IN-VEHICLE INFORMATION SYSTEM FUNCTIONS*

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Paper Accepted for Presentation At:

Seventh Annual Meeting and Exposition of the Intelligent Transportation Society of America

Washington, DC

June 2-5, 1997

***Research sponsored by the Department of Transportation, Federal Highway Administration Contract No. 1883E020 A1, under Department of Energy Contract No. DE-AC05-96OR22464 with Lockheed Martin Energy Research Corp.**

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ABSTRACT

This paper describes the functional requirements for an In-Vehicle Information System (IVIS), which will manage and display all driving-related information from many sources. There are numerous information systems currently being fielded or developed (e.g., routing and navigation, collision avoidance). However, without a logical integration of all of the possible on-board information, there is a potential for overwhelming the driver. The system described in this paper will filter and prioritize information across all sources, and present it to the driver in a timely manner, within a unified interface. To do this, IVIS will perform three general functions: 1) interact with other, on-board information subsystems and the vehicle; 2) manage the information by filtering, prioritizing, and integrating it; and 3) interact with the driver, both in terms of displaying information to the driver and allowing the driver to input requests, goals and preferences. The functional requirements described in this paper have either been derived from these three high-level functions or are directly mandated by the overriding requirements for modularity and flexibility. IVIS will have to be able to accommodate different types of information subsystems, of varying levels of sophistication. The system will also have to meet the diverse needs of different types of drivers (private, commercial, transit), who may have very different levels of expertise in using information systems. It is assumed that each on-board information subsystem will be responsible for gathering and processing data relevant to its class of information. The IVIS will be the recipient of this information and will provide an integrated gateway between the diverse subsystems and the driver. The ongoing effort to define the IVIS functional requirements, described here, is complemented by parallel efforts, within this project, which address system prototype development and testing. This work is being conducted by the Oak Ridge National Laboratory for the U.S. Federal Highway Administration as part of the Intelligent Transportation System Program.

INTRODUCTION

Driver information systems are being developed and installed in vehicles at a dramatic rate. These systems provide information on diverse topics of concern or convenience to the driver, such as: routing and navigation, emergency warnings, and collision avoidance. Most of these systems are being developed in isolation from each other, with separate means of gathering the information and of displaying it to the driver. The current lack of coordination among on-board systems threatens to create a situation in which separate messages on separate displays will be competing with each other for the driver's attention. Urgent messages may go unnoticed, and the number of messages may distract the driver from the most critical task of controlling the vehicle.

The goal of the In-Vehicle Information System (IVIS) is to manage and display all in-vehicle information for the driver in a safe and efficient manner. As such, IVIS is seen as an integrated gateway between the driver and all of the other on-board information systems. This paper describes the functions which must be performed by an IVIS in order to provide the driver with a coherent and unified source of information. IVIS will functionally integrate the diverse information systems into a single system. For this reason the other information systems are referred to, in this paper, as information subsystems. A companion paper (1) discusses the issues associated with IVIS development and testing, and includes a discussion of system concepts.

As shown in Figure 1, IVIS will mediate the driver's interaction with the information subsystems. It will communicate with the subsystems via an on-board data communication medium (e.g., a data bus). The data provided by the subsystems will be managed by the IVIS in the sense that separate messages will be prioritized and filtered and in some cases fused. IVIS will also manage the messages sent from the driver to the subsystems, allowing the driver to make a high-level request (e.g., call for help) with IVIS completing the message with the additional information required (e.g., type of vehicle, location). Interaction with the driver will be done via a unified interface. The precise nature of the display and control technology comprising the interface is a design issue and will not be discussed here.

