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Issues of In-Vehicle Information Management

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Issues of In-Vehicle ITS Information Management

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This paper presents issues associated with the introduction into road vehicles of multiple information sources related to the Intelligent Transportation System (ITS). Also, an argument is made for an In-Vehicle Information System (IVIS) to manage messages from the associated Intelligent Transportation System Services, as well as other information to be presented to the driver. The IVIS serves as the interface between the driver and all the information sources, including both input from and information display to the driver. Increasingly, aftermarket systems, such as routing and navigation aids, collision avoidance warning systems, "yellow pages", can be added to vehicles to aid in travel and/or the conduct of business in the vehicle. The installation of multiple devices, each with its own driver interface, increases the likelihood of driver distraction and thus the risk of an accident. However, introduction of an IVIS raises a number of issues which relate to things such as proprietary messages, message prioritization across devices from different manufacturers, and safe access to the vehicle manufacturer's proprietary data bus. These issues are the focus of this paper.

Sections I and II of this paper present short summaries of the efforts in a variety of areas related to in-vehicle information systems. In the first two sections, a summary of two Department of Transportation (DOT) initiatives is followed by a description of U.S. standards development efforts. Next is a brief consideration of institutional, jurisdictional and legal issues associated with in-vehicle systems and the accompanying infrastructure. Section III of the paper is devoted to systems integration and driver interface engineering issues.

I. DOT initiative

A. Driver-Vehicle Interface Program -- With the continuing evolution of the new "Information Age", a variety of information sources are finding their way into road vehicles, with the ability to bridge the gap between the highway and the driver. These devices can provide information on route guidance, safety and hazard alerts, and traffic congestion advisories in real time, as a function of driver needs and the traffic and/or environmental conditions affecting the driver's travel. Another specific application of ITS technology is the variety of collision warning/avoidance systems. The passive versions of these systems, collision warning systems, provide warning of impending collisions in all directions around a moving vehicle; while the collision avoidance systems provide active braking to help prevent the collision.

In an effort to systematically address the concerns which arise from having multiple information sources signaling the driver simultaneously, the Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration have developed a coordinated program of research [1]. This program is entitled "Driver-Vehicle Interface for ITS" (DVI). The goal of the DVI program is to foster the development of well-designed, fully-integrated information systems which filter, prioritize and communicate driving-related information. These systems are a core component of the ITS Program, and their optimization will enhance the safety and efficiency benefits of other ITS components. A critical component of the DVI Program is the FHWA's In-Vehicle Information System project at Oak Ridge National Laboratory, which is discussed later in this paper.

B. Intelligent Vehicle Initiative -- The Intelligent Vehicle Initiative (IVI) is intended to provide a near-term focus for the delivery and demonstration of emerging in-vehicle and associated infrastructure technologies related to ITS initiative. These technologies comprise advanced vehicle safety and information systems which will be installed in vehicles for both research and demonstration. The platforms encompass three levels of capability which transition from only providing information to drivers, to providing fully automatic vehicle control. Multiple generations of vehicle testbeds include increasingly sophisticated new technologies in four vehicle classes: light, heavy, transit and emergency vehicles. Because the IVI involves installation of multiple systems into the testbed vehicles, there are serious issues of safety and interoperability raised. While still under development, the IVI program plan was presented and reviewed at a workshop held in San Diego, California, in August, 1997.

C. Standards -- Internationally, the International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from some 100 countries. ISO is a non-governmental organization established in 1947. The mission of ISO is to promote the development of standardization and related activities in the world with a view to facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological and economic activity. ISO's work results in international agreements which are published as International Standards. Many people notice a seeming lack of correspondence between the official title when used in full, International Organization for Standardization, and the short form, ISO. In fact, "ISO" is a word, derived from the Greek isos, meaning "equal ", which is the root of the prefix " iso-" that occurs in a host of terms, such as " isometric ". From "equal" to "standard", the line of thinking that led to the choice of "ISO" as the name of the organization is easy to follow. In addition, the name has the advantage of being valid in each of the organization's three official languages - English, French and Russian. ISO/TC204 is responsible for the standardization of information, communication, and control systems in the field of urban and rural surface transportation, including intermodal and multimodal aspects, public transport, commercial transport, emergency services and commercial services in the of Transport Information and Control Systems (TICS) field.

