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Summary & Proceedings

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Michael Perel played a key role in the AVST forum.

16. Abstract

The National Highway Traffic Safety Administration sponsored a public forum in January 2007 to explore human factors issues related to Advanced Vehicle Safety Technologies (AVST). The broad goal of the forum was to initiate a dialogue on the nature of driver performance in relation to AVST and identify high-priority research areas. Forum attendees were stakeholders from safety organizations, Federal and State governments, industry executives and researchers from private organizations and academia. Participants at the forum explored the anticipated benefits from AVSTs as well as possible risks. The forum took place over two days and consisted of 12 presentations by an international slate of invited speakers and five expert working groups. The presentations focused on applications such as CICAS (Cooperative Intersection Collision Avoidance System) and IVBSS (Integrated Vehicle Based Safety Systems); the development of adaptive technologies that respond to the state of the driver (e.g., fatigue); the question of applying standards to AVST; and the application of human factors design to the driving task and AVST devices. The five working groups identified high-priority research concerns, prepared research problem statements for NHTSA and developed initiatives to strengthen the collaboration among the stakeholders. This report provides a summary of the presentations, group discussions, and outcomes of the working group sessions.

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The participation and contributions of the invited presenters, group moderators, and attendees of the Human Factors Forum on Advanced Vehicle Safety Technologies (AVST) made it a success. The presenters provided a rich and varied perspective on AVST and human factors; the moderators skillfully facilitated the breakout sessions; and the scribes and breakout session assistants documented the group discussions, prepared the presentations to the plenary, and contributed to the final report.

Invited Speakers

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John Campbell (Battelle)
Joanne Harbluk (Transport Canada)
Sarah Koskie (Indiana University-Purdue University)
Robert C. Lange (General Motors)
John Lee (University of Iowa)
Toyohei (Tony) Nakajima (Honda)
Vicki Neale (Virginia Tech Transportation Institute)
Jim Sayer (University of Michigan Transportation Research Institute)
Dan Selke (Society of Automotive Engineers Safety & Human Factors Committee)
Michael Shulman (Ford)
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Breakout Session Moderators

Bob Lange (General Motors)
Neil Lerner (Westat)
Jim Sayer (University of Michigan Transportation Research Institute)
Mary Stearns (Volpe National Transportation Systems Center)
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Executive Summary

In January 2007 the National Highway Traffic Safety Administration sponsored a public forum to explore the human factors issues of Advanced Vehicle Safety Technologies (AVST). The forum took place over two days, had about 100 attendees, and consisted of presentations from an international slate of invited speakers and breakout sessions of expert working groups who identified high-priority research issues and topics.

Systems such as AVST that are designed to increase safety do not necessarily do so. Currently, the empirical knowledge to determine whether AVST provide safety benefits is not available. Only when AVST are widely deployed; until then, it is not known if AVST will reduce crashes. It is even possible that AVST will introduce unintended, negative effects, such as driver distraction or complacency.

The presentations provided different perspectives on AVST and human factors research needs and methods. The breakout sessions consisted of five expert working groups that identified research needs and initiatives for future collaboration between stakeholders. The expert working groups addressed the research and policy aspects of the following subtopics within AVST:

Group 1 - Driver-Centered Design
Group 2 - Unintended Consequences
Group 3 - Standardization and Commonality
Group 4 - Integrating Multiple Systems
Group 5 - Mechanisms for Future Collaboration

The groups held discussions on the top priority areas within these subtopics. A major outcome of the sessions was a set of high-priority areas, i.e., those deemed to be essential by the groups to advance knowledge of the issues or have the highest impact on safety. The groups generated research statements on the high-priority research areas and the moderators presented the statements to the forum in the final plenary session. A second outcome of the breakout sessions was to propose 10 specific ideas or initiatives for maintaining and strengthening the collaboration between stakeholders.

This document summarizes the activities and outcomes of the forum. It includes a synopsis of the presentations and breakout sessions, the research problem statements and initiatives for future collaboration.

Introduction

The National Highway Traffic Safety Administration sponsored a forum in January 2007 to explore human factors issues of Advanced Vehicle Safety Technologies. AVST are an array of driver assistance and crash warning systems designed to reduce crashes. They include systems that provide:

- safety alerts, such as forward collision warning systems (FCW), road departure warning (RDCW), lane departure warning (LDW), and intersection collision warning),
- automated control (e.g., FCW combined with automatic braking)
- driver assistance systems, such as adaptive cruise control (ACC), brake assist; backing safety systems; and automatic lane keeping

AVST are relatively uncommon but are becoming increasingly available in the passenger and commercial vehicle market. Currently, the empirical evidence and experience with AVST is insufficient to assess their safety benefits. The introduction of AVST in the vehicle fleet may improve safety but, like all innovative technologies, includes a risk that they will not be effective or will produce unintended consequences, such as driver distraction or complacency. Similarly, it is possible that drivers who trust crash avoidance technology to provide protection may increase their risk-taking behaviors, thereby compromising potential safety benefits. Unintended consequences may also arise from faulty driver assumptions about the operation of AVST. For example, some systems only work within specified speed ranges but drivers may come to expect the systems to perform at all speeds and in all conditions. Thus, a key focus of the forum was to present and discuss perspectives on designing AVST with the aim of increasing the likelihood of success and reducing potentially adverse effects on safety.

An important question about design is whether the variability in AVST devices within and across vehicle models and manufacturers will create confusion, leading to ineffective or inappropriate behaviors. There is the potential for negative transfer of learning as drivers increasingly use vehicles with new or unfamiliar AVST characteristics. For example, a driver familiar with a warning sound from System A may not respond as quickly when hearing the warning sound from System B.

Full safety benefits may not be achieved unless the systems are designed with drivers' capabilities and limitations in mind. Driver performance can vary across groups, from person to person, situation to situation, and from time to time. Relative to younger drivers, older drivers on average have poorer eyesight, slower reaction times, and a decreased ability to perform multiple tasks simultaneously. Likewise, the same driver may respond differently in heavy traffic versus light traffic or when they are fatigued or alert. Mismatches between the system outputs and driver capabilities could lead to inappropriate (or a complete lack of) driver response to system information or degraded driver acceptance. AVST also may unintentionally incur negative driver behaviors (e.g., distraction).

The forum addressed the question of AVST as individual technologies and as integrated systems containing multiple technologies. The presence of multiple AVST, each providing information or warnings to drivers, raises additional design and safety concerns. Integrated systems have the potential to prevent a large portion of crashes but they pose unique design challenges (such as creating different warnings which drivers can easily comprehend and distinguish). The Department of Transportation is conducting a large-scale field operational test under the Integrated Vehicle-Based Safety Systems (IVBSS) Initiative to address this emerging issue and to improve our understanding of the human factors of multiple warnings integration.

Purpose & Outcome

NHTSA emphasizes the importance of deploying AVST that are compatible with the driving task and driver capabilities, and identifies research as having the central role in the design of AVST. NHTSA views the interaction with stakeholders as a crucial means to identify the research priorities affecting the safety of AVST. As noted above, the unanswered questions about the interaction between drivers and AVST demand a thorough exploration by stakeholders. NHTSA organized the public forum to promote the collaboration between stakeholders and help advance our knowledge and understanding of the research needs underlying the successful development and deployment of AVST. In this regard, the forum supports NHTSA's mission to "save lives, prevent injuries, and reduce vehicle-related crashes" and the meeting's main goal was "to facilitate the deployment of advanced vehicle safety technologies that are compatible with drivers' capabilities and needs to help them achieve maximum safety benefits and experience minimum unintended, adverse consequences."

The participation at the forum by two of NHTSA's leaders -- the Administrator, Nicole Nason, and the Senior Associate Administrator for Vehicle Safety, Ronald Medford -- underscores the importance with which NHTSA views the question of safe AVST. Nason and Medford delivered the opening remarks to the plenary. Following the opening remarks, an international slate of 12 invited speakers from industry, academia, and research agencies delivered presentations on a range of human factors and AVST topics. Following the presentations, forum attendees participated in two working sessions on five major areas. NHTSA had pre-assigned the participants to five groups so that each group would include individuals from diverse backgrounds and expertise. The groups met in two sessions, one on each day of the conference, in order to give attendees sufficient time to brainstorm and deliberate the issues. The groups developed research problem statements and initiatives for future collaboration.

The Breakout Groups

The five breakout groups were each given a unique topic (shown in Table 1). The groups had a charge to "identify the research and policy needs" of the specific topic area required to ensure the safety and effectiveness of AVST. Groups were instructed to produce one or more problem statements by the end of the session. To jump start and frame the group discussions, the moderators asked the groups to address a series of questions developed before the forum (shown in Table 2). Groups 1 through 4 followed the questions in Table 3 and Group 5 addressed the questions in Table 4.

The moderators used the Nominal Group Technique to facilitate the breakout groups. The Nominal Group Technique allows for a structured variation of a small group discussion in which the views of everyone are considered and the end result is the identification of key issues and priorities. The process included discussing the issues and questions, identifying gaps in knowledge, voting on the highest priority areas, developing them into problem statements or next steps and presenting the results to the plenary. The groups used a template to develop the statements (shown in Appendix B).

