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Research Directions For In-Vehicle Computing:

Delivering an Integrated Suite of ITS Applications for Driver Assistance and Mobile Services & Information

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Research Directions for In-Vehicle Computing

Delivering an Integrated Suite of ITS Applications for Driver Assistance and Mobile Services & Information

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EXECUTIVE SUMMARY

Over the next five to ten years, the number and variety of in-vehicle computer-based applications will escalate dramatically. Some Driver Assistance (DA) systems, such as adaptive cruise control and curve warning systems, are already available in world markets. Computer-based Mobile Services & Information (MSI) products are already available, such as in-vehicle navigation, Mayday and emergency roadside assistance services, and other convenience-enhancing applications for en-route travelers.

As the variety of DA and MSI products expands, there is an urgent need to consider how these systems interact with one another, with drivers, and with passengers. Intelligent Transportation Systems (ITS) professionals are recognizing this need.

This topic was the centerpiece of a two day workshop, "Research Directions for In-Vehicle Computing," hosted by the Transportation Research Board Committee on Intelligent Transportation Systems (A5009). On August 25-26, 1998, over 50 professionals from government, industry, and academia met in Newport Beach, California, to attend this workshop. Briefly stated, the goals of this workshop were to

- Identify research needed to appropriately advance the overall in-vehicle computing environment and related DA and MSI applications;
- Prioritize research needs and areas where additional research attention is needed; and
- Identify and recommend appropriate strategies and frameworks for pursuing this research.

These objectives were met through discussions and structured exercises in breakout group sessions. Breakout groups were organized around two product areas: Driver Assistance (DA) and Mobile Services & Information (MSI), and three issues areas: Human Factors, System Integration, and Research Models. Breakout group results were shared and reviewed among all workshop participants during four general sessions held over the course of the two-day workshop.

Human factors was recognized as a paramount issue throughout the workshop. Participants noted that humans are limited in the number of tasks they can safely execute while driving, which will impose special constraints on future in-vehicle computing applications that require driver interaction.

Workshop discussions revealed that participants held different expectations for the future direction and pace of DA and MSI products development. Some issues were particularly difficult to resolve, such as timing and market feasibility of specific ITS products. Despite these differences, there was important agreement that the emergence of DA and MSI applications is creating new requirements for the in-vehicle computing environment. Attendees generally agreed that future vehicles equipped with multiple DA and MSI systems will require

- Consistent operating characteristics/human factors across car makes and models;
- Integrated, prioritized information delivery to drivers;
- Creation of practical, practicable human factors guidelines for system designers;
- Human-machine interfaces that are shared among several applications;
- Further refinement of mobile positioning, voice recognition, and wireless technologies;
- Secure, reliable communications between in-vehicle systems and service providers; and
- Secure, reliable communications between vehicles (vehicle-to-vehicle communication).

INTRODUCTION

The information superhighway is merging with traditional highways. Driver Assistance (DA) systems such as adaptive cruise control, lane departure warning systems, and obstacle warning systems have the potential to significantly enhance road safety. Mobile Services & Information (MSI) systems like navigation, roadside assistance, electronic fee payment, real-time traffic information, driver-specific comfort and convenience adjustments, and office-in-the-car services will help to make travel more pleasurable, productive and efficient. Together, DA and MSI systems can usher in an era of safer, more convenient, more productive road transportation.

However, for DA and MSI systems to operate effectively and cooperatively in the vehicle, a significant in-vehicle hardware and software computing capacity is required. The in-vehicle computing platform of the future should be capable of handling, supervising, controlling, and coordinating a wide array of integrated functions and applications, including

- Multiple cooperating DA and MSI applications;
- Automated interactions with outside services;
- Effective, secure communication among on-board components and with the outside world; and
- Management of the firewall that isolates and protects engine and vehicle control functions from other in-vehicle activities and protects all in-vehicle activities from external interference.

There is a shared expectation within the ITS industry that future in-vehicle computing is likely to be a serious, large-scale, integrated system, not the relatively isolated, small-scale processors of today. The effective planning and development of in-vehicle computing depends on approaching the problem as a large-scale computer development project and starting from an architecture that provides a cost structure suitable for road vehicles and a vision for development and deployment.

Research for individual Driver Assistance and Mobile Services & Information products is already being conducted on multiple fronts, and in some cases, on suites of products. A number of research consortia, mainly private sector based, are beginning to consider application and communications architectures, primarily in the MSI arena.

At present, there is less large-scale cooperative research and development work being done in the DA arena and on the overall in-vehicle computing environment. Particularly in the U.S., there has been relatively modest government involvement in or funding of this kind of research, despite strong government and public interest in the DA field.

Workshop Goals

On August 25-26, 1998, the Transportation Research Board ITS Committee (A5009) sponsored a workshop to assess emerging in-vehicle computing needs. The workshop drew wide support from across the ITS industry. Related committees that co-sponsored the workshop included

- TRB Committee on Communications (A3A01);
- TRB Task Force on Vehicle-Highway Automation (A3A53);
- TRB Committee on Transportation Safety Management (A3B01);
- TRB Committee on Vehicle User Characteristics (A3B02);
- TRB Committee on Simulation and Measurement of Vehicle and Operator Performance (A3B06);
- TRB Committee on Statistical Methodology and Statistical Computer Software (A5003);
- TRB Committee on Information Systems and Technology (A5003);
- TRB Task Force on National Data Needs and Requirements (A5T53);
- ITS America ATIS Committee;
- ITS America Safety & Human Factors Committee;

- ITS America Standards & Protocols Committee;
- ITS America System Architecture Committee;
- Society of Automotive Engineers (Intelligent Transportation Systems Division); and
- The California Alliance for Advanced Transportation Systems (CAATS).

The ITS industry has tended to focus on computing issues in system-specific and application-specific contexts. This meeting was a departure from these efforts because it drew attention to the in-vehicle computing environment in a holistic, systemic way. Multiple follow-on meetings will be needed to address this subject thoroughly.

The primary orientation and objectives of the workshop were

- To identify areas where research is needed to appropriately advance the overall in-vehicle computing environment and its DA and MSI applications;
- To prioritize research needs and to highlight priority areas where additional research attention is needed; and
- To identify and recommend appropriate strategies and frameworks for pursuing this research.

A significant subtext of the workshop was to characterize the role and relationship of the public and private sectors in funding and conducting this research and, ultimately, transforming this research into products and services which

- Meet individual needs for safer and more satisfying travel;
- Meet corporate needs to make, sell, and deliver attractive and profitable products and services; and
- Meet government needs to enhance public safety and manage the overall transportation system.

Those attending the workshop came from a cross-section of industry and government organizations and a wide range of professional disciplines, including

- Automotive and computer manufacturers and suppliers;
- Engineering and industry societies;
- Information service providers;
- National labs;
- State Departments of Transportation;
- Universities; and
- U.S. Department of Transportation.

This diverse group came together to consider research needs that would address, and to some extent anticipate, the future in-vehicle computing environment. To accomplish this, attendees were asked to consider in-vehicle computing needs in several specific contexts:

- Mobile Service and Information (MSI) systems;
- Driver Assistance (DA) systems;
- Integration of multiple DA and MSI systems;
- Human factors and safety issues; and
- Research frameworks best suited to each identified research priority.

The results of these discussions are presented in Section V of this Circular.

WORKSHOP OVERVIEW: STRUCTURE OF MEETING

August 25

The workshop included four general sessions and two sets of breakout sessions. ITS Committee Chair Richard Weiland opened the first general session of the workshop. He welcomed attendees and provided comments on the methodology and procedures to use for each breakout group, along with the desired format for delivering conclusions to the general assembly.

The first general session provided a broad overview of the central workshop themes through presentations by recognized industry leaders:

- Axel Fuchs of Daimler-Benz Research and Development - North America discussed new directions and challenges of MSI applications;
- Michele Roser of Navigation Technologies provided an overview of DA systems, including future product development trends; and
- Eugene Farber of Ford Motor Company discussed the human factors and safety implications of DA and MSI systems.

At the conclusion of the first general session, participants were assigned to breakout groups covering three topics:

- ***Mobile Services & Information Systems***. Jim Bauer of Toyota Technical Center and Rick Noens of Motorola led the MSI breakout groups A1 and A2.
- ***Driver Assistance Systems.*** John Pierowicz of Calspan Corp led the DA Breakout Group B;
- ***Human Factors & Safety.*** Barry Kantowitz of Battelle led the HF&S Breakout Group C.

The MSI and DA groups were asked to select the enabling technologies and applications they thought were most important to the industry over the next 3-5 years. The HF&S group was asked to consider the introduction of multiple MSI and DA systems into vehicles and, from this scenario, to identify human factors and safety issues that required additional research.

There was a special workshop dinner on the evening of August 25 at which John MacGowan, Chief of the Intelligent Systems and Technology Division of the Federal Highway Administration, gave an address. His presentation outlined a framework for the emerging vehicle-highway research agenda, focusing on the complementary roles of the public and private sectors.

August 26

The second day of the workshop also began with a general session. During this general assembly, breakout group leaders from the first day of the workshop reported their results and conclusions.

On the second day of the workshop, another set of in-vehicle computing topics were examined:

- ***System Integration*** involved examining issues that arise when multiple MSI and DA systems are introduced in vehicles. This topic was examined in two, separate groups: D1 and D2 led by Richard Pearlman of Denso and Bill Knee of Oak Ridge National Laboratory. Participants were asked to construct architectural diagrams reflecting possible ways the in-vehicle computing environment might be structured to accommodate multiple ITS systems. These groups were also asked to list the most cogent research issues relating to system integration and to answer brief questions on each.
- ***Research Models*** asked participants to consider ways in-vehicle computing R&D might be conducted. This topic was addressed in two separate groups: E1 and E2 led by G. Sadler Bridges of Texas Transportation Institute and Ray Starsman of ITS America, respectively. Participants in these discussions were asked to assess the

potential risk, cost, and time frame for conducting research in the high-priority research areas identified during the first day of the workshop.

A final general session concluded the workshop. Breakout group leaders from the System Integration and Research Frameworks groups reported their findings to the general assembly. Breakout group reports were followed by a general discussion by all participants and concluding remarks by the ITS Committee Chairperson. Chair Richard Weiland expressed his thanks to the workshop speakers, breakout leaders, participants, Steve Weiland who handled workshop logistics, and Lara Baughman Purser who had primary responsibility for developing and organizing the workshop and preparing this Circular.

A special thanks is also due to those who provided thoughtful review of the Circular draft, including: Jim Bauer et. al. of Toyota Technical Center, Eugene Farber of Ford Motor Company, Barry Kantowitz of Battelle, Steven Shladover of University of California at Berkeley/Institute of Transportation Studies, and Ray Starsman of ITS America.

BREAKOUT GROUP SUMMARIES

Mobile Services & Information (MSI) Systems Breakout Group

Overview

Mobile Services & Information (MSI) systems provide drivers and passengers with information and entertainment services. They give en-route travelers the ability to plan and follow routes, secure routine and emergency roadside assistance, and connect the vehicle and its occupants to the National and Global Information Infrastructure for a variety of travel, business, and entertainment purposes. MSI functions include

- ***Business Services and Information*** ("office in the car"), which provide access to email, voice mail, address book, fax, the Internet, news reports, financial information, and other related services.

- ***Convenience and Entertainment Services***, which include both driver comfort features such as automatically-adjusting mirrors, seats, radio buttons, etc., and multimedia entertainment, mainly for passengers.

- ***Emergency Assistance***, including mayday services (manual requests for emergency assistance), routine roadside assistance (fuel, dead battery, flat tire), remote interface services that enable service centers to remotely unlock a vehicle or blink the lights to assist in finding a vehicle, and theft protection services, which provide vehicle tracking and monitoring on request.

- ***Route Guidance***, which provides turn-by-turn, door-to-door driving directions to any desired destination.

- ***Travel Information and Assistance***, which includes real-time traffic and weather advisories, concierge services, and automatic fee payment capabilities, such as ETC.

Advanced Mobile Services & Information systems (MSI) have been prototyped by several major consortiums and are starting to come to market. For example

- IBM, Delphi Delco Electronics Systems, Netscape, and Sun Microsystems have teamed up in the production of the Network Vehicle, first demonstrated at COMDEX '97. The Network Vehicle is a concept car aimed at establishing standards for the automotive industry and bringing advanced in-vehicle information products and services closer to reality. The Network Vehicle concept car features advanced voice recognition technology and speech synthesis, several MSI services such as news, traffic and weather information, and a customized Internet browser.

- Microsoft has partnered with over 20 companies to develop the Auto PC, which is expected to be available in US markets in 1999. The Auto PC has an open architecture that can support any application that conforms to the Windows CE operating system. It features advanced speech recognition, speech synthesis technology, in-vehicle navigation services, an address book, "wireless services" (weather, traffic info, news, paging, etc.), AM/FM stereo, and a CD player. The Auto PC fits into a standard 1 DIN dashboard slot.

- Intel unveiled the first prototype of its Connected Car PC in September 1997, and has plans for deployment in 1999. Recently, Intel joined Microsoft to develop a platform based on Intel processors and the Windows CE operating system.

- Several telematics organizations that provide DA and MSI services are already active in Europe and the U.S.,

such as the BMW Emergency Phone, Tegaron Info and Traffic, and ITGS for Daimler Benz, GM's OnStar, Honda's Inter Navi System, Peugeot's Inf-Flux, Renault Telematics System, Volvo's Dynaguide, and Gedas Telematics, a division of Volkswagen.

