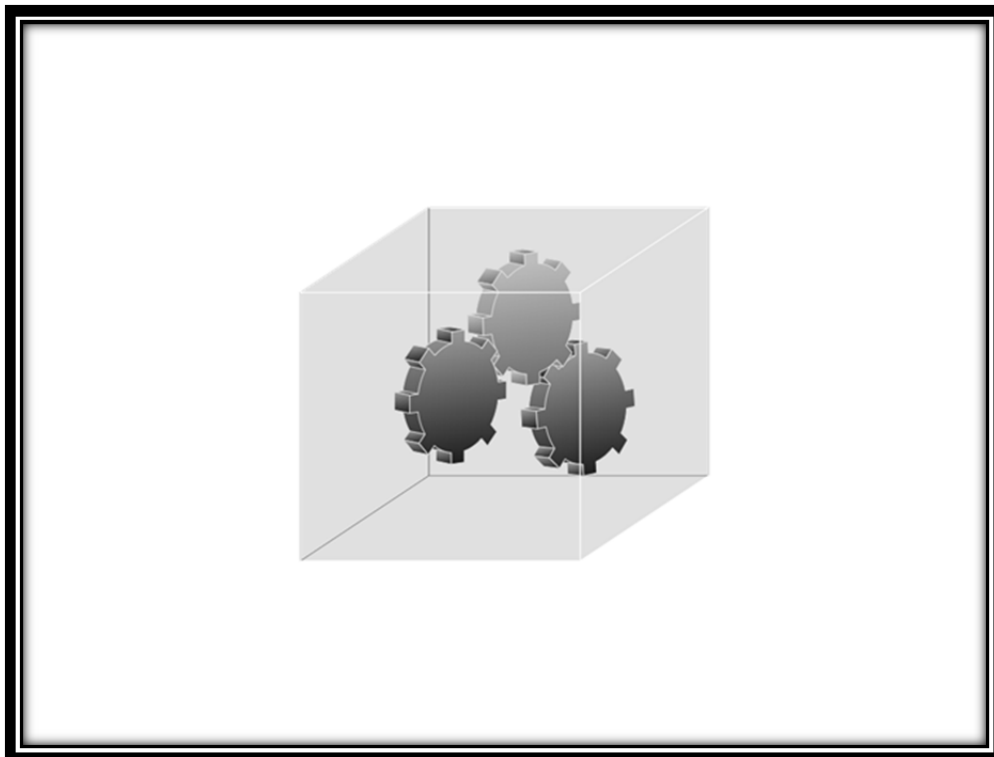
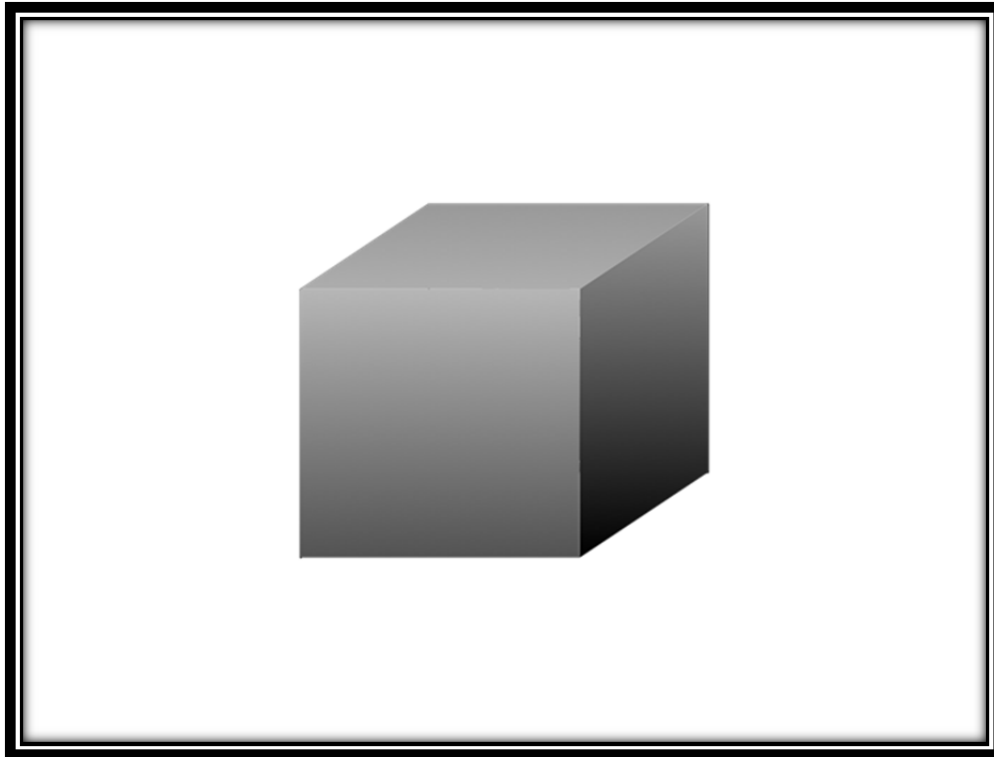
Vic Riley

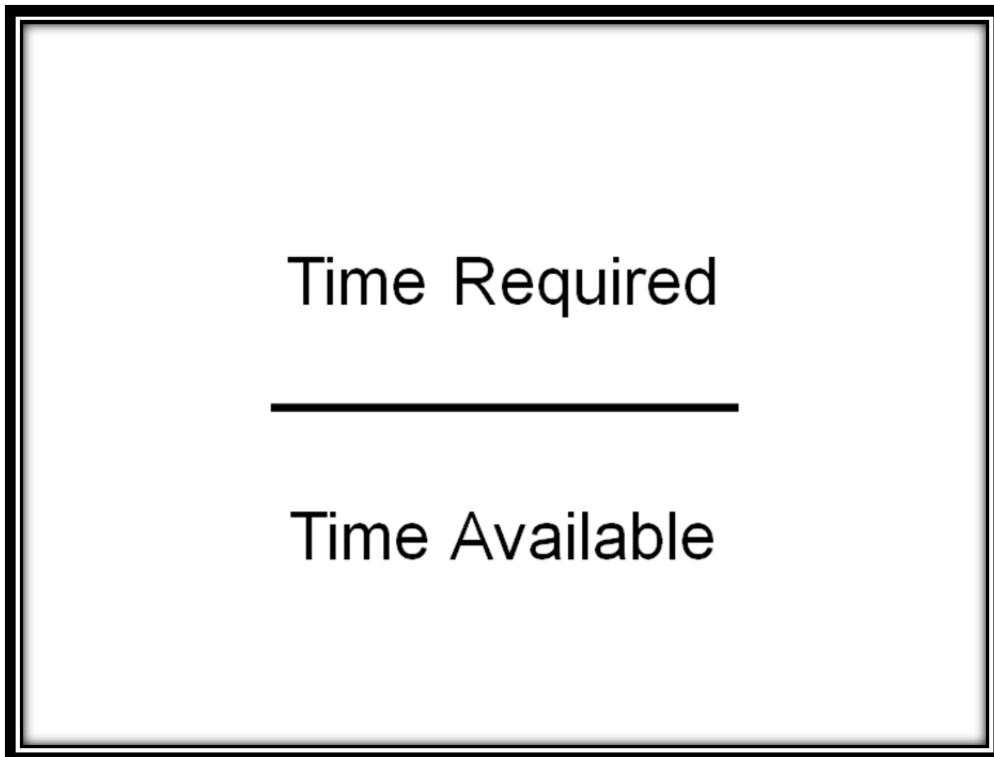
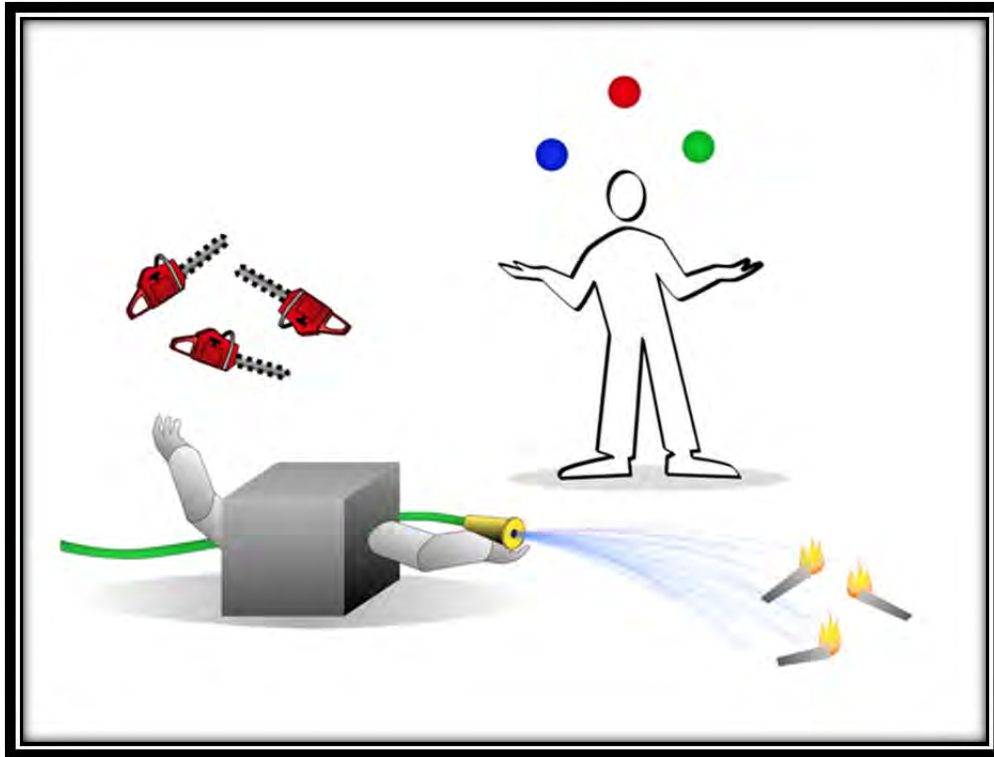


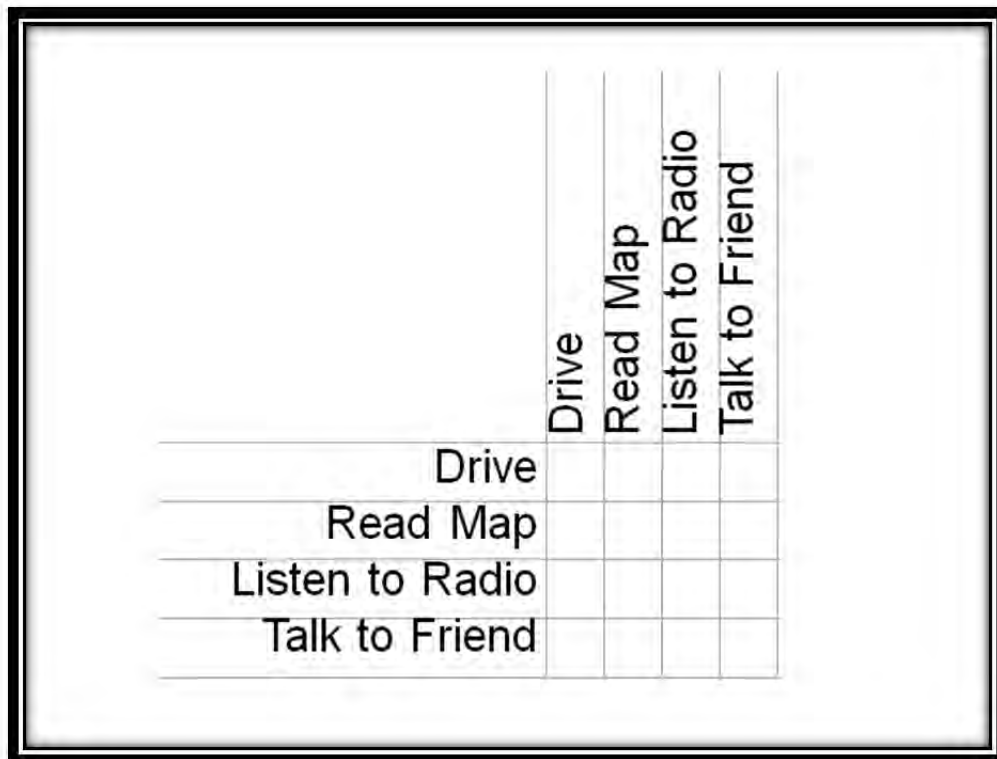
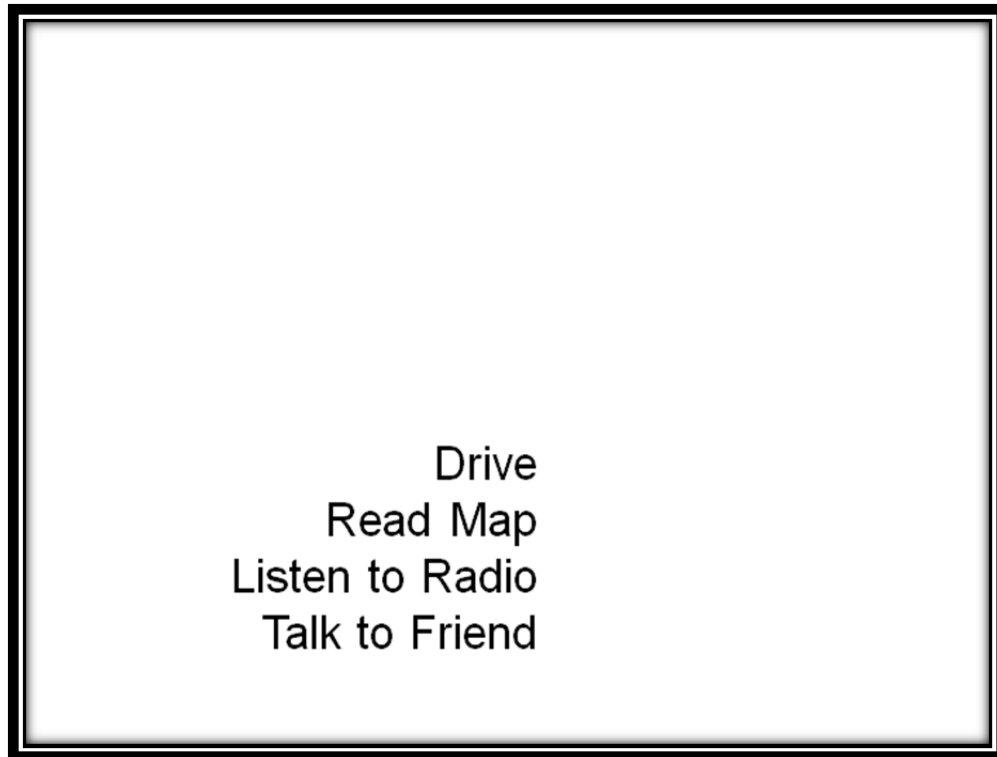












	Drive			
	Read Map			
	Listen to Radio			
	Talk to Friend			
Drive				
Read Map				
Listen to Radio				
Talk to Friend				

A green checkmark is located in the cell at the intersection of the 'Listen to Radio' row and the 'Listen to Radio' column.

