IN-VEHICLE SAFETY ADVISORY AND WARNING SYSTEM (IVSAWS)

VOLUME III: APPENDICES A THROUGH H (REFERENCE MATERIALS)

NOTE TO READER:

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Due to its large size, this document has been segmented into multiple files. All files separate from this main document file are accessible from links (blue type) in the table of contents or the body of the document.

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Invehicle Safety Advisory and Warning System (IVSAWS),

Volume III: Appendixes A Through H (Reference Materials)

U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101-2296

FOREWORD

This report presents the results of a comprehensive study to identify candidate advisory, safety, and hazard situations where motorists would benefit from an Invehicle Safety Advisory and Warning System (IVSAWS). Functional specifications are also provided in sufficient detail to describe how these functions could be gradually incorporated into existing and future automotive vehicles. The IVSAWS, designed for rural, urban, and secondary roads, uses a proposed communication architecture based on transmitters placed on roadside signs and at roadway hazards to communicate with approaching vehicles equipped with IVSAWS invehicle radio receivers. This study will be of interest to transportation planners and engineers involved in motorist advisory and emergency communication systems.

Sufficient copies of the study are being distributed by the FHWA Bulletin to provide a minimum of two copies to each FHWA regional and division office, and five copies to each State highway agency. Direct distribution is being made to division offices.

Lyle Saxton
Director, Office of Safety and Traffic
Operations Research and Development

NOTICE

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16. Abstract

The Invehicle Safety Advisory and Warning System (IVSAWS) is a Federal Highway Administration effort to develop a nationwide vehicular information system that provides drivers with advance, supplemental notification of dangerous road conditions using electronic warning zones with precise areas of coverage. The research study investigated techniques to provide drivers with advance notice of safety advisories and hazard warnings so drivers can take appropriate actions. The technical portion of the study identified applicable hazard scenarios, investigated possible system benefits, derived functional requirements, defined a communication architecture,and made recommendations to implement the system.

This volume is the third in a series. The other volumes in the series are:

FHWA-RD-94-061 Volume I: Executive Summary
FHWA-RD-94-190 Volume II: Final Report
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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd ❑ 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2 = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2 = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (Lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp ❑ 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] ^{0}F ❑ y ^{0}C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliters (ml) ❑ 0.03 fluid ounce (fl oz)
1 liter (1) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] ^{0}C ❑ x ^{0}F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES: 0 1 2 3 4 5 6 7 8 9 10

CENTIMETERS: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. Cl3 10286.

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APPENDIX A: WORKPLAN FOR THE INVEHICLE SAFETY ADVISORY AND WARNING SYSTEM (IVSAWS)

This appendix outlines the initial Invehicle Safety Advisory and Warning System (IVSAWS) workplan that included several tasks: establishment of the study workplan (task A), definition of a prioritized list of driver hazards and determination of adequate driver warnings (task B), definition of the baseline IVSAWS communications subsystem design (task C), selection and procurement of equipment to demonstrate key features of the baseline IVSAWS communication subsystem design (task D), definition of the baseline Driver Alert Warning System (DAWS) (task E), design and fabrication of DAWS testing of program equipment (task F), test IVSAWS equipment using a mix of subjects (task G), development of a system-level specification for the baseline IVSAWS design (task H), provision of a technical summary of key results (task I), preparation and presentation of a draft technical report (task .l), and preparation and presentation of a final technical report (task K). This initial IVSAWS workplan was later revised in accordance with COTR approval to eliminate tasks D and F, and further limit the remainder of the study to design analysis without any actual IVSAWS equipment manufacturing/tests.

Section A - Workplan Overview

The IVSAWS Study Program is a multi-phase study intended to provide the Government with an assessment of the IVSAWS concept, a baseline design for the development of operational IVSAWS hardware, and preliminary testing of most aspects of the IVSAWS system. These aspects include the RF communications, the in-vehicle human-machine interface, and the measured responses of a scientifically selected population of mixed ages to the utility of the hazard alert warnings.

The phases of the IVSAWS study and the key issues or outputs of each phase are summarized in Table A-I. Interim results from all tasks will be documented in Engineering Notebooks (ENBs). All ENBs will be forwarded to the FHWA for information purposes only. Tasks C and E require careful systems engineering effort to determine the optimum design for the RF communications equipment and message structure (Task C) and the man-machine interface (Task E).