MSI Breakout Group Instructions

The Mobile Service & Information topic generated strong interest from workshop participants. As a result, two breakout sessions were created. Each MSI Breakout Group was given identical instructions.

To begin, participants reviewed and refined a list of MSI systems and enabling technologies. The groups also determined what criteria (called "success criteria") they expected would have the strongest effect on the deployment of MSI systems, such as cost and appeal to specific consumer segments.

Group participants determined how each success criterion would affect each application, on a scale of –2 to 2. –2 indicated that the criterion had a strong, adverse affect on deployment, and a +2 indicated that the criterion would affect deployment very favorably.

The MSI Breakout Groups identified the most significant enabling MSI technologies and applications and the level of research needed for each technology to be market-ready.

From this exercise, participants concluded the session by generating a list of top priority research issues for MSI systems. Where possible, group members identified the most appropriate entity to carry out this research.

MSI Breakout Group Results

In judging which criteria would figure most prominently in the deployment of MSI systems, participants were asked to use a scale of 1-5. Each criterion could affect deployment positively or negatively. If the criterion was expected to affect deployment very strongly, a score of '5' was used. If the criterion was expected to have a very weak affect on deployment, a score of '1' was appropriate, etc.

The breakout discussions culminated in the following list of ranked criteria:

- Appeal to traveling families: 5
- Ease of use: 5
- Quality of service: 5
- Cost, as an absolute: 4.5
- Benefit to Cost ratio: 4
- Appeal to business commuters: 4
- Appeal to business travelers: 4
- Appeal to early technology adopters: 3
- Appeal to luxury market: 3
- Appeal to elderly motorists: 2.5

The breakout group identified the universe of potential MSI applications as follows:

- Standard route guidance
- Dynamic route guidance (takes real-time traffic information into account)
- Real-time traffic information (separate from navigation functions)
- Road-side assistance requests
- User-initiated Mayday requests
- Voice mail
- E-Mail
- Fax
- Internet access
- Entertainment; self-contained (e.g., DVD movies, Nintendo available in the back seat)
- Entertainment; wireless, passive (e.g., broadcast TV and movies, "wireless cable")
- Entertainment; wireless, active (e.g., multi-user games, viewer choice music/movies)
- Concierge services (e.g., find me a florist, reserve a hotel room, get me tickets, etc.)

- Address book/calendar access and management
- Parking space location and reservation
- Vehicle diagnostics
- Driver preference adjustment (mirrors, suspension, seats, shift points, radio buttons and volume, HVAC settings)
- Weather reporting
- Intermodal information
- Location (fleet management, etc.)
- Roadway, driving information
- Local transactions

The breakout groups identified the following set of potential enabling technologies:

- GPS
- High accuracy GPS
- Other high-accuracy vehicle positioning sensors
- Data on historical travel patterns and link transit speeds
- Voice recognition
- Voice synthesis
- Call-switched cellular
- Cellular packet switching
- Other RF packet switching
- Call processing center
- Vehicle data broadcasting
- Low speed data bus
- High speed data bus
- Service provider
- Content provider
- Radar/Laser sensors
- Video sensors
- Standard navigation map database
- Extremely high-accuracy map database
- Tire pressure and other operating characteristic sensors
- Road condition sensors
- Sensor fusion software
- Device interface standards
- Message set standards
- RF protocols
- Priority management software (allocation of computing resources)
- Demand resolution software (how display screen, common channel, brakes, etc. are handled in case of demands from multiple applications)
- Machine learning (intelligent agent)
- Advanced displays
- Reliable/effective mobile computing technology
- Network connectivity
- Speech recognition
- Mobile Wireless LANs
- DSRC (Microwave/IR)
- Global communications
- Radio broadcast: FM subcarrier, TV, etc.

After much discussion, participants identified the following enabling technologies as most crucial to the successful deployment of MSI systems:

- Wireless Connectivity;
- Position, Location Determination;
- Voice Recognition;
- Network Security; and
- Information Fusion & Integration.

The most important/most promising MSI applications were identified as follows:

- Real-time Traffic Information;

- Mayday/Roadside Assistance;
- Dynamic Route Guidance; and
- Location Information.

Participants concluded that considerable research remains before the full potential of Mobile Services & Information systems can be realized. For example, it was widely understood that providing a reliable, secure, and private in-vehicle computing environment was extremely important to the industry.

Many participants emphasized the importance of creating sensible human-machine interfaces (HMI) that interact safely with drivers. Some participants were hopeful that high-quality voice recognition and speech synthesis technologies would help improve the MSI HMI. Other qualities group members listed as important to this technology area are

- Speaker-independent voice recognition;
- Natural language processing; and
- Noise insensitivity (can operate effectively in vehicles with high levels of ambient noise).

Ubiquitous location capability was another area that members agreed was important to the future of MSI systems. The creation of predictive traffic models was highlighted as an important aspect of providing current, reliable real-time traffic information. While it was agreed that accurate and predictive traffic models were desirable, some workshop participants remained doubtful that an acceptable solution would be forthcoming in the near term.

The communications technologies used to relay information to and from the vehicle was identified as another critical research area. Wireless communications to support Internet connectivity, voice, video images, and database updates were considered highly desirable.

Driver Assistance (DA) Systems Breakout Group

Overview

Driver Assistance Systems offer a significant change in the orientation of safety-related technology, from mitigating the consequences of crashes (e.g., air bags, roll bars, seat belts, etc.) to avoiding and preventing crashes altogether. DA is an evolving suite of products and technologies to improve highway safety. These include

- *Adaptive Cruise Control*, which maintains a safe interval to the vehicle ahead;
- *Curve Warning Systems*, which alert drivers (or automatically slow down vehicles) when a curve is being approached too fast;
- *Intelligent Automatic Transmission***,** which calculates the optimal gear shift, up or down, based on information about the road ahead (curves, grades);
- *Intersection Collision Avoidance Systems*, which warn drivers to slow down based on intersection locations and data about those locations, such as the presence of a stop sign or traffic signal;
- *Lane Drift and Run-Off Road Detection*, which alerts (or automatically adjusts steering) if the vehicle appears to be drifting out of its lane or off the road;
- *Obstacle Warning and Avoidance Systems*, which detect and warn of obstacles on the front, sides, and rear of a vehicle;
- *Smart Headlights*, which automatically aim to provide better illumination around curves;
- *Smart Throttles*, which anticipate road conditions (curves, grades) to save fuel and improve engine performance; and
- *Stability Control Systems*, which help prevent lateral sliding on curving or slippery roads.

A particular challenge in DA systems product development is achieving multi-function cooperation. For example, in some critical

situations ABS, stability control, collision avoidance, and the driver may all be making simultaneous demands on the brakes.

Because of their potential to increase road safety, there has been worldwide interest in Driver Assistance systems both in the public and private sectors. For example

- The Japanese Ministry of Transportation established the Advanced Safety Vehicle (ASV) program in 1991. This program explores technologies such as driver monitoring, obstacle detection, and headway keeping systems. Now in its second phase (1996-2000), the ASV project is focusing on human factors research and integration, with a goal of making products available to the public by 2000. Thirteen manufacturers are participating in this phase of the program. Several Japanese government agencies have also provided funding for the Advanced Cruise-Assist Highway System Research Association (AHSRA), which ultimately aims to improve road safety through the creation of completely automated driving.

- In Europe, the public-private consortium AC-ASSIST (Anti-Collision Autonomous Support and Safety Intervention System) aims to demonstrate and validate autonomous longitudinal collision avoidance systems. In another EU-funded project, UDC (Urban Drive Control), researchers are specifying, building and evaluating the integration of traffic management and vehicle longitudinal control in urban areas. A third EU public-private consortium is titled: Integration of Navigation and Anticollision for Rural Traffic Environment (IN-ARTE). This project aims to increase traffic safety through the integration of driver support systems.

- In the U.S., the Intelligent Vehicle Initiative (IVI), a joint program among NHTSA, FHWA, and FTA, is aimed at reducing the number of motor vehicle crashes by accelerating deployment of collision avoidance systems.

Current Status

Several DA systems are already on the market. Adaptive Cruise Control (ACC) systems have been successfully released in Japan and Europe. In May 1998, Toyota announced the launch of the Progres in Japan. The Progres is a sedan that features ACC, automatic transmission adjustment in anticipation of corners and curves, a VICS real-time traffic information receiver, and a connection to MONET, Toyota's vehicle-oriented data network. Overall, DA R&D is being conducted by almost every major automobile manufacturer and automotive supplier in the U.S., Japan, and Europe.

DA Breakout Group Instructions

The Driver Assistance discussion group (Breakout Group B) was given similar instructions to the Mobile Services & Information Breakout Groups. Participants were first asked to create lists of MSI systems and potentially enabling technologies. The group determined what criteria were expected to have the strongest effect on the deployment of DA systems, such as cost and appeal to specific consumer segments.

In a separate but related group exercise, members were asked to determine how criteria would affect each application, on a scale of –2 to 2. –2 indicated that the criterion had a strong, adverse affect on deployment, and a +2 indicated that the criterion would affect deployment very favorably.

Groups identified the most significant enabling technologies and applications, based on the extent of their use in various DA systems, and the level of research needed for each technology to be market-ready. From this exercise, participants concluded the session by generating a list of specific research issues that should be explored for DA systems and to identify, where possible, the most appropriate entity to carry out this research.

DA Systems Breakout Group Results

Following is a list of DA applications identified:

- Adaptive Cruise Control

- Smart Throttle/Transmission
- Automated Mayday
- Automatic Door Unlock
- Suspension Control
- Collision Warning
- Curve Warning
- Engine Compartment Fire Warning
- Collision Avoidance
- Intersection Collision Avoidance
- Lane/Roadway Departure Warning
- Smart Headlights
- Stability Control
- Drowsiness Warning
- Vision Enhancement
- Braking Assistance
- Docking
- System Diagnostics
- Road Condition Sensing

The group agreed on the following set of enabling technologies:

- GPS
- High accuracy GPS
- Other high-accuracy vehicle positioning sensors
- Data on historical travel patterns and link transit speeds
- Voice recognition
- Voice synthesis
- Call-switched cellular
- Cellular packet switching
- Other RF packet switching
- Call processing center
- Vehicle data broadcasting
- Low speed data bus
- High speed data bus
- Service provider
- Content provider
- Radar/Laser sensors
- Video sensors
- Standard navigation map database
- Extremely high-accuracy map database
- Tire pressure and other operating characteristic sensors
- Road condition sensors
- Sensor fusion software
- Device interface standards
- Message set standards
- RF protocols
- Priority management software (allocation of computing resources)
- Demand resolution software (how display screen, common channel, brakes, etc. are handled in case of demands from multiple applications).

In judging which criteria would most strongly effect the deployment of DA systems, participants were asked to use a scale of 1-5. Each criterion could affect deployment positively or negatively. If the criterion is expected to affect deployment very strongly, a score of ‘5’ was used. If the criterion is expected to have a very weak affect on deployment, a score of ‘1’ is appropriate, etc. From these instructions, the breakout group generated the following list of criteria:

- Cost, as an Absolute: 5
- Safety: 5
- System Reliability: 5
- Benefit to Cost Ratio: 4
- Appeal to average motorist: 4
- System Integration: 4

- Appeal to early technology adopters: 3
- Appeal to elderly motorists: 3
- Appeal to luxury market: 3
- Appeal to business commuters: 2
- Appeal to business travelers: 2
- Appeal to traveling families: 2
- Reduced Damage: 2

The group identified the following enabling technologies as most critical to DA systems overall (list is rank-ordered):

1) Road Condition Sensor
2) High Speed Databus
3) Message Set Standards
4) Highly Accurate Map Database
5) Other High Accuracy Positioning.

Additionally, a reviewer of the draft version of this Circular noted the vital importance of ranging sensors in Driver Assistance systems.

In identifying high-priority research areas for DA systems, group members agreed that systematic analysis of multiple DA systems was the most urgent research topic. In particular, members felt that more needs to be known about

- Fusion of multiple sensor systems in the vehicle;
- Effects of integration on cost-benefit;
- Most appropriate/safest HMI for DA systems;
- Best modality for issuing DA warnings (e.g., visual, audio, haptic);
- Level of accuracy required for enhanced map databases to support DA applications;
- More technology development for high precision, low-cost positioning equipment such as GPS; and
- Determine overall driver behavior interacting with DA systems (level of acceptance, possibility of behavior modification using these systems, etc.)

The DA Breakout Group shared a general belief that the Federal government should take a leading role in deploying a cooperative infrastructure to support DA systems, such as communications towers and differential GPS. Other issues that would benefit from public sector leadership include

- Standardization of messages/data content from the vehicle to Public Safety Answering Points (PSAP);
- Quantifying the safety benefits of smart headlights, stability control systems, and assisted braking; and
- Investigating the applicability of light-vehicle applications to the CVO and transit communities.

Overall, members agreed on the need to develop metrics for precise measurement and analysis of the vehicle, traffic, and roadway environments. High precision positioning systems, high accuracy databases, sensor fusion, and vehicle-to-vehicle communication via DSRC/transponders were all identified as worthwhile areas for investigation.

The desirability for utterly consistent warnings, operating characteristics, and interfaces across car lines was a recurrent theme in the discussion of DA applications. The group stressed the continuing need for human factors research within the DA arena. Determining the most appropriate warning content and modality are two, specific areas that require attention. A final research area identified by the group was the need for algorithm development, optimization and field tests to support DA systems.