The ISO/TC204 is responsible for the overall system aspects and infrastructure aspects for TICS, as well as the coordination of the overall ISO work program in this field.

In each of its member countries, the ISO recognizes a single standards-related institution as the official representative of the ISO in that country, and through which all standards efforts are channeled. In the United States, that organization is the American National Standards Institute (ANSI). However, the organization of standards development bodies is rather complex in the United States. ANSI delegates authority for running the U.S. Technical Advisory Groups to other organizations which have the appropriate expertise. In the case of TICS standards, that body is the Intelligent Transportation Society of America (ITS America). ITS America, acting as the U.S. Technical Advisory Group (TAG), has unofficially delegated responsibility to relevant U.S. national standards groups, including the Society of Automotive Engineers (SAE) and the Institute for Electrical and Electronics Engineers (IEEE), to help the TAG form the U.S. position. While there is no official process for submitting U.S. standards to the ISO, it is assumed that U.S. standards efforts will be used as the bulk of the U.S. input to ISO where such relevant U.S. standards efforts exist.

II. Standards Development

As indicated in the previous section, U.S. standards development efforts for in-vehicle systems are centered primarily in two organizations, the SAE, and the IEEE. The following sections present a sampling of the standards development efforts for those two societies.

A. IEEE -- Standards development efforts within the IEEE for TICS are centered in SCC32 - Standards Coordinating Committee on Intelligent Transportation Systems. The mission of SCC32 is to coordinate, develop, and maintain standards, recommended practices, and guidelines related to ITS within the scope of IEEE interests. SCC32 works with other national and international standards writing bodies to coordinate involvement in a variety of ITS-related standards areas, including:

- Ground Based Transportation Collision Avoidance Radar
- Message Sets for Vehicle/Roadside Communication
- Data Dictionaries for Intelligent Transportation Systems

Some of these efforts are also coordinated with the SAE efforts described below, at least through dual participation by some committee members.

B. SAE -- SAE standards development activities cover a wide range of vehicle-related areas. Those efforts for TICS standards fall under the SAE's ITS Division. The Division is comprised of several committees, some of which are directly concerned with the development of standards for in-vehicle information:

- ITS Data Bus Committee -- J2366 et al, scheduled for vote December, 1997
- Safety & Human Factors Committee -- five funded standards efforts
- In-Vehicle Systems Interface Committee
- Advanced Traveler Information Systems Committee
- Map Database Committee
- Navigation Committee
- Systems Architecture Committee

These committees are involved in a variety of ITS Standards Projects, many of which are partially funded by a grant from the Federal Highway Administration. In the next few years, these projects will produce SAE Standards and Recommended Practices which support the National Architecture and Intelligent Transportation Infrastructure.

The work of the ITS Data Bus Committee is of particular interest for this paper. The ITS Data Bus (IDB) is the primary standard development effort of this committee of the SAE [4, 5]. The IDB standard, the development of which is supported by U.S. and foreign automobile manufacturers as well as manufacturers of consumer electronics, provides for a new data bus in the vehicle which supports simple and easy "plug-and-play" installation of the devices discussed in this paper . Because the presence of multiple devices can permit multiple simultaneous messages to the driver, the IDB provides for rudimentary message prioritization, thereby providing for increased safety. In addition, because of the simple installation of IDB-compliant devices, interoperability among devices is also increased. Finally, by permitting bi-directional information flow across a "gateway" between the IDB and the vehicle data bus, the IDB supports easy data acquisition for devices on the IDB [9]. The gateway also provides a "firewall" to protect mission-critical vehicle data. In addition to the gateway, the IDB standard specifies the physical layer (layer 1 of the ISO's Open System Interconnectivity standard, or OSI), the data-link layer (layer 2), and the application layer (layer 7) [6, 7, 8]. These three layers are sufficient to provide all the planned IDB functions.