Hughes envisions taking a systems approach to the design of the IVSAWS receiver. Task B will provide the data base for the selection of hazards and the choice of the warning messages. UMTRI and Hughes Human factors engineers will work together to define a prioritized list of hazard scenarios and to synthesize an appropriate advisory/warning message for each scenario.

In Task C, Hughes communication engineers will define the RF communication link needed to reliably deliver the message to the IVSAWS receiver. This task will include analyses of propagation, selection of an appropriate frequency band, the development of a set of messages for reliable transmission of the data including error detection codes for identifying error free messages, and an assessment of the interference on the channel coupled with the need for sophisticated processing including spread spectrum and excision processing. Emphasis will be placed on the development of a flexible system which will support the needs of the rural driver but which can also be used in the urban environment and to support other services such as the intelligent highway programs.

In Task E, Hughes Human Factors engineers will examine the options for alerting the driver to the hazard, including audio and visual stimuli. This study will incorporate all of the options being considered in the automotive industry, such as the heads up display, touch panel displays, entertainment override as well as the constraints including limited display space, the legal liability issues, the driver's ability to interpret the message and his perceptual limitations.

The postulated test program is based on a strawman design using a commercially available spread spectrum radio, probably in the 902-928 Mhz band and a PC display. The actual radio selected for the test program will be based on the analyses in Task C. The radio will be tested for propagation range and data transmission reliability in both co-channel interference and in the presence of another IVSAWS transmitter. A live road test will be conducted with the radio and driver alert warning system installed in a GM-supplied automobile.

The results of these analyses and tests will be summarized in our final report and design specification. Because it is anticipated that the design will be appropriate to multiple systems with a market of millions of units, it is anticipated that sophisticated semiconductor chip technology will be applied to the design, resulting in a low cost Application Specific Integrated Circuit (ASIC) based design. The cost of such a design is expected to be appropriate for a low cost application.

Figure A-l shows the task flow envisioned by Hughes. The program schedule (Section L) presents an accelerated schedule (with respect to the plan laid out in the contract) which Hughes believes would result in more efficient manpower utilization without change to the overall level of effort by minimizing work gaps for key personnel.

TABLE A-1.
HIGHLIGHTS AND KEY ISSUES OF THE IVSAWS PROGRAM

Task A Establish a plan for the study and obtain written COTR approval.

Task B Define a prioritized list of hazards together with likely road geometries, terrain, speed, and other factors. Human factors and traffic engineers must reach a consensus on the amount and type of information that will provide adequate warning without distracting or annoying the driver.

Task C Define the baseline IVSAWS Communication Subsystem design. Obtain written approval of results by COTR. The communications engineers must define a communications architecture to support general evolutionary services and to support reliable message transmission with sufficient flexibility to allow processing of inhibit and multi-mode antenna message overhead. The choice of frequency, bandwidth, and modulation structure must support an affordable design.

Task D Select and procure readily available, affordable radio and digital modem equipment to demonstrate key features of the baseline IVSAWS Communication Subsystem design.

Task E Define the baseline Drive: Alert Warning System (DAWS) which provides the display/control interface with the driver. Then equipment to announce IVSAWS hazard alert messages for the test program will be selected. This equipment will implement the key features of the baseline DAWS. Obtain written approval of the COTR. Human factors engineers must look at the range of available and projected man-machine interface technologies to ensure that the architecture will support evolutionary changes. The display and audio alerts will be tested on a scientifically selected range of volunteer subjects with ages from 16 to above 65 at both Hughes and GM simulation facilities,

Task F Design and fabricate DAWS test program equipment and install DAWS Subsystems in test vehicles and vehicle simulator.

Task G Test IVSAWS equipment using a mix of young, middle aged, and over age 65 drivers to determine the utility of the key design features. The test must be designed to allow a clear validation of the baseline architecture and to support the development plans for subsequent phases.

Task H Develop a system level specification for the baseline IVSAWS design to support a later development phase.

Task I Provide a four-page technical summary of the key results in the selected two-column format.