Human Factors & Safety (HF&S) Breakout Group

Overview

As new ITS technologies proliferate, such as multimedia computing systems, DA systems, and others, the ITS industry must make products operate consistently for the user, both across different car models and potentially across borders.

Research on how drivers react to DA warnings and other information provided by systems is essential for improving road safety through ITS deployment. Highly sophisticated simulation labs, such as the National Advanced Driving Simulator (currently under construction at the University of Iowa) and the driving simulator developed by the Japan Automotive Research Institute, provide valuable opportunities to study how drivers interact with ITS systems.

HF&S Breakout Group Instructions

The breakout group charged with exploring safety and human factors issues was asked to review/edit/restate a preliminary set of research issues. Once the list was refined and accepted by the group, members were asked to characterize each issue in terms of

- The current state of knowledge;
- The level of importance;
- Technical breakthroughs required to pursue the research;
- Appropriate avenues for research (e.g. who should lead the research effort, who should participate, etc.); and
- The benefits and drawbacks of international participation in each area.

HF&S Breakout Group Results

Group members immediately recognized the need to build upon recent efforts to create guidelines and standards in this area. These prior developments included the Federal Highway Administration (FHWA) guidelines for Advanced Traveler Information Systems (ATIS)/Commercial Vehicle Operations (CVO) developed by Battelle, National Highway Traffic Safety Administration (NHTSA) guidelines for crash avoidance, and safety and human factors standards being developed by the Society of Automotive Engineers (SAE) and the International Standards Organization (ISO).

The group generally agreed that the most cogent human factors issue in the area of in-vehicle computing is how to integrate and manage warnings and the presentation of information to the driver, including

- Effective display modalities;
- Consistent message/warning form;
- Minimizing driver distraction and workload;
- Minimizing false alarms; and
- Guidelines for dealing with multiple collision avoidance/warning systems.

Within this broad research agenda, participants agreed that integration of information for the driver was the issue of paramount importance.

Another challenge identified was that optimizing each individual ITS *device* was unlikely to result in an optimized integrated, in-vehicle *system*. Methods for developing HF guidelines for integrated systems need to be developed, which to some extent must anticipate new in-vehicle computing developments. This is an added challenge that may be met by conducting functional analysis of integrated systems—even if all of the specific systems' components are not yet known.

Overall, participants agreed that driver functions, not individual systems, should be the focus for HMI design. Such a human-centric approach would focus on driver workload and human information processing capabilities.

While everyone in the ITS industry has an interest in employing sound human factors, few firms devote enough attention or resources to this area. For example, human factors are often addressed only *after* a product has been prototyped. This limits the ability for system designers to make wholesale changes to their systems. Members believe that government can play a positive role by offering incentives to corporations to increase their attention to human factors issues.

Group members suggested a number of research areas that would further the industry's understanding of human factors for integrated DA/MSI systems. They emphasized the need for research to yield practical suggestions that could be easily understood and implemented by system designers.

The Human Factors & Safety Group have subdivided their research statements into two categories. The first category focuses exclusively on integration of multiple Driver Assistance (DA) systems. The second category of research issues deals with integration of all in-vehicle computing devices (DA+MSI), as defined by the US DOT's Intelligent Vehicle Initiative (IVI).

I. Integrate Driver Assistance Systems

- *Driver Overload*. What constitutes driver overload? Develop metrics for driver workload and develop redline.
- *Message Prioritization/Overlap***.** How should conflicting messages be resolved? Can integrated messages reduce driver workload?
- *False Alarms*. Develop consistent way to define and treat false alarms. Determine threshold for human tolerance (e.g., at what point will drivers become so frustrated with frequent false alarms that they will ignore warnings altogether)?
- ***Guidelines/Standards*.** Human factors standards for individual systems are being developed by SAE. Existing research is adequate to accomplish this work. However, it is more difficult to develop human factors guidelines that deal exclusively with integration. Need to research integration in order to devise specific recommendations that will be useful to system designers, standards developers, etc. Guidelines must be in format useful to non-human factors experts; and
- ***Modality*.** Human decision making changes as a function of different display modalities. How should display modalities vary as a function of message content and situation? Existing research has been done, except for haptic warnings. This body of research needs to be codified to be useful to system developers.

II. Integrate DA and MSI Systems

As system developers move into a broader integration phase that includes both DA *and* MSI systems, group members restated four issues from Category I (Integrate DA Systems, as described above) that will remain pivotal, namely

- Driver Overload;
- Message Prioritization/Overlap;
- Guidelines/Standards; and
- Modality.

Participants identified two additional issues that will require attention, namely

- *Voice Activation.* Explore ways that systems can use voice recognition to help reduce driver workload; and
- *Science of Driving.* Determine baseline driver data. Normative driving data exists, but models of human behavior are needed for this data to be useful.

The group agreed that both the government and the private sector have a role in researching these issues. Due to the stringent nature of liability laws in the U.S., domestic participation should be the current focus. However, some group members noted that international manufacturers might also seek to participate collectively in these research areas.

System Integration Breakout Group

Overview

Integrating DA and MSI functions, along with the communications capabilities to link these functions to outside information and service providers, creates an unprecedented requirement for in-vehicle computing. The in-vehicle computing architecture required for DA and MSI products will need to be far more complex and powerful than any current in-vehicle computer. Future in-vehicle computing systems face significant challenges, including

- Affordability for passenger car buyers;
- Need for high reliability (e.g., safety critical systems must not fail while a vehicle is in operation); and
- Maintaining the security/integrity of information flows between system components.

As development of DA and MSI products accelerates and initial market roll-outs are planned, serious consideration needs to be given to how multiple products might interact with each other, with the driver, and with vehicle operation itself.

For instance, will drivers have to process multiple messages, each originating from a different, in-vehicle device? How will the vehicle handle conflicting messages from these devices? For instance, what would happen if one system indicates that brakes should be applied while another system indicates precisely the opposite? How should information be shared among these in-vehicle devices?

System Integration Breakout Group Instructions

Two breakout groups (D1, D2) were assigned to explore system integration issues. Both groups were given identical instructions.

First, the groups were asked to create a block diagram that might predict what the future in-vehicle computing environment will look like. Participants were given a list of preliminary building blocks that they could use to create this architecture and were encouraged to add others. This list of architectural elements included

- DA products;
- MSI products;
- Sensors;
- Vehicle devices (such as brakes, steering, and display screen); and
- Firewalls.

The second task for the System Integration Breakout Groups was to identify integration issues that require research attention. Members were asked to characterize the priority of each research item, measure the magnitude of effort required, enumerate risk factors, assess potential institutional and/or technical obstacles, and identify who should sponsor and participate in this research.

As a third and final component of the breakout group instructions, members were asked to determine the role of various public and private sector actors in creating the future in-vehicle computing environment.

System Integration Breakout Group Results

The architectural diagrams the System Integration Breakout Groups created are reproduced in Appendix B. While each picture offers its own, unique view of the future in-vehicle computing environment, both share some common elements:

- Fusion of multiple sensors;
- Information sharing between in-vehicle components;
- Firewalls to protect safety-critical applications; and
- Communications between in-vehicle components and the outside world.

The System Integration groups strongly recommended research directed at studying cooperation among multiple products, with special attention to developing communications protocols and ensuring reliability and timeliness. Management of information to the driver was another research issue identified along with driver workload, modality of messages and warnings, and consistency of warnings between vehicle makes and models.

Providing security for mission/safety-critical data was another high-priority research issue. The idea of creating a “black box” in the vehicle to capture data was raised, but group members were unsure what kinds of information should be collected, how it should be used, and who should have access to it.

There was a general consensus among group participants that more rigorous study of the integration issue itself was needed. Determining which MSI and DA systems were candidates for integration was one possible first step. Group members believed that industry-wide capacity, reliability, and usability requirements for system integration were needed. One thorny issue identified during these discussions was whether product liability could migrate as a function of integration.

The research roles of various public and private sector agents were identified as follows:

a. **US DOT (especially FHWA and NHTSA)**
Funding and oversight, attention to market driven issues. Continued involvement in the IVI and continued funding for demonstrations. Investment in the technology infrastructure. Support of standards development activities. Research and outreach to users.

b. **Automotive Manufacturers**
Consortia activity. Proof of concept. Building platforms for demonstrations. Third-party conformance testing. Technical research, particularly in the area of sensor development. Research funding.

c. **Computer Manufacturers**
Continued R&D, focusing on integration and system reliability issues. Technical research and associated R&D funding.

d. **Automotive Suppliers**
R&D, focusing on integration, system reliability, and sensor development. Develop tools and techniques. Research funding.

e. **Software and Content Suppliers**
Consumer R&D. Development of tools and techniques. Research funding.

f. **Other Technology Providers** (including communications carriers and computer suppliers, etc.) R&D. Build infrastructure to support MIS and DA systems. Provide R&D funding.

g. **Private Research Laboratories**
For-profit R&D.

h. **National Laboratories**
Carry out Federally sponsored R&D. Participate in the development of industry standards.

i. **University Research Facilities**
Focused research. Support and participation in standards development activities.

j. **Professional Organizations (e.g. SAE/IEEE/TRB)**
Promote and write standards.

k. **Transportation Consultants**
Independent evaluation and testing. Cooperative research. Standards Development.

l. **Consumer Groups and Other Stakeholders**
Address environmental concerns. Facilitate public-private cooperation.

m. **State and Local Government**
Testing and program participation.

Research Frameworks Breakout Group

Overview

As with many emerging, high technology areas, engaging in Intelligent Transportation Systems R&D is a high risk, high reward proposition.

Many factors must be taken into account when fashioning an R&D strategy, among them

- Cost
- Availability of necessary expertise, facilities, and other finite resources
- Intellectual property rights

- Desirability of market-driven or standards-driven consistency (versus product differentiation)
- Market timing
- Impact on competitiveness
- Impact on national safety
- Participation; and
- Roles (i.e., who does what within the R&D project).

In many cases, individual firms have neither the resources nor the expertise to engage independently in a comprehensive research program. Many creative solutions to this R&D dilemma have been fashioned, including cost sharing arrangements among firms or between Federal and state governments and industry. Some examples

- *Vertically integrated research consortia* that bring together a number of several unlike but cooperative players. For example, an automotive manufacturer, an electronics manufacturer, a communications company, plus consultants and/or university researchers pursuing joint research.

- *A horizontally integrated research consortium* which includes firms that are potential competitors in the ITS market, but who join together to perform pre-competitive research that is in the common interest of all participants. Horizontally-integrated research consortia enable research on a scale that would be impossible for any firm alone. Examples of this type of R&D partnership include joint research among automotive manufacturers or among automotive electronics manufacturers, with only incidental participation from other players.

- *A public-private research consortium* (e.g. SEMATECH), with members drawn from U.S.-owned firms and the U.S. Federal government. Member dues and Federal funding support the consortium's activities. Research is carried out by private firms acting as independent contractors or, where appropriate, under the auspices of the consortium itself. The consortium puts a priority on R&D areas that have the potential to become fully-realized, manufactured products in the near-term, but for which pre competitive research is needed prior to commercialization.

- *Cooperative Research and Development Agreement (CRADA) model* is a contractual agreement through which a government lab and one or more partners outside of the Federal government agree to collaborate, share costs, and pool the results of a particular research and development program. The laboratory may provide its partners with personnel, facilities, equipment, or other resources, but not typically funds. The non-Federal participants may provide funds, personnel, equipment or other resources to conduct specific research and development efforts that are consistent with the mission of the laboratory or facility. Private researchers usually have the option to negotiate exclusive licenses on inventions made under the research program of the agreement.

- *Scientific User Facilities:* A private sector entity may submit a research proposal to use Federal laboratories and facilities. Proposals are peer reviewed for appropriateness and quality and approved based on scientific merit. The government will not charge the user for use of facilities if the results are published. If the work is proprietary, the user must pay the full cost for the use of the lab or facility.

- *Technical Personnel Exchanges:* Exchanges conducted through specific research and development programs or arranged on an informal basis with laboratories or facilities.

Research Issues Breakout Group Instructions

Two breakout groups (E1, E2) were asked to consider the appropriateness and feasibility of different research models for the research

priorities identified by the DA, MSI, and HF&S breakout groups.

The top 3-4 topics from each breakout group on Day 1 were chosen. For each, it was determined whether the research constituted basic R&D, applied R&D, or commercial R&D. The level of risk for each topic (on a scale of 1-5, with 5 being very high-risk) was assessed, and the elements that contributed to this risk evaluation were identified, including

- Time to market;
- R&D cost;
- Availability of expertise to perform research; and
- Availability of suitable research facilities.

The second part of the breakout groups' instructions were to identify the R&D model most appropriate to carry out each research topic. The following models were identified, though group members were encouraged to add to this list as needed:

- Private-sector industrial consortium;
- Public-private sector research consortium;
- Publicly funded research program carried out in the national laboratory system and universities; and
- Publicly funded research program carried out by private firms and universities, based on competitive proposal selection.

Research Issues Breakout Group Results

During the breakout sessions, several high-priority research topics and corresponding research models were identified. In the MIS area, *end-to-end security* was identified as a crucial technology need. Group members did not agree what stage of research was needed, however. Some characterized the research as commercial and others applied. Participants believed that end-to-end security could be achieved between 1999-2001, and that research costs would be moderate. Because the computer and information technology industries have done prior work in this area, existing facilities and expertise are in abundance. A number of research models may be appropriate in this R&D area, including independent efforts, private sector consortia, and joint public-private efforts.