The number and types of information subsystems with which IVIS will interact are not fixed. Therefore, the overall nature of the integrated system will have to be modular. In addition, the system will have to be flexible enough to accommodate information subsystems of varying levels of sophistication. For these reasons, IVIS will need to be able to reconfigure the rule base it uses for prioritization, filtering, and fusion in order to be compatible with whatever kinds of subsystems may be present. IVIS will also have to accommodate the different needs and levels of expertise of different types of drivers operating under diverse conditions. For example, the driver of a private automobile in unfamiliar territory will have very different information needs than an operator of a transit vehicle in a familiar area who receives routing requests from a central dispatcher. In addition, some drivers will have little or no training in how to use the system to its fullest extent, and will need to be accommodated by a minimum default capability, requiring little or no driver input. Other drivers may wish to exercise greater control over the system by configuring it to conform to their preferences on how certain functions will be performed (e.g., filtering rules).

The IVIS project is being conducted by the Oak Ridge National Laboratory for the U.S. Federal Highway Administration.

IVIS FUNCTIONAL REQUIREMENTS

Flowdown Process

The process of defining the functional requirements of an IVIS began with the stated goal of managing and displaying all in-vehicle information for the driver in a safe and efficient

IVIS Functional Context

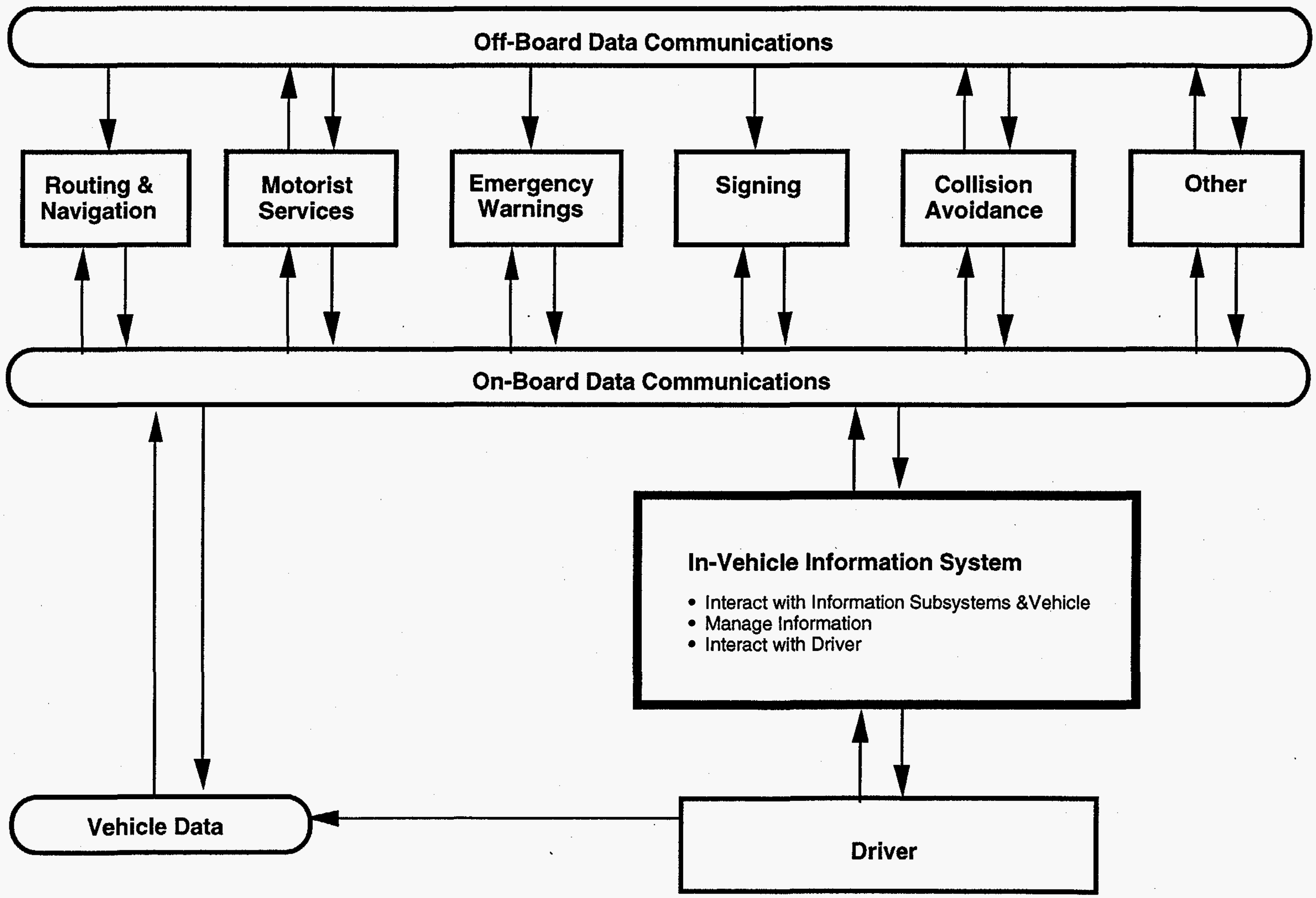

Figure 1

manner. From this goal, two high-level functional goals were derived: tailor the management and display of information to the type of driver; and tailor IVIS functionality to the operational situation (e.g., the vehicle, conditions, type of information). IVIS will perform three general functions: 1) interact with other on-board information subsystems and the vehicle; 2) manage the information; and 3) interact with the driver. The functional requirements described in this paper have either been derived from these three high-level functions or are directly mandated by the overriding requirements for modularity and flexibility. These overriding requirements are necessary for the system to accommodate the diversity of information subsystems and drivers with which it will have to interact.