Task J Prepare and deliver Draft Technical Report for COTR approval.

Task K Prepare and deliver Final Technical Report.

FIGURE A-1. IVSAWS TASK FLOW. Encircled letters represents connections to other parts of the task flow. Subtasks identified in the workplan text are identified by an alphanumeric (e.g. B-1 for Task B, Subtask 1)

FIGURE A-1 (continued). IVSAWS TASK FLOW.

Section B - Task B Workplan and Applicability of the SHAWS Report to the Highway Problem

The FHWA Report (FHWA/RD-8 l/124) provides a base from which to develop candidate situations for the application of IVSAWS. While much of the information provided in this report is accurate and useful in situation selection, inconsistencies exist which make examination of other data necessary. Probably the most glaring inconsistency in the report is the contention that "Nonintersection accidents of any sort are rare events" (page 2-1, emphasis original). An examination of the 1987 CARDfile data developed by NHTSA from crash reports from Indiana, Maryland, Michigan, Pennsylvania, Texas, and Washington shows that 46.8% of all crashes are not "driveway related" or "intersection related." Perhaps "rare" used in the context of the report meant rare with respect to vehicle volume or miles traveled. This point is not clear from the report; however, this anomaly points out the need for further examination of crash data and careful selection of criteria to be used in IVSAWS situation selection.

Subtask 1: Analvsis and Prioritization Plan Development.

First, the criteria by which crash hazards are to be prioritized will be determined. It is necessary to first determine how the crash situations will be ranked to determine what data elements should be extracted from crash data files, and how cross-tabulations of crash data should be constructed. This prioritization scheme will be developed by a panel of traffic data and safety experts from UMTRI, Hughes, and the Michigan Department of Transportation who will discuss the merits of alternate prioritization schemes. At a minimum, the prioritization of crash scenarios will require crash severity measures (including both vehicle damage and occupant injury data), segmentation of the crash population into logical and workable units (e.g., urban-rural, intersection-nonintersection, road curvature, road grade, road classification, traffic control device availability and type), and measure of crash exposure (e.g., vehicle miles traveled and traffic volume).

The prioritization scheme will, in part, be developed based on results from earlier studies conducted to examine crash scenarios which may prove amenable to IVSAWS. In addition to the SHAWS report FHWA/RD-81/124, UMTRI personnel have conducted studies of crash data to determine IVHS suitability and needs using NASS, CARDfile, and crash data from Washington state and Michigan. This experience should facilitate development of a prioritization scheme that can anticipate data requirements and availability, as well as possible IVSAWS development opportunities and needs.

Subtasks 2 and 3: MIDAS-MALI and CARDfile Data Analysis.

Once a prioritization scheme has been developed, Michigan crash data files (i.e., MALI--Michigan Accident Location Index and MIDAS--Michigan Dimensional Analysis Surveillance System) and data from the CARDfile states will be analyzed in detail to determine candidate situations that may prove to be amenable to IVSAWS applications. Analyses will focus on crash scenarios components identified to be important in the prioritization-model development task described earlier. In addition to identifying general groups of crash characteristics which may prove amenable to IVSAWS solutions, a set of six to ten specific locations will be identified which have proved to be particularly hazardous and have remained hazardous despite application of traditional crash reduction treatments.

Subtask 4: Situation Hierarchy Development.

By applying the prioritization model to the data obtained from the MIDAS-MALI and CARDfile analysis runs, situations will be ranked in a hierarchical order based on potential benefits to safety and traffic operations that may be obtained through application of IVSAWS technologies. Development of several hierarchies may prove to be most beneficial for identifying situations most promising for IVSAWS application. Depending on data availability and amenability to analysis, separate hierarchies will be developed based on total crash count, total vehicle count, crash casualty and vehicle damage severities, as well as crash and outcome severity rates per vehicle mile traveled and traffic volume. By developing several different hierarchies, the tradeoffs between frequency of occurrence, rate of occurrence, and outcome severities can be assessed directly for use in selecting the most desirable situations for the application of IVSAWS. The situations identified will be reviewed by automotive safety and accident engineers and entered into an Engineering Notebook (ENB).

Subtask 5: Signalling Recommendations.