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

A red 'X' is located in the cell at the intersection of the 'Read Map' row and the 'Read Map' column. A green checkmark is located in the cell at the intersection of the 'Listen to Radio' row and the 'Listen to Radio' column.

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

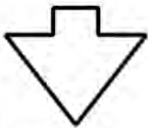
	Drive	Read Map	Listen to Radio	Talk to Friend
Drive		X	✓	✓
Read Map				
Listen to Radio				X
Talk to Friend				

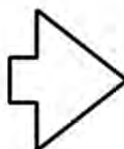
	Drive			
	Read Map			
	Listen to Radio			
	Talk to Friend			
Drive		X	✓	X
Read Map				
Listen to Radio				X
Talk to Friend				

	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

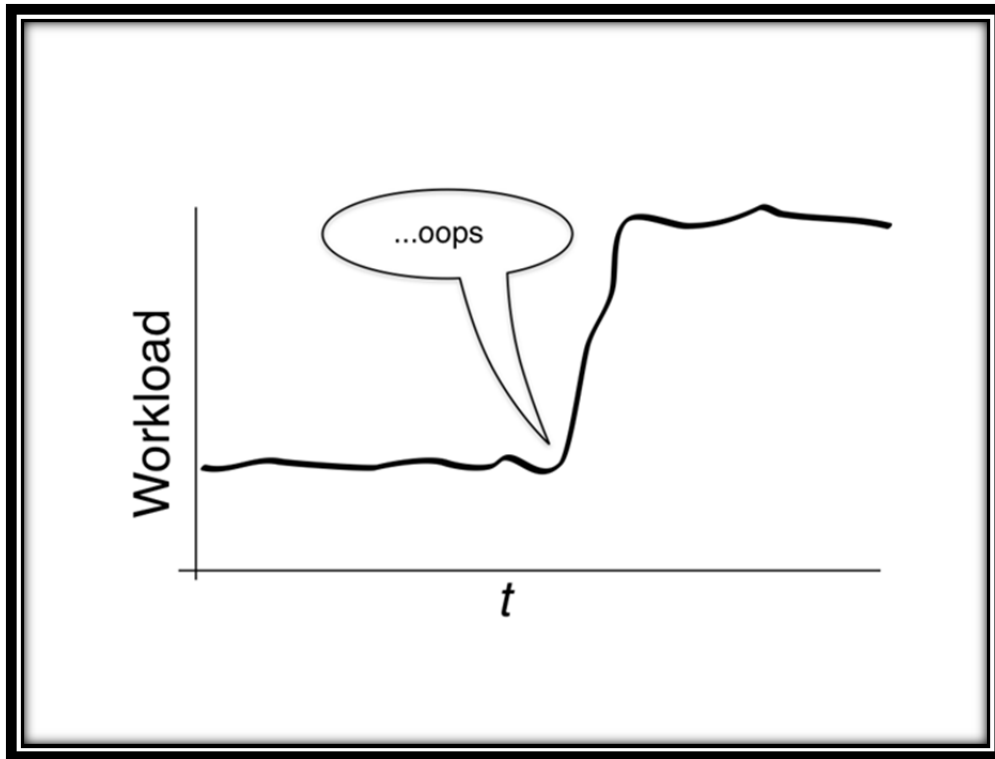
	Windshield	Map	Gauges	Radio
Windshield	0.7	1	0.9	0.3
Map		0.8	0.8	0.3
Gauges			0.7	0.3
Radio				1

$$\frac{\text{Time Required}}{\text{Time Available}} \rightarrow \text{OK} \rightarrow \checkmark$$



 Not OK 

	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



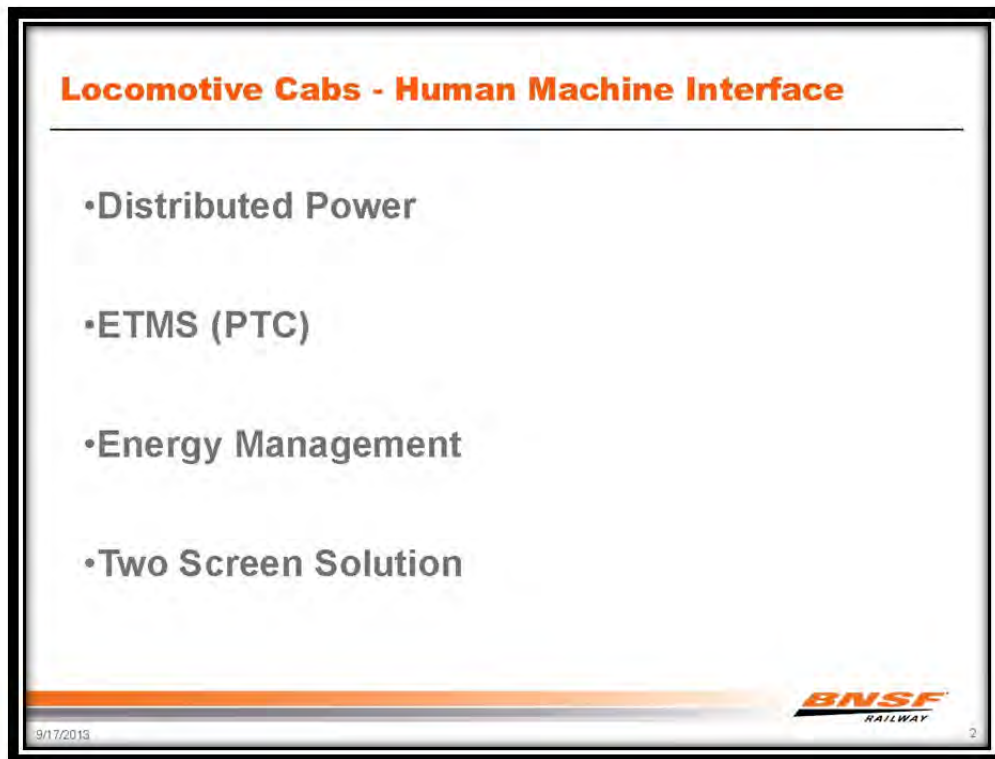


**Distributed Power, ETMS and Energy Mgmt. Usage
on BNSF Railway**

Aaron Ratledge – Director Operating Practices
Omaha TRB Midyear Meeting – July 2013


9/17/2013  1

This slide features a background image of a BNSF freight train in motion, blurred to indicate speed, against a sunset sky. A signal tower is visible on the left side of the track. The text is overlaid in white and orange.



Locomotive Cabs - Human Machine Interface

- Distributed Power
- ETMS (PTC)
- Energy Management
- Two Screen Solution

9/17/2013  2

This slide has a white background with a thin horizontal line below the title. The title and list items are in orange and black text. The BNSF logo and date are at the bottom.

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


Steam Engine Cab




9/17/2013 **BNSF** RAILWAY 3

This slide features a photograph of the interior of a steam engine cab. The space is filled with a dense network of pipes, gauges, and mechanical levers, characteristic of early 20th-century locomotive technology. The lighting is somewhat dim, highlighting the metallic textures and the intricate layout of the control systems.

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



EMD FT



S Class Loco

9/17/2013 **BNSF** RAILWAY 4

This slide contains two photographs. On the left is a black and white historical photograph showing a locomotive engineer in profile, seated at the controls of an EMD FT locomotive. The engineer is wearing a cap and heavy work clothes. On the right is a color photograph of the interior of an S Class locomotive cab, which shows a more modern control panel with numerous gauges, switches, and a prominent throttle lever.

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



9/17/2013



7

Locotrol III - DASH9-44CW

- GE Harris Box
- Used as lead or DP remote



9/17/2013



8

Locotrol III - DASH9-44CW

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



9/17/2013

BNSF
RAILWAY

9

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



9/17/2013

BNSF
RAILWAY

10

GE's ES44DC/AC – Integrated DP (IDP)

Engineer has choice:

- Right or left screen
- DP Control
- DP Combined



9/17/2013

11

EMD's SD70ACe – Integrated DP (IDP)





9/17/2013


12

PTC – ETMS Screen Placement

AC4400CW and C44-9W Retrofits

Conductor Side	Engineer Side
----------------	---------------





9/17/201313


PTC – ETMS Screen Placement

GE Evolution Retrofits

Conductor Side	Engineer Side
----------------	---------------








CDU Installs Here

9/17/201314

PTC – ETMS Screen Placement

GE Evolution Retrofits and New Deliveries




<p>Conductor Side</p>  <p>Conductor Side equipped with 3 GE Screens</p> 	<p>Engineer Side</p>  
--	--


 15

9/17/2013

PTC – ETMS Screen Placement

EMD SD70ACe Retrofits


<p>Conductor Side</p>  	<p>Engineer Side</p> 
---	---

 16

9/17/2013

PTC – ETMS Screen Placement

EMD SD70ACe New Delivery




BNSF
RAILWAY

9/17/2013 17


PTC – ETMS Screen Placement

EMD SD70MAC Retrofits

Conductor Side



Engineer Side




CDU Located Here

BNSF
RAILWAY

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PTC – ETMS Screen Placement

EMD SD60 Retrofits




The photograph shows the interior of a locomotive cab. On the left is the traditional wooden dashboard with several green-faced analog gauges. On the right, a new black monitor is mounted on the dashboard. A window is visible on the right side of the cab.

BNSF
RAILWAY

9/17/2013 19

PTC – ETMS Screen Placement

EMD Dash 2 Retrofits Conductor Side




The left photograph shows a white door with a red 'DANGER 600 VOLTS' sign and a dark rectangular panel below it. The right photograph shows the interior of the cab from the conductor's perspective, featuring a new monitor mounted on the wall above the window. A 'BNSF' logo is visible on the wall above the monitor.

BNSF
RAILWAY


9/17/2013 20


Energy Management/PTC/DP

SD 70ACe



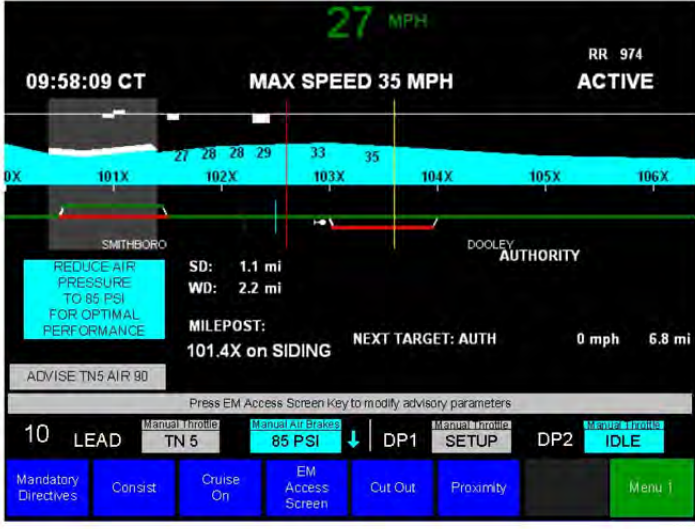
GE Evolution Series






9/17/2013 21

PTC/EMS Integration





9/17/2013 22

Two Screen Solution

Half PTC/EM and Full Screen DP Operations

ID	A=2005	B=1544	C=2356	D=4567	E=5678
Throtle	100%	10%	10%	10%	10%
Lead TE	100%	10%	10%	10%	10%
Consist TE	100%	10%	10%	10%	10%
BF	100%	10%	10%	10%	10%
Flow	100%	10%	10%	10%	10%
Route	100%	10%	10%	10%	10%
ER	100%	10%	10%	10%	10%
SC	100%	10%	10%	10%	10%
VF	100%	10%	10%	10%	10%

23

Two Screen Solution

Full Screen PTC/EM and Half Screen DP Operations

ID	A=2005	B=1544	C=2356	D=4567	E=5678
Throtle	100%	10%	10%	10%	10%
Lead TE	100%	10%	10%	10%	10%
Consist TE	100%	10%	10%	10%	10%
BF	100%	10%	10%	10%	10%
Flow	100%	10%	10%	10%	10%
Route	100%	10%	10%	10%	10%
ER	100%	10%	10%	10%	10%
SC	100%	10%	10%	10%	10%
VF	100%	10%	10%	10%	10%