III. IVIS Issues

The following sections discuss briefly a variety of issues associated with the introduction of multiple information sources, and an IVIS to manage them, into a vehicle. Each topic could be a paper by itself, but such a lengthy presentation is beyond the scope of this paper.

A. Institutional and Jurisdictional -- Institutional issues derive from fact that many ITS-related devices require supporting infrastructure to operate properly. In addition, they must function smoothly and as users travel around the country. Infrastructure requirements result in questions concerning which institutions should fund the development and installation of the required infrastructure. For most in-vehicle devices, it is clear that private companies bear the cost of product development, and consumers bear the cost of purchase and installation in the vehicle. However, the distribution of infrastructure costs (purchase, installation, operation and maintenance), is not so clear, and often requires public/private partnerships [2, 3]. Similarly, operation of the infrastructure installations requires cooperation between and among multiple sectors and/or levels of government, and between government and independent service providers. Such cooperation is complicated by concerns about cost-sharing, responsibility for the various aspects of system operation and maintenance, and liability in case of component or system failure. Institutional issues associated specifically with the in-vehicle devices concern such things as access to proprietary data on the vehicle data bus, the ability to insert data from the various devices onto the vehicle data bus, and the need to protect the integrity of the mission-critical vehicle data. These issues are of particular concern for the SAE ITS Data Bus work.

Jurisdictional issues also arise from cooperative efforts among public sector agencies and private companies. The data transmission media, as well as data formatting, structuring and ownership are all issues which must be agreed upon, and revisited as new services and systems are introduced. Service boundaries and the seamless transfer of responsibility across those boundaries for providing information to the end-user create additional problems. These problems have all been addressed, with varying degrees of success, in the Field Operation Tests (FOTs) which have been run, and in the Model Deployment Initiatives (MDIs) currently under way.

B. Legal -- Legal issues primarily cover things related to liability, copyright ownership and infringement, and ownership of data and information. As with institutional and jurisdictional issues, legal issues associated with supporting infrastructure deployment have been addressed in the FOTs and MDIs sponsored by the Department of Transportation. Legal issues directly associated with the in-vehicle systems, however, are potentially much more complex. One might initially assume that legal issues would primarily center around active devices such as adaptive cruise control and active collision avoidance systems. However, it is likely that drivers will alter their driving behavior in the presence of "passive", information-only devices such as navigation and route guidance and "yellow-pages" systems. This phenomenon has already appeared with the use of active anti-lock brake systems. As drivers become dependent on systems such as collision warning systems, navigation systems, and other systems which alert them to impending events, the average driver can be expected to pay less attention to the details of driving, with a possible result of having more near misses and/or accidents. While this did not occur with the TravTek project in Orlando, it should be noted that no user had a particularly long-term exposure to the navigation system (i.e., several years' continued use). Should accidents happen which might be attributed to an in-vehicle device, we can expect litigation to sort out the liability issues, and the resolution is not likely to beeasy or clear.

C. Devices -- Issues associated with multiple devices in vehicles can be classified in four categories: physical, logical, information management, and driver interface. As part of the DVI program, an In-Vehicle Information System project at the Oak Ridge National Laboratory is creating a demonstration prototype of an IVIS to provide a unified and consistent driver-vehicle interface in the presence of multiple in-vehicle information systems [10, 11]. An IVIS provides management, integration, fusion and enhancement of information from multiple systems, presented through a single interface. It also receives input from the driver to the installed set of devices through the same interface. These functions are discussed in the following sections.