Table 1 Topics for the Breakout Groups

Group	Topic	Products
Group 1	Driver-Centered Design	Research Problem Statements
Group 2	Unintended Consequences	Research Problem Statements
Group 3	Standardization and Commonality	Research Problem Statements
Group 4	Integrating Multiple Systems	Research Problem Statements
Group 5	Mechanisms for Future Collaboration	Next Steps

Table 2 Questions for Framing the Topic (used in all groups)

- What are potential safety and driver acceptance problems associated with each topic?
- What is the strength of existing research in each topic?
- How can safety-related problems be identified?
- What metrics and criteria help assess problems and effectiveness of solutions?
- What are the criteria for whether a system will be effective and acceptable?
- What are the research needs and approaches?
- What are the most important research needs?
- What is the relative cost and effort needed for research?
- What kinds of research methods are needed?
- What organizations might support the research?
- What is the role of design guidelines, performance standards, regulations, common performance measures, consumer ratings?
- How should driver benefits and problems with deployed systems be evaluated?

Table 3 Questions for the Problem Statements

- What is the relative cost and effort needed for the research?
- By what methods should researchers investigate this problem?
- What organizations might support the research?
- What organizations might be interested in the results?
- Does this problem involve design or performance guidelines or standards?
- Does this problem have implications on policy that are noteworthy?

Table 4 Questions for Group 5

Group 5 addressed two key issues:
(1) Turning research into practice
(2) Next Steps: Following up after the HF forum

Turning Research Into Practice

- What is the process needed to translate HF research into practice (i.e., product design and operation)?
- What are the barriers to implementing research findings? What are the ways to overcome them?
- What types of public or internal human factors guidelines are available in AVST?
- What role does human factors research have in preparing a system for deployment or for confirming that the system is ready for deployment?

- For the purposes of deploying effective and acceptable AVST, define the role and value of:
  - human factors guidelines (both design guidelines and performance guidelines);
  - standardization, regulations, common performance measures; and
  - product evaluations by independent testing organization or the Government.

- When needed, how should standardization be achieved? (Note: focus on mechanisms. Group 3 will focus on research.)
  -What organizations should have a role? What role should they have?
  - What information do they need from research?

Next Steps

- After today's forum, how should we continue the discussion on these topics?
- What are the next steps for achieving the goal of advancing deployment of effective and acceptable safety-related driver assistance systems?
- What are the appropriate entities to address and resolve the research problems, implement findings, and develop necessary guidelines/standards?
- What are the roles for relevant organizations, such as the Government, OEMs, SAE, ITSA, AAM, AIAM, universities, etc.?

Collaboration should address the common interests, goals, and approaches to addressing the human factors challenges with AVST.

- Identify the competitive interests, goals, and approaches and the areas for common ground.
- Should future collaborations include efforts to disseminate research findings?
- What are the options for funding research?
- What are the legal considerations?

A synopsis of the discussions for each group is provided in the section below.

Group 1: Driver-Centered Design

Moderator: Dr. Mary D. Stearns, Volpe National Transportation System
Scribe: David Band, NHTSA

The Problem: Driver-centered design is an approach that considers the driver to be the critical element in the system. Driver-centered design helps ensure that AVST are effective for the broad range of the driving population, which includes individuals with varying levels of experience, abilities, and skill. This group was charged with determining how best to ensure driver-centered design with AVST.

Discussion Summary: The group discussed different ways to support driver understanding and performance with AVST, as follows:

- Driver Training. The group theorized that training will help drivers understand and appropriately use AVSTs. However, there is no obvious way to deliver training or ensure its effectiveness. For example, vehicle manuals often remain unread. Training at dealerships may be possible for new car purchases but its effectiveness is unknown. In addition, the training may not be available for used car purchasers.
- Adaptive Interfaces. Adaptive interfaces are those in which the interface can be adjusted to accommodate driver characteristics; however, it is a task that is difficult to do well. The group noted that the SAfety VEhicle using adaptive Interface Technology (SAVE-IT) program is near completion and should have relevant information on adaptive interfaces. The program implements a prototype vehicle-based adaptive interface system to minimize driver distraction (The SAVE-IT program is designed to, "demonstrate a viable proof-of-concept vehicle capable of reducing distraction-related crashes and enhancing the effectiveness of collision-warning systems" by assessing the driving environment, including driver state, and adapting the driver interface. Additional information is available at http://www.volpe.dot.gov/hf/roadway/saveit/saveithlt.html)
- Information Overload. The introduction of AVSTs and other in-vehicle devices may present a level of information that would overwhelm, or overload, the driver. The group agreed that it is imperative that technology developers consider the amount of information presented to the driver and design AVSTs to minimize this potential.
- Rare events. The group expressed concern that drivers may not know how to respond to AVST warnings in view of the fact that crashes and near-crashes are rare events, so that experience with the warnings may not be common. The rarity of crashes and warnings emphasizes the importance of an intuitive design for warnings. The group mentioned the option of using a system test or warning reminder so that drivers become increasingly familiar with the warning.
- Designing for the lowest common dominator. An alternative to adaptive systems is to design for the lowest common denominator of driver abilities. However, this approach may lead to systems that average drivers find annoying (as with early

warnings). The group viewed the approach of designing to the lowest denominator less favorably than developing an adaptive approach.

- Defining driver groups. Whether designing for the worst performing drivers (the lowest denominator) or designing for multiple settings of an adaptive system, the first step is determining how to define the driver groups. What characteristics matter the most? Are the critical factors the inexperience of novice drivers, the reaction time of older drivers or the risk-taking propensity of younger drivers?
- Modeling human behavior in terms of driver characteristics To assure that AVST are designed effectively they must meet the capabilities, limitations, and needs of the driver. A uniform driver model can be used for design and evaluation, and for establishing guidelines and standards.

The top research needs for driver-centered design as voted on by the group are listed in Table 5. These research needs are interrelated. For example it was assumed that an adaptive interface (Topic 1) would need to be based on driver performance modeling (Topic 4). Also, the methods of testing a system (Topic 3) would need to incorporate an understanding of the driver (Topic 4). "Driver Performance Specifications" received the most votes, and was selected as the first problem statement to be created because it was viewed as providing a foundation to the other needs identified by the group.

Table 5 Driver-Centered Design: Top Research Topics

Research Topic/Need	Description
1. Adaptive Interfaces	Should the driver centered design be adaptive to meet the needs of the individual drivers? Identify which aspects of the systems need to be adapted vs. those which can be standardized.
2. Driver Training	What is the best method to train people to use new systems? How would training also deal with rare events? How effective is training?
3. Access Understanding	How do we assess if drivers understand new systems? Is the system meeting the driver's needs? Do drivers accept new systems?
4. Driver performance specification/modeling	How do we determine what cognitive/sensory/attitudinal aspects characterize drivers?
5. Driver Workload	How do we develop performance specifications to minimize workload?

Group 2: Unintended Consequences of AVST

Moderator: Dr. Neil Lerner, Westat
Scribe: Dr. Kathryn Wochinger, Noblis

The Problem: AVST are intended to produce positive benefits by reducing the frequency and severity of crashes. However, the introduction of innovative technologies may produce negative, unanticipated effects on driver behavior.

The Discussion: The group identified several areas in which AVST may introduce negative consequences as well as the need for empirical data to determine the safety benefits of AVST.

- Risk Compensation. An increase in the safety of an activity may correspond with an increase in risk-taking, in turn potentially increasing the actual risk. It is possible that the driver perception of a safety net provided by AVST may induce drivers to relax their vigilance. For example, drivers who are fatigued or impaired may choose to drive a vehicle equipped with AVST but not an unequipped car.
- Driver Learning and Performance. The mechanisms of AVST may affect the means by which novice drivers learn to drive. For example, will Lane Departure Warning Systems have the effect of reducing the perceived need for drivers to scan side view mirrors? If so, will novice drivers learning to drive with AVST-equipped vehicles be less likely to develop good driving habits?
- Safety Culture. AVST may produce changes in individual driving behavior that when widely adopted could lead to broad cultural shifts. For example, feedback provided by AVST may create a positive effect on safety culture if it encouraged drivers to increase good driving habits (such as increasing turn signal use or selecting a safer headway). In contrast, safety culture would be negatively affected if AVST encourages risk-taking.
- Data Needs. Researchers and policy makers require empirical data to document the crash experience of AVST-equipped vehicles. Without real-world data, it is difficult to measure with a high degree of confidence how AVST influences safety. As AVST vehicles are deployed, the ability to obtain safety and performance data would enable NHTSA to determine the benefits of AVST. The group believed that obtaining empirical data was a high priority. Developing systems and processes to acquire safety data would be a significant undertaking but one that would generate a large pay-off by improving our understanding of the safety benefits of AVST.

The highest priority areas for the Unintended Consequences topic as voted on by the group are shown in Table 6.

Table 6 Unintended Consequences: Top Research Topics

Top Research Needs
Data sharing between OEMs, NHTSA,and international stakeholders (e.g., European and Japanese transportation agencies)
Identification of driver behaviors that may be affected by AVST Encouraging good driving habits via AVST (such as maintaining safe headways or using turn signals)
Understanding of safety culture and the ways to improve safety attitudes and behaviors
Developing a taxonomy of potential unintended consequences based on a literature review of driver performance
Understanding how inadequate driver mental models, or understanding of the system, may affect safety and determining how design can strengthen mental models
Assessing whether AVST increases the risk that impaired drivers would be more likely to drive if the vehicle is equipped with AVST
Understanding the effects of AVST on the ability of novice drivers to acquire skills

Group 3: Standardization and Commonality

Moderator: Dr. Nicholas Ward, University of Minnesota
Scribe: Dr. Jim Foley, Noblis

The Problem: Variation in driver-vehicle interfaces for AVST can create potential safety problems, such as driver confusion when switching vehicles (due to negative transfer of training), improper response to unexpected and unfamiliar interfaces, and lack of robust mental models of system functionality.