Participants believed that improved wireless connectivity, particularly service quality and the ability to establish dynamic connections, would hasten the development of both MSI and DA systems. Public-private research consortiums and publicly funded research carried out by private firms based on competitive proposal selection are the most appropriate research models for this topic. Breakout groups noted that this was a high-risk R&D area due to the high start-up cost of establishing wireless communications networks.

Voice recognition research and the development and refinement of *predictive traffic models* are two other important research topics in the MSI arena. The risk and cost of voice recognition research is high. Workshop participants noted that these gating factors are mitigated to some extent because existing work in this area has already been undertaken in the computer and information technology industries. Due to the immediate commercial rewards of voice recognition technology, private sector firms working jointly or independently should pursue this research.

The creation of predictive traffic models has been an elusive goal in the ITS industry for some time. However, the escalating traffic problems on the nation's roads only increase the value of research in this area. Participants tended to believe that universities are best positioned to conduct predictive traffic modeling research.

In the DA arena, *further development of sensor technology* was given paramount importance. Developing sensing technologies for the roadway and other vehicles requires the integration of many technologies that are at different stages of maturity, which poses an added challenge. Due to high research costs, a joint public/private, government-funded consortium is a favored research model.

Fusion of multiple sensors was another targeted area for research. While many sensor technologies are already available, basic sensor technology still needs improvement. Because research in this area is relatively advanced

compared to other R&D areas, this research can be funded and carried out by private sector automotive suppliers and manufacturers working independently.

Improved mobile positioning made possible through reliable location referencing, vehicle positioning, and highly accurate digital maps, is another high-priority R&D area. This research topic will require both basic and applied research. Workshop participants identified only moderate risk in this area and recommended that private sector industrial consortiums lead this research effort. Pubic-private research consortiums could supplement these independent, non-collaborative efforts, if needed.

System management issues were identified as an extremely urgent research need. How *probe data* (gathered from appropriately equipped vehicles) would be gathered and disseminated was characterized as a high-risk R&D area for private sector firms. Establishing a private sector industrial consortium can reduce this risk. After some basic research has been conducted within a collaborative environment, firms would be free to pursue independent R&D.

There was unanimous agreement that *human factors* for both MSI and DA systems were a pivotal issue for the in-vehicle computing/ITS industry. For DA systems, research on warning content and modality was noted as the most crucial short-term research need. With imminent DA product deployment, group members recommended that this research begin immediately. An open, industrial consortium is one possible research mechanism. Others noted that, due to the safety implications of in-vehicle user interfaces, government funding and participation by the national laboratories are justified.

Managing information for the driver was another area was deemed important to the future of in-vehicle computing. Human factors expertise has been historically scarce. Given this limitation, a collaborative, publicly funded human factors research agenda is ideal. Pooling resources will provide the speed of results needed, particularly in light of imminent DA and MSI system deployment. After much discussion, group members agreed that the appropriate R&D model would be a publicly funded research program carried out by universities with buy-in from key industrial parties. Some group members suggested pursuing a two-phase approach. *Integrating Driver Assistance warnings* was seen as an initial research step, to be completed within 3-5 years. Once warnings and messages from DA systems are made consistent across the industry, *integration of all IVI messages and warnings* should be pursued. This second stage of harmonization would be conducted in the 5-8 year time frame.

More broadly, participants underscored the need for human factors guidelines and standards. The SAE Human Factors Committee, the International Standards Organization, and others are already beginning work in this area. Participants agreed more remains to be accomplished. Current human factors work focuses on *individual* DA and MSI systems. Better understanding of the human factors implications of integrated, multifunctional systems is needed. The goal is to create a consistent operating environment across car makes and models, and potentially across national borders.

CONSOLIDATED RESEARCH/PROBLEM STATEMENTS

CONTENTS

Please note the interrelated and reinforcing nature of problem statements #2-4. The results of research described in Problem Statement #2, *Driver Behavior and In-Vehicle Computing Systems,* will inform research undertaken in Problem Statements #3 and #4. Furthermore, it is recommended that Problem Statement #3, *Effective Modalities for Delivering Messages/Warnings to Drivers,* directly tie into the research effort described in Problem Statement #4, *An Information Manager to Prioritize Messages from Multiple In-Vehicle Systems.*

Format for TRB Research Statements:

1. **Title:** This should be specific and concise, preferably not exceeding 10 words, for inclusion in HRIS and TRIS.
2. **Problem:** A statement of the problem and the need, in one or more paragraphs.
3. **Objective:** A clear, concise, and specific statement of what the research is expected to achieve and the benefits that may accrue.
4. **Key Words:** For clarification purposes, suggest key words not apparent in the title.
5. **Related Work:** Provide a context for the proposed research by briefly describing related work currently under way or recently completed.
6. **Urgency/Priority:** A statement concerning the urgency or relevance of the suggested work to transportation needs in general, and/or an indication of the priority given this research need relative to other RPS generated by the committee.
7. **Cost:** Give best estimate of the cost of conducting the research proposal.
8. **User Community*:** A description of the audience that should receive this research problem statement (e.g., AASHTO, APTA, FHWA, NHTSA).
9. **Implementation:** A statement describing possible ways in which the findings of the proposed research might be implemented.
10. **Effectiveness:** Give a best estimate of the societal impacts of this research. If possible, describe the relevant measures of effectiveness.

* *Note that this is not the same as the end user community who will use the results of the research and development.*

CONSOLIDATED RESEARCH/PROBLEM STATEMENTS

PROBLEM STATEMENT #1

Title: Ensuring End-to-End System Security and Reliability of the In-Vehicle Computing Environment

Problem

Historically, there has been an effort to make automotive functions independent and self-standing. However, the widening availability of Driver Assistance (DA) and Mobile Services & Information (MSI) products is putting a new premium on cooperation among multiple, in-vehicle systems. It is likely that steady improvement in computing capacity will make an integrated computing environment technically feasible sometime in the next decade. This new focus on integration and cooperation is predicated on the need for advanced ITS systems to share information and components among each other for reasons of efficiency and effectiveness. The desirability of cooperation and integration must be balanced by the need for adequate protection in the event one subsystem fails or malfunctions.

The expanding array of advanced in-vehicle applications is increasing the importance of an extremely secure, reliable computing and communications environment. The criticality of end-to-end security and reliability is heightened because some of these systems, particularly Driver Assistance (DA) products, interact closely with basic vehicle operations, such as steering and braking. It is very important that continuous system operation is maintained even in the event that one of the vehicles' computing subsystems fails or malfunctions.

System security is also important. Spurious information must be kept away from safety-critical systems and the integrity of the vehicles' communications network must not be intentionally or unintentionally compromised. Moreover, the privacy of driver information contained in the in-vehicle computing system needs to be safeguarded. To accomplish this, architects must explore the use of firewalls, encryption and verification technology, and failsafe mechanisms to ensure the future in-vehicle computing environment is extremely reliable and secure.

Objective

This research agenda involves designing system architecture(s) to facilitate cooperation among multiple DA and MSI products. To begin, research will be conducted to identify minimum levels of reliability and security for the in-vehicle computing environment under all possible operating conditions. This research will address communications between vehicles and the outside world, communications between vehicle subsystems, requirements for sufficient system memory and processing power, data validation procedures, etc.

Architectural models that meet or exceed these requirements will be designed. System designers will create and test prototypes in accordance with these requirements. Designers will experiment with LANs and other vehicle networks to promote the exchange of information between subsystems. Prototypes will be tested for their security, reliability, and ability to manage numerous in-vehicle functions.

Key Words

Safety, system architecture, in-vehicle computing environment, failsafe mechanisms, firewalls, network security, LANs, WANs, wireless communications, Internet, black box, IDB.

Related Work

- Extremely valuable work in the area of system security and reliability has been done in the computing and IT sectors, particularly in the areas of encryption and verification technologies. It would be worthwhile to investigate if these results are applicable to the in-vehicle computing environment.
- Crash Avoidance Research Technology Support for Communications, Electronic Controls and Computers. This multi-phase

project funded by the NHTSA, helped to identify the main features of automotive computer and electronic interface architectures that may affect the deployment of advanced technology crash systems. This research project also determined the architectures, interfaces, and data flows needed to support the safety related ITS user services.

- SAE ITS Division is developing interface standards for ITS equipment operating in a vehicle or connecting to a vehicle or to a vehicle's on-board sensor suite. SAE is also progressing in its efforts to create a standardized ITS Data Bus (IDB). The IDB will simplify the inclusion of multiple ITS products in the vehicle by providing a standardized "plug and play" environment. Related work items include: ITS Data Bus Architecture Reference Model Information Report (J2355), ITS Data Bus Protocol Standard (J2366), ITS Data Bus Vehicle Gateway Reference Design Recommended Practice (J2367).

Urgency/Priority

Extremely High. While there has been serious effort to create secure, reliable MSI and DA subsystems, new challenges and vulnerabilities arise when systems are integrated with one another. To date, there has been insufficient attention given to end-to-end security issues in this holistic context. Vigorous research into the reliability of the overall in-vehicle computing environment is needed.

Cost

System-level management of multiple advanced in-vehicle systems is a vastly complex undertaking that will require the concerted effort of experts from inside and outside the ITS and automotive industries. As such, it will be a time-intensive and resource-intensive research agenda requiring $10 million to complete successfully. Defining minimum requirements for system security is a first step in this larger research framework and will cost approximately $1 million.

User Community

Basic architectural research is typically undertaken by automotive and systems manufacturers, and is regarded as highly proprietary in nature. As a result, the private sector has the most pivotal role in this research area. This is a large-scale effort that will require the joint effort of many different industrial parties. Vertical research consortia comprised of large computer and consumer electronics firms, automotive manufacturers, and other interested private firms are the most appropriate research mechanism. IEEE, TRB, SAE, and ITSA, ITE, universities, and Federal labs may also have potential roles in this project.

Implementation

Participating private sector firms in the consortia will use the results of this research to independently design an in-vehicle computing environment that supports the introduction of integrated MSI and DA products.

Effectiveness

By creating a safe and robust in-vehicle computing environment that can support multiple in-vehicle applications, driver and passenger safety and convenience will be greatly enhanced.

** Please note the interrelated and reinforcing nature of problem statements # 2-4. The results of research described in Problem Statement #2, Driver Behavior and In-Vehicle Computing Systems, will inform research undertaken in Problem Statements #3 and #4. Furthermore, it is recommended that Problem Statement #3, Effective Modalities for Delivering Messages/Warnings to Drivers, directly tie into the research effort described in Problem Statement #4, An Information Manager to Prioritize Messages from Multiple In-Vehicle Systems.*

PROBLEM STATEMENT #2

Title: Driver Behavior and In-Vehicle Computing Systems

Problem

New in-vehicle computing systems can be used to summon emergency assistance, broadcast urgent traveler advisories, and warn drivers if a vehicle is traveling faster than road conditions warrant. However, for all of these systems' safety-enhancing potential, poorly integrated and designed systems could contribute to unsafe driving.

Experts do not have a comprehensive understanding of how humans interact with vehicles, particularly with in-vehicle computing devices. For example, it is unclear whether Driver Assistance systems could give drivers a false sense of security and encourage them to take driving risks that they would otherwise avoid. There is also a fear that too many false alarms will distract drivers to the point that they will begin to ignore warnings altogether, even where there is immediate danger. There is strong consensus among human factors experts that there should be constraints on information exchanges between the driver and the HMI, though there has yet to be consensus on precise thresholds of acceptability.

Objective

This research will include studying driver behavior, both with and without the aid of Driver Assistance (DA) and Mobile Services & Information (MSI) systems. Researchers will assess driver performance using accepted human factors research models, simulation experiments, and real world road tests. Areas of investigation will include:

- How drivers interact with DA systems, particularly system operating characteristics;
- How drivers interact with MSI systems, particularly in operating and processing information from these systems in a dual-task environment (e.g., while driving);
- How drivers react when multiple in-vehicle computing systems are introduced into the vehicle.

The focus of this study will be on driver functions, not individual systems. Research will result in human factors guidelines for integrated MSI and DA systems. Guidelines will include, for example, metrics and redlines for driver workload and human thresholds for false alarms (point at which drivers will ignore warnings altogether). Special attention will be paid to publish human factors guidelines in a way that is useful for product developers. Specific, practical, easy to understand recommendations for integrated devices will result.

Key Words

Human factors, human-machine interface, cognitive skill, warning modality, driver attention, driver workload, operating characteristics.

Related Work

- The SAE Safety and Human Factors Committee is currently developing standards in the following areas: adaptive cruise control (ACC) human factors, forward collision warning (FCW) human factors, and measurement of visual workload.

- An in-vehicle information systems behavioral model is being developed at Virginia Polytechnic Institute, with Federal funding. A design support system will also be developed, consisting of a set of human factors tools to aid in the design of in-vehicle information systems (*due for completion: 1999*).
- FHWA, New Jersey DOT, New Jersey Highway Authority, TRANSCOM, and Hughes have provided oversight for FHWA's Human Factors group projects between 1994-1998. Partners in this effort offered guidance in transforming empirical human factors research into design guidelines, and focused on both integrated and independent systems.

Urgency/Priority

Extremely high. MSI and DA systems are arriving in the market in the absence of a clear understanding of how they might interact with one another and with drivers. Focused attention on the human factors of integrated, in-vehicle systems is essential for these products' ability to enhance the safety and convenience of travel.