Derivation of functional requirements from the functional goals was done in a hierarchical flowdown process (see Figure 2). This requirements flowdown process provides the audit trail through which all subordinate functions can be traced back to the functional goals and, ultimately, to the top level goal. It also provides the structure for configuration management during the subsequent design phase and supports traceability of all design decisions made in that phase.

Because of the manner in which functions were derived within the flowdown process, there is necessarily some redundancy in the following narrative descriptions of the different levels of the hierarchy. Before the steps in the flowdown hierarchy are described, brief descriptions of the system operational assumptions and overriding requirements are given.

System Operational Assumptions

The system operational assumptions concern the relative autonomy of the information subsystems' capabilities. IVIS is seen as being the recipient of information which has been gathered and processed by the subsystems. As such, IVIS will not be responsible for communication with off-board entities, or for providing on-board sources of data (e.g., map data bases), which may be required by the individual subsystems. Similarly, the execution of algorithms necessary for the provision of a class of information (e.g., routing and navigation) will also be the responsibility of the indivual subsystems.

Overriding Requirements

There are several overriding requirements which will affect the development of IVIS. These requirements stem largely from the institutional and market environments in which IVIS will operate. Meeting these requirements is critical to the success of the systems which are eventually deployed. As "overriding" requirements, they have a determining impact on the definition of the IVIS functional requirements at all levels. Even though there is a requirements flowdown process, within which requirements are derived from and are traceable to the system goal, there are lower level functional requirements which are directly traceable to one or more of the overriding requirements.