The Discussion: The group raised several questions regarding standardization:

- How should the safety impact of standardization of system operation and interface characteristics be quantified?
- To what degree is standardization needed for driver acceptance and use of AVST?
- Is there a way to determine the degree of standardization needed?
- Is it possible to achieve a balance between consumer and manufacturer desire for product differentiation while maintaining safety?

The group discussed the following ideas.

- Impact of Standardization. While standardization of safety-relevant interfaces has a strong logic, some members of the breakout group were concerned that standardization might have a negative impact on innovation. Because AVST are just entering the marketplace, standardization might inhibit or even prohibit innovation. It was agreed that research to determine the quantification of benefits and/or costs of standardization is needed.
- Exposure to Lack of Standardization. While it is easy to imagine a case where the driver is unfamiliar with a specific vehicle and its subsystems (e.g., driving a new purchase or a rental car), it is not known what the impact of changing vehicles might be on safety. The finding (Perel, 1983) that drivers in unfamiliar vehicles have a higher crash involvement (1.6 times) than drivers in a familiar vehicle may be an indication that using unfamiliar, nonstandard AVST introduces a risk.
- Existing Standardization Efforts. Existing standard development organizations depend on volunteer membership and rarely have funding for the research required for standards development. If funding were available to support standardization efforts perhaps the process could be improved. Among the questions about standardization is the appropriate role of suppliers and OEMs in developing and specifying an AVST, as well as the role of other interested organizations such as the Crash Avoidance Metrics Partnership and The Alliance of Automotive Manufacturers.
- Influence of Driver State. The development of driver monitoring systems raises the question of whether standardization could or should accommodate driver characteristics and/or the state of the driver. However in view of the current early development stage of monitoring systems, this is a long-term issue.
- Negative Transfer. Standardization of AVST human-machine interfaces (HMI) may prevent potential negative transfer that would inhibit an effective response to safety critical system interfaces. Negative transfer refers to the condition in

which the knowledge, skills, and expectations gained from interacting with the HMI of one system interferes with the correct operation of another system with a different HMI. The risk of negative transfer is highest when the HMI of different systems differ in terms of the physical appearance and location of the display elements.

- What would happen if there was standardization of AVST? What sort of actions would NHTSA take? What is the specific product of standardization? Would it be specific such as only a red light of a certain size and in a certain location can be used for forward crash warning or would it be similar to a guideline, e.g., all forward crash warnings must have a visual and an auditory alert?

Table 7 Standardization and Commonality: Top Research Topics

Research Needs
Develop a methodology to quantify the benefits of standardizing HMI
Standard evaluation methodologies and AVST HMI taxonomy
Nomadic devices (portable devices that are brought in by the driver, e.g., cell phone, mp3 player) are typically not designed for use by drivers, but are frequently used while driving. The need for prohibition or standardization of the HMI for functions to be used while driving was discussed because of the potential for degrading safety. (While this topic generated a lot of interest, it is out of scope of the workshop.)
Framework to identify the most important system parameters to standardize
Standard to provide prioritization of warnings scheme
How will standards be applied by NHTSA? What will product of standardization be?

Group 4: Integrating Multiple Systems

Moderator: Dr. James Sayer, University of Michigan Transportation Research Institute
Scribe: Eric Traube, Noblis

The Problem: Many of the technologies installed to date have been stand-alone systems. As more and more technologies are introduced, multiple systems are expected to be installed in vehicles of all types, prompting the need for effective and usable integration. An integrated system is expected to prevent conflicting warnings, reduce false alarms, and reduce unintended consequences, such as causing a road departure crash while trying to prevent a rear-end crash. The use of a common suite of sensors and crash warning methods could have substantial benefits, if integrated in such a way that driver acceptance and understanding is maximized.

This issue leads to a wide variety of questions, including the following:

- Will drivers be overwhelmed and confused from the feedback provided when vehicles have too many safety assistance systems?
- How should priorities be set for different messages and warnings?
- Will the number of non-useful alarms increase with multiple systems and affect driver acceptance and performance?
- How will multiple systems affect the usability of warning systems?

The Discussion: As shown by the large number of research topics that were introduced by the group participants, discussion was wide ranging. Key areas included:

- Driver Acceptance. The group members agreed that this topic is very complex, and started the conversation with the question, "Do multiple systems introduce warnings people won't accept?" Most of the people in the group agreed that the answer to the question is most likely yes, but assessing acceptance was agreed to be a complicated issue.
- Driver Understanding. Participants agreed that "overwhelmed" and "confused" could—and should—be two separate questions when looking into how drivers might respond to integrated warnings. The group discussed whether overwhelmed drivers could cause long term confusion was brought up, as well as whether systems already overwhelm drivers, even if a driver isn't in a state of panic.
- Lessons learned from other models. One discussion thread focused on the idea of looking at potential models from systems and technologies not necessarily vehicle-based. The idea was that looking at best practices and lessons learned from other technology-based industries may provide additional insight.
- Other topics. Additional discussion focused on the difficulty in arbitrating warning outputs, the challenge of designing unique signals so people know how to respond, and the benefits versus costs of multiple systems. One participant raised the question "Do we really want to give two warnings simultaneously?", while another suggested perhaps integrated systems should focus only on imminent crash warnings. Another question raised was "What is the interaction between warning discrimination and the frequency of the high-risk event?"

Table 8 Integration of Warnings: Top Research Topics

Research Needs
How do you measure the effectiveness of an integrated crash warning approach? Is there more than one effective integration approach? How does effectiveness relate to acceptance, and how is it measured? How do you ensure the effectiveness for the vast majority of the user population?
What modalities are most effective for integrated crash warnings? Does it depend on whether it is imminent (ex., response within 1.5 s) or cautionary (ex., response within 3 s)? What affect does timing approach consistency have on integrated crash warning effectiveness (e.g., all systems require responses within 3 s)?
Are there benefits in creating an integrated CWS approach which has a simple mental model of the system? How complicated of a mental model can drivers understand? Can multiple systems be grouped on the basis of general threat location (e.g., Lane Departure Warning and Lane Change/Merge)?
How to integrate crash warning systems with non-crash warning elements of the vehicle? What about systems brought in the vehicle?
Will multiple systems create operator overload? Do graded warnings contribute to overload? To what extent can driver monitoring systems mitigate operator overload? Is this effect largely driven by false alarms?
What are the incremental benefits of multiple warning systems?
How do you ensure warning discriminability of individual warnings?
How do you arbitrate/prioritize for simultaneous, and near simultaneous events between systems? What is the relative frequency of co-occurring warnings?

Group 5: Mechanisms for Future Collaboration

Moderator: Robert Lange, General Motors Corporation
Scribe: Stephanie Binder, NHTSA

The Problem: A goal of the forum was to maintain and build upon the ideas and collaborations that emerged from the breakout groups, plenary sessions and presentations. This breakout group defined mechanisms for future collaboration and suggested ways to continue the collaboration among researchers and practitioners in industry and government after the forum.

The Discussion: The group identified several mechanisms by which to maintain and increase the dialogue on AVST and human factors and strengthen the collaboration between government, industry and academia on common research areas.

- Information Access. There should be accessibility to completed research data and various mechanisms to enable the sharing of data, not just results. Organizations such as Society of Automotive Engineers, etc., could serve as facilitators by which researchers could share knowledge, including research conclusions, research methods and data.
- Systematic Approach to Research. The need for a systematic approach to future research was identified. Sharing information between stakeholders on current and near-term research programs would allow other stakeholders to optimize research by reducing duplicate efforts and/or collaborating to expand on current efforts.
- Prioritizing Research. Prioritization of research needs would help organizations better allocate limited resources. Such an effort might be appropriate for NHTSA, as NHTSA already conducts extensive crash analyses and these analyses could help map real-world crashes to technologies.
- Regulatory Issues. The group raised the question as to what standard regulatory agencies such as NHTSA would apply when evaluating advanced technologies for defects and compliance with safety standards.
- Definition of Terms. The need to define test mechanisms and establish a definition of proper functioning was discussed. While some large-scale studies use similar metrics of user acceptance, many do not. Therefore, while the data produced in user acceptance studies are valuable, the commonality between the data is lacking and need to be documented to be useful.
- Voluntary Standards. Voluntary standards are good practice, with one caveat: if not all stakeholders agree with the standard then its effectiveness is diminished. Therefore, voluntary standards are not the only solution needed to address the issues associated with AVST.
- Fleet Testing. A government and industry collaboration on government vehicle fleets (i.e., vehicle pools operated for government employee use) may be a good opportunity for deployment, especially for high-risk technologies (e.g., air bags). This approach may support standardization, visibility, and analyses. In addition, there is the challenge of determining a test sample that is representative of "normal" drivers interacting with the technology.