Cost

Approximately $1.5 million.

User Community

This research will be led by the public sector, with substantial private sector participation, such as component suppliers and automotive manufacturers. SAE, TRB, and Federal labs are four possibilities.

Implementation

The guidelines that result from these studies will be used by system designers to create a human-centered driving environment.

Effectiveness

Straightforward human factors guidelines to govern the integration of multiple in-vehicle ITS products will improve public safety and the effectiveness of these products for widespread public use.

PROBLEM STATEMENT #3

Title: Effective Modalities for Delivering Messages/Warnings to Drivers

Problem

Drivers need a predictable way of receiving information from in-vehicle systems that are consistent across car lines and vehicle models. Otherwise, drivers can be surprised or confused by messages that are presented in ambiguous or unfamiliar manners (e.g., receiving a haptic response from a curve warning system when the driver is accustomed to auditory warnings).

Objective

Global literature review of prior research in the area of effective warning/message modalities for in-vehicle systems. Undertake additional cognitive and behavioral research, as needed. Develop a series of guidelines to ensure that integrated DA/MSI systems are designed in accordance with human information processing capabilities in a demanding driving environment.

Key Words

Driver Assistance systems, Mobile Services & Information systems, icons, GUIs, speech synthesis, haptic warnings, HMI, MMI, DVI, human factors.

Related Work

Prior research has been done in the area of effective display modalities for single-function in-vehicle systems, such as navigation and backup warning devices. This research topic needs to be expanded to deal with multifunctional, integrated systems. Prior and current work includes:

- SAE Safety and Human Factors Committee is undertaking standards development in the following areas: adaptive cruise control human factors, forward collision warning human factors, message priority and access to navigation functions in moving vehicle, and measurement of visual workload.
- Battelle Transportation Research Center has received Federal funding to conduct research into in-vehicle display icons and other information elements. Optimal modes of conveying information types (e.g., routing, safety advisories, traffic information, crash avoidance warnings) will be identified. While icons are the predominant research focus, text and aural messages are also being considered (*due for completion: 2000*).
- Advanced Traveler Information System (ATIS) Guidelines developed by Battelle under contract from the FHWA detail recommended practices for presenting ATIS/CVO information, such as traffic advisories, to drivers.
- Calspan Corporation, under contract with the Federal government, developed human factors (as well as hardware performance) requirements for intersection collision avoidance systems. Autonomous vehicle-based systems, vehicle-vehicle communication systems, and cooperative highway-vehicle systems requiring instrumentation of intersections were all considered.
- Between 1991 and 1996, COMSIS, Inc. (later acquired by Westat) received funding from NHTSA to develop human factors guidelines for in-vehicle warning systems. Empirical research enabled COMSIS to determine acceptable HMI design characteristics, human tolerance levels for false alarms, and ways to deliver effective acoustic alarms for rear object crash avoidance systems.

Urgency/Priority

High. Sufficiently consistent display modalities are essential for warnings to elicit the appropriate driver response. Otherwise, warnings may surprise drivers, thereby creating a potentially hazardous driving situation.

Cost: Approximately $1.5 million.

User Community

System developers, SAE, TRB, and IEEE.

Implementation

This research will culminate in a series of guidelines that will be developed and agreed upon by interested industrial parties. These guidelines will serve as informal specifications for system designers, and may become adopted as industry standards.

Effectiveness

Automotive manufacturers and suppliers have traditionally differentiated HMIs as a way of gaining competitive advantage in the market. Working toward consistent warning modalities will require unprecedented collaboration and is essential for realizing the safety-enhancing potential of DA/MSI systems.

Problem Statement #4

Title: An Information Manager to Prioritize Messages from Multiple In-Vehicle Systems Problem

Driver Assistance (DA) and Mobile Services & Information (MSI) systems are being readied for deployment and, in some cases, have already been introduced to market. The presence of multiple DA and MSI systems in a vehicle can result in simultaneous, potentially conflicting messages to the driver.

In order to maintain a safe driving environment, messages must be prioritized so the driver is presented with the most critical information first and is not unduly distracted from his/her primary task, safe vehicle operation.

Objective

In-vehicle messages from multiple MSI and DA systems will be codified, prioritized, and integrated through the creation of rules and guidelines for an information manager. The information manager will act as a gateway for information flows to the driver. System-level analysis of how to manage information flows between in-vehicle applications will be undertaken, with particular attention to situations where messages could conflict with one another. To accomplish this, standardized messages for integrated in-vehicle computing systems will be developed and prioritized based on urgency. Safety-critical information, for example Driver Assistance warnings, will be given higher priority than convenience-enhancing information, such as traffic updates. Efforts will be made to eliminate redundant messages to the driver so minimal attention is required for drivers to interact with the in-vehicle computing systems.

This research will culminate in a series of recommendations for creating an information manager. Automotive manufacturers can then build unique implementations that conform to these general specifications.

Key Words

Message sets, Driver Assistance systems, Mobile Services & Information systems, driver workload, databus, protocols, guidelines, standards.

Related Work

- Development of an in-vehicle information system (IVIS) is under way at Oak Ridge National Labs (ORNL). The ORNL IVIS Project aims to create an integrated driver-vehicle interface for multiple in-vehicle information systems such as in-vehicle signing, routing and navigation, real-time traffic, motorist services, and collision avoidance subsystems. Operational tests are planned and three workshops have been held.
- The SAE In-Vehicle Systems Interface Committee (IVSIC) has focused on developing standardized message sets and data dictionaries for route guidance and ATIS applications, as well as Mayday services.
- The SAE Safety & Human Factors committee is developing an ITS In-Vehicle Message Priority standard (J2395).

Urgency/Priority

Extremely high. Some DA and MSI systems are already deployed and more will be introduced to market soon. A framework and mechanism for integrating messages must precede mass-market penetration of these systems if they are to enhance road safety.

Cost

This research agenda entails a two-phase approach. The first phase will be a paper study to identify the universe of potential in-vehicle messages (including, but not limited to DA and MSI) and develop an architectural schema for prioritizing and filtering these messages. Estimated cost: $100,000.

The second phase of this project will be to create an information manager based on the recommendations/guidelines set forth in the paper study. The information manager will be prototyped and tested at an estimated cost of $2.5 million. The project is expected to be 2-3 years in duration.

User Community

NHTSA, FHWA, TRB, ITS America, SAE, universities, Federal laboratories, and system developers.

Implementation

System developers will use these guidelines and initial prototypes to design commercial products that will safely interact with other in-vehicle systems and with the driver.

Effectiveness

This research is essential for driver acceptance and will have a positive impact on public safety. Having guidelines and/or recommended practices in place prior to system deployment will reduce development costs (as opposed to retro-fitting products).

PROBLEM STATEMENT #5

Title: Wireless Communications to Support In-Vehicle Computing Systems

Problem

Many Mobile Service and Information systems, including traveler information, mayday, roadside assistance, and dynamic route guidance rely on the delivery of perishable, time sensitive information to the driver. Real-time delivery of information from central sites to vehicles requires affordable, reliable, high-quality wireless service. Wireless communications is also an important enabling technology for Driver Assistance information systems, because it enables vehicles to receive extremely accurate information about the road and surrounding vehicles.

Existing wireless technologies have been used in ITS applications with modest success, such as cellular, packet data networks, and radio systems. Each of these networks has drawbacks, however, such as prohibitive expense, limited geographic coverage, and inconsistent service quality. Current wireless limitations constrain ITS product offerings, functionality, and service quality.

Objective

This research will explore how to optimize existing wireless networks for in-vehicle computing applications. Research will be a preliminary step towards the establishment of wireless data communications protocols for in-vehicle computing. Ideally, wireless communications will support

- Seamless, nationwide coverage;
- Vehicle-vehicle communication;
- Vehicle-roadside communication;
- Internet connectivity (e.g., for PC-based office applications, etc.);
- Voice delivery (e.g., for roadside assistance services, etc.);
- Video images (e.g., for in-vehicle; entertainment systems, etc.); and
- Data transmission (e.g., for map database updates, etc.).

Key Words

Wireless communications, FM Subcarrier, DSRC, cooperative AVCSS, wide area communications, data networks, Driver Assistance systems, Mobile Services & Information systems, ATIS, Internet, in-vehicle entertainment, CDMA, TDMA, GSM, roadside-vehicle communications, vehicle-vehicle communications, LEOs, GEOs, spectrum allocation, FCC.

Related Work

- The FHWA is sponsoring an investigation into the communications technologies and issues associated with ITS systems. Wireless and wireline communications will both be considered, along with associated protocol and spectrum allocation issues. Preferred communications alternatives will be recommended for specific ITS functions.
- In May 1997, ITS America filed with the Federal Communications Commission (FCC) a petition to request that the frequency band between 5850-5925MHz be reallocated to allow DSRC (Dedicated Short Range Communications) services to operate in the band. DSRC is the communications link identified by the ITS National Architecture to support 11 existing, emerging, and future ITS user services.
- Federally-sponsored Model Deployment Initiatives are experimenting with a variety of wireless communications technologies on a regional basis. One example is the San Antonio TransGuide project, where the Texas DOT (in association with AlliedSignal Technical Services Corporation, Southwest Research Institute, and Texas Transportation Institute) installed a communications infrastructure to support ATIS/MSI applications, including a digital communication network that supported voice, data, and video and a redundant fiber optic network.
- PATH is creating an integrated physical/link-access layer model of packet radio architectures to support vehicle-roadside and vehicle-vehicle communications used in both DA and MSI applications.
- Experimentation with wireless technologies for DA and MSI applications has also occurred in Europe and Japan, through the PROMETHEUS and VICS projects, respectively.

Urgency/Priority

High. Delivery of real-time information to the vehicle is an enabling technology for many advanced in-vehicle applications. More rigorous research into wireless connectivity is needed to support the rising need for real-time data delivery, including a host of new, bandwidth-intensive ITS applications (e.g. in-vehicle entertainment systems, Internet connectivity, etc.).

Cost

This is a technically challenging area of research that will require, at minimum, $4M for a combination of basic and applied research. Ideally, this research should to be carried out as a piece of a larger, more comprehensive public-private research agenda focusing on improving wireless communications.

User Community

SAE, TIA, ITS America, ISO TC204/WG16, ITE, communications providers and information service providers, EIA/CEMA, CTIA, and ITU.

Implementation

Results of this research will make information service providers better able to communicate real-time traffic information, including traffic delays, weather reports, dynamic route guidance, and hazardous road conditions to en-route travelers. Improved wireless communications will also benefit the PSAP/Emergency response community by helping them to reach disabled vehicles more quickly. Wireless communications technology is a linchpin for a number of other applications, including: in-

vehicle office and entertainment functions, electronic toll collection, transmission of probe data from equipped vehicles, and may be essential for some Driver Assistance functions such as adaptive cruise control, curve warning systems, etc.

Effectiveness

Local, state, and regional government agencies will use the results of this research to increase the effectiveness of public sector emergency services. Improved wireless communications is also expected to have positive effects on traffic congestion by allowing drivers (through ATIS service) to optimize their routes according to current travel conditions and thereby increase the efficiency and productivity of the nation's transportation infrastructure.

PROBLEM STATEMENT #6

Title: Sensor Development

Problem

Many next-generation in-vehicle computing applications, particularly Driver Assistance systems, depend on the availability of affordable, reliable sensor technology. Further development and refinement of sensor technology is needed, especially attention to increasing sensor accuracy and affordability, and the improvement of sensory conclusions, by fusing information from multiple in-vehicle sensors.

Objective

This research problem requires two mutually reinforcing research programs. The first is to conduct a combination of basic and applied R&D to refine basic sensor capabilities. Improving the ability to sense the roadway and other vehicles requires integrating existing sensor technologies in different stages of maturity, which poses substantial challenges. The second, concurrent research program will be devoted to developing mechanisms for fusing sensors, which will require basic R&D. Effort should be made to apply research results towards the development of performance guidelines for in-vehicle sensor technologies.

Key Words

Sensors, sensor fusion, Driver Assistance systems, AHS, lidar, radar, CCD, AVCSS, map database, microwave, laser.

Related Work

- This recommended research program should leverage results from the Federally funded National Automated Highway System Consortium (NAHC). The NAHC demonstration showcased important sensor research that can be built upon in future R&D efforts; and
- At the Berkeley Sensor and Actuator Center (BSAC), PATH has undertaken research in integrated microsensors to support vehicle control. PATH is also involved in developing a machine vision based system for guiding lane following and lane change maneuvers and sensor validation and fusion work to support vehicle control.

Urgency/Priority

Medium-High. Reliable and affordable sensor technology is a linchpin for DA systems, such as adaptive cruise control and obstacle warning systems.

Cost

Refining basic sensor technology will cost approximately $5 million a year over five years. Fusing multiple vehicle sensors is expected to cost approximately $2.5 million a year over five to eight years.

User Community

Much of the development and refinement of sensor technology is already being undertaken in the private sector, and this will remain a primary research mechanism into the future. However, due to the technical complexity of sensor R&D, it may be necessary to pool resources and expertise from private firms, universities, and public facilities in targeted research areas. Follow-on efforts to create performance guidelines based on research results should be undertaken. Potential users include: SAE, TRB, FHWA, IEEE, and ITE.

Implementation

Results of this research will help advance the development of Driver Assistance products. Sensor information can also become probe data for traffic information services. For example, a vehicle instrumented with appropriate sensors can communicate sensor data to a traffic management center. The center, in turn, can pool this data with information from other sources to determine the location of severe traffic congestion and use this information to generate real-time traffic reports/dynamic routing.