IVIS Functional Requirements Flowdown

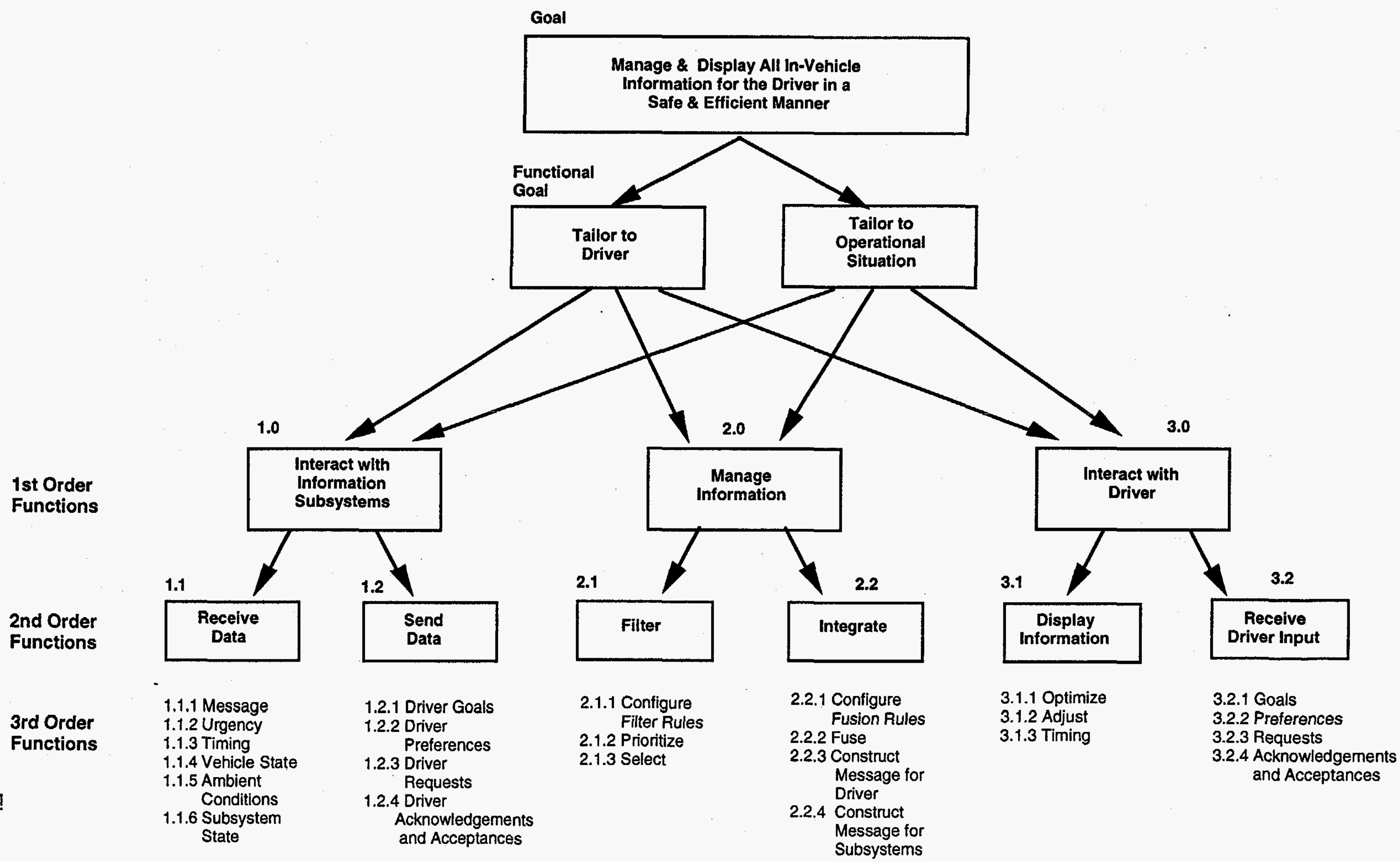

Figure 2

The system will have to be modular in order to accommodate different types and numbers of subsystems which may or may not be present in the vehicle. This modularity will be necessary because vehicle owners may choose to purchase some information subsystems when they buy the vehicle, and may add others later. IVIS will also have to be flexible in order to be responsive to the varying levels of sophistication that will be possible for each type of subsystem. Such flexibility anticipates the liklihood that there will be "high end" and "low end" versions of each type of subsystem. Similarly, IVIS will have to accommodate the diverse information needs of the diferent types of drivers who will be using it (private, commercial, transit). The system will also need to accommodate the different levels of expertise in using electronic information systems, which can be expected across the driving population. The greatest impact of these requirements is on the information management functions. The system will have to reconfigure the rule bases it uses to determine how it filters, prioritizes, and integrates information.