While the ITS Data Bus and the In-Vehicle Information Systems project were conceived and initiated as independent efforts, it became clear that they share many of the same goals, and are inherently mutually supportive of each other. As a result, the two projects have adopted partially merged paths, with development efforts in each one supporting efforts in the other. As discussed below, the IDB can serve as the logical mechanism by which a variety of devices would be installed into a vehicle -- providing both the power and logical connections to the vehicle and other devices. In this scenario, there is no requirement for a "bus master" or controller to arbitrate among the devices, since the IDB standard provides for a simple message prioritization mechanism. However, the ITS Data Bus standard permits such a controller, a function provided by an IVIS device installed on the IDB. In fact, one concept for an IVIS is as a device manufactured for installation on the IDB, to serve as the information-managing interface between the IDB devices and the driver. Such a device would embody the information management logic developed in the IVIS project, as well as providing a unified input interface enabling the driver to enter requests and other information into the various other devices installed on the IDB.

1. Physical -- Physical issues concern installation and power consumption. Installation real-estate is a severe problem, especially in the cases of devices which require a graphical display. Other installation issues center on the power and logical connection to the vehicle, and to the manner in which the devices interact with one another. Much of the "real-estate" problem concerns display area. If each device requires its own (graphical) display, there is not room to mount them all. This problem was addressed in the ALERT police vehicle designed by the Texas Transportation Institute at Texas A & M University, in which the display requirements are now all handled on a single LCD screen, similar to the IVIS concept. Power requirements are addressed by the IDB physical layer specification, and will be handled when the standard is adopted by automobile and equipment manufacturers.

2. Logical -- Logical issues surrounding the installation of multiple devices in vehicles are much more complex than the physical ones. Devices must function without interfering with each other, and must also communicate among themselves without interfering with other devices (e.g., message passing between a pager and a cell phone, or between a "yellow pages" system and a navigation system). As with the power requirements, these issues are addressed by the IDB standard, particularly the data-link layer.

D. Information Management -- In order for an IVIS and the driver to communicate, additional devices installed in the vehicle must be connected to the IVIS by means of either a data bus, or by a point-to-point wiring scheme. Ultimately, this connection will be through the IDB. In this arrangement, communication between the vehicle and the infrastructure is performed by the various devices, or "subsystems", each with its own communication path, as detailed in the National Architecture. The subsystems, in turn, do whatever information processing they are designed to do, and then send the prepared information to IVIS to be presented to the driver. The information management function, performed within the IVIS, is a logical manipulation of the information received from the variety of subsystems connected. This function requires a system which accounts for driver preferences and needs, as well as taking into account the source of the information and its relative importance. Two kinds of information management rules must be developed: integration and filtering. Integration rules determine the manner in which separate pieces of information get combined. This combining applies to both information destined for presentation to the driver and information being sent from the driver to the information subsystems. For example, messages from a collision warning system and a real-time traffic information system may need to be presented to the driver in an integrated fashion. Similarly, a driver's request for help, being sent out to the infrastructure, should be combined with other pieces of information, such as the vehicle's location. Filtering rules select certain messages for presentation to the driver and suppressing others, as well as determining on which channel (visual or auditory) the messages are presented.

Rule Reconfigurability: In the IVIS demonstration prototype, the information management functions are performed by an expert system, consisting of an inference engine and one or more sets of rules, to make decisions about information display. Because the user can either dismount devices or turn them off at various times, an IVIS must operate with different numbers and types of information subsystems. In addition, for each type of information system, there will be different levels of capability and functionality, because there will be more than one supplier for each type of system. Finally, an IVIS usually must conform to the preferences and goals of more than one driver. For these reasons, the rule sets, which IVIS uses to perform its information management functions, will have to be reconfigurable based on the numbers and types of subsystems installed and on driver inputs.