Effectiveness

Increasing the sophistication of sensor technology will hasten the development of life-saving Driver Assistance products. The ability to fuse data from multiple sensors will enable sensor data to be shared across applications, putting a downward pressure on the cost of Driver Assistance products. Pooling information from multiple in-vehicle sensors also enables data to be compared, validated, and reduced thereby reducing the incidence of false alarms and streamlining information flows to the driver.

PROBLEM STATEMENT #7

Title: High-Quality Voice Recognition

Problem

Voice-activated HMIs are viewed favorably in the ITS community for their potential to reduce driver workload and promote ease-of-use, particularly with new Mobile Services & Information systems. While there have been significant inroads in the development of voice recognition in the computer industry, this technology is not yet robust enough to work well in the driving environment.

Objective

Conduct further voice recognition research, with an aim to provide affordable, speaker-independent, natural language voice recognition technology that can operate in driving environments with high levels of ambient noise.

Key Words

HMI, MMI, Mobile Services & Information systems, user interface, speech synthesis.

Related Work

There has been a large-scale effort to improve voice recognition technology in the computer industry. The ITS industry should leverage this work and expand it to address the special conditions encountered when using VR systems in moving vehicles. Prior R&D to optimize VR technology for the in-vehicle environment has been done in the private sector.

Urgency/Priority

Medium-High. Voice recognition technology is expected to improve regardless of the attention it receives from the ITS industry. However, VR technology is considered by many to be a preferred MMI in vehicles, which makes it of

special interest in the ITS field. There is sufficient incentive to accelerate the introduction of this technology into vehicles by addressing the special needs and constraints posed by VR in the driving environment.

Cost

Despite prior investments in this area, new expenditures on VR research are expected to be quite high, amounting to approximately $5 million.

User Community

Due to the immediate commercial potential for robust VR technology, information technology firms working independently or in concert with vertically-related firms are the most likely research mechanisms (e.g., privately-funded vertically-integrated research consortia).

Implementation

The results of this research will be selectively shared among participating research parties, who will use the results to generate profit in the IT and ancillary markets.

Effectiveness

VR is expected to promote ease-of-use for MSI/DA systems, and by consequence, encourage their adoption. Creation of robust VR technology will also have immediate, positive spillovers on many computer-related markets, and can become a source of competitive advantage for US products worldwide.

PROBLEM STATEMENT #8

Title: Creation of Predictive Traffic Models

Problem

Despite serious efforts to create predictive traffic algorithms, a robust and reliable model has yet to be developed. Data collection methods/infrastructure, an essential input to the algorithm development process, needs to be improved. A renewed commitment to research in this area is needed, in light of increasing congestion on U.S. roads and the advent of advanced traveler information systems that can use these traffic models to help optimize traffic flow.

Objective

Develop predictive traffic models and measure their reliability and accuracy in FOTs. Assess ways that data collection can be improved.

Key Words

ATIS, traffic information, algorithms, data collection.

Related Work

- Oak Ridge National Labs has received Federal funding to create a Real-Time Dynamic Traffic Assignment (DTA) system. The DTA system will be able to estimate and predict traffic network states, in addition to other functions (*due for completion: 2000*).
- The University of Michigan Transportation Research Institute (UMITRI) is conducting traffic modeling research to support dynamic route guidance and coordinated signal control. The objectives of this research are to develop models and algorithms based on time-dependent link travel time predictions.

Urgency/Priority

Medium-High. Over the coming years, congestion on the nation's roads will continue to escalate. Increasing traffic will have a negative impact on the productivity of the nation's distribution system and workforce, as well as the environment. Multiple efforts need to be undertaken to reduce the strain on the nations' road infrastructure. Predictive traffic models, coupled with a robust traffic speed collection infrastructure, are promising steps in this direction.

Cost

Data gathering and improvement of collection methods, factor analysis, model building, experimentation in multiple environments, and refinement are expected to cost approximately $6 million. Field tests will cost approximately $100,000 in each of four recommended test beds (sites TBD).

User Community

Universities are the most appropriate entities to carry out this research, in addition to public sector organizations, such as Federal laboratories. Public research entities may chose to partner with private firms that have demonstrated expertise in this area.

Implementation

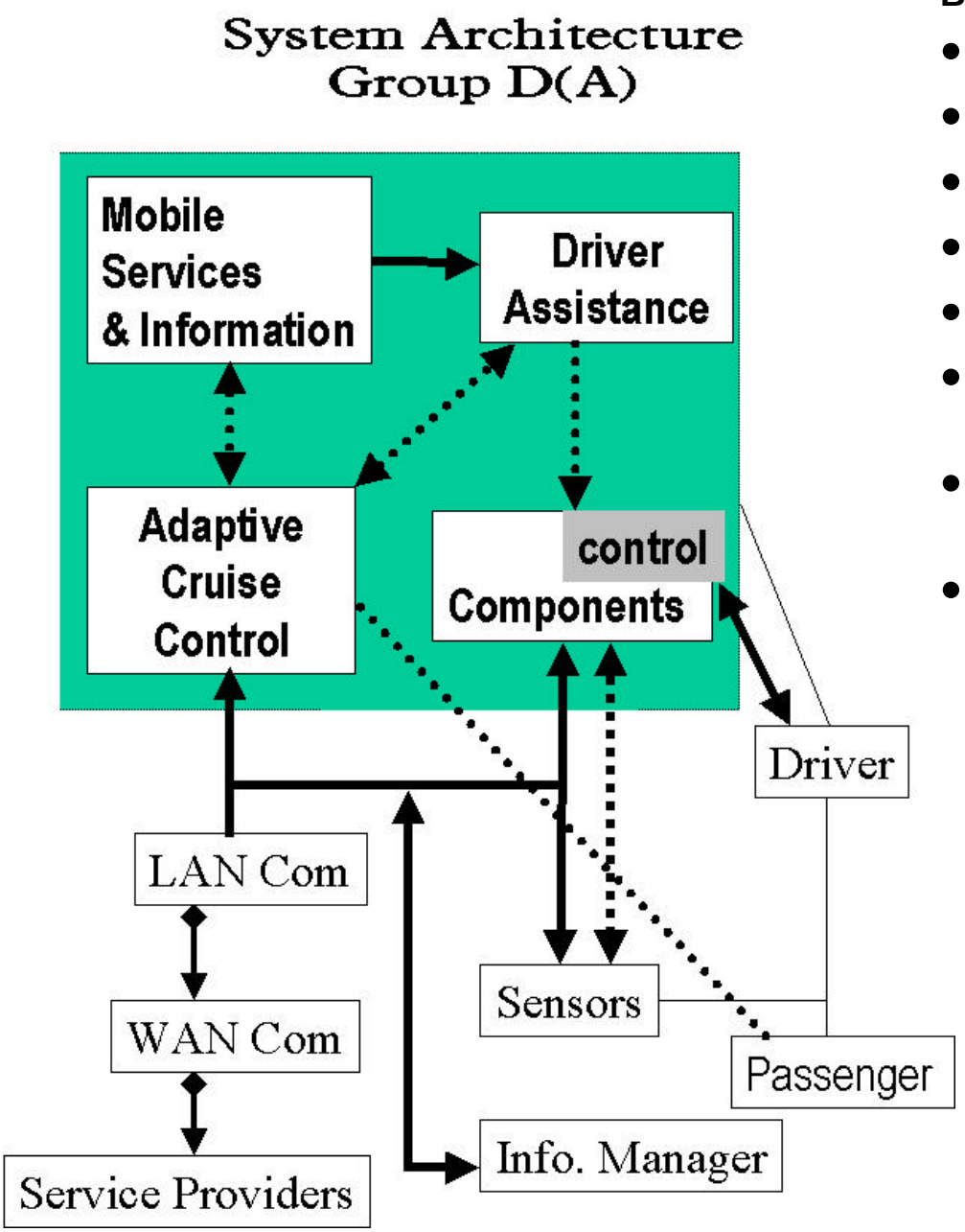
Reliable data collection and traffic modeling programs will be used by state DOTs to help predict and mitigate heavy roadway congestion. Navigation system developers may use traffic data to support dynamic routing. Traffic management centers may also use data and predictive models to advise drivers when poor travel conditions prevail.

Effectiveness

Reducing congestion on the nation's roadways will result in a quality of life improvement for commuters and fleet operators. Using predictive traffic information (to redirect travelers to alternate routes and/or suggest alternate travel times) will also increase the productivity of the nation's transportation infrastructure.

VI. Appendix A: System Integration Results

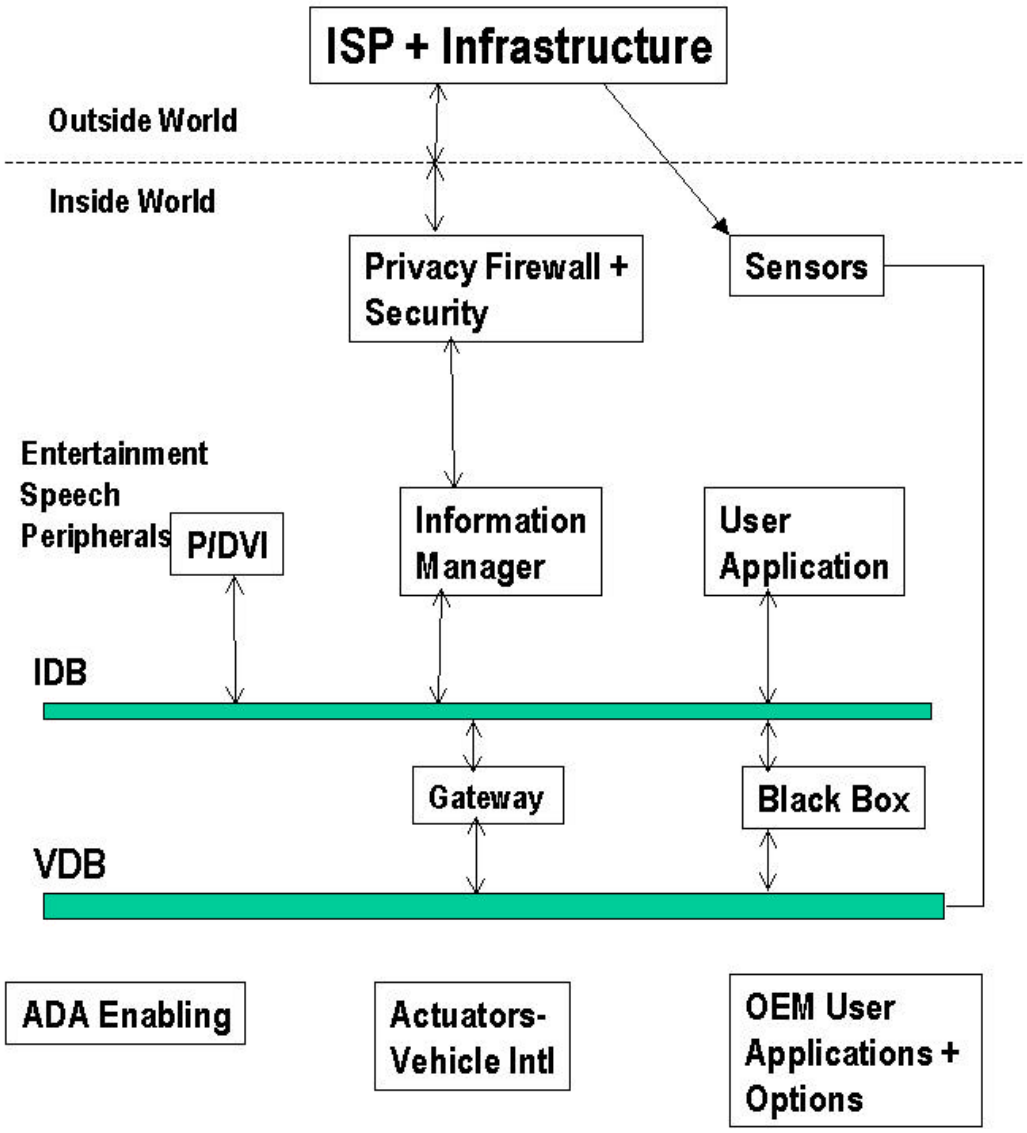
Issue	Effort Required?	Risk Factors?	Institutional and/or Technical Issues?	Who to Sponsor? Participate? Benefit?
Other (specify): **Information Manager** - **Prioritization** - **Driver/ Passenger Access** - **Overload**	**Moderate to extensive**	**Non-technical/ Institutional issues**	**Institutional: Standards and guidelines** **Technical Issue: Feasibility**	**Sponsor: TRB** **Participants: Vendors** **Benefactors: Public & Vendors**
Other (specify): **LAN or Vehicle Network**	**Moderate to extensive**	**Lower than but dependent upon it**	**Institutional: Standards and guidelines** **Tech Issue: Strongly technical**	**Sponsor: SAE** **Participants: SAE community** **Benefactors: Drivers & Industry**
Other (specify): **Decision Making**	**Limited**	**Getting funding**	**Institutional**	**Sponsor: Feds** **Participants: Universities** **Benefactors: Drivers & Universities**



Building Blocks

- DA Products
- MSI Products
- Sensors
- Service Providers
- Firewalls
- Communication (LAN and WAN)
- Vehicle Components
- Vehicle Accessories