- Stakeholder Roles. The different stakeholder's roles change across time during the product lifecycle. For example, early in the lifecycle the Federal government's role may be to identify research needs, where later in the lifecycle their role is to ask questions on unintended consequences. The goal is to establish how organizations can best work together throughout the product lifecycle.
- Comparing research across Markets. Some research is conducted in markets outside the United States that are more accepting of technology-based solutions. Because user acceptance is critical, the stakeholders need to be able to harvest previous findings to leverage market forces; how best to accomplish this is not yet determined.
- Examples of Collaborative Approaches. The Japanese Automobile Research Institute (JARI) model is an example of a successful collaborative approach. JARI is equal parts government and industry, and very responsive to the governance board and industry. It should be noted, however, that statutory and regulatory restrictions applicable to activities of the U.S. Government may limit the nature and extent of government-industry collaborations, e.g., Freedom of Information Act, Competition in Contracting Act, etc.
- Role of Expertise. The group discussed the appropriate role of various groups in assessing the crash problem, the needs of the driver, and what technology to use as a countermeasure.

The group then identified questions as starting points when considering next steps:

- What qualifies as active safety?
- What is the level of readiness of a research program?
- What is the current state of knowledge?
- What are the holes/unknowns for each?

Table 9 Mechanisms for Future Collaboration: Top Research Needs

Research Needs
Public Inventory of current technology status
Information repository
Overall NHTSA plan
Common metrics database
External advisory committee
Develop voluntary guidelines
Develop collaborative consumer information packet
Complete ITS "gap" analysis
Identify "third party" supervisory committee
Annual HMI conference

The Research Problem Statements

The breakout groups identified topics that they considered to be essential to the safety and effectiveness of AVST. The groups then selected the topics they deemed to have the most importance of AVST and prepared statements that reflects the rationale for the high-priority topics and proposed the means to address the topics. The statements prepared by each group are presented below.

Table 10 Research Problem Statements

Research Problem Statements
Assuring AVST compatibility with driver capability and needs (from Group 1)
Behavioral adaptation and cultural response to AVST (from Group 2)
Methodology to quantify benefits of standardization (from Group 3)
Methodology to identify best practice for AVST HMI performance (from Group 3)
Integrated Crash Warning effectiveness (from Group 4)
Effective modalities and timing approach consistency for integrated crash warnings (from Group 4)

Statement 1: Assuring AVST Compatibility with Driver Capability and Needs

Background and Rationale

- There is no system to determine drivers' responses to various warnings.
- This is needed for system design and to ensure the acceptance and performance of safety systems.
- Modeling (which may help predict responses) is already standard practice in the crashworthiness area.

Research Objective

- To document the driver characteristics which relate to warning response.
- Fill in knowledge gaps.
- Develop a way to present, catalog or model. Perhaps develop a virtual driver (Reference: Boff and Lincoln).
- Determining the critical driver factors for response (e.g., reaction time, response type, visual capability, cognitive ability, mental/physical state etc.).
- Incorporate assessment of spare cognitive capacity.
- Determine workload demands of the task.
- Diagnosis of driver capability.
- How many levels of drivers are there (high, medium, low).

Research Method

LR (Literature Review/Synthesis)
MA (Meta-Analysis)
LS (Laboratory Test)
FT (Field Test)
US (Usability Study)
DDS (Driver Simulation Study)

Estimated Funding and source

$1 million a year over 5 years
Analytical
New empirical work
Production of a tool or model (>500k)
Funding Sources:
-Standards organization (e.g., SAE, ISO)
-Cooperative Agreement (e.g., CAMP)
-Government (e.g., U.S. DOT, TRB)
-International (e.g. UN, EU, OECD)
Need to identify core competent groups

Research Implementation

All (OEM, Supplier, Government, Research)

Other Considerations

This should be flexible enough to incorporate new upcoming technologies
Standards organizations should be incorporated

Statement 2: Behavioral Adaptation and Cultural Response

Background and Rationale

Current safety systems (e.g., ABS, first generation air bags) have led to negative unintended consequences. This suggests that there is an incomplete understanding of the problem space of unintended consequences. This research will support design changes to AVST systems to support safety.

Research Objective

- Develop a taxonomy of behavioral responses to safety systems in general, to technology in general, and then specifically to AVST
- Identify changes in driver attitudes and behaviors associated with AVST and specific AVST characteristics
- Identify changes in cultural and societal attitudes and behaviors associated with AVST

Research Methodology

Objective 1 - Literature Review/Synthesis; Integrative Research Review
Objective 2 – Field Test; Focus Group; Lab Study; Driving Simulator Study; Survey
Objective 3 – Survey; Focus Group; Workshop

Research Period and Level of Effort

one year, three-four years, two years

Research Implementation

OEMs, NHTSA, suppliers

Other Considerations

Objective 1 is the first step.

Statement 3: Methodology to Quantify Benefits of Standardization

Background and Rationale

Standardization of the driver/vehicle interface may have a benefit for safety and acceptance.

This research is intended to provide a quantitative basis to determine if standardization is justified. The may include an empirical investigation of either the costs of non-standardization or the benefits of standardizing. Costs/benefits may be quantified in terms of operator and system performance.

Research Objective

The goal of the project is to provide a method and criteria to determine if standardization is necessary. Phase 1 is to develop and document an evaluation protocol for application to AVST. Phase 2 is to apply the evaluation protocol to a target set of ASVT systems.

Research Method

Crash Data Analysis, Literature Review, On-Road Study, Closed-Track Study, Driving Simulator Study, Lab Study, Usability Study.

Estimated Funding and source

Both phases of this project are expected to require up to 3 years – estimated $5 million.

Research Period and Level of Effort

Up to 36 months at high effort. Effort included validating evaluation methodology and then applying to AVST examples. Will require multiple partners covering a range of methodology.

Research Implementation

NHTSA, OEMs, standards organizations,

Other Considerations

-At what point during the product life cycle should standardization be considered?
-Consider the wide range of users.
-Consider the impact of innovation.

Statement 4: Methodology to Identify Best Practice for AVST HMI Performance

Background and Rationale

There are potentially many variants of HMI design for AVST. In order to standardize the interface it is necessary to identify performance-based criteria for selecting HMI design, that is criteria that provide objective measures to determine the adequacy of the interface.

Research Objective

The goal of the project is to develop a methodology and criteria for selecting HMI designs based on performance metrics.

Research Method

Crash Data Analysis, Literature Review, On-road Study, Closed-Track Study, Driving Simulator Study, Lab Study, Usability Study.

Estimated Funding and source

2 years, $3 million

Research Period and Level of Effort

Up to 24 months at high effort. Effort includes validating evaluation methodology. Will require multiple partners validating a range of methodologies and criteria.

Research Implementation

NHTSA, OEMs, suppliers, standards organizations.

Other Considerations

Focus on performance standards to minimize innovation restraint. Methods should consider potential system unintended consequences.

Statement 5: Integrated Crash Warning Effectiveness

Background and Rationale

How to determine if a crash warning that is one of several in an integrated system is deemed "effective"? There may be multiple measures, as opposed to a single one, that result in an "effective" system.

Research Objective

The objective is to determine how to measure effectiveness and acceptance of an integrated crash warning for the majority of the driving population.

Questions include: How do you measure the effectiveness of an integrated crash warning approach? Is there more than one effective integration approach? How does effectiveness relate to driver acceptance, and how is it measured? How do you ensure the effectiveness for the vast majority of the user population?

Some of the key issues discussed included: the need for naturalistic observation, use of driving simulators, observation of behavior effects, customer acceptance of individual vs. integrated systems, the difficulty in making generalizations about the driving population, and defining changes in driving behavior. Also, if these systems are optional, are safe drivers more likely to purchase them, and how does that affect safety?

Research Method

Crash Data Analysis, Literature Review, Integrative Research Review, On-road Study, Closed-Track Study, Driving Simulator Study, Survey.

Estimated Funding and source

This project is estimated to take 5 years, and estimated at $15 to $20 million, although it could be broken down into smaller studies.

Research Period and Level of Effort

Up to 60 months at high effort.

Research Implementation

OEMs and suppliers.

Other Considerations

Develop method for sharing data across OEMs/data accessibility. Look at non-traditional analysis approaches.

Statement 6: Effective Modalities and Timing Consistency for Integrated Crash Warnings

Background and Rationale

Timing and modality (i.e., visual, auditory, haptic) of warnings will be critical in designing an effective warning. More research on the haptic modality and various modality combinations will be needed, as will research on timing needed to ensure an effective, understood warning.

Research Objective

Determine which modalities are most effective and acceptable for integrated crash warnings, and determine the impact timing has on integrated crash warning effectiveness.

Questions include: What modalities are most effective for integrated crash warnings? Does it depend on whether it is imminent (ex. response within 1.5 s) or cautionary (ex. response within 3 s)? What effect does timing approach consistency have on integrated crash warning effectiveness (e.g., All systems require responses within 3 s)? What modalities/combinations of modalities (visual + visual, auditory + visual, haptic + haptic, auditory + auditory, visual + haptic) are most effective? How do we effectively combine warnings of different modalities (may require more research on haptic warnings). What is the best approach to deal with systems with different response characteristics? What about thresholds?

Research Methodology

Literature Review, no crash data analysis; pre-design stage.

Estimated Funding and source

5 years, at least $15 million.

Research Period and Level of Effort

Up to 60 months at high effort.

Research Implementation

Peer revised proposals; OEMs, Academia; Applied Work.

Other Considerations

Map these methods to research questions—should be part of the process.