24



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

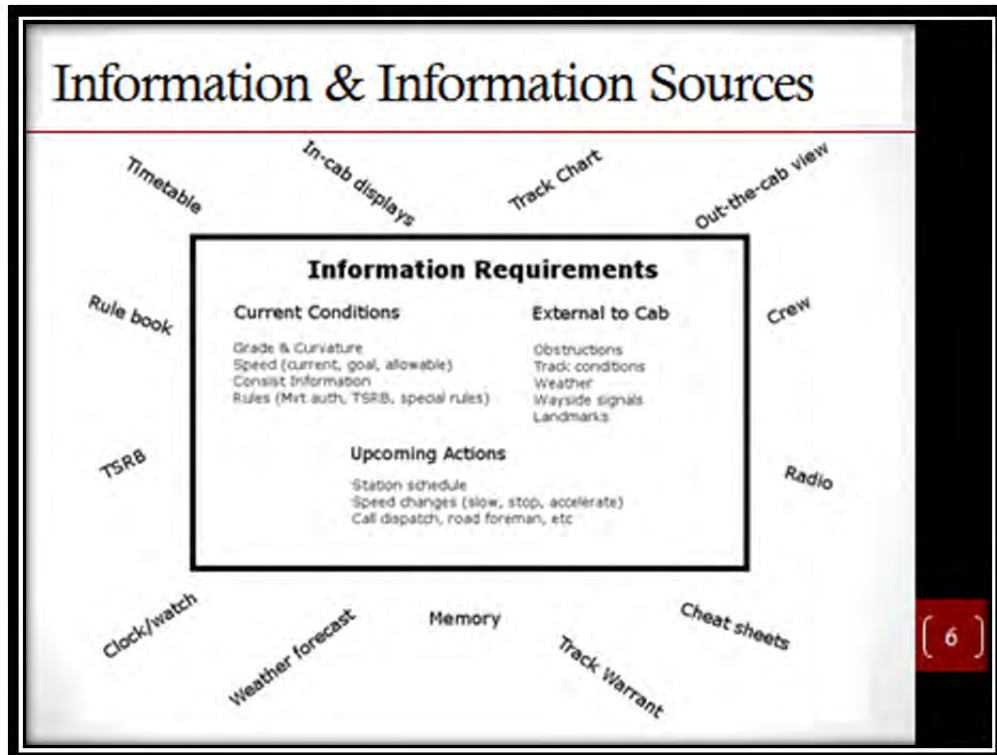
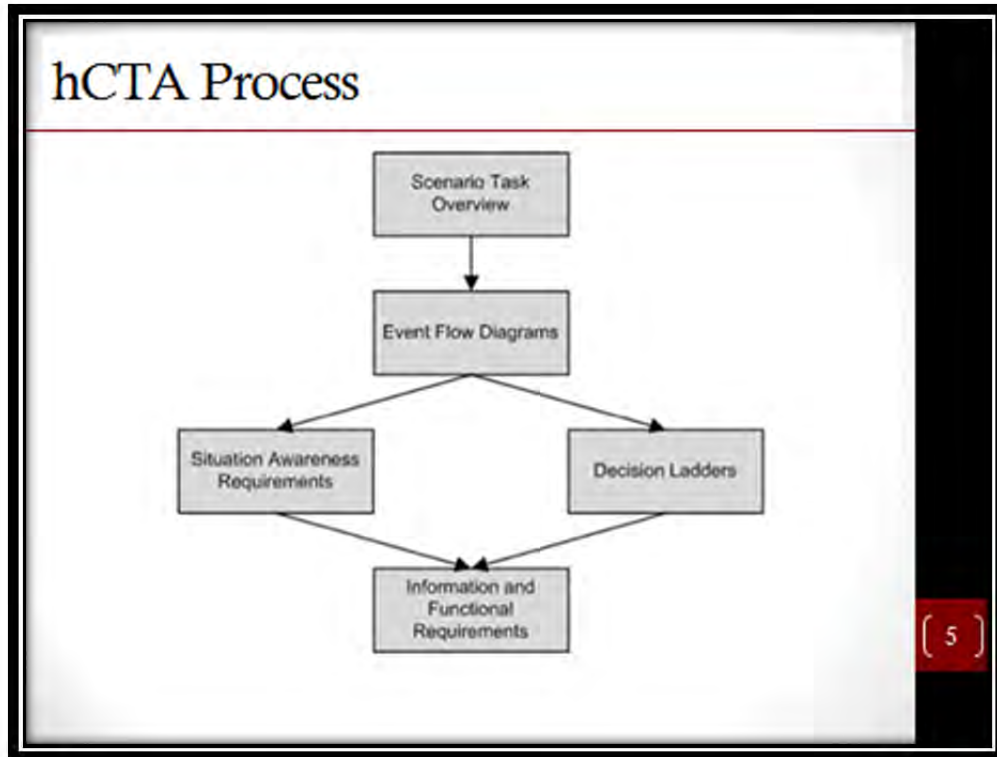
[3]

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 CTA¹
 - hCTA conducted for Alstom Transport in France by HAL in 2011²

1. Roth, E. M., Jordan (2009) Technology Implications of a Cognitive Task Analysis for Locomotive Engineers.
2. http://web.mit.edu/aerostro/labs/halab/papers/MILLO_Final_Report-02-25-11.pdf

[4]



Pain points

- Many sources of information & no streamlined way to integrate
- No standard for remembering temporary route changes
- Prospective memory

Information Requirements

Category	Items
Current Conditions	Grade & curvature, Speed (current, grad. ahead), Control information, Rules (for ATP, TSM, speed rules)
External to Cab	Restrictions, Time, conditions, weather, trackside signals, Landmarks
Upcoming Actions	Signal schedule, Speed changes (over, into, under), Cab signals, road blocks, etc.

Time	Location	Signal	Speed	Notes
10:00	1000	Red	10	
10:05	1050	Green	20	
10:10	1100	Yellow	30	
10:15	1150	Red	10	
10:20	1200	Green	20	
10:25	1250	Yellow	30	
10:30	1300	Red	10	
10:35	1350	Green	20	
10:40	1400	Yellow	30	
10:45	1450	Red	10	
10:50	1500	Green	20	
10:55	1550	Yellow	30	
11:00	1600	Red	10	

7

Prospective Memory-

"memory for intended actions that need to be completed in the future"¹

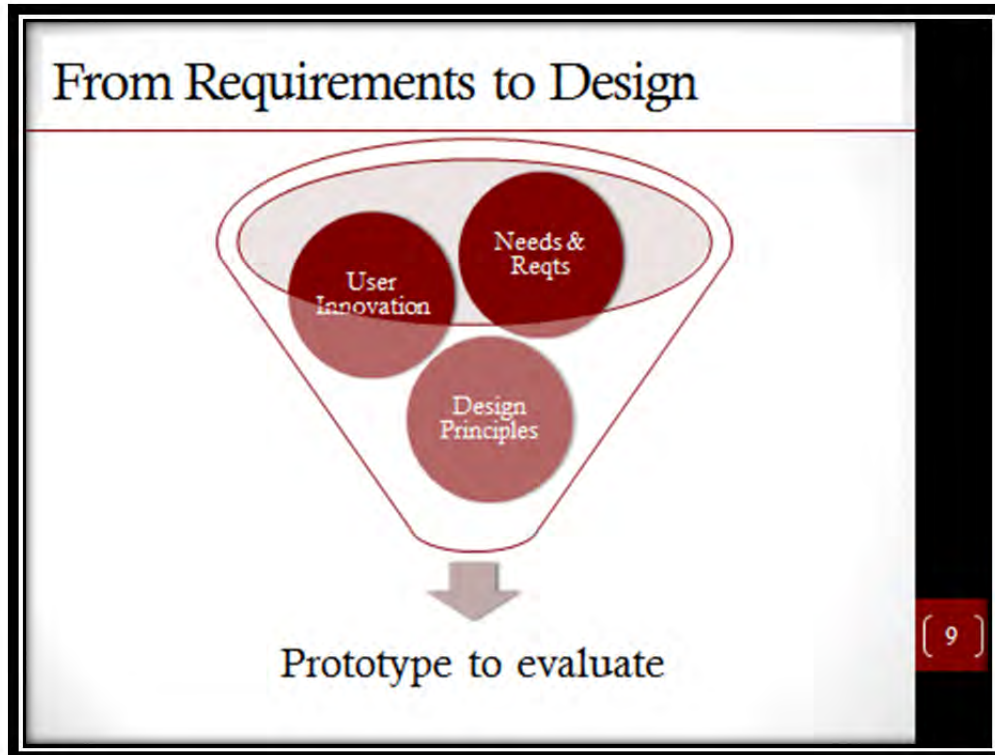
Event Flow Diagram for complex decision, "Is action required within current mental track segment?"

```

graph TD
    A[Monitor Current Location] --> B{Is action required now?}
    B -- Yes --> C[Perform Action/Procedures]
    B -- No --> D{Is action required in next mental track segment?}
    D -- Yes --> E[Determine next action & location using memory, conductor reminder, timetable, notes, last signal, etc.]
    D -- No --> A
    E --> A
    
```

1. Fisk, 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



User Innovation

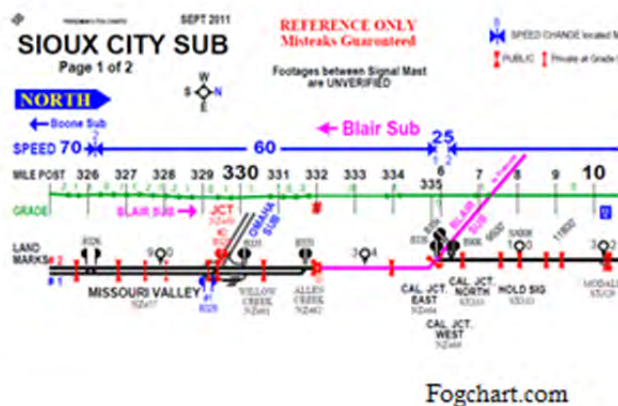
- Consumer-Innovators develop for their own benefit, i.e., to make their life easier
 - Usually share openly
 - Collaborative communities can form and improve innovation
- Users have an in depth understanding of the use cases and context
- If innovation is produced by a company, there is already a group of users
- People improve products all the time-6% of UK consumers created or modified software or hardware for their own needs

10

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): 1609-1631.

What are current strategies?

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



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

12

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

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

05:54:11
Stop at station in 2.2 miles

9 mph

Rule Book Log Book Phone Book

The display features four main horizontal panels:

- ROUTE:** Shows a train icon on a track with a red triangle marker. A station is labeled "S. Attleboro A. 9:03 D. 9:15".
- SPEED:** Shows two tracks, Track 1 and Track 2. Track 2 has a red "10" and a "30" marker.
- GRADE:** A green line graph showing track elevation with values like 1.44, 0.74, 0.37, 0.38, 1.07, 0.94, and 2.00.
- CURVATURE:** A green line graph showing track curvature with various step-like values.

At the bottom, there are navigation buttons: List View, Form D, New Note, Mov Auth, and Tr. Number.

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)

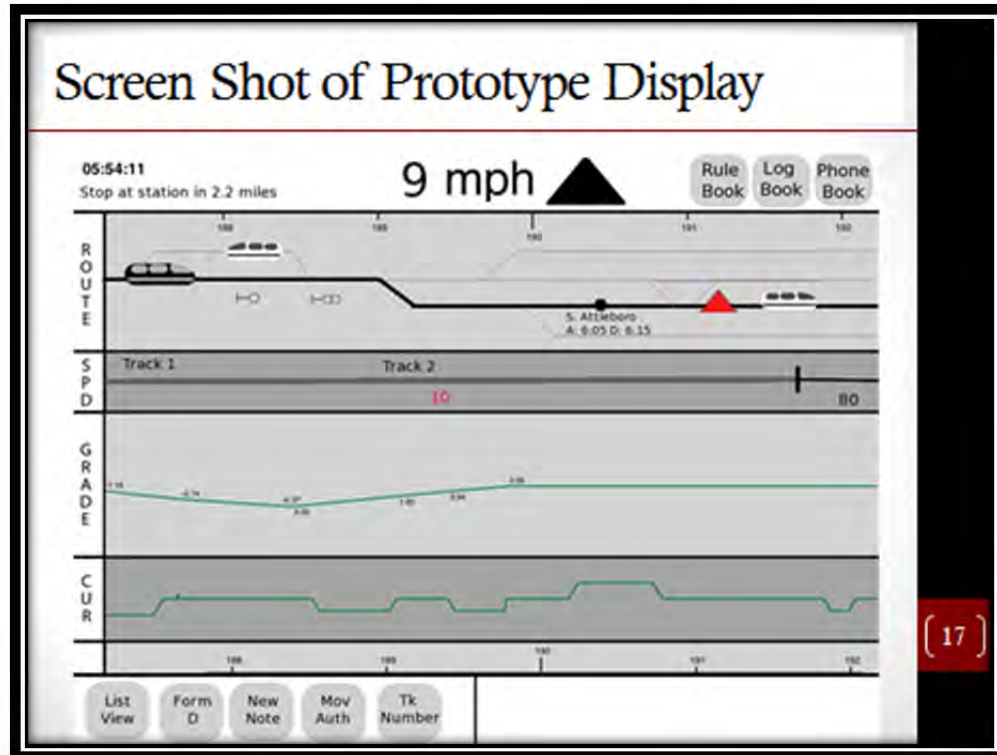
* Although not available everywhere today, did not want to constrain design

[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]



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 respond correctly to changes in the normal route over the current standard (i.e., relying on memory, viewing multiple displays and using paper notes)?