Information Management Logic: There are numerous IVIS functional requirements related to information management. The system must prioritize each message based on the message's a priori importance and on the current driving situation. Prioritization forms the basis for a logical filter, used to resolve conflicts among multiple messages coming either from multiple systems or from the same system. In addition, IVIS must have logic which integrates two or more messages which complement each other. The IVIS information management and interface requirements must be met by a rather sophisticated logic underlying the driver's interface with the system. A major issue, therefore, concerns the degree to which the information management logic should be transparent to the driver. In other words, how much should the driver be told of the inner workings of the system? Do drivers need this information? Do they want this information? If so, should they be informed of the system's logic during operation? All these issues are being explored in the IVIS development being done at ORNL.

E. Other Interface Issues -- In addition to the information management issues just discussed, there are issues associated with information display, as well as the user's input of information and requests to the IVIS. Driver input permits the user to enter a variety of types of information, such as route and destination information, filtering and prioritization preferences, cell phone calls etc., both prior to and during the trip. Because the input functions must address multiple devices through a single interface, these input issues are unique to the IVIS setting. The user must know to which device the information is being sent, and that the desired impact of that information entry has been achieved. This process is likely to use multi-function input devices (e.g., buttons or screen touch areas). These issues must be addressed in the successful IVIS.

Controls: Because the system will be able to accept driver preferences on how its information management logic will operate, driver input requirements, and therefore system control issues, are implied. There are also requirements to allow the input of driver preferences on how the messages will be displayed. For example, a driver who does not want to listen to an auditory speech display, will be able to de-select it. These input needs are over and above those which already exist for the driver's interaction with the functions associated with each of the individual devices. While there are a number of potential solutions, many design approaches will have to be tested. The design and testing of solutions to IVIS control interfaces will also be coordinated with several SAE standards which are currently under development.

Displays: The filtering and integration of multiple messages generate information display issues. As with control issues, there are a number of design alternatives for handling message conflicts. Integrating multiple messages may involve simultaneous presentation on a visual display, or may be done by sequencing the messages, over time, on either a visual or an auditory display. A multi-modal display represents another design solution. For example, one message may be presented visually and the other aurally. In addition to the display issues associated with the filtering and integration function of IVIS, there are also requirements for dynamic display salience associated with changing levels of message urgency. Methods for varying the salience of a displayed message are quite numerous; e.g.: size, brightness, loudness, flashing, color, etc. It may also be desirable to have a finite number of discrete levels of salience to reflect different levels of urgency. Again, as with the control designs, these methods will be developed and the attendant issues will be evaluated in light of SAE standards presently under development.

IV. SUMMARY AND CONCLUSIONS

This paper has presented a summary of issues associated with introducing multiple devices which present information to a driver, and require inputs from the driver to use them. These issues range from Institutional and legal issues, through systems integration issues, to the many problems related to information management and presentation to drivers. Two developing technological efforts were described, which mutually support each other in creating a methodology to safely, easily and effectively install advanced electronic devices in modern road vehicles. The ITS Data Bus, resulting from the SAE Standard J2366, provides for safe, easy and effective "plug-and-play" installation of devices which provide a variety of information to drivers, especially the newly developing traveler information systems such as navigation and route guidance, and various motorist services systems. An In-Vehicle Information System project at Oak Ridge National Laboratory is creating a demonstration prototype of a system which will manage, prioritize and enhance the information which the devices on the ITS Data Bus need to present to the driver. In this process, a benchtop development and demonstration platform has been created. This platform permits development and evaluation of rules for managing information, as well as a methodology for integrating multiple devices into a smoothly-functioning in-vehicle information package.

Finally, a discussion of the various driver interface issues was presented. These issues pertain to both information presentation to the driver, and the process of permitting the driver to enter information into the system. A number of issues unique to the setting in which multiple devices are integrated in to the vehicle were discussed, including the necessity of merging related messages into a meaningful single presentation, deleting duplicate messages from different devices, and the need to selectively present messages in different sensory channels and/or to distribute messages over time and space. All these techniques are required to assure driver comprehension of the information, and to reduce or prevent driver information overload in the presence of multiple messages.

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