Other overriding requirements state the need for IVIS to conform to national and industry standards. Conformance to architecture and data communication standards will have a direct impact on design decisions involving the choice of hardware and software and the data structure and protocol with which IVIS will have to communicate. As such, these two requirements will affect the design of the system, but not the functional definition contained in this document.

Functional Goals

The functional goals were defined to support the top-level goal to manage and display all driving-related information for the driver in a safe and efficient manner. The two functional goals state that the management and display of information shall be tailored to: the driver and the operational situation. Tailoring IVIS operation to the driver implies information requirements in three classes: the driver's capabilities (e.g., sensory and psychomotor); the driver's goals (e.g., long distance travel along a particular route); the driver's preferences (e.g., for display modality and type of information filtering); and the driver's requests (e.g., for motorist services or for reservations). Tailoring IVIS to the operational situation implies requirements for three general classes of information: the type of information (e.g., sign type, message, and location); the vehicle state (e.g., vehicle weight and speed); and the ambient conditions (e.g., light level, glare, roadway conditions, weather).

IVIS FUNCTIONS

There are three first-order functions: interacting with the information subsystems and the vehicle; managing the information; and interacting with the driver. Each first order function has two second-order functions associated with it. The second-order functions comprise numerous subordinate functions, which are not explicitly labelled in the following narrative.

1.0 Interact with the Information Subsystems and the Vehicle.

IVIS will receive data from the information subsystems and the vehicle; and it will send data to the information subsystems. This function will determine what information IVIS will use to perform its information management functions, before presenting it to the driver. When the driver has requests, or wishes to respond to a message from one of the subsystems, this function will provide the means of communicating with the various information sources.

1.1 Receive Data.

The system will receive data from the information subsystems, the vehicle, and sensors regarding: message content, message urgency, message timing, vehicle state, and ambient conditions. Message content information will be received regarding: routing information (e.g., guidance, destination, and distance), vehicle location, responses to calls for help, responses to requests for reservations, hazards, weather conditions, road surface conditions, traffic conditions, roadway signs and signals, collision warnings, and advisories. Determination of message content and applicability will be made by the separate information subsystems. Message urgency information will be used to determine the dynamic salience of the display. If the system displays a message requiring the driver to stop the vehicle (e.g., a stop sign or impending collision), and senses that the driver is not responding, then it would increase the attention-getting nature of the display. Determination of message urgency will be made by the separate information subsystems. Message timing information will be used to determine the onset and duration of a displayed message. Accurate timing of the message is necessary to ensure that the driver receives the information when it is needed, for the entire time that it is needed, and only when it is needed. Determination of message timing will be made by the separate information subsystems. Vehicle state information will be received regarding: vehicle type, weight, speed, relevant driver inputs (e.g., brakes, accelerator, steering, turn indicators), and status (e.g., fuel). Vehicle information will be needed, for example, for the system to monitor the driver's responses to critical messages. Ambient conditions information will be received regarding ambient light and sound conditions. This information will be used to optimize the display. Subsystem state information will be received from each subsystem regarding its: presence, type, level of sophistication, and the types of data it will provide. This information will be used to configure the information management logic, in order to accommodate a diverse number and types of subsystems.

1.2 Send Data.

The system will send data to the information subsystems regarding: driver goals, driver preferences, driver requests, and driver acknowledgments and acceptances. Driver goals information will be sent regarding the driver's desired: destination(s), route name or type, service, or interests. Information on the driver's preferences will concern the driver's prefered: route(s) or information filter settings. Driver's requests sent to the information subsystems will cover: help (tow, police, ambulance), destination information, routing, and reservations. For drivers receiving requests or instructions from dispatchers (e.g., route deviation, on-demand routing and pick-up), IVIS will have to send messages from the driver acknowledging the receipt of the dispatcher's message and indicating the driver's acceptance of the request.