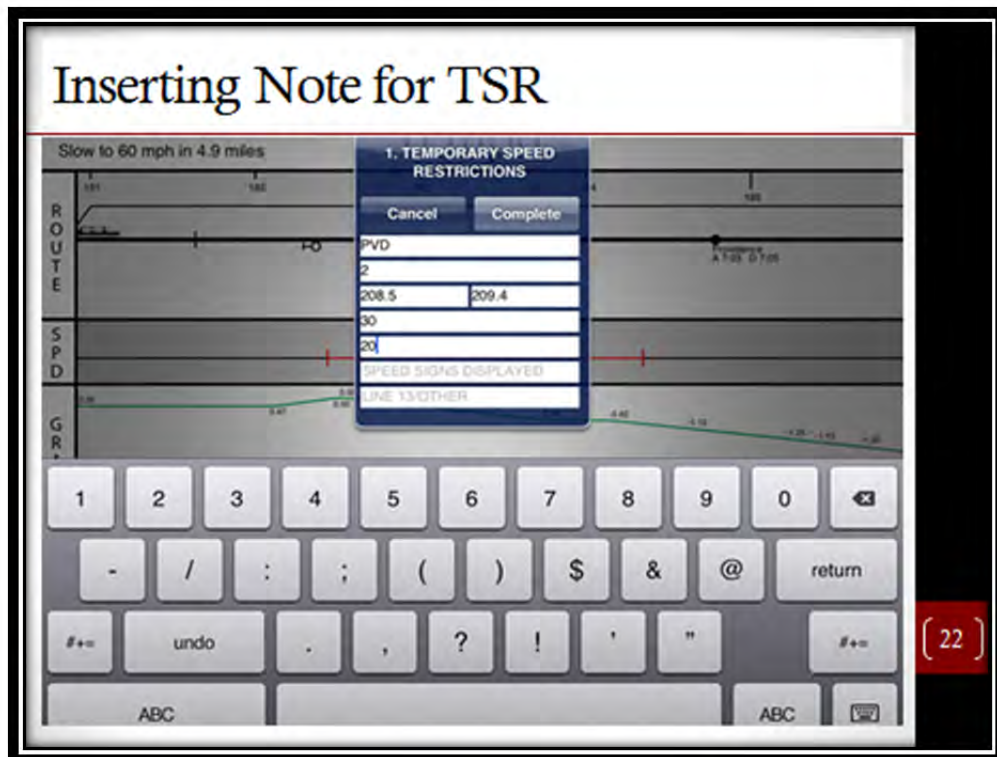
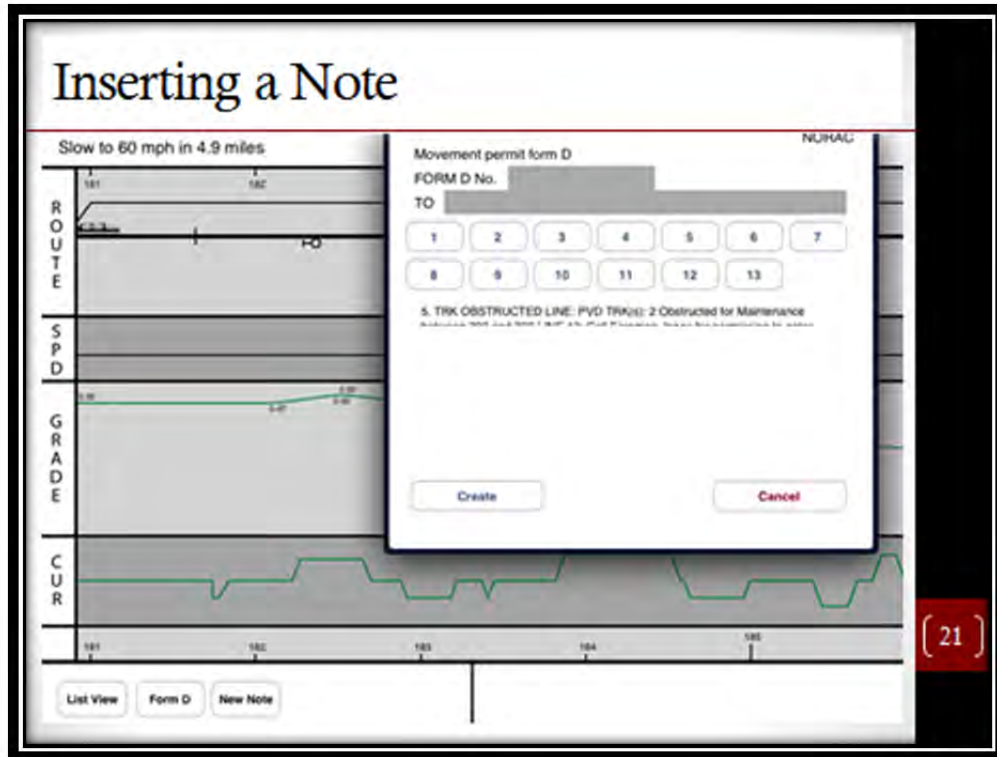
18

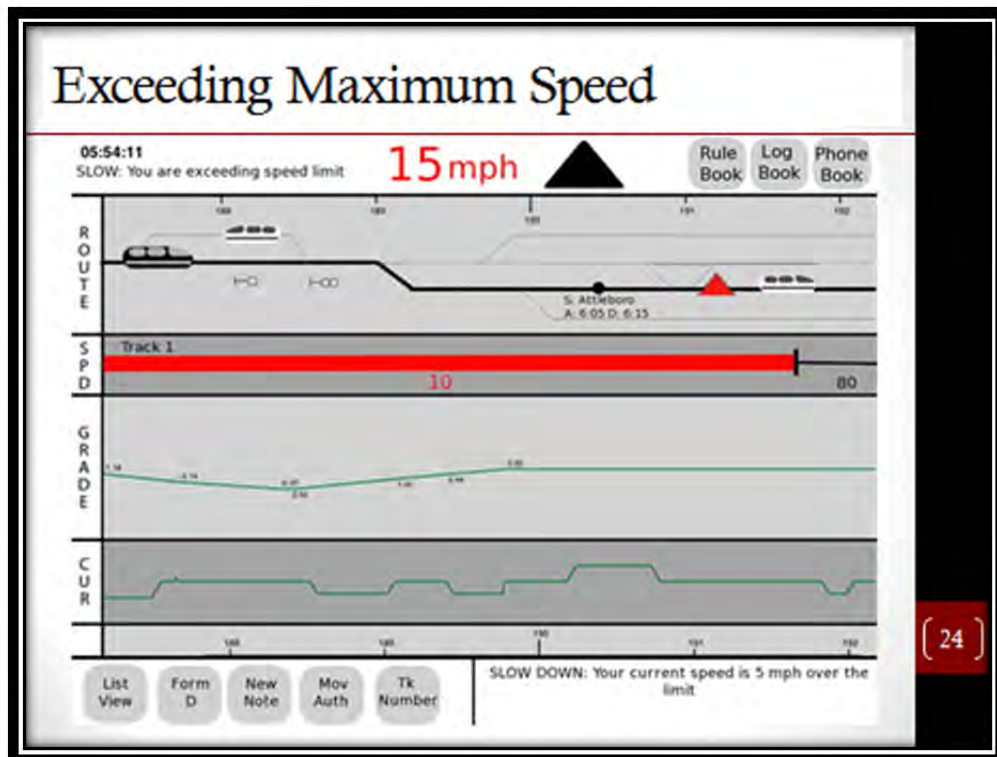
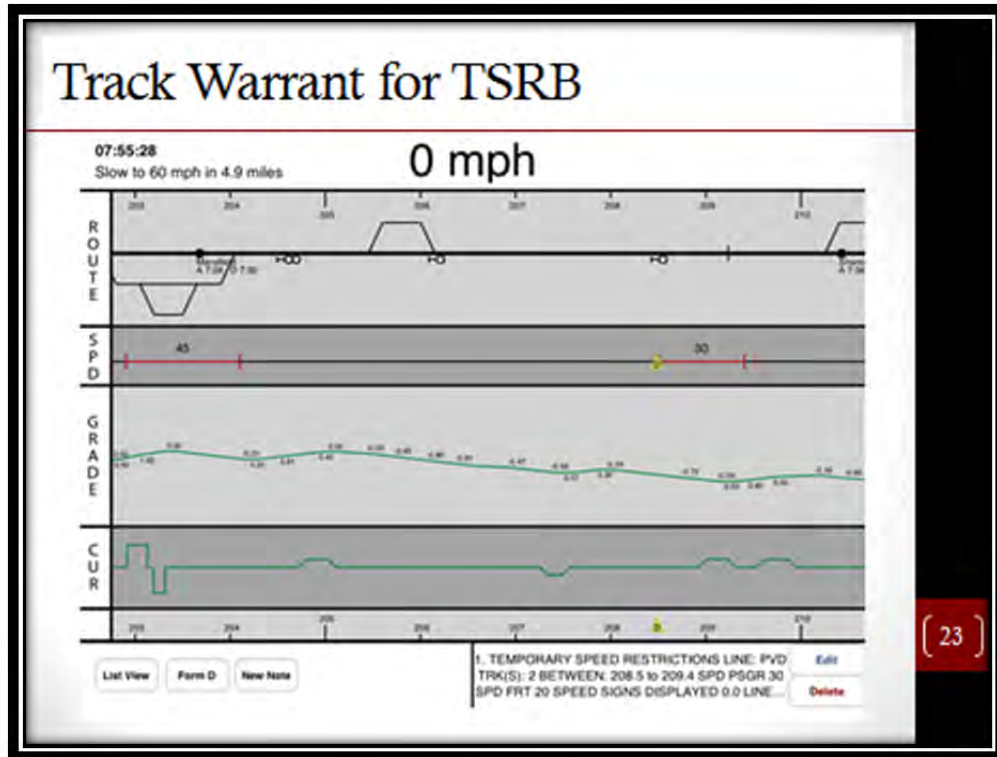
Follow-up

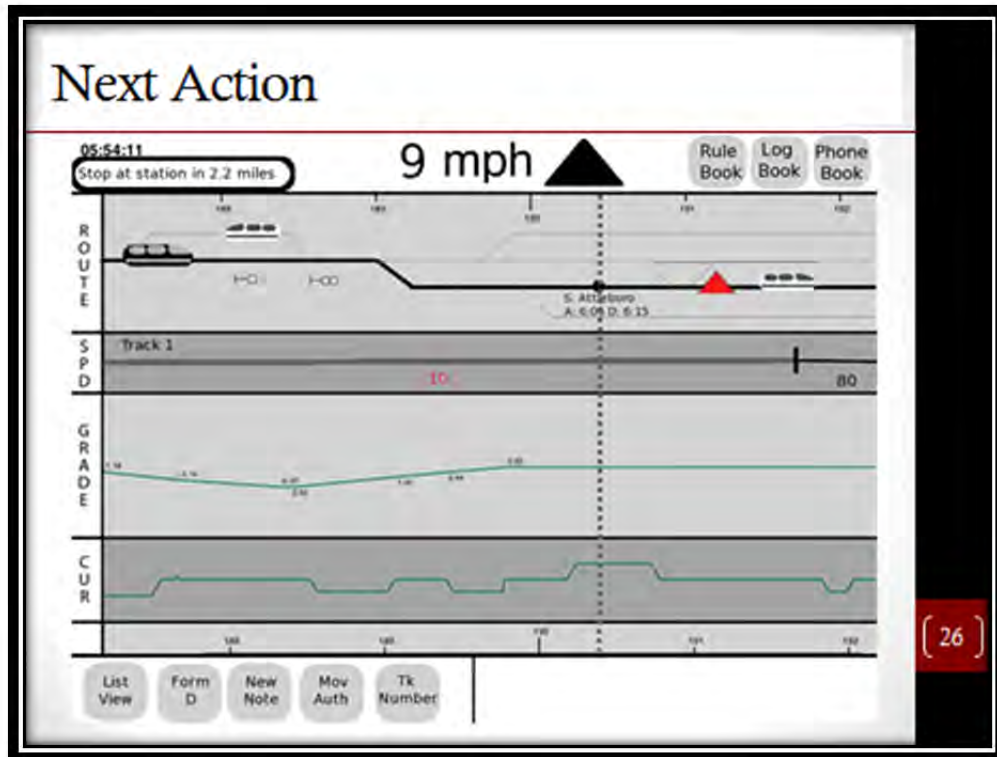
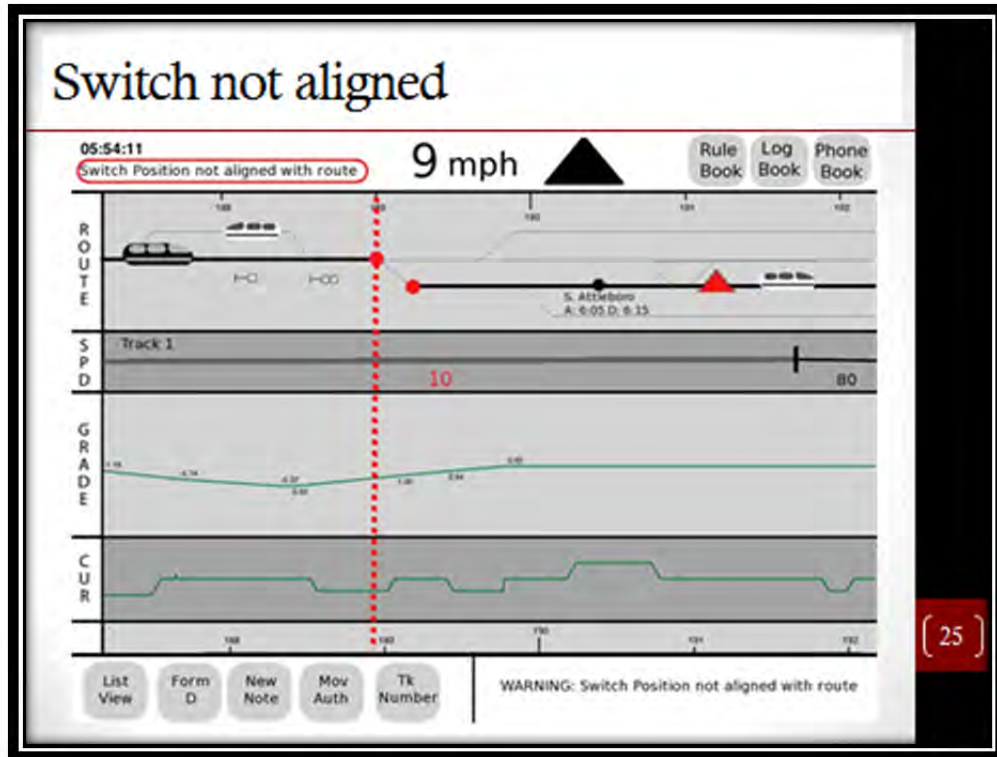
- You are welcome to interact with the display-I will have the iPad with me during the conference
- Contact info:
 - Kathleen Voelbel
 - kv@mit.edu