System Architecture - Group D(B)



Building Blocks

- DA Product Classes
  - Warnings
  - Control Impacting
- MSI Product Classes
  - Comm. Devices/Office Fits
  - Entertainment
  - Driver Guidance (info. to driver)
  - Personal Security
- Sensors
- Vehicle Devices
  - Brakes
  - Steering
  - Display screens
- Service Providers
  - Communication to outside world
- Firewalls
  - VDB Integrity
  - Privacy
  - Message integrity, etc.
- Information Management (to driver)/System Administration
- Black Box
  - DA enabling

VII. APPENDIX B: RESEARCH MODELS BREAKOUT GROUP RESULTS

FILL IN THE TOP 3 MSI RESEARCH TOPICS:	End-to-End Security	Voice Recognition	Predictive Traffic Models
What Research Stage?	Commercialization	Applied R&D	Applied R&D
Time to Market?	1-3 years	3-5 years	5-8 years
R&D Cost?	Medium	High	Medium
Available Expertise?	Abundant	Abundant	Scarce
Availability of Suitable R&D Facilities?	Abundant	Abundant	Abundant
Other (Please specify)	Existing work in the computer/IT industry to draw upon (e.g., resources available outside ITS sector)	Existing work in the computer/IT industry to draw upon, e.g., resources available outside ITS sector)	
Level of Risk?	Low (1)	Moderate-High (4)	Very High (5)
Which R&D Model?	Independent Effort Or Private Sector Consortium	Independent Effort	Publicly funded program carried out by private firms or academic institutions, based on competitive proposal selection
Who to Participate, Who to Lead Research?	Private Sector IT Companies	Private Sector IT Companies	Universities

**** Note: there are enough possible facilities to use, but they are not currently addressing this issue.***

FILL IN THE TOP 3 DA RESEARCH TOPICS:	Fusion of Vehicle Sensors	Sensing of Roadway and Other Vehicles	Warning Content & Modality
What Research Stage?	Basic R&D	Basic/Applied*	Commercialization
Time to Market?	5-8 years	5-8 years	1-3 years
R&D Cost?	Medium	High	Low
Available Expertise?	Available	Available	Available
Availability of Suitable R&D Facilities?	Available	Available	Available
Other (Please specify)	Basic sensor capability needs improvement	Need to integrate technologies at different levels of maturity	Product deployment imminent
Level of Risk?	Moderate (3)	Very High (4.5)	Low (1)
Which R&D Model?	Independent, private-funded efforts	Public-private sector research consortium	Private sector industrial consortium (open to all interested firms)
Who to Participate, Who to Lead Research?	Auto suppliers and manufacturers	Joint governance (similar to AHS consortium)	SAE

** Note: Enabling technologies at different stages of development.*
Note: Have research, need to coordinate.

VII. APPENDIX B: RESEARCH MODELS BREAKOUT GROUP RESULTS (cont.)

FILL IN THE TOP 3 HF&S RESEARCH TOPICS:	Integrate DA Warning to Drivers	Integrate all Driver IVI Messages	HF Guidelines/ Standards
What Research Stage?	Applied	Applied	Applied/ Commercialization*
Time to Market?	3-5 years	5-8 years	1-3 years
R&D Cost?	Medium	Medium	Low
Available Expertise?	Scarce	Scarce	Scarce
Availability of Suitable R&D Facilities?	Scarce	Scarce	Scarce
Other (Please specify)	Focus specifically on safety-critical systems.	Focus: Info. overload in general of all systems in vehicle.	Good templates for models and guidelines exist, need to apply them.
Level of Risk?	Low-Moderate (1)	Moderate (3)	Low (1)
Which R&D Model?	Publicly funded research program carried out by universities or private firms with buy-in from industry interests	Publicly funded research program carried out by universities or private firms with buy-in from industry interests	Publicly funded research program carried out by private firms
Who to Participate, Who to Lead Research?	Public-led	Public-led	Public-led

**** Note: Last step toward commercialization.***

VIII. Appendix C: Application Definitions & General Glossary

ABS - Antilock braking system.

ACN – Automated collision notification. Systems that solicit assistance from an emergency response provider automatically upon impact of collision or when automated vehicle diagnostics detect mechanical failure. The emergency response provider will locate the vehicle on the road network and dispatch immediate assistance.

Adaptive cruise control - Systems that helps vehicle maintain a safe interval to the vehicle ahead.

Address book/calendar access and management - Enables the en-route traveler to access and modify a personalized address book and appointment calendar program.

AHS - Automated highway system. Operation of fully automated vehicles on specially instrumented freeway lanes, separated from manually controlled vehicles.

Algorithm - The method used to do a task, a computer program, for example.

ATIS - Advanced traveler information systems. Vehicle features and other media that give drivers information about traffic and transit conditions used to help plan trips.

AVL - Automatic vehicle location. A system that senses, at intervals, the locations of vehicles carrying special electronic equipment that communicates a signal back to a central control facility.

Bandwidth - The range of frequencies that a signal occupies, the larger the number of frequencies the broader the bandwidth.

Beacons - Short-range roadside transceivers that link vehicles and the traffic management infrastructure. Usually use infrared and/or microwave technologies in addition to vehicle transponders. Can be one- or two-way, such as dedicated short-range communications (DSRC).

Benefit-cost ratio - An analytical tool used in public planning; ratio of total measurable monetary benefits to initial capital cost.

Braking assistance systems - Sensors that automatically slow down/stop a vehicle if sensor information indicates the vehicle is in imminent risk of collision and/or running off the road.

Broadband PCS - Personal communications services offered in the United States in the 2-GHz spectrum.

CDMA - Code division multiple access. An advanced type of digital cellular (and PCS) that converts the human voice into a stream of digital information (includes a series of 1's and 0's) called a digital speech packet. The packet is transmitted via a wide band channel consisting of several radio frequencies.

CDPD - Cellular digital packet data. Sending digital data over the existing AMPS system by transmitting dense packets on vacant analog channels.

Cellular telephone - Mobile and portable radio telephone service that uses networked base stations or cells.

Collision warning systems - Systems that warn drivers when a vehicle is in danger of impact.

Concierge services - Services that allow drivers to make reservations and access other point of interest information, such as hotel room and restaurant reservations, airline and theater ticket purchases, etc. These services require a dynamic wireless voice link between the traveler and service provider(s).

Curve warning systems - Systems that alert drivers (or automatically slows vehicles) when a curve is being approached too fast.

CVO -Commercial Vehicle Operations. Addresses applications of ITS technologies to commercial roadway vehicles (trucks, commercial fleets, intercity buses). Many CVO technologies enable automated, no-stop-needed handling of the routine administrative tasks that have traditionally required stops: toll collection, road use calculation, permit acquisition, vehicle weighing, etc.

DAB - Digital audio broadcasting.

Data dictionary - A catalog of all data types in a given system giving their names, structures, usage information. Advanced data dictionaries can represent and report on the cross-references between components of data and business models.

Data model - A logical map of data representing the inherent properties of the data independent of software, hardware, and machine performance considerations.

Database - A collection of interrelated data sorted with controlled redundancy to serve one or more applications. Data are stored independently of programs that use the data, and a common and controlled approach is used to add, modify, and retrieve data.

Dead reckoning - Calculating a vehicle's current location by measuring the distance and direction traveled since leaving a known starting point.

Demand resolution software - Used to determine how the display screen, common channel, brakes, etc. are handled in the event there are simultaneous demands from multiple applications.

DGPS - Differential global positioning system. Land station method of improving GPS accuracy to compensate for U.S. Department of Defense-imposed selective availability encryption.

Digital - A method of storing, converting, and sending data as binary digits (0s and 1s).

DOT - Department of Transportation, U.S.

Driver preference adjustment - A function which allows a driver to automatically adjust vehicle mirrors, suspension, seats, shift points, radio buttons and volume, HVAC settings, etc. based on individualized presets.

Drowsiness warning systems - Systems that are instrumented to alert drivers if they become fatigued. By monitoring the driver (eye closure, etc.) or vehicle handling, such as lane-keeping, the system will issue an auditory, haptic, or other warning if the driver appears at risk.

Dynamic route guidance - Route guidance enhanced with current traffic information. Centrally assembled digital traffic information is transmitted to vehicles to permit real-time route adjustments to optimize travel. In this arrangement, more technology must be present in the car compared to standard route guidance systems.

EIA - Electronic Industries Association.

Engine compartment fire warning/extinguish systems - Systems that detect and extinguish engine fires in a wholly automated process.

Entertainment; self-contained - In-vehicle, computer-based entertainment applications designed for passengers, such as DVD movies and Nintendo. These applications are self contained in that they do not rely on dynamic communications with the outside world.

Entertainment; wireless, active - Interactive in-vehicle entertainment applications designed for passengers, such as multi-user games, viewer-chosen music and movies. These computer-based entertainment applications require two-way wireless communication between vehicles and service providers.

Entertainment; wireless, passive - Non-interactive in-vehicle entertainment applications designed for passengers, such as broadcast TV and movies. These computer-based entertainment applications require unidirectional wireless communication between a service provider(s) and the vehicle.

ETC – Electronic toll collection. Enables the collection of fees from drivers without requiring the vehicle to stop at toll booths. It also allows for more sophisticated billing systems; vehicles can be charged according to the time of day they travel, how far they travel, or how much they use congested traffic facilities. Distance-based toll collection can be open or closed. In an open system, vehicles pay at toll booths along the route. In a closed system, vehicles pay when they leave the tollway, based on total travel distance.

EU - European Union.

Extremely high-accuracy map database - Provides an accurate representation of the road ahead, including a high level of detail about road geometry and other physical characteristics required for advanced driving applications. Relevant road characteristics such as number of lanes, lane width, radius of road curvature, road grade, and banking information can be provided for the road network. A digital map can also provide information about static objects alongside or over the road. This information enables an equipped vehicle to map its current position and “look ahead” in the map, regardless of line of sight, to determine upcoming curves, hills, or objects that might cause false alarms in the image processing systems. With this information, the application can then calculate the equipped vehicle’s position relative to the upcoming road configuration and determine appropriate timing for an advance warning or notification, and if necessary, intervention at any given vehicle speed.

Fax/facsimile - A system of transmitting and reproducing graphic matter (as printing or still pictures) by means of signals sent over telephone lines.

FCC -Federal Communications Commission. Handles civilian requests for radio spectrum allocations and allotments in the United States.

FHWA - Federal Highway Administration. An administration of the U.S. Department of Transportation. By coordinating highways with other modes of transportation, FHWA seeks to achieve the most effective balance of transportation systems and facilities through cohesive Federal policies.

FM Subcarrier - An additional signal included in regular commercial broadcasts that transmits data or background music, used for driver information (see RDS and RDS-TMC).

FOT - Field operational test.

Gateway - A device allowing consumer products to interface with the communication system in vehicles, while protecting the vehicle's system from defective devices or inappropriate messages.

GEOS - Geosynchronous-earth-orbit satellite. Circular orbit 22,300 miles above the Earth's surface; satellites travel with the rotation of the Earth and appear stationary from the Earth's surface.

GPS - Global positioning system. U.S. government-owned system of satellites that allow receivers to compute latitude and longitude for high-accuracy position.

GSM – Global system for mobile communication (formerly, Groupe Système Mobile). European digital cellular radio standard.

GUI - Graphical user interface.

High accuracy GPS - GPS which uses differential correction techniques to overcome global positioning system errors. GPS receivers in precisely identified control locations measure the difference between indicated GPS positions and the actual known positions.

HMI - Human-machine interface. *See Man-machine interface.*

HUD - Head-up display. Display that projects vehicle information in front of drivers to allow them to keep their eyes forward.

IDB (ITS Data Bus) - A medium-speed multiplexed bus intended for command and control of devices in vehicles. A proposed SAE standard that will allow device manufacturers to create products that will be compatible with all vehicles (versus today's data bus systems that differ among automobile manufacturers). It will interface to an existing vehicle bus through a gateway.

IEEE - Institute of Electrical and Electronics Engineers. Professional society and standards-making body composed of 38 individual societies, including the Computer Society and the Vehicular Technology Society. Includes an ITS Standards Coordinating Committee.

IN-ARTE - A public-private EU research program focusing on the development of advanced Driver Assistance applications. In progress.

Infrastructure - In transportation planning, all the relevant elements of the environment in which a transportation system operates. In transit systems, all the fixed components of the system such as rights-of-way, tracks, signal equipment, stations, park-and-ride lots, bus stops, maintenance facilities, and other elements connected to the ground.

ITE - Institute of Transportation Engineers. An international scientific and educational association of approximately 10,000 transportation professionals in 70 countries. Sponsors annual conferences.

ITU - International Telecommunications Union.

IVI - Intelligent Vehicle Initiative. A major component of the U.S. Department of Transportation's national ITS program, intended to accelerate the development, availability, and use of the latest driving-assistance and control-intervention systems to boost the safety and efficiency of U.S. motor-vehicle operations. Systems to be developed include provisions for warning drivers of roadway hazards and inclement weather, recommending appropriate control actions, and intervening with driver control.

Internet - An electronic communications network that links computing facilities around the world.

Interoperability - Ability of products from different manufacturers to communicate and function together.

Intersection collision avoidance systems - Warn a driver of the need to slow down based on intersection location data (such as the presence of a stop sign) and information about potentially interfering vehicles.

ISO - International Standards Organization. An international standards umbrella organization. Includes a Technical Committee (TC 204) on Transport Information and Control Systems.