Initiatives for Future Collaboration

Group 5 identified and described ten potential initiatives for future collaboration. The titles of the topics are in Table 11, and their descriptions are summarized below.

Table 11 Proposed Initiatives for Future Collaboration

Ten Initiatives for Future Collaboration
1. Public Inventory of Current Technology Status
2. Information Repository
3. Overall NHTSA Plan
4. Common Metrics Database
5. External Advisory Committee
6. Develop Voluntary Guidelines
7. Develop Collaborative Consumer Information Packet
8. Complete "Gap" Analysis
9. Identify "Third Party" Supervisory Committee
10. Annual Conference

Initiative #1: Public Inventory of Current Technology Status. Understanding the current landscape of AVST applications was considered to be very important. The highest number of votes went toward establishing a public repository of current technology. The repository should include at a minimum the technology, a description of the HMI used and any supporting technical documentation (e.g., conference proceedings, journal publications). The inventory should be updated yearly, perhaps as part of the NCAP updates. The inventory could be presented in a spreadsheet format. It was suggested that NHTSA be the key player in this effort with industry supplying the information.

Initiative #2: Information Repository. Tying for the issue with the most number of votes, was to develop an information repository. The intent of this effort would be to consolidate all data, research, and knowledge into one central location. Having all information in one place would facilitate research and optimize efforts – stakeholders would have complete knowledge of research already completed. This repository would provide a crucial first step to validate what we think we know about human reaction to these systems.

This initiative is not without challenges, namely in regard to proprietary information. To overcome this issue, all stakeholders would have to agree to the type of information and the level of detail they will share. This level of commitment will put all stakeholders on the same level, with equal opportunities to lose (or gain). One group member suggested using the National Institutes of Health example, where users submit the data. Because the data could be added at the author's discretion, this process would provide access to the data more quickly than relying on the peer review process for publications.

Another issue is database management. Members in the group suggested NHTSA would be the appropriate entity to house the database, as the agency is a neutral stakeholder without some of the proprietary concerns that pervade in industry; however, it should be noted that having NHTSA as the manager of such a database may have unintended consequences because government agencies are subject to the Freedom of Information Act, a Federal statute mandating public access to agency records in all but a limited number of cases.

Initiative #3: Overall NHTSA Plan. The next suggestion involved NHTSA assembling and publishing an overall plan for AVST development and deployment, including objectives and their perceived roles. Many of the group members felt that this document would serve as a roadmap for current and future priorities. It would also provide other stakeholders an opportunity to contribute to the Agency's vision.

Initiative #4: Common Metrics Database. Inconsistencies in data collection inhibit development, specifically in regard to methodologies. There is variability even in basic measures, e.g., lane deviation, where some researchers count a lane deviation when the outside of the tire touches the lane marker whereas others count it when the inside of the tire touches the lane marker. Without a common protocol, it is difficult, if not impossible, to synergize the research. While this initiative has been taken up in part by the DriPOD project, the group suggested NHTSA coordinate efforts to expand on that database.

Initiative # 5: External Advisory Committee. A central body made up of representatives from all the stakeholders should meet regularly to monitor progress, establish priorities, identify communication channels, encourage academic centers of excellence, resolve issues, and plan future events. The need to organize annual events was emphasized to maintain the lines of communication and collaboration; such a forum could accommodate more people and would provide a place to discuss research and findings for human factors issues.

The External Advisory Committee could also identify technical barriers to taking next steps then develop a cooperative group to meet those needs. Ideally, NHTSA would sponsor this committee and serve as a key player with the support of other stakeholders. However, because formation and use of Federal advisory committees are subject to the Federal Advisory Committee Act, its implementing regulations and a Federal policy that makes it difficult to form new committees, this approach may not be achievable.

Initiative #6: Develop Voluntary Guidelines. There should be a continuation of voluntary standards. The Alliance of Automobile Manufacturers, SAE, and similar organizations could continue to help develop such guidelines. The guidelines could also address the issues surrounding second and third owners who typically do not receive information on the systems nor actively select the technologies.

Initiative #7: Develop Collaborative Consumer Information Packet.

The group then discussed how best to get information to consumers. The group agreed that the public's lack of knowledge/understanding of the technology could inhibit its success in the marketplace. Therefore, a consumer information packet, perhaps based on the "Buying a Safer Car" model was suggested for these technologies.

Initiative #8: Complete "Gap" Analysis. This process involves identifying the most frequently occurring crashes and the technologies that may reduce/prevent those crashes. This analysis has been initiated by NHTSA. Once this is complete, the technologies that could potentially provide the most benefit could be given higher research priority.

Initiative #9: Identify "Third Party" Supervisory Committee. In addition to, or in lieu of a NHTSA-sponsored External Advisory Committee, a third party supervisory committee might be useful to address issues relating to these technologies. A University group might be a good candidate to serve in this capacity.

Initiative #10: Annual HMI Conference. The momentum of this initial forum should be continued in future conferences. The idea of additional meetings was covered in Initiative #5, and therefore was a lower priority as a separate initiative. One possibility that was discussed was the option of combining future AVST conferences with preexisting conferences, such as the Driving Assessment Conference, which meets biannually.

Synopsis of Presentations from Invited Speakers

The forum included invited speakers from academia, industry, and government to make presentations to the forum on their perspective of the human factors issues involved in the development and deployment of AVST. Twelve speakers made prepared remarks on a range of relevant topics. The presentations were an important part of the forum because they provided a springboard of ideas and issues with which the participants could develop and pursue in the breakout sessions. Below is a summary of each speaker's remarks. A copy of the presentation slides are in the appendix of this report. The presentation and audio recordings are available on the NHTSA Web site (www.nhtsa.dot.gov).

Human Factors Concerns for Design and Performance of Warnings
Joanne Harbluk

Dr. Joanne Harbluk is a Human Factors specialist with the Ergonomics and Crash Avoidance Division of Transport Canada. Her current research is focused on the safety of in-vehicle information and communication systems, driver distraction, its assessment, and mitigation. She is an adjunct research professor in the Psychology Department at Carleton University, and an associate member of the Center for Applied Cognitive Research.

Dr. Harbluk emphasized the importance of the human-machine interface of in-vehicle warning systems and the potential role of guidelines and standardization in the design of the interface. To be effective, warnings need to lead the driver to a timely and appropriate response, and the system will fail if the warning (1) is not noticed by the driver, (2) confuses or is misunderstood by the driver, or (3) is not trusted by the driver. For these reasons, a system can be no better than the effectiveness of its interface. Although current guidelines are valuable, to increase their usefulness, they need to be consolidated, easily and widely available, and made more specific.

Standardization provides clear human factors benefits. For example, standardization will lead to increased warning effectiveness by increasing driver comprehension and reducing confusion about the meaning of warnings and the action required. Standardization could be applied in the following two areas. First, the set of driver responses is limited and it is possible to design a warning that is unique to each of these five response options:

1. Immediate hard braking for evasion of crash
2. Immediate steering maneuver for evasion of crash
3. Immediate termination of initiated action
4. Seek awareness of situation and perform one of the above responses

5. Immediate decision to retake control by the driver

Second, standardization can have a role in conveying the priority of warnings. There are typically three levels of warning priority, and each could have its own unique characteristics:

1. Low-level - driver prepares action or decision within 10 seconds to 2 minutes; may escalate to a higher level if not acted upon
2. Med-level - requires action or decision within 3 to 10 seconds; may escalate to high-level warning if not acted upon
3. High-level - warning requires the driver to take immediate action or decision (0 to 3 seconds) to avoid severe injury or death.

Unique warnings could be designed for each level.

Warnings assessment procedures should be reviewed because it is important to know how to measure the effectiveness of warnings. Standard assessment procedures and criteria for testing warning performance must be practical, meaningful, reliable and objective.

Crash Warning System Interfaces: Human Factors Insights and Lessons Learned
John Campbell

John Campbell is a research leader with Battelle's Center for Human Performance and Safety. Since 1985, his research activities have focused on the development and evaluation of advanced driver interfaces, including Crash Warning Systems head-up displays, and Traveler Information Systems.

Battelle conducted a NHTSA-sponsored research project to develop a set of clear, easy-to-use guidelines on Collision Warning Systems (CWS), with particular emphasis on building on an earlier effort by COMSIS in 1996. The project supported the IVBSS program by determining guidelines for forward collision, lane change and road departure warnings. The guidelines for visual and auditory warnings, controls, and FCW devices are based on a stronger body of research that the guidelines on haptic warnings, roadway departure systems, and warnings integration (which is a relatively newer area of study). The guidelines document identifies issues that require additional research, many of which are amenable to low risk and low-cost efforts.

The speaker provided several examples of the current status and research needs related to CWS. For example, there is a wealth of information on the basic characteristics of visual warnings (e.g., display or icon size, use of color, location) and auditory warnings (tone intensity, sound type), reflecting many years of human factors study, but comparatively less information on haptic warnings. Similarly, through recent efforts, robust designs of forward collision warnings are available, but the information is insufficient on important aspects of warnings such as the acceptable rates for false/nuisance alerts.

Important research questions include understanding the impact of impaired driving (e.g., impairment, fatigue) on CWS DVI design and whether the diverse driving population requires a broad range of driver-selectable features (e.g., timing, intensity, muting, message priorities). A related question is if CWS affects driving habits in the long-term. For example, will drivers neglect important behaviors (e.g., visual scanning) because of the perceived safety advantage provided by CWS devices?