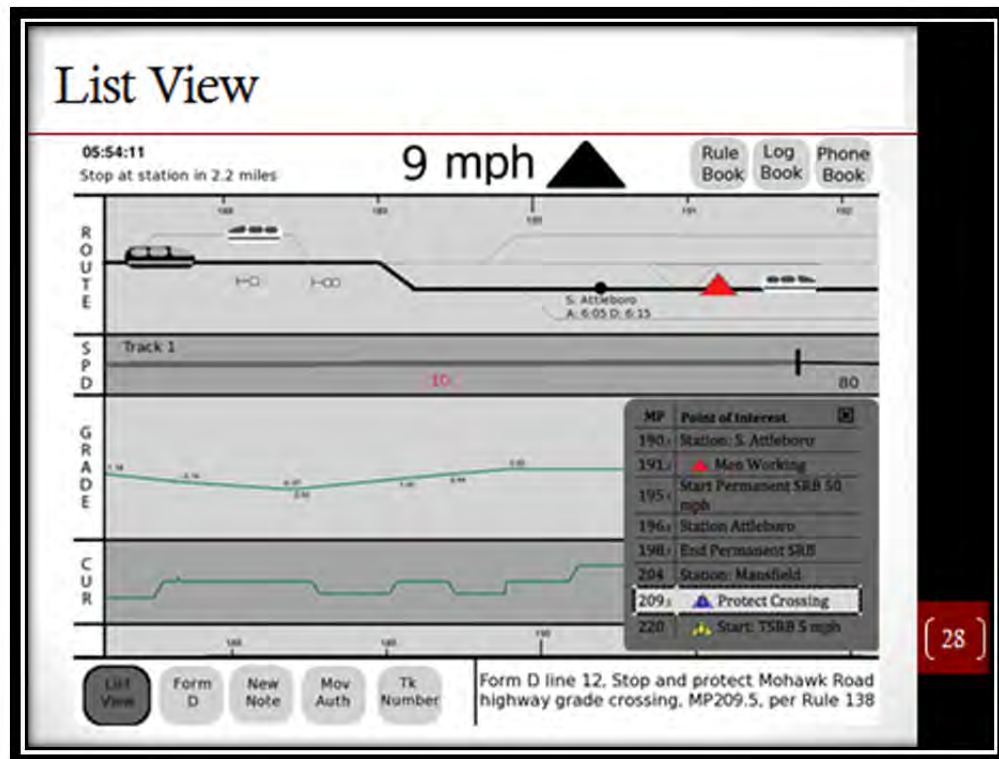
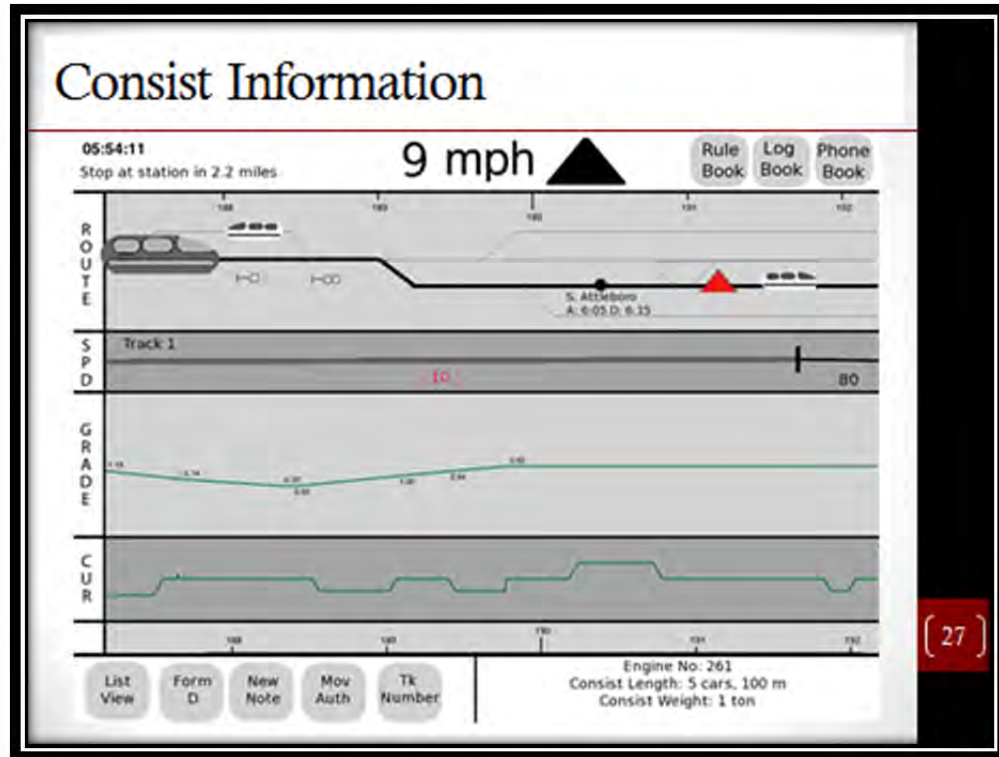
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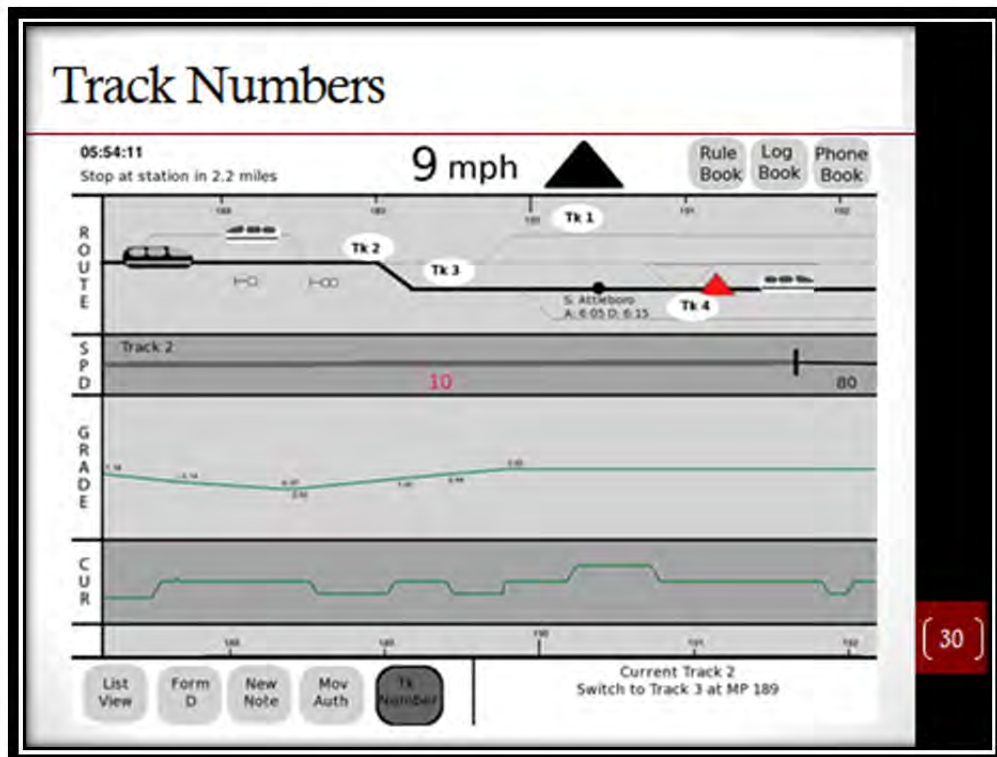
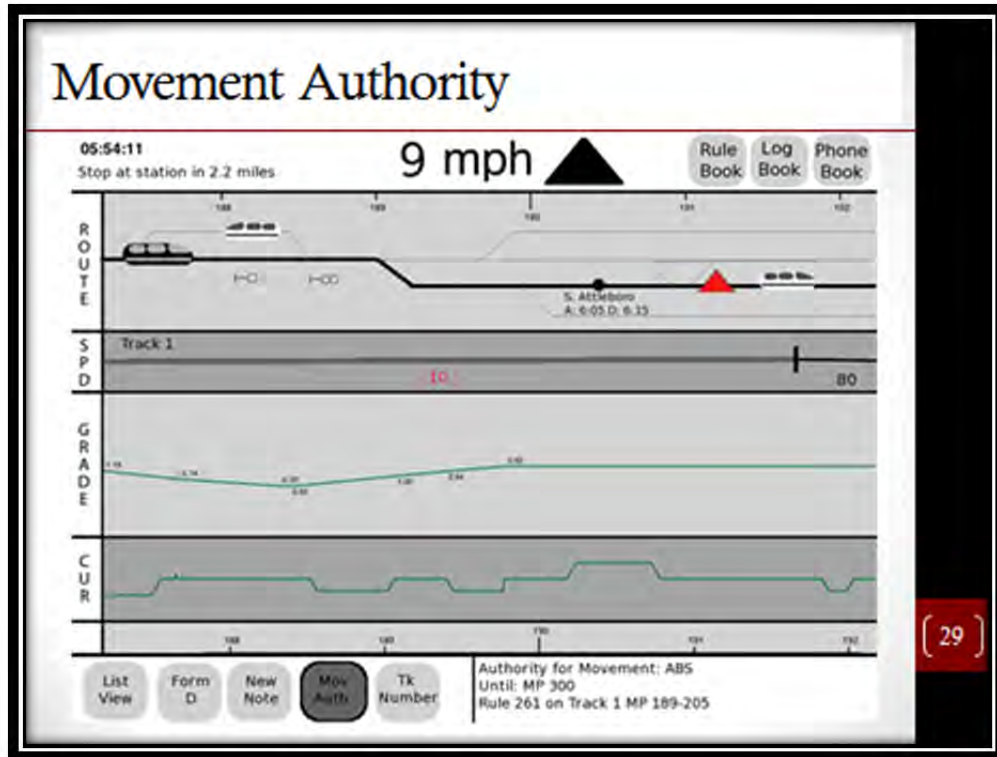
Back up











CT 401 R2 1-93 **NORAC**
Movement permit form D

FORM D No. _____ FORM D NO.(S) _____ DATE _____
 DELIVERED TO _____

TO _____

1. TEMPORARY SPEED RESTRICTIONS

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

2. OPERATE IN _____ DIRECTION(S) ON _____ TRK BETWEEN _____ AND _____
 ON _____ TRK BETWEEN _____ AND _____ DSPPR _____ TIME _____
 ON _____ TRK BETWEEN _____ AND _____ DSPPR _____ TIME _____
 ON _____ TRK BETWEEN _____ AND _____ DSPPR _____ 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 CDS 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. CDS RULES OUT OF SERVICE ON _____ TRK(S) BETWEEN _____ AND _____

12. PROTECT CROSSING(S) _____

13. OTHER INSTRUCTIONS/INFORMATION _____


[31]

Receiving Changes

- Before Departure
 - Bulletin Orders
- En route
 - Track Orders
 - NORAC Dispatcher might call with the following:

“copy Form D number M 4, dated 11/14/12, mark line 5, track obstructed for maintenance men and equipment per NORAC rule 135 at MP 202.2. Circle line 13, other instructions-Contact Employee In Charge Jones for permission to enter restriction, flags are displayed, repeat, over.” (Veolia Distraction Study)

[32]




Locomotive Alerter Technology Assessment


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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.




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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 Contrôle 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

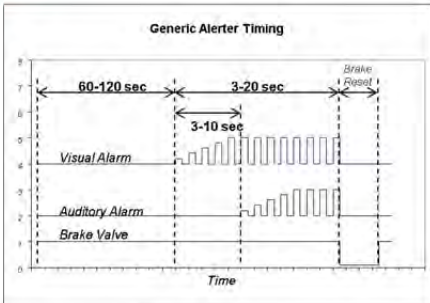
- Detect operator inattention, sleepiness or incapacity without sustained physical effort.
- 60-120 sec countdown timer
- Button/lever for manual pre-emptive reset on console or stand, usually near horn or bell.
- After timeout, visual and horn alarms activate, usually successively.
- If no manual reset 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.



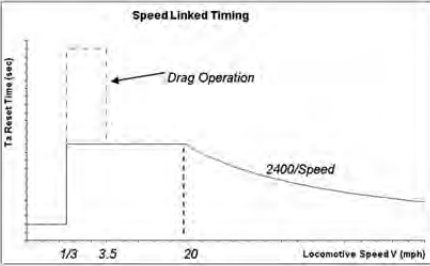
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Alerter reset logic


- 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.




Generic Alerter Timing




Speed Linked Timing




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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
8-5513

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



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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.

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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.

consecutive RTs across a 10-min PVT performance task

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Vigilance Technology


- 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






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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"





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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 microsleeep accidents like Macdona.
- Nonetheless, in newer locomotives with software based alerters, logic improvements could be introduced at relatively minor cost.






FEASIBILITY OF HEAD UP DISPLAYS IN DRIVING CABS

Dr Ann Mills
RSSB, UK






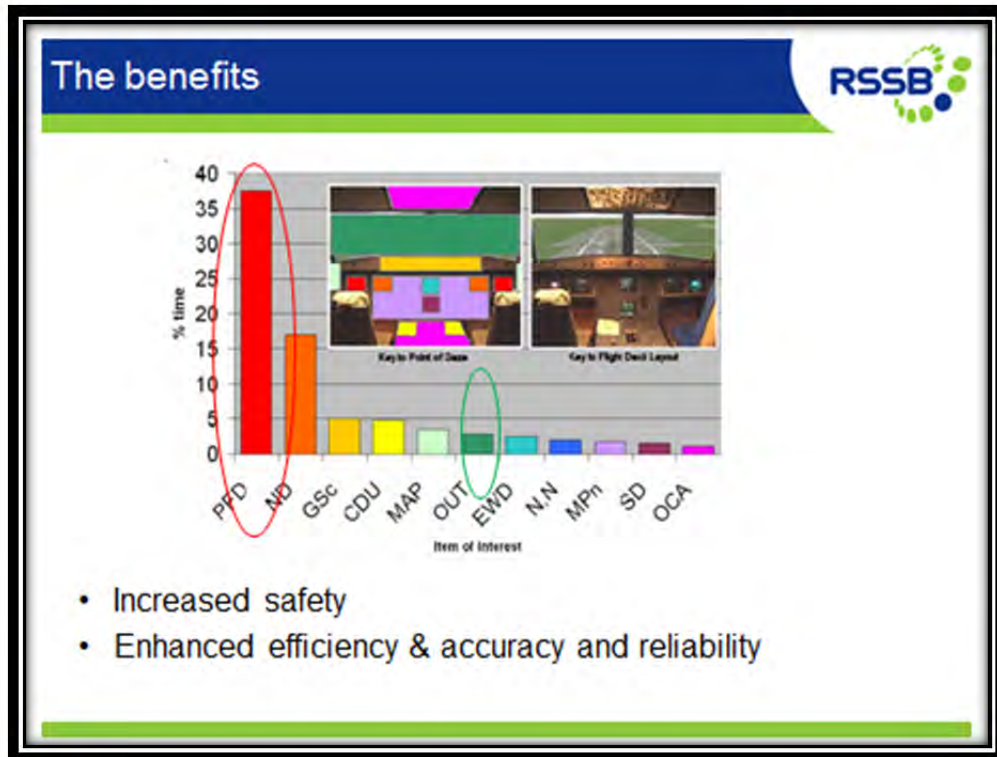
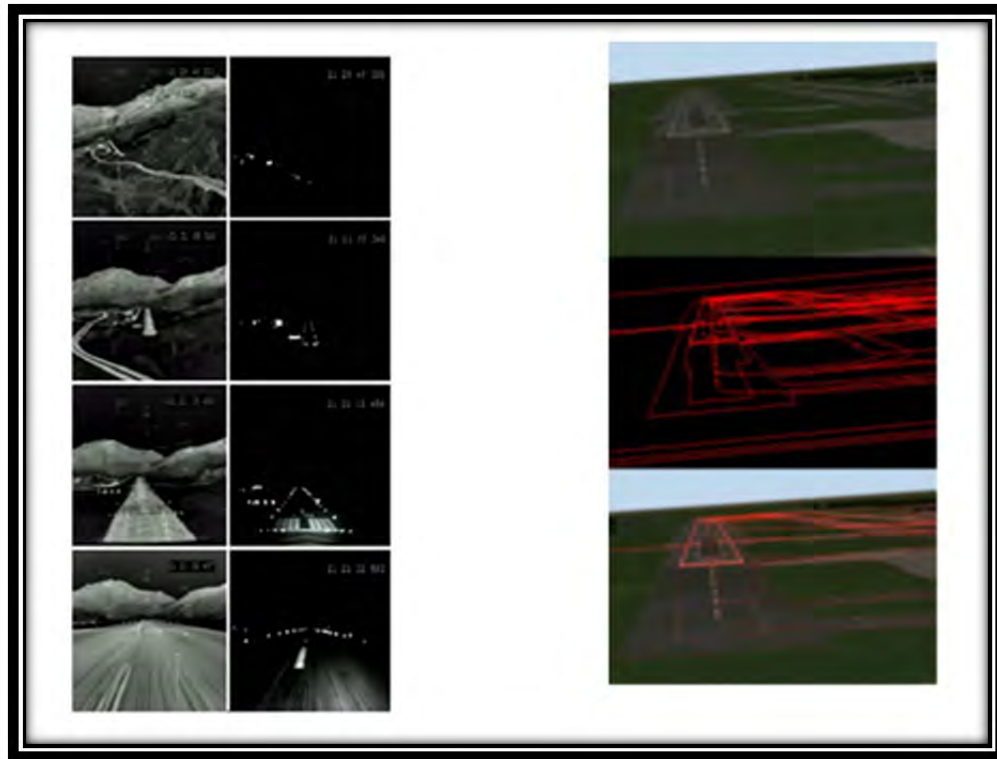


What is a Head Up Display?