ISP - Information service provider.

ITS - Intelligent transportation systems. Originally called IVHS. A collection of diverse technologies, including information processing, communications, control and electronics, which, when joined to our transportation system, can save lives, time and money.

ITS America - A nonprofit, public-private scientific and educational corporation working to advance a national program for safer, more economical, energy-efficient, and environmentally sound highway travel in the United States.

IVIS - In-vehicle information system.

LAN - Local area network.

Lane departure warning - Systems that alert drivers if the vehicle appears to be drifting out of its lane or off the road.

LEO - Low-Earth-orbit satellites. Positioned in low-altitude orbits to provide inexpensive, low-frequency, low-power positioning and two-way messaging services.

Machine learning/Intelligent agent - Executes tasks on behalf of a business process, computer application, or an individual. For example, intelligent agents have been written to search through e-mail messages for certain keywords or simple concepts (phrases).

MMI - Man/Machine Interface. The means by which the user interacts with the machine or device. In the past, knobs, dials and displays, dependent upon a user's hand, were common functions on technological devices. Today, MMI includes more advanced and easier-to-use functions, such as voice recognition, speech synthesis and touch screens.

Map matching - A technique to enhance and correct dead reckoning. Software follows vehicle progress on a digital map and matches the dead-reckoning estimate of the current position to the closest point on the map.

NADS - National Advanced Driving Simulator. Being built under the direction of the US Department of Transportation. When completed, NADS is expected to be the most sophisticated driver simulator in the world. The site for building and maintaining NADS is the University of Iowa's Oakdale Research Park.

NAHSC - National Automated Highway System Consortium. Public-private U.S. project to develop fully automated vehicles on specially instrumented freeway lanes, separated from manually controlled vehicles. Technologies were demonstrated on a test tract in 1997, as mandated by the Intermodal Surface Transportation Efficiency Act (ISTEA).

NHTSA - National Highway Traffic Safety Administration. An administration of the U.S. Department of Transportation established to promote public welfare by helping to reduce the number of deaths, injuries, and economic losses resulting from motor vehicle crashes.

NTSB - National Transportation Safety Board. An independent agency of the U.S. Federal government responsible for investigating traffic accidents, conducting studies, and recommending transportation safety measures and practices to government agencies and the transportation industry.

Obstacle warning systems - Systems that detect and warn drivers when obstacles are to the front, rear, or side of a vehicle's intended path.

OEM - Original equipment manufacturer.

Parking space location and reservation - A service that allows the en-route traveler to identify available parking in a given locale and reserve a space prior to arriving at the specified location.

PATH - Partners for Advanced Transit and Highway. ITS research program in collaboration with Caltrans and the University of Berkeley, Institute of Transportation Studies.

PCS - Personal Communications Service. Wireless service that bundles voice communications, numeric and text messaging, voice-mail and other features into one device, service, or bill.

Predictive data fusion - A technique for processing real-time data to ascertain future conditions.

Priority management software enables the efficient allocation of discrete computing resources for optimized, continuous functionality.

PROMETHEUS - Program for a European traffic system with highest efficiency and unprecedented safety. Primarily a private-sector initiative trying to develop a uniform European traffic system that incorporates ITS technology.

PSAP - Public Safety Answering Point.

R&D - Research and development.

Radar/Laser sensors - Sensors, such as light-based, lidar, and microwave-based, that provide information about obstacles and other vehicles in the vicinity of the equipped vehicle. Different types of radar yield various levels of accuracy, distance reliability, range, and resolution.

RDS - Radio Data System. A use of FM subcarrier for wide area transmission of digital information, program information, radio control, etc. One application is the Traffic Message Channel (TMC).

RDS-TMC - Radio data systems incorporating a traffic message channel.

Real-time traffic information - Real-time traffic information (travel times, traveler advisories, etc.) is collected by a traffic management center from a variety of sources, such as traffic signal monitors, highway surveillance, and the police. The traffic management center then disseminates this information, providing updates to equipped vehicles for a modest subscriber fee. Traffic reports can be communicated through a variety of media, including radio, cell phone, etc. Real-time traffic updates enable drivers to re-route to their destination based on the most current travel conditions.

Remote door unlock - A remote interface service that enables service centers to remotely unlock a vehicle.

RF - Radio frequency.

Road condition sensors - Measure tire friction on the roadway.

Roadside Assistance (routine) - Enables drivers to request assistance for routine vehicle maintenance problems, such as fuel, dead battery, flat tire, etc.

Road-side assistance (emergency)/User-Initiated Mayday requests - By using mayday/roadside assistance services, the driver can call for help by pressing a dashboard "button." Upon receiving this distress call, a central emergency response provider will locate the vehicle on the road network and dispatch assistance immediately.

Route guidance - Systems that allow the driver to specify a destination and an optimal route is calculated from the vehicle's current location to the desired location. Directions are typically presented to the driver in the form of a simple graphic display or computer voice, or both. In these systems, the onboard system includes a database and computer processing technology to allow the vehicle to determine its own route and track its own progress along the route.

Sensor fusion software - Software that combines data from numerous in-vehicle sensors to generate a comprehensive "picture" of the vehicle in the current driving environment.

Smart headlights - Headlights that automatically aim in the direction of a curve to provide better illumination of the road.

Smart throttle - System that anticipates road conditions (curves, grades) to save fuel and improve vehicle performance.

Smart transmission - Calculates the optimal gear shift, up or down, based on information about the road ahead (curves, grades).

SAE - Society of Automotive Engineers - Technical society aimed at developing, collecting, and disseminating knowledge about mobility technologies worldwide. Involved in the development of consensus standards for automotive applications. Includes an ITS/IVI Division. Sponsors annual conferences.

Stability control systems – Systems that help vehicles avoid lateral sliding on road curves.

Standard - Documented agreement on technical specifications and other precise criteria for use in production.

Standard navigation map database - A fundamental requirement for navigation and route guidance systems is a comprehensive digital street map database. Such maps must have the geographical coverage, accuracy, and detail to support such applications as: address location, route determination, route guidance, map displays, etc. This implies highly accurate geometric representation of the roadways (typical maximum tolerance: 10-15 meters), inclusion of address ranges, street names, directionality, turn restrictions, highway ramp configurations, etc. These databases may also include demographic and political data, business listings ("electronic yellow pages"), and other information keyed to the underlying roadway geometry.

Suspension control - Automatically adjusts the vehicle's suspension according to prevailing driving conditions (e.g. for highway travel, driving on unpaved/rocky terrain, etc.).

System architecture - Master plan including both components and interfaces describing the fundamental components of the system and the information that is to be exchanged or communicated among the components. A modular framework that encompasses a variety of implementations based on current technology, while allowing for growth, change, etc.

TDMA - Time Division Multiple Access. A digital channel access method that divides a sequence of conversations into packets of data according to time. Uses a single radio frequency to transmit packets.

Transponder - A transmitter-receiver facility, the function of which is to transmit signals automatically when the proper interrogation is received.

TRB - Transportation Research Board. Part of the National Research Council, National Academy of Sciences. Purpose is to bring scientific and technical information to bear on transportation problems by encouraging and conducting research, and disseminating information. Includes committees on ITS and Communications.

Vehicle diagnostics - A computer-based application which provides vital information about vehicle performance, including oil and gas levels, engine temperature, etc. This data may be available to the en-route driver as well as accessed remotely via a dynamic wireless communications link.

Vehicle positioning – (Longitudinal, Lateral). Precise vehicle position includes not only the longitudinal and lateral location of the vehicle along the road but, for many applications, the location of the equipped vehicle relative to other vehicles or obstacles. Longitudinal location enables an application to determine the distance between the equipped vehicle and an

impending obstacle, curve, or hill. Lateral location helps an application determine whether an impending obstacle or vehicle is actually in the path, or lane, of the equipped vehicle.

VICS - Vehicle Information and Communications System. Japanese traveler information system developed through a public-private consortium. Overseen by the Ministry of Posts and Telecommunications.

Video sensors - Vision-based image processing systems that provide important information about obstacles and other vehicles in the vicinity of the equipped vehicle. To a large extent, these systems can discern the type and precise location of an obstacle and whether it requires driver notification or intervention. For example, video sensors can provide lane keeping functionality by following the lane markers painted on the road or the variances in color in the roadbed caused by vehicles traveling on the roadway. This helps determine the lateral and longitudinal position of a vehicle relative to "targets" or other obstacles on the road when combined with the radar data.

Vision enhancement systems - Systems, such as head-up displays, help drivers navigate when visibility is poor (due to weather, night driving, etc.).

Voice mail - An electronic system in which spoken messages are recorded or digitized for later playback to the intended recipient.

Voice recognition - Software that can process human voice inputs.

Voice synthesis - Software that can interface with users via synthesized (computer-generated) speech.

WAN – Wide area network.

IX. Appendix D: Workshop Agenda

Tuesday, August 25

8:30-9:00 am	Registration & Continental Breakfast
9:00-9:30 am	Opening Remarks and Introduction to the Workshop
9:30-10:00am	***"****Internet based Information Services for Vehicles - Designing the Connected Vehicle of the Future."* Axel Fuchs, Manager, Transportation & Mobility Group, Daimler-Benz Research and Technology - North America.
10:00-10:30am	*Advanced Driver Assistance Systems.* Michele Roser, Manager, Strategic Development, Navigation Technologies.
10:30-10:45am	Morning Break
10:45-11:15am	*"ITS Safety & Human Factors Standards."* Eugene Farber, Manager, IVHS Safety & Regulatory Issues, Ford Motor Company.
11:15-11:45am	"*SAE Cooperative Research Program Overview."* Gary Pollak, Program Manager, Cooperative Research, The Society of Automotive Engineers.
11:45-12:00pm	Discussion of Agenda for Day One
12:00-1:15pm	Lunch
1:15-3:00pm	Breakout Group Sessions
3:00-3:15pm	Afternoon Break
3:15-4:00pm	Breakout Group Sessions Continue
4:00-5:30pm	Presentation of Breakout Group Results
5:30 pm	Workshop Adjourns for Day
6:00-8:00pm	Dinner *"Attaining Public-Private Partnerships in the IVI,"* C. John MacGowan, Chief of Intelligent System Technology Division, Federal Highway Administration

Wednesday, August 26

8:15-8:45am	Continental Breakfast
8:45-9:00am	Welcome and Discussion of Agenda for Day Two
9:00-10:30am	Breakout Group Sessions
10:30-10:45am	Morning Break
10:45-12:15pm	Breakout Group Sessions Continue
12:15-1:30pm	Lunch
1:30-3:00pm	Presentation of Breakout Group Results
3:00-3:15pm	Afternoon Break
3:15-4:00pm	General Discussion
4:00pm	Conclusion

X. Appendix E: Workshop Participants

Name	Organization
Luiz Bacellar	*United Technologies*
Takehiko Barada	*Sumitomo Electric*
Jim Bauer*	*Toyota Technical Center*
Lara Baughman	*NavTech*
David Benson	*SRI Consulting*
Bill Birge	*SAE*
G. Sadler Bridges*	*Texas Transportation Inst.*
Vicki Cobb	*CADOT New Technology*
Michael Daly	*CA Community College*
Regina DeCoster	*ORBCOMM*
Eugene Farber	*Ford Motor Company*
Robert Ferlis	*USDOT, FHWA*
Axel Fuchs	*Daimler-Benz R&T NA*
Ramez Gerges	*CalTrans*
Jon Hankey	*VT-Center for Transportation*
Mark Haslam	*DriverTech, Inc.*
Gwenne Henricks	*Caterpillar Inc*
Miyoko Honma	*Denso Intl. America, Inc.*
Emma Hospelhorn	*NavTech*
Shi-Ping Hsu	*TRW*
Akhtar Jameel	*Daimler-Benz Research*
Barry Kantowitz*	*Battelle HF Transp. Center*
Mo Kapila	*Denso Sales Calif. Inc*
Helmut (Bill) Knee*	*Oak Ridge Nat'l Lab*
John Lau	*Viggen*
Gunnar Lindstrom	*Honda R&D Americas*

Name	Organization
John MacGowan	*FHWA*
Joseph Masso	*Maxwell Technologies Systems Division, Inc.*
Chris Monk	*SAIC/FHWA*
Joseph Muller	*RoadRider Solutions Group, Inc*
R. Jeffrey Murdock	*Denso Intl. America, Inc.*
Jim Nickel	*Motorola*
John Pierowicz*	*Calspan Corp.*
Jeff Rogers	*Denso Sales Calif. Inc*
Amit Ronen	*USDOT Volpe Center*
Michele Roser	*NavTech*
Tina Sayer	*ERIM International*
Susan Scott	*Mitretek Systems, Inc.*
Byron Shaw	*BMW Technology Office*
Akira Shiratori	*Nissan R&D*
Ron Silletti	*IBM*
Ray Starsman*	*ITS America*
Erin Sullivan	*NavTech*
Harry Voccola	*NavTech*
Richard Weiland	*NavTech* **
Steve Weiland	*NavTech*
Bonnie Wells	*State of CA DOT*
Darrell Williams	*Denso Intl. America, Inc.*
Robert Winick	*Motran Maps, LLC*
Wayne Yamada	*Denso Intl. America, Inc.*
Yilin Zhao	*Motorola*

* Denotes Breakout Group Leader
** now Weiland Consulting Co.

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Eugene Farber, Ford Motor Company
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Steven Shladover, University of California, Berkeley/Inst. of Transportation Studies
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