2.0 Manage Information.

The system will manage all information being sent to the driver and the subsystems by filtering it and integrating it. This function will be the gate between the driver and the potentially overwhelming amount of information which may be coming from all of the information subsystems. Besides filtering and prioritizing messages, this function will also integrate information, where appropriate. When the driver wishes to communicate with one of the subsystems (a request or response), this function will find any additional information needed to complete the driver's message.

2.1 Filter.

The system will filter all information to be presented to the driver using rules for prioritization and selection which are configured to accommodate the types of subsystems, data, and drivers. The function of reconfiguring the filter rules traces directly to the overriding requirements that the system be modular and flexible. Message priority will be used to determine whether and how to display each message to the driver. Prioritization will be based on a combination of: predetermined ratings of importance set in the IVIS logic; priority ratings supplied by the subsystems; and the driver's goals. Selection of a message for display will also accommodate the driver's preferences for the filtering of specific classes of information. For example, a driver in familiar territory may want to filter out all information related to navigation, and just be told safety and regulatory messages.

2.2 Integrate.

The system will integrate information received from and sent to both the driver and the information subsystems. This function is important for two reasons. First, there may be situations in which different subsystems send messages which relate to the same operational situation. For example, if the signing system senses a lane ending sign and the collision avoidance system senses a vehicle in the driver's left-side blind spot, these two pieces of information would be combined. The second reason for the integration function is to complete messages the driver may wish to send to one of the information subsystems. When the driver wants to send a request to a subsystem, IVIS will: identify the appropriate subsystem, determine what additional data are needed, and combine the driver's input with the additional data. This will allow the driver to interact with the subsystems at a relatively high level, with IVIS filling in the details. For example, if the driver wishes to send a call for help requiring a tow truck, IVIS would add information on the type of vehicle and its present location. The rules used to integrate information will be configured to accommodate the types of subsystems present, subsystem data types, and types of drivers. Just as with the reconfiguring of the filter rules, this function traces directly to the overriding requirements for system modularity and flexibility. Where appropriate, IVIS will combine information from separate subsystems. The system will also construct messages for the driver and for the information subsystems. When there are multiple messages for the driver, IVIS will either concatenate them in a temporal sequence or submit them to the display function for simultaneous display either spatially separated or for presentation via different sensory modalities (i.e., vision or sound). Separation across modalities may help to minimize the attentional difficulties posed by competition for the driver's cognitive resources within a single sensory channel.

3.0 Interact with Driver.

The system will interact with the driver by displaying information to the driver and by receiving input from the driver. This function will give the driver a unified and coherent interface, as an alternative to having separate displays and controls for each of the on-board information subsystems. As such, meeting this requirement will be critical in fulfilling the goal of safety and efficiency.

3.1 Display Information.

IVIS will perform three functions related to the display of information to the driver. It will optimize the display in order to enhance its legibility and intelligibility. The system will dynamically adjust the salience of the display to convey a changing sense of urgency to the driver. Finally, IVIS will determine the timing of a message's onset and duration.

Before or during the display of information, the system will optimize the parameters of visual and auditory displays to current ambient light and sound conditions and in accordance with driver preferences. If multiple messages are selected for presentation, the system will separate the display of the messages over space (i.e., different locations), over time (i.e., sequencing), across display modalities (i.e., auditory and visual), or any combination of the above. Separation of message presentation will be done in accordance with the relative priorities of the multiple messages.