1960s Military Aircraft
1970s Commercial Aircraft
1980s Automotive





The rail context



Research



Stage 1) Assessment of Potential Safety Benefit
Review of Rail Incidents

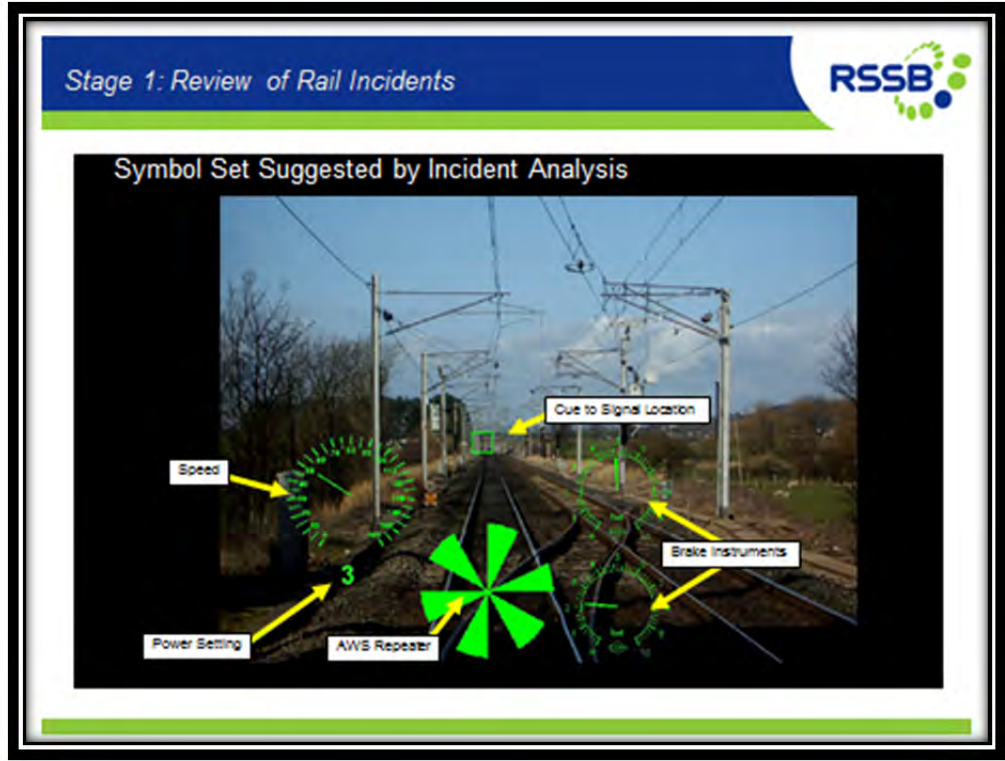
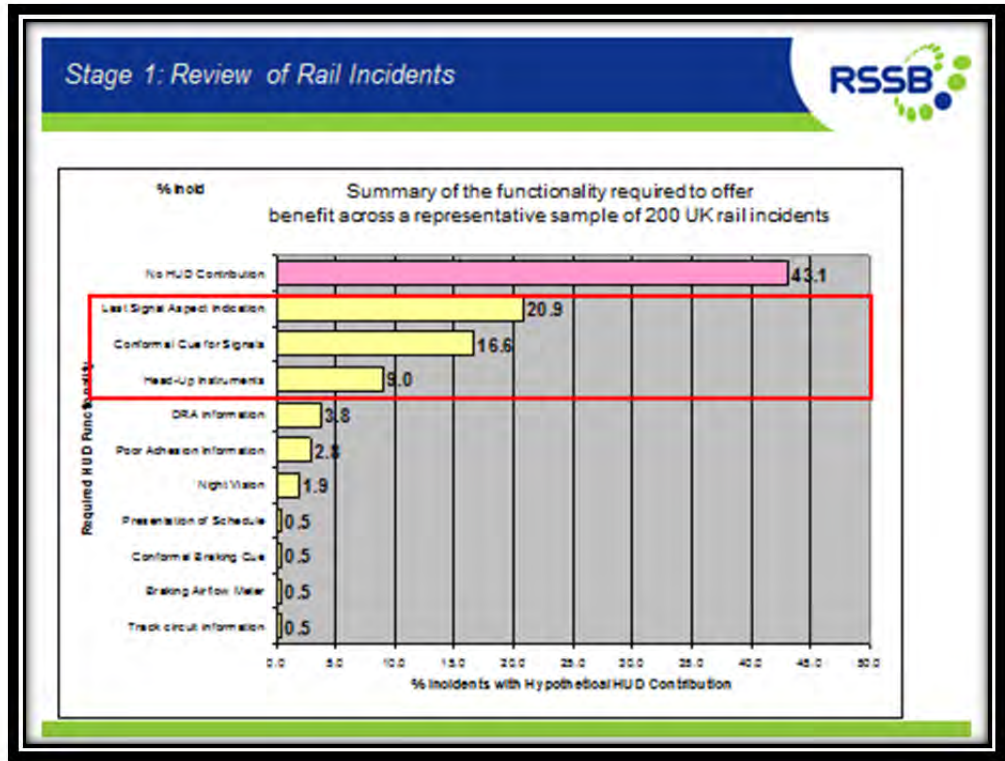



Stage 2) Review of Integration Issues for the Rail Environment
Engineering Review



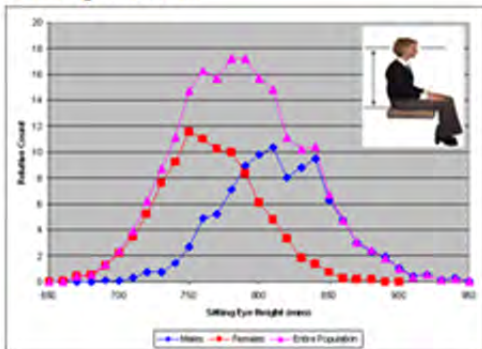
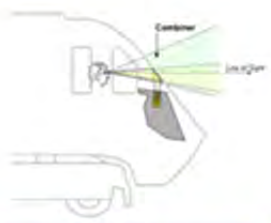
Stage 3) Assessment of Potential Benefits from Driver's Perspective
Simulator Study






Stage 2: Review of Integration Issues 


Seating Position


Conclusion: A valid issue but one which is not insurmountable




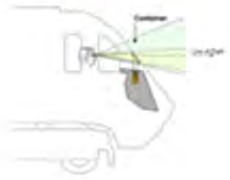
Extreme



Normal




Stage 2: Review of Integration Issues 

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 




Based on Class 390 'Pendolino'
Located at **BAE SYSTEMS** in Bristol

Stage 3: Simulator Assessment 

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
- HeadUp display

Stage 3: Simulator Assessment 

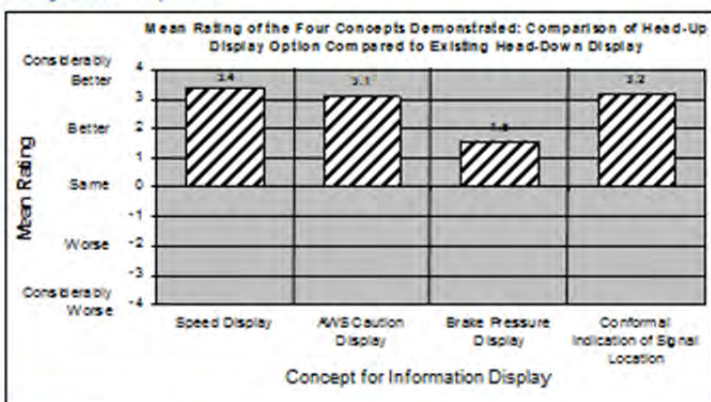
Assessments

- 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 

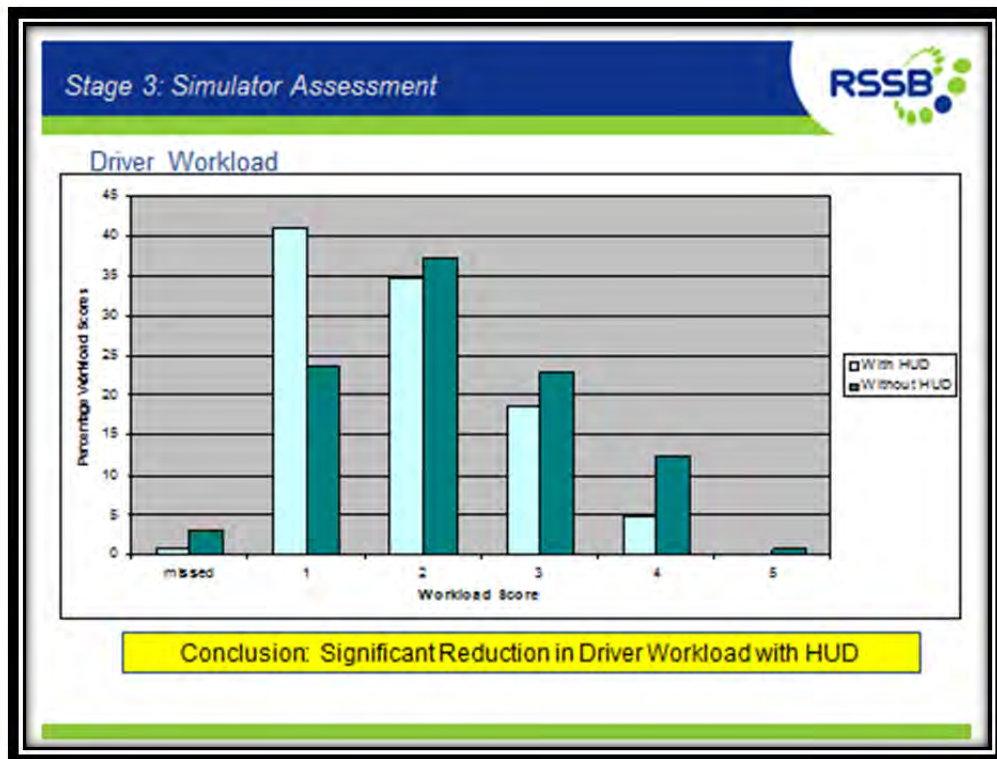
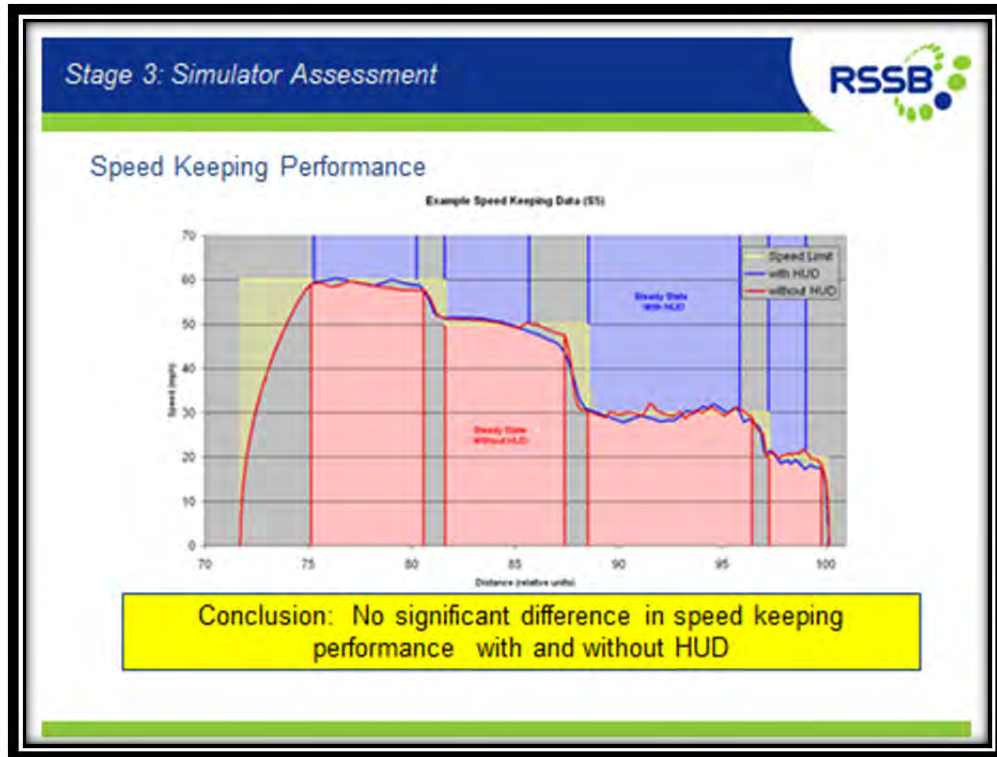
Driver Subjective Opinion