The speaker discussed the role of guidelines in the integration of multiple CWS devices. This review of the current research showed that key integration scenarios for a range of CWS devices have been identified, and that International Standards Organization heuristics for prioritizing in-vehicle messages have proven useful for CWS design. Successful "integration" will occur at the sensor, sensor processing, warning algorithm, and DVI levels. Significant future research questions revolve around situations involving simultaneous hazards. For example, research has yet to determine how best to present warnings for simultaneous hazards. Among the relevant questions about multiple warnings are their relative timing, modalities and potential for masking.

Human Factors Evaluation Considerations for Safety Enhancing Systems
Robert C. Lange

Robert C. Lange has been directing GM's traffic safety activities since 1995 and was appointed executive director for safety integration on January 2, 2001. His research topics included occupant restraint system design and performance, fuel system design; vehicle structures, vehicle size and safety, crash risk analysis, and brake systems.

Lange discussed the collision avoidance technologies that industry is working on and that government is investigating. The speaker spoke of the inherent potential in these systems while emphasizing that the fundamental responsibility of safety resides in the driver. A poor outcome of implementing AVST would be if drivers abrogated that responsibility to systems. These systems cannot serve as a substitute for driver control.

The frequency of false alerts may influence the perception of value for the drivers perspective. The trick will be to determine, from the wide array of potential threats, which to issue warnings for.

System efficacy can be measured with the following data types:

1. Direct data that shows the safety benefits (compare vehicles with the technology to those without). For example Electronic Stability Control was proven to be effective, much more originally thought.
2. Indirect data. Safety benefits indirectly suggested based on data gathered under well-controlled, realistic conditions where the experimentation is specifically designed to place drivers in "target" crash scenario(s) *(e.g., "Distract and*

Surprise" methodology). Use an element of surprise in simulated or test track situations. The point is to measure the driver reaction without and with the safety technology. For example, the CAMP FCW study in which there was a target vehicle on a spring-loaded beam testing when the following vehicle would brake and how they would brake.

3. Implied data. Safety benefits implied based on "improved driving behavior" observed, under less-controlled, realistic conditions where the experimentation is not specifically designed to place drivers in "target" crash scenario(s) *(e.g., A decrease in tailgating behavior with a ACC system observed).*

Lange concluded the presentation by noting that research needs in this emerging area should focus on developing common evaluation methodologies and techniques. The presenter stated that it is the OEM's role to integrate safety enhancing systems (including the HMI approach). The standardization process must be handled with care. Premature decisions could hinder system deployment because standards could discourage 'healthy' OEM competition, and premature standards for these emerging systems could hinder system deployment. Standards could discourage "healthy" OEM competition to develop effective and well-accepted safety enhancing systems. Even within an OEM, vehicle models will vary in the number of these systems on a given vehicle, as well as system combinations.

Active Safety Features and Active Safety Human Factors Issues
Michael Shulman

Michael Shulman joined the Ford Motor Company in July, 1976. He is currently the program manager and treasurer of the Ford-GM Crash Avoidance Metrics Partnership (CAMP) and leads a team who works with vehicle product programs to introduce new features such as Adaptive Cruise Control, Lane Departure Warning, Forward Collision Warning and Collision Mitigation by Braking.

Active safety is about preventing and minimizing accidents, primarily about road departure and vehicle-to-vehicle crashes. Much work has been completed to develop active safety features to preventing road departure crashes and an expansion of safety features in the use of sensors to detect lane markings, monitor driver status, and the ability via GPS to track the road ahead. The presence of radar in many vehicles for ACC will facilitate additional radar-based applications, such as FCW and collision mitigation by braking. Because the ability to detect will not be perfect, there will be false alarms. So, we need to think about the false alarm consequences. System effectiveness is influenced by the relationship between true and false crash predictions.

Besides radar, vision, GPS/digital maps, and similar, we are now exploring vehicle communications to aid in our understanding of the vehicle environment. The CAMP

VSC2 Consortium (DCX, Ford, GM, Honda and Toyota) is working with the NHTSA and FHWA on CICAS-V (Cooperative Intersection Collision Avoidance System for Violations) and the VSC-A (Vehicle Safety Communications Applications).

The implementation strategy is to follow a progression from Information to Warning to Limited Intervention to Full Control of the vehicle. Ford will start with Information Warnings. At Ford Motor Company, Volvo is leading the introduction of Active Safety features. The new S80 includes a blind-spot monitoring system and radar for ACC and FCW. It also includes is a first-generation Collision Mitigation by Braking System that pre-charges the brakes and interfaces to the brake assist system to reduce the impact speed. Later, Ford will introduce active safety features that include Full Automatic Control. It will introduce wide field-of-view radar that will monitor multiple traffic lanes, earlier, full automatic braking for crash avoidance in scenarios when the driver cannot steer to avoid the crash, and Emergency Lane Assist that will also monitor oncoming vehicles. If the driver crosses the lane markers and does not respond to the warning, the system will automatically steer the vehicle back into the lane.

Europe has developed a Code of Practice for Advanced Driver Assistance Systems, which may be useful as a framework for the development of common design guidelines and standards in the United States.

Consideration of the Driver Interface for Future Active Safety Systems
Toyohei (Tony) Nakajima

Toyohei Nakajima joined Honda Motor Co., Ltd,. in April 1977. In 2005, he was promoted to senior chief engineer, responsible for the entire automotive electronics R&D activities including body electronics, intelligent system, chassis control and power train control. Nakajima is now the senior chief engineer/senior manage,: Electrical & Electronic System R&D, for Honda R&D Co., Ltd.

The number of warnings and alerts will increase as more systems are developed. Therefore, it will become is necessary to develop the means to prioritize warnings. Warnings need to provide 1) information that leads to good situation awareness, 2) intuitiveness (so the driver understands when to do immediately and correctly), and 3) instantaneousness (enabling drivers to make quick responses). Human-machine interface (HMI) warning types (visual, auditory, and tactile) have properties that differentially promote these requirements. For example, visual information is a strong way to present textual data but may not support instantaneousness because eye glances and gazes may be distracting and too time-consuming. In contrast, the amount of information provided by an auditory beep is small, but it can support the need for instantaneousness. Similarly, the amount of tactile information that can be conveyed is small, but can lead to fast (instantaneous) reactions.

One conclusion is that, when prioritizing warnings and selecting modalities, it is important to take advantage of the characteristics of each HMI warning type in terms of Urgency, which is related to the Time to Respond and Time to Collision (TTC)) and Criticality (i.e., the severity of a predicted consequence).

Upon concluding his presentation, the speaker noted that the harmonization between agencies and organizations is a key component to the successful development of guidelines and standards of HMI. In this context, the speaker stated that it would be beneficial for the development of HMI if NHTSA were to participate in the international standardization activities of ISO and IHRA.

Human Factor Issues of Driving Assistance Systems
David Benedict

David Benedict is general manager of vehicle performance development at Toyota Technical Center U.S.A., where he oversees three engineering groups: Human Factors, Seating, and Heating, Ventilation and Air Conditioning. He has responsibility for human factors assessment activities at Toyota.

The Toyota Technical Center assesses pre-collision driver factors in terms of the current pre-collision system capabilities. While passive safety devices (e.g., seat belt, multiple air bags) have advanced, the greatest advances are likely to be made with active safety devices. Active safety has a significant potential to reduce fatalities. As a result, many researchers and OEMs are moving forward, trying to approve and implement active safety devices in vehicles.

In Japan, based on 61,531 fatal and serious crashes, about 71 percent of the crashes were based on recognition problems, either insufficient attention, inadequate safety precautions (like people not detecting objects); in frontal crashes (1, 031 vehicles), 39 percent of people basically hit the vehicle in front at full velocity, with no braking or steering as a mitigating behavior. In the United States, 24 percent of crashes are attributed at least in part to distraction. In the 100-car study, in the 15 crashes (rear-end) 47 percent had no avoidance (i.e., no steering or braking maneuvers to avoid it).

Benedict presented two guiding principles: warning systems should only be activated only when a crash is imminent, and warnings should be provided at the appropriate time so that the driver can perform an evasive maneuver, then posed the question, “How should these principles be implemented in the pre-collision system?”

Toyota has pre-collision systems, such as pre-collision brake assist, pre-collision seat belts and suspension control that can reduce collision damage. Have also developed a "Driver Face Direction Sensor" and introduced it in Japan and Europe, soon to be introduced in the United States. It picks up the rotation of the head and provides information whether the driver is facing forward (doesn't provide eye glance data or drowsy alert). The purpose is to determine whether the person is looking forward. If the driver is not looking forward, then an advance warning is provided to the driver.

Voluntary Standards Development of Advanced Safety Systems
Dan Selke

Dan Selke has been the chair of the Society of Automotive Engineers Safety & Human Factors Committee for the last two years. He is also the chair of the SAE Driver Vision Committee as well as a member of the SAE Human Accommodations & Design Devices Committee, and Secretary of the SAE Vehicle Event Data Interface Committee. He has been employed at Mercedes-Benz USA since May 1997, where he is currently working on product compliance, recalls, and TREAD issues.

The SAR Safety and Human Factors Committee focuses on human factors as a cross-cutting discipline that has applications to the design, operation and evaluation of human-machine operating characteristics for advanced vehicle systems. The mission of the SAE safety and human factors committee is to address issues of interface design, driver workload, safety system complexity, ease of use, and the response of drivers to automatic control systems, especially with regard to risk compensation.