During the display of information, the system will adjust the salience of the display in accordance with varying levels of the information's urgency. The determination of increasing or decreasing urgency will take into account the nature of the response required and the time and distance available for the driver and vehicle to execute the required response. Increasing or decreasing display salience will serve two purposes: 1) adjust the conspicuity of the displayed information; and 2) convey information to the driver about the changing level of urgency. For information requiring changes in the lateral (e.g., steering) or longitudinal (e.g., braking) movement of the vehicle, the system will increase or decrease the salience of visual and auditory displays in accordance with the urgency attributed to the message. Two obvious examples of messages requiring vehicle control inputs from the driver are: to avoid an imminent collision, or to stop for a stop sign. This function would also be useful in preventing a driver from missing a turn which is suggested by the routing and navigation system. Some design alternatives which may be considered in meeting the requirement to adjust display salience might include a subset of the following manipulations: intensity; addition or subtraction of an auditory speech display supplement; addition or subtraction of a non-verbal auditory display supplement; ratio of display "on" duration to "off" duration (i.e., duty cycle); display blink rate; and display spectral content (e.g., auditory display pitch). For information not requiring changes in lateral or longitudinal movement of the vehicle (e.g., warnings and advisories of upcoming regulatory signs), the system will display sign messages at a constant level of salience. This constant salience level will be determined during system design.

IVIS will time the initiation of the display of a message in accordance with: initiation data from the subsystems, an initiation command from the driver, and the driver's initiation timing preference. Termination of a message display will also be based on data from the subsystems, commands from the driver, and the driver's preferences. As stated above, the timing function will be important to ensure that a message is presented at the precise time that it is needed, for the entire duration over which it is needed, and only when it is needed.

3.2 Receive Driver Input.

The system will allow the driver to input goals, preferences, requests, and acknowledgments and acceptances. Through this function the driver will be able to tailor the system's operation to his or her desires. It will also mediate the driver's communication with the information subsystems and the outside world. The goals will be with regard to destination, route name or type, service desired, and interests. If, for example, the driver has entered a particular route name as a goal, then IVIS will configure its filtering rules so that it will only show guidance signs related to reaching that route. The preferences will concern how the driver wants the information displayed and filtered. In this case the driver can directly reconfigure the filter rules by specifying a type of information (e.g., routing and navigation) which is not desired. The driver will also be able to indicate the manner in which the information is displayed. For example, a driver who considers speech displays to be annoying can enter a preference that speech not be used. The driver will be able to make requests for routing and navigation assistance, motorist services, and calls for help. The types of services covered will include vehicle service, parking, entertainment and recreation, and reservations. For transit operators, IVIS will provide a means for the driver to input acknowledgment and acceptance of commands or requests from dispatchers (e.g., route deviation, on-demand routing and pick-up). The driver's requests, acknowledgments, and acceptances will initiate communication with the information subsystems or with systems or people outside the vehicle. The particular types of controls the driver will use to make these inputs will be determined during system design, and will reflect the human factors guidelines currently being developed.

SUMMARY AND CONCLUSION

The goals of the IVIS have been directly driven by the need to integrate the growing number of information sources being developed and installed in vehicles. The functions will support the objectives of making the driver's uptake of the available information more efficient, and of minimizing the potential for driver distraction, thus enhancing safety. IVIS must also be responsive to the unbounded diversity of the vehicle electronics market and the widely varying needs and capabilities present in the driving population. Safety and efficiency will be fostered by two general features of IVIS: the management of information by one on-board system, and a unified driver interface. Responsiveness to driver and system diversity will be accommodated by the reconfigurable rule bases used to manage the information.

The IVIS functions described here will form the basis for the development and testing of a prototype system. This prototype will incorporate the evolving data communications standards, current and emerging vehicle information subsytems, and human factors guidelines which are being developed by the Battelle Seattle Research Center and others in the transportation community. The ultimate goal of this project is to foster the deployment of in-vehicle information systems which will assist drivers and which will support diverse configurations and system functionality.

ACKNOWLEDGMENTS

This work was supported by the Federal Highway Administration, contract #1883E020-A1. This paper reflects the opinions of the authors and does not necessarily reflect the opinions, policies, or regulations of the United States Department of Transportation or the Federal Highway Administration.

ENDNOTES

1. P.F. Spelt, D.R. Tufano, and H.E. Knee, "Development and Evaluation of an In-Vehicle Information System," Proceedings of the ITS America Seventh Annual Meeting (Washington, D.C.: ITS America, 1997).