Mean Rating of the Four Concepts Demonstrated: Comparison of Head-Up Display Option Compared to Existing Head-Down Display




Concept for Information Display	Mean Rating
Speed Display	3.4
AWS Caution Display	3.1
Brake Pressure Display	1.6
Conformal Indication of Signal Location	3.2

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




Stage 3: Simulator Assessment




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 reduce SPADs and assist drivers during adverse weather conditions can only be welcomed".*
- *"A HUD is a better invention than TPWS".*

Conclusions



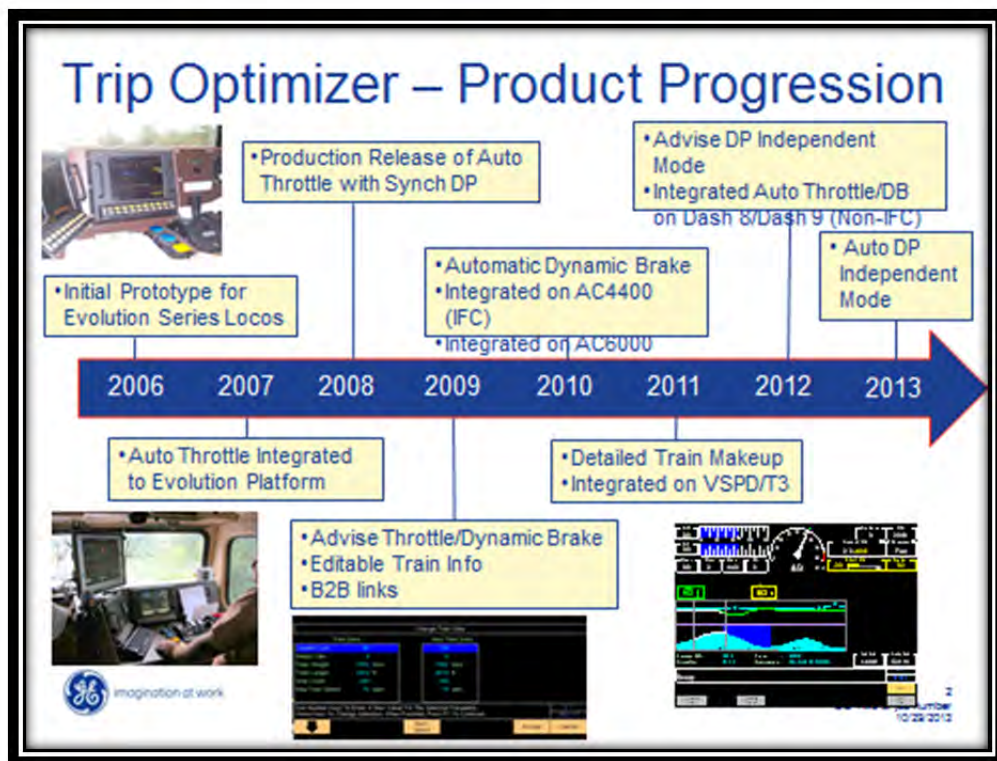
- Most aspects of a HUD are likely to be adaptable to the rail environment
- There may be little inherent opposition to HUDs from train drivers
- No significant effect on driver performance was measured
- The use of a HUD results in a significant reduction of driver workload



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



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

The diagram shows the system architecture. On the left, three blue arrows labeled 'Engineer', 'Track Database', and 'Trip Manifest' point towards a central blue box labeled 'Trip Optimizer System' which contains a gear icon. A blue arrow labeled 'SAD' points down into the 'Trip Optimizer System' box. A large grey arrow labeled 'Train Speed' points from the 'Trip Optimizer System' box to the right. To the right of this arrow is a screenshot of the HMI interface, which displays a speedometer showing 48 mph, a speed profile graph with a white line and a blue area, and various control buttons like 'Lead' and 'Cut In'.

Energy Management: Auto Throttle

The two screenshots show the original HMI interface. The left screenshot shows a speedometer at 47 mph and a speed profile graph with a brown ground area and a yellow zone. The right screenshot shows a similar view but with a white speed line and a white auto throttle box. The interface includes various data fields, buttons, and a speedometer.

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)


imagination at work

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 10/22/2012

Energy Management: Advisement

The screenshot shows a locomotive control interface. At the top, there are two speed indicators showing '90' and a central speedometer showing '49'. Below these are various status indicators and a 'Distance' readout of '2.3 113 K'. A 'PARK AHEAD' prompt is displayed in a yellow box, with a red arrow pointing to a 'Notch' button. The interface also shows a track profile and various control buttons at the bottom.

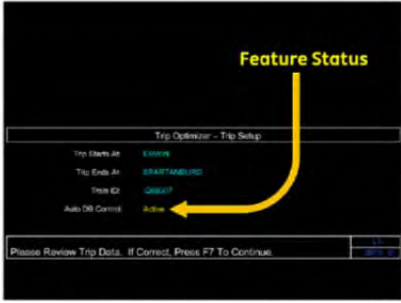
- Prompts operator to control train speed via simple visual prompts on the display. Arrow indicates if the next prompt will be a higher (↑) or lower (↓) command
- Open loop control

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Automatic Dynamic Braking

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Energy Management: Auto Dynamic Brake




Feature Status



System User Interactions

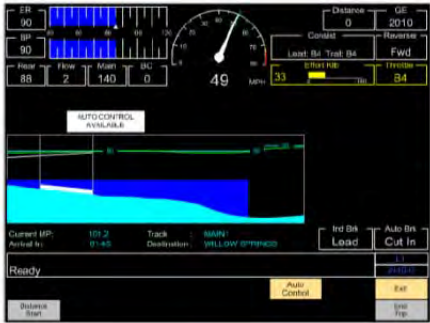
- Trip Set Up Screen: Shows Auto DB Control
- Auto Control available in Dynamic Braking and Motoring
- User Interface Changes:
 - Control Transitions: Manual to Auto/ Auto to Manual
 - Motoring, Braking, and Transitions
- Originally, Auto DB only available up to DB7. Later designs allow DB8
- Controlled Lead/Trail/Synchronous Remotes

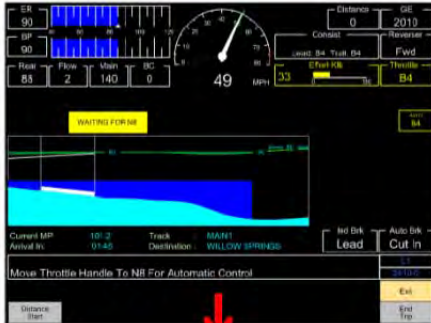


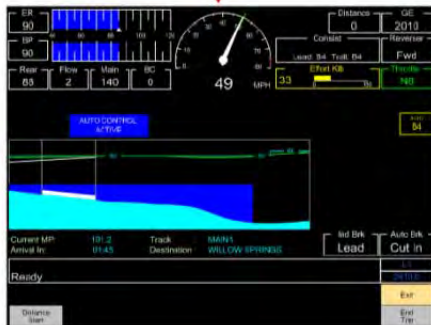
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Energy Management: Auto Dynamic Brake






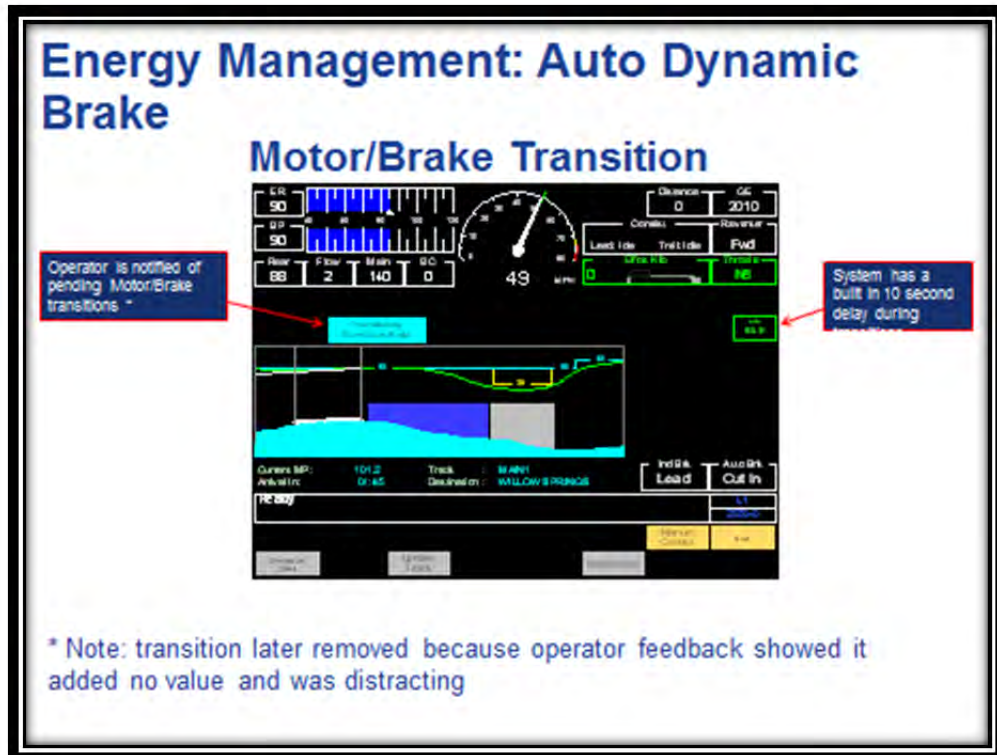
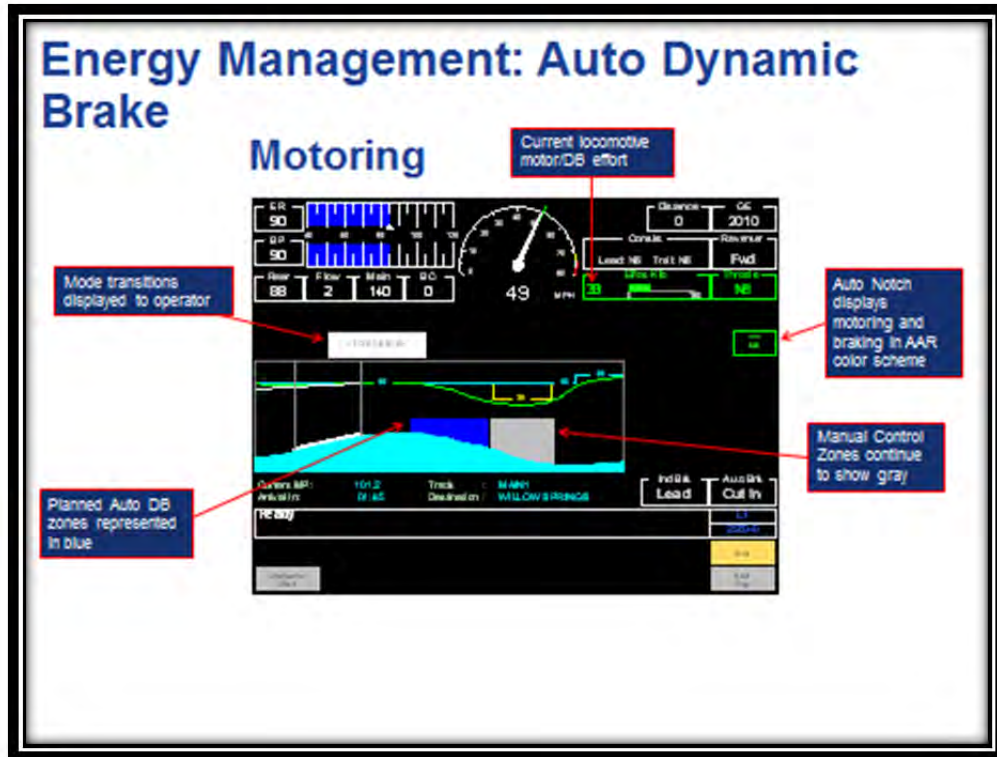


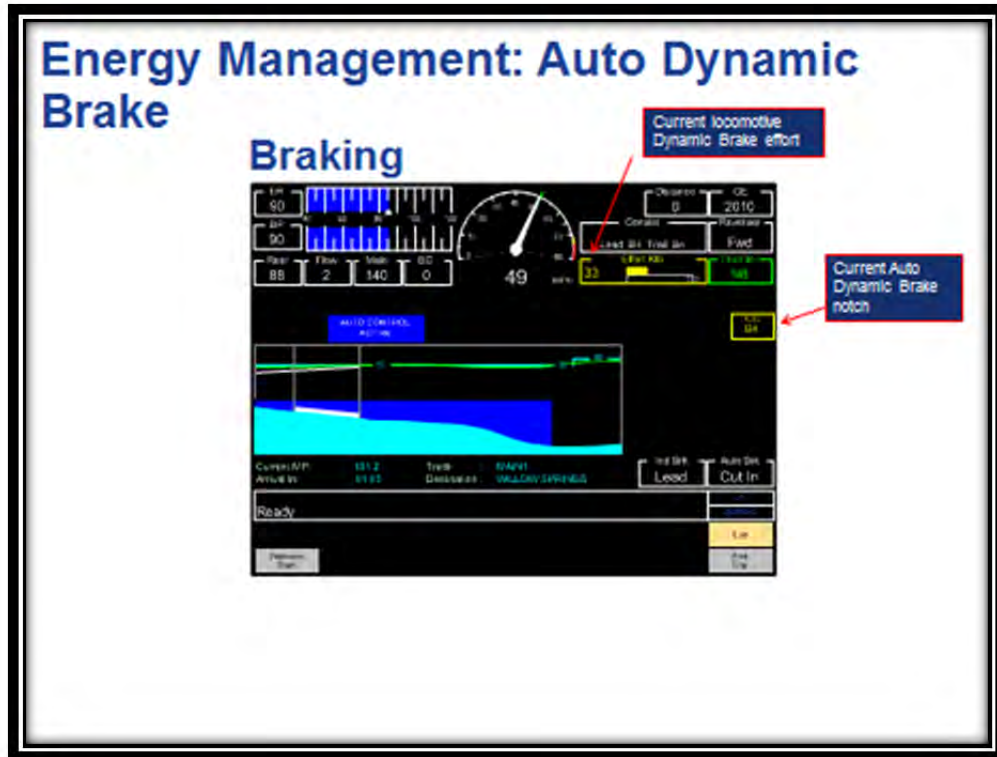
Transitioning Manual To Auto

- Auto available in DB as well as Motoring
- System begins regulating DB until transition is completed
- Operator has completed transition, handle in N8