The committee has 28 to 30 voting members who meet three times a year. In addition, about 220 people on the mailing list review and provide comments on the activities of the committee.

An important part of the committee's work is its input to the work of ISO TC22/SC13. The SAE committee works closely with the ISO in developing standards. The working groups within TC22/SC13 include:

1. WG3 – Localization of Controls and Telltales
2. WG5 – Symbols
3. WG7 – Hand Reach and R- and H-Point Determination
4. WG8 – TICS On-Board MMI (e.g., HMI of telematics systems)

The six SAE Safety and Human Factors subcommittees are:

1. Warning Integration;
2. ITS Symbols;
3. Blind Spot Monitoring;
4. Driver Interface Design Requirements for In-Vehicle Text Messaging;
5. Road/Lane Departure; and
6. Driver Performance Operational Definitions.

The committee is able to react quickly to the consumer market by introducing recommended practices before a regulation or standard is promulgated. The committee works closely with ISO in developing common practices for all markets. The committee considers itself a partner with NHTSA and DOT in promoting road and vehicle safety.

Transportation Active Safety Institute: Our Focus on the Human-Machine Interface
Sarah Koskie

Dr. Sarah Koskie is an assistant professor of electrical and computer engineering at the Purdue School of Engineering and Technology, Indiana University/Purdue University at Indianapolis (IUPUI).

One of the biggest obstacles to introduction and acceptance of Active Safety Systems is absence of a standard HMI protocol. For example, when drivers use a different car than their own, they should be able to customize the interface to their own usage or preferences, such as the likelihood of false alarms. Some drivers would prefer zero false alarms and fewer alerts, but other drivers may be willing to tolerant false alarms in exchange for a higher sensitivity to threats.

The key to HMI design is determining how people will react to warnings. Warning systems will interact with drivers having a range of abilities (such as reaction time, attention span, etc). Standards may eliminate a source of driver confusion.

Integrated Vehicle Based Safety Systems (IVBSS): Crash Warning Integration Challenges
Jim Sayer

Dr. James Sayer is an assistant research scientist at the UMTRI, where he has conducted transportation safety related research since 1993. His research interests include the development of driver safety systems, understanding driver behavior, and driver vision with an emphasis on pedestrian safety. Dr. Sayer currently serves as the project director for the Intelligent Vehicle-Based Safety Systems Field Operational Test.

AVST, including ACC, lane departure warning and forward collision warning systems, are offered as options on some light vehicles. Currently, most AVST are offered in isolation on a vehicle, resulting in only one system providing feedback to the driver. However, the installation of multiple systems into the same vehicle provides the potential to have multiple warnings sources presented to the driver at any one time.

The IVBSS Initiative is intended to integrate multiple systems into a single platform from a hardware and software perspective, and also from the driver's perspective. With more than one stimulus alternative, there could be one response alternative. Some of the questions that we will be addressing are:

- How do you accurately convey the warning?
- Will drivers respond appropriately to multiple rare events?
- How will warnings be arbitrated?
- When multiple threats exist, which warning should be presented?
- Can warnings be effective in series?

UMTRI's general strategy of grouping warnings for longitudinal control (FCW, CSW) because the same response – decrease speed – is needed; and warnings for lateral control (LDW, LCM) because the response needed is the same – remain in your lane.

Over time, training may become more important, but it must be designed to the average driver (i.e., the average education level of 7th grade in the United States). So, as with the case of ABS, incorrect or incomplete understanding of the technology may lead to additional training needs. Standards, however, are not a panacea – subtle differences between manufacturers and standards do not consider multiple systems. The shift toward crash mitigation over warning systems will help because the vehicle will intervene for the driver when the driver misses the warning.

Human Factors Research Issues for Cooperative Intersection Collision Avoidance Systems

Vicki Neale

Dr. Vicki Neale is the director of the Center for Vehicle-Infrastructure Safety at the Virginia Tech Transportation Institute. In this role, Dr. Neale directs two research groups: Cooperative Safety Systems, and Lighting and Infrastructure Technology. Dr. Neale's recently completed projects include the 100-Car Naturalistic Driving Study, the Intersection Decision Support project, and the Intersection Collision Avoidance – Violation project

The Cooperative Intersection Collision Avoidance Systems (CICAS) will address intersection crashes by using vehicle/infrastructure communications to address traffic signal and stop sign intersection crashes. Intersection crashes represent 32 percent of all police-reported crashes (NHTSA, 2005). CICAS-V is designed to stop drivers from violating stop signs or stop signals at intersections. CICAS-V signal system is intended to address straight-crossing path and some left-turn across path (LTAP) crashes. CICAS-LTAP/AP (led by California PATH, CALTRANS) is planned to address situations when the driver is attempting to turn left across the path of the opposite direction, and CICAS senses a vehicle coming in the opposite direction. CICAS-GAP (led by University of Minnesota) will help drivers cross a stop-sign controlled intersection because CICAS will know when other vehicles are present and if there is gap sufficient for a vehicle to cross.

There is a need to develop an algorithm for the timing of the warning for each of the CICAS programs. But there are differences between the groups. In CICAS-V, the vehicle has to come to a stop, and the driver may be distracted or willful. For CICAS-GAP, the vehicle has come to a stop, but the driver needs help in maneuvering across the road.

The Application of Real-Time Distraction Monitoring to Driver Safety Systems
Mathew Smith

Matthew Smith is a senior Human Factors scientist for Delphi Electronics and Safety in Kokomo, IN. He currently leads the Human Factors team for the NHTSA-sponsored SAVE-IT program. Prior to this, his research efforts have focused on the design of driver vehicle interfaces for safety warning systems, and more specifically on the adaptation of these warning systems to take into account environmental and driver state information.

Dr. Smith discussed the SAfety VEhicle using adaptive Interface Technology (SAVE-IT) program with a focus on adaptive warnings. The program investigates a wide range of topics, including distraction monitoring and mitigation, and adaptive warnings. The system is designed to modify the warning depending on whether the driver is alert (i.e., looking forward). Dr. Smith presented two types of adaptation. The first, positive adaptations, provides accentuation during "attention not-forward" episodes is designed to primarily improve safety. The second, negative adaptations, is implemented during "attention forward" episodes and is designed to improve driver acceptance. For example, when a vehicle drifts from a lane, and if the driver is looking forward, the driver is likely to detect the drift quickly. This type of tuning should improve driver acceptance. And it is important to note that safety benefits are not independent of driver acceptance.

In a simulator study of an on-road lane departure warning system, 14 drivers drove the adaptive and lane departure system (80 miles with each). The adaptive system did not issue an alert when the driver was attentive, whereas the non-adaptive system issued an alert regardless of the driver's attention. The adaptive system reduced nuisance alerts by 95 percent (from 81 to 4 alerts), and 86 percent of subjects preferred the adaptive system. Subjects appeared to be willing to spend significantly more money on an adaptive system compared with a non-adaptive system.

Towards an AVST/Driver Partnership: Research and Implementation Implications
John Lee

John D. Lee is a professor in the Department of Mechanical and Industrial Engineering at the University of Iowa. He is also affiliated with the Department of Neurology, the Public Policy Center, the Injury Prevention Research Center, the National Advanced Driving Simulator, and the Center for Computer-Aided Design. His research focuses on the safety and acceptance of complex human-machine systems by considering how technology mediates attention.

Dr. Lee discussed the need to develop a partnership between the technology and the driver. Technologies should be used to augment the human, as opposed to automating the driving task. New technologies present challenges, such as distraction (e.g., in telematics) and diminish the feedback from the world (e.g., the “living room type environment” of the vehicle). Automating elements of the driving task leaves the driver less connected with the driving world. At the same time, these technologies also have the potential to make driving safer.

Convergence of technologies, such as sensors, GPS, and wireless, allows the car to perceive and control that which is complementary to the driver. The car can “know” who the driver is, with biometric technology or smartcard, and know the state of the driver. This information can be used to create a dialogue with the driver. While a holistic approach to integration is most desired, the way subsystems are deployed, i.e., piecemealed, may make a holistic approach difficult. New technologies need to address fundamental crash mechanisms such as speed and how we can influence speed. The technology can help change expectations and maybe even the culture of driving.

The type of conceptual model of the driver is important because it guides the design of systems and warnings. A model that considers feedback and the continuous task of controlling the vehicle prompts people to consider graded information as a context for warning, and uses ambient information (signals in environment that help us adapt to situations) to provide pre-attentive information that is important (e.g., ambient sound governs speed control). If you provide ambient information you can reduce reaction time by guiding expectations. Expectation is a powerful factor on reaction time; change expectations and the reaction time will also change. As engineers make the car quieter, and drive-by-wire separates the driver from the roadway environment, we need to redesign in the sound and vibration cues to convey information to the driver.

Summary & Conclusions

This report synthesizes the proceedings of the NHTSA-sponsored Human Factors Forum on AVST held in January 2007. The forum provided the opportunity for leaders and researchers from industry, government, and academia to examine the potential benefits as well as risks from AVST. Twelve invited speakers delivered presentations on a range of topics, including specific applications such as CICAS and IVBSS, the development of adaptive technologies that adjust system settings to match the driver's level of alertness and capability, the role of standards in AVST, and principles of human factors design.