Based on these hierarchies and the six to ten specific problem sites identified, suggestions will be made on which warning and regulatory signs should be provided to drivers in the vehicle. While one obvious strategy is to directly replicate Manual of Uniform Traffic Control Devices (MUTCD) signing at the roadside, modifications of these signs may also be desirable to augment the information available at the roadside. Suggested signing will be based on information needs and problems identified in the analysis of the crash data.

Subtask 6: Signalling Presentation Human Engineering (HE) Analysis.

Human Engineering analysis will identify how the recommended signalling accessed and identified in Subtasks 4 and 5 should be presented to the driver. At a minimum, the analysis will evaluate the following:

1) The use of visual displays including icons and/or text and/or color.

2) The use of audio including tones and/or speech synthesis.

3) Driver alert control including driver over-ride and/or message acknowledge and/or message repeat.

4) The format and length of the message to be presented to the driver,

Section C - Task C Work Plan and Applicability of the SHAWS Report to Communications Technology Selection

Based upon the results of Task B, a baseline Communication Subsystem design will be defmed that will alert drivers to advisory and safety signing, and roadway hazards. The baseline design and work performed during the subtasks defined below will be inputs to the development of a functional system specification. Additionally, requirements for the IVSAWS to support highway/driver information systems will be projected. The Communications Subsystem design will include all assumptions and design tradeoffs. As appropriate, the assumptions and tradeoffs will be supported with equations. Results will be presented in tabular and graphical form. A detailed block diagram of the baseline design will be provided. The block diagram will include maximum and minimum signal levels, noise levels, bandwidths, modulation type, path losses and message structure.

Subtask 1: Communication Path Geometry Analysis.

The geometry of communication paths for the four most significant signing and hazardous roadway situations identified in Task B will be determined. In this context, "most significant" means those situations with geometries which will make communication most difficult, such as through dense foliage or over a large obstacle. As applicable, geometry will be analyzed for transmitters placed on signs, at hazardous sites, on overpasses, and those operating from school buses and police/emergency/maintenance vehicles.

The SHAWS report is directly applicable to this subtask. Figure 6- 1 of the report presents an effective method of evaluating communication path geometry for various combinations of signing/hazard situations and transmitter deployments. This method, or a variation thereof, will be used to perform this subtask.

9 Subtask 2: Driver Alert Distance Analysis.

Communications engineers will review the scenarios evaluated by the University of Michigan in Task B to determine how the road geometry and worst-case speed of the automobile determines the minimum coverage range for receiving the alert and the corresponding minimum time to repeat the message. The Driver Alert Distances will be evaluated for the four most significant signalling and hazardous roadway situations identified in Task B. In this context, "most significant" means those situations which, based upon a precursory review by UMTRI personnel, will maximize the required Driver Alert Distances.

The SHAWS report tabulates preliminary Decision Sight Distances (DSD) required to perform a corrective-action lane change. The DSD is defined as the period of time required in order for a driver to detect and recognize a hazard, decide upon hazard avoidance response, initiate the response and perform the maneuver. The report shows that the necessary distance required to alert a driver to a hazard is the sum of the DSD and the Advanced Warning Time (AWT). The worst-case Driver Alert Distance will be evaluated by verifying or correcting assumptions made in the SHAWS report with respect to driver hazard identification and response times, and determining the worst-case AWT and avoidance maneuver times.

Subtask 3: Frequency Selection and Transmit Power Analysis.

FCC regulations will be examined in order to identify frequency band options including factors of available bandwidth and transmit power. Licensing requirements, if any, will be identified. Within the candidate frequency bands, the use of traditional and non-traditional modulation techniques will be examined, specifically the use of narrow band spread spectrum. Hughes will investigate the following frequency bands for the IVSAWS application:

510-1705 KHz (leaky cable systems)
26.9-27.4 MHz (Citizen's Band)
45-47 MHz (highway maintenance)
54-72 and 76-88 MHz (excluding 73.0 to 75.4 MHz, perimeter protection systems)
88- 108 MHz (FM single sideband transmissions)
285-3 15 MHz (garage door openers)
806-821 MHz and 851-866 MHz (mobile phones)
825-845 MHz and 870-890 MHz (cellular phones)
902-928 MHz (FCC