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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

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Automatic Independent Mode

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10/22/2012

Energy Management: Auto Independent

User Interface Changes

Feature Status

➤ Trip Set Up Screen: Shows Auto Ind Control

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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


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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

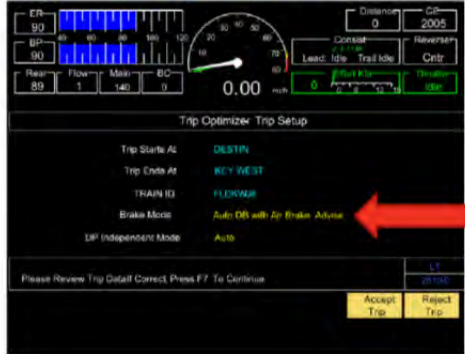


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Energy Management: Air Brake Advisement


Trip Set Up Screen



Please Review Trip Detail Correct Press F7 To Continue


Accept Trip Reject Trip

Rolling Map



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

Eliminated blue dynamic braking zones



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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

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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

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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

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 10/22/2013

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


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

Anita Scott
Senior Human Factors Specialist, RSSB




Projects

- 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




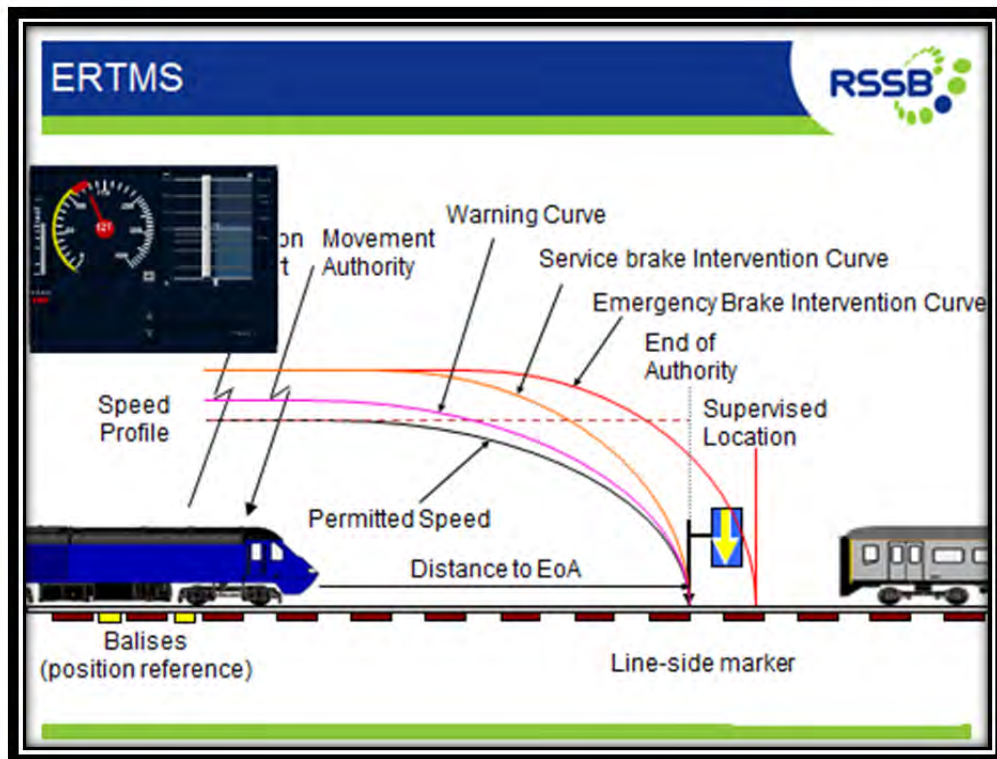
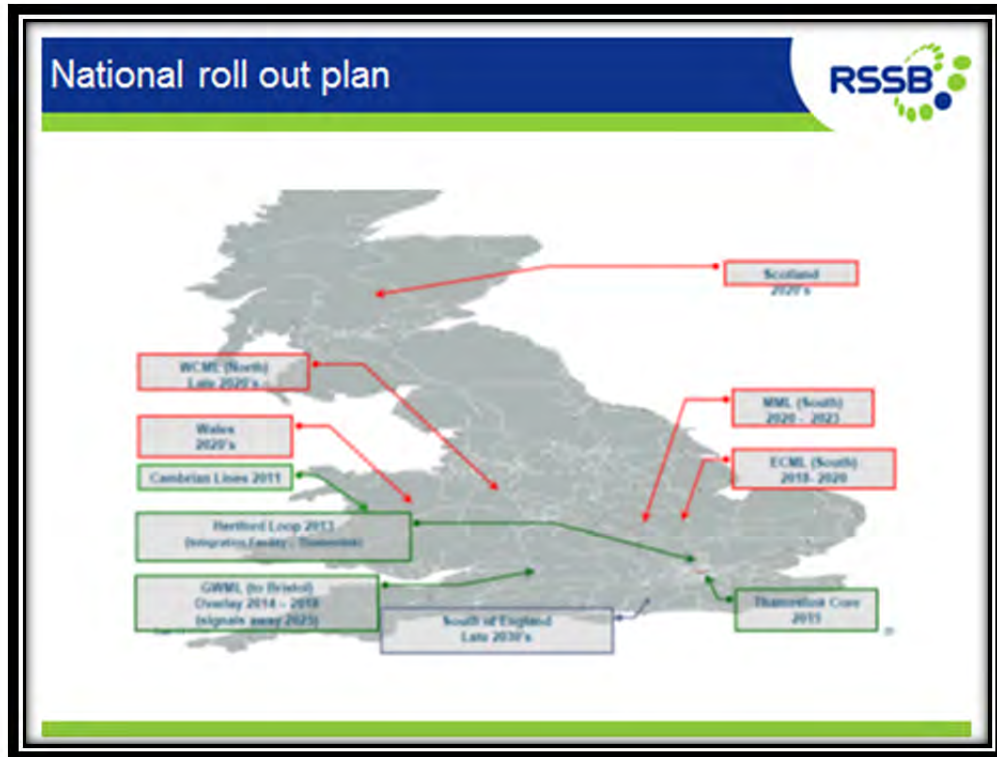
- To successfully integrate you must consider:
 - Operability of equipment
 - Physical design of equipment
 - Functional safety and system security
 - Staffing and training development
 - Procedures and staff organisation
 - Integrating human factors into system development

ERTMS



Case study - ERTMS





Operability – Integrating with legacy systems



- Converting a hardware interface to a touch screen



Existing hardware train protection system interfaces



Possible solution: Existing train protection system interface when integrated into ETCS DMI touchscreen



Physical design





97303






- Most important and frequently used equipment:
 - Within reach
 - Within visual field

Anthropometry

Functional safety & system security



- 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



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



- 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




- **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

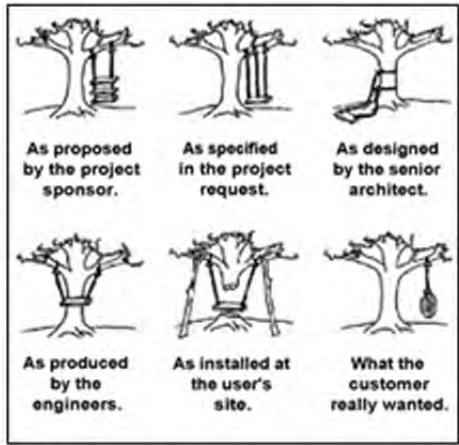
Integrating HF into system development



- 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





As proposed by the project sponsor.

As specified in the project request.

As designed by the senior architect.

As produced by the engineers.

As installed at the user's site.

What the customer really wanted.

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

'Tree Swing'



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

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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

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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



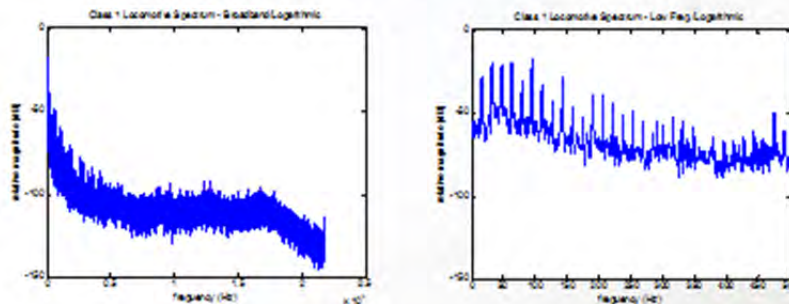
Locomotive Cab Noise

- 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



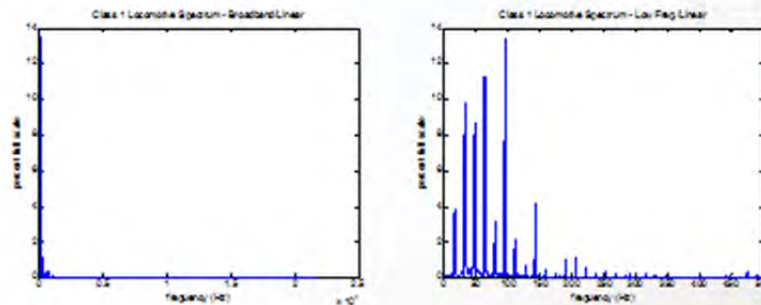
Example of Locomotive Sound

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



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?

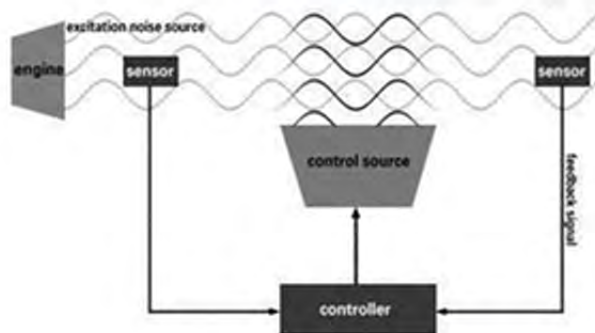
- Active control can be differentiated from passive control in that active control uses energy to destroy the energy present in a disturbance.
- Passive controllers merely dissipate energy by converting it into heat.
- Adaptive control can be differentiated from fixed control in that an adaptive controller 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.

2.1



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.

2.2

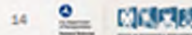


Project Scope

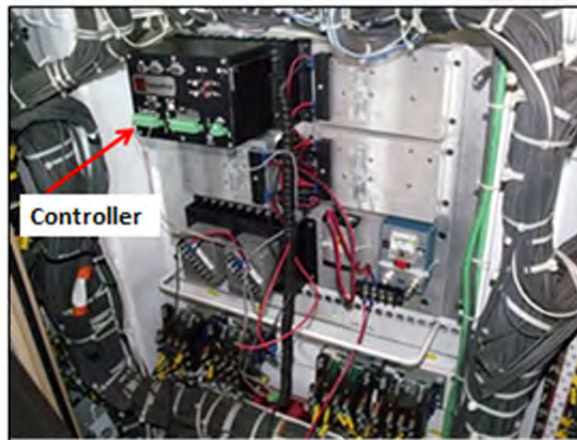
- The system was installed and tested on two locomotives
 - An older EMD built GP-40 unit @ TTCI
 - A newer GE built ES44AC unit @ a North American Railroad
- The evaluations @ TTCI were conducted at test track conditions, whereas the RR evaluations were conducted in revenue service
- In each case, baseline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




Test Locomotive @ TTCI

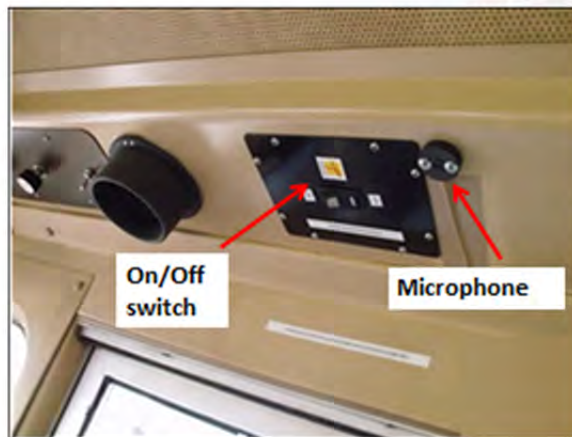


ANC Installation Example – Controller – in electrical cabinet



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



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ANC – Installation – Speakers above windshield

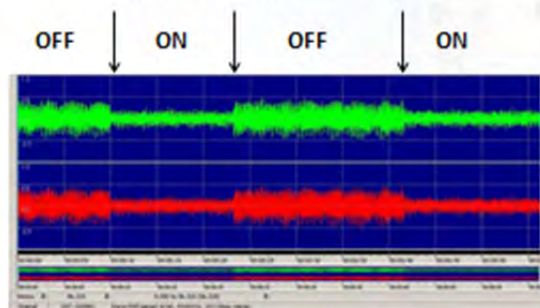


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ANC – Test Results Example

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

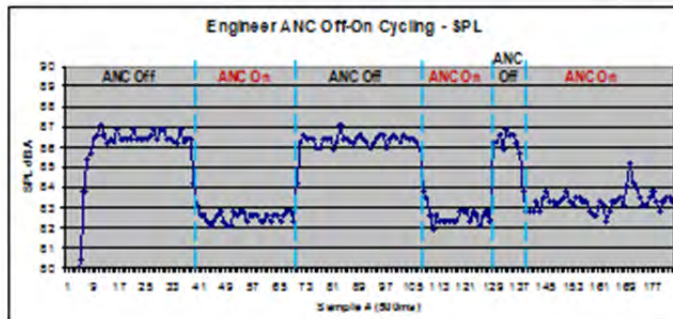


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ANC – Test Results Example

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

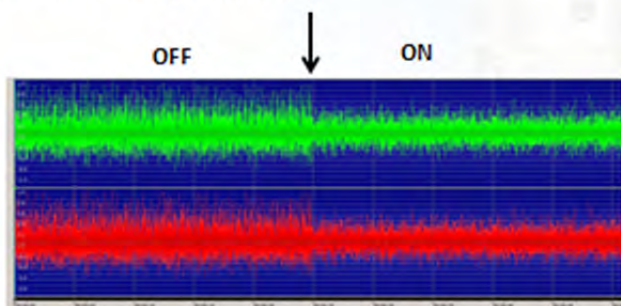


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ANC – Test Results Example

- 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 measurable 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.

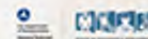
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