The invited presentations provided attendees with valuable insights that laid the groundwork for the breakout groups. Attendees were divided into five groups, with each group focusing on a specific topic. The topics were Driver-Centered Design, Unintended Consequences, Standardization and Commonality, Integrating Multiple Systems, and Mechanisms for Future Collaboration. The groups identified six high-priority research needs and 10 ways to continue the interchange initiated in the forum. The research problem statements were:

1. Assuring AVST compatibility with driver capability and needs. The motivation behind this problem statement was the need for a system to determine drivers' responses to various warnings to ensure the acceptance and performance of safety systems. Objectives included documenting the driver characteristics which determine the response to a warning; developing a way to present, catalog or model driver responses; determining the critical factors underlying driver response; determining workload demands of the task; and diagnosing driver capability.
2. Understanding and predicting behavioral adaptation and cultural response to AVST. As suggested by the unintended consequences produced by previously deployed safety systems (e.g., ABS, first generation air bags), there may be an incomplete understanding of the problem space of unintended consequences; the proposed research includes developing a taxonomy of behavioral responses to safety systems in general, technology, and AVST; identifying changes in driver attitudes and behaviors associated with AVST and specific AVST elements; and identifying changes in cultural and societal attitudes and behaviors associated with AVST.
3. Methodology to quantify benefits of standardization. The research proposed is intended to provide a quantitative basis, method and criteria to determine when standardization is necessary. The proposed research would develop and document an evaluation protocol for application to AVST, and apply the evaluation protocol to a target set of ASVT systems.
4. Methodology to identify best practice for AVST HMI performance. This project proposed identifying performance-based criteria for selecting HMI design. The goal of the project is to develop a methodology and criteria for selecting HMI designs based on performance metrics.
5. Integrated crash warning effectiveness. The issues of how to determine if an integrated crash warning is deemed "effective" and whether there are in fact many approaches result in an "effective" system are still debated in the traffic safety

community. The objective of the proposed research is to determine how to measure effectiveness and acceptance of an integrated crash warning for the majority of the driving population.

6. Effective modalities and timing approach consistency for integrated crash warnings. More research on the haptic modality, modality combinations and the timing of warnings is needed to ensure an effective warning. The objective of the proposed research is to determine which modalities are most effective for integrated crash warnings, and determine the impact timing approach consistency has on integrated crash warning effectiveness.

The participants noted that there is a need for information, ideas and data to be shared in the community. Several options for a rich exchange and dialogue were put forth by members of one of the breakout groups, as follows:

1. Information repository for researchers. The repository should include at a minimum the technology, a description of the HMI used and any supporting technical documentation (e.g., conference proceedings, journal publications). The inventory should be updated yearly, perhaps as part of the NCAP updates.
2. Common metrics database. The intent of this effort would be to consolidate all data, research, and knowledge into one central location. Having all information in one place would facilitate research and optimize efforts – stakeholders would have complete knowledge of research already completed.

In summary, the forum showed that while a wide breadth of research exists, many unanswered questions remain. Attendees and presenters identified the need for stakeholders to improve the communication of research methods and findings. All attendees agreed that the challenges of deploying effective and acceptable AVST are substantial, and only through research and collaboration will the challenges be met.

Appendix A - Meeting Agenda

Human Factors Forum on Advanced Vehicle Safety Technologies (AVST)
Agenda

January 25, 2007		
Time	***Topic/Title***	***Speaker***
8:00 – 8:30	Registration/coffee in cafeteria	
8:30 – 8:40	Introduction to Noblis[1]	Craig Janus, Noblis
8:40 – 9:00	Opening remarks	Nicole Nason Ron Medford, NHTSA
9:00 – 9:05	Review agenda	NHTSA moderator

[1] At the time of the forum, Noblis was Mitretek Systems Inc.

9:05 – 9:20	"Human Factors Concerns for Design & Performance of Warnings"	Joanne Harbluk, Transport Canada
9:20 – 9:50	"Crash Warning System Interfaces: Human Factors Insights and Lessons Learned"	John Campbell, Battelle
9:50 – 10:10	Break	
10:10 – 10:25	OEM views: GM	Robert Lange, GM
10:25 – 10:40	OEM views: Ford	Michael Shulman, Ford
10:40 – 10:55	OEM views: Honda	Toyohei Nakajima, Honda
10:55 – 11:10	OEM views: Toyota	David Benedict, Toyota
11:10 – 11:25	"Voluntary Standards Development of Advanced Safety Systems"	Dan Selke, SAE Safety & Human Factors Committee
11:25 – 12:00	Open Discussion /Questions	NHTSA moderator
12:00 – 1:00	Lunch – Noblis Cafeteria	
1:00 – 1:15	Promoting Active Safety Systems	Sarah Koskie, Indiana University-Purdue University Indianapolis, Transportation Active Safety Institute
1:15 – 1:35	Integrated Vehicle Based Safety Systems (IVBSS): Crash Warning Integration Challenges	Jim Sayer, UMTRI
1:35 – 1:55	"Human Factors Research Issues for Cooperative Intersection Collision Avoidance Systems (CICAS)"	Vicki Neale, VTTI
1:55 – 2:15	Adaptive Interfaces and Warnings	Mathew Smith, Delphi
2:15 – 2:35	"Towards a AVST/Driver Partnership: Research and Implementation Implications"	John Lee, U. Iowa
2:35 – 3:00	Open Discussion/Questions *Charge to Breakout Groups*	*Moderator* *Mike Perel, NHTSA*
3:00 – 3:15	Break	
3:15 – 4:45	Breakout groups convene	Group moderators: Robert Lange, GM Neal Lerner, WESTAT Jim Sayer, U. Michigan Mary Stearns, Volpe Nick Ward, U. Minnesota

4:45 – 5:00	Summary of the Day and Adjournment	NHTSA moderator
January 26, 2007		
Time	***Session***	
8:30 – 9:45	Complete breakout group discussions	
9:45 – 10:00	Break	
10:00 – 11:00	Review of breakout group recommendations to all	Group moderators
11:00 – 11:30	Plenary group discussion and questions to moderators	
11:30 – 12:00	Closing remarks/Adjourn	NHTSA

Appendix B - Templates for Research Problem Statements

Problem Title	Use as few words as possible
Background and Rationale	Answer why this research is necessary. Address a specific problem. Provide a clear explanation for the research in one or two paragraphs.
Research Objective	Identify the specific goals and outcomes.
Research Method	Select a category from the List of Methods below.
Estimated Funding and source	Estimate the required funding. Use the Rule of Thumb below and add the rating scale value from the **Expected cost of conducting research** listed below. Who might fund it?
Research Period and Level of Effort	Estimate the number of months needed to complete the research.
Time Frame	Is it necessary to address this issue immediately or is the issue likely to emerge over time?
Research Implementation	Who will implement the research findings and how? Are the research results relevant to guidelines or standards?
Other Considerations	Include other issues that may be relevant

A Rule of Thumb: 100 percent of a professional employee's time per year, fully loaded, averages between $150,000 and $200,000. Average rates for supporting staff is about ½ of that. Consider the cost of other big expenses.

Research Methods: This represents the best primary and secondary (if needed) research approaches needed to investigate the research question.

Analytical		Empirical	
CDA	Crash Data Analysis	ORS	On-road Study
LR	Literature Review/Synthesis	CTS	Closed-Track Study
		DSS	Driving Simulator Study
MA	Meta Analysis	FT	Field Test
DG	Design	LS	Laboratory Study
IRR	Guidelines/Standards Integrative Research Review	AA	Anthropometric Analysis
		US	Usability Study
		URA	User Requirements Analysis
FS	Feasibility Study	S	Survey
AN	Data Analysis	FG	Focus Group
		WS	Workshop

Expected cost of conducting research: This represents the expected cost of conducting the research to answer the research question.

Relatively short project duration with small project team, and minimal or no equipment investment		One or two year project with small to medium sized project team working less than full time & possibly some equipment investment		Multi-year, multi-phase, project requiring a large research and engineering team and significant equipment investment
1	2	3	4	5

Template for Group 5: Mechanisms for Future Collaboration

Group 5's task is to identify issues related to turning research into practice (i.e., the design and deployment of effective and acceptable advanced vehicle safety technologies) and develop mechanisms for following up on the forum.

Turning Research into Practice	Identify the challenges and approaches for turning research into practice (e.g., technical, organizational, legal, and financial). What are the advantages and disadvantages of human factors guidelines, standardization, common performance measures, common evaluation protocols, or other means to assure that human factors considerations will be accommodated in vehicle safety technologies?
Common interests and Competitive Interests	List the common interests, goals, and approaches for addressing human factors challenges with AVST. Identify the competitive interests, goals, and approaches
Organizations and Funding	Identify the organizations relevant to this discussion and define their roles in the effort to conduct research, support mechanisms to share research information, and turn research into practice (i.e., to develop technologies that are effective and acceptable to drivers with minimum adverse impacts).
Next Steps	List ideas for continuing the dialogue from the HF forum that are needed to achieve deployment of effective and acceptable AVST.

References

Perel, M. (1983). Vehicle Unfamiliarity and Safety. Report Number DOT HS 806 509. Washington, DC: National Highway Traffic Safety Administration.

NHTSA (2005). Traffic Safety Facts. Report Number DOT HS 810 631. Washington, DC: National Highway Traffic Safety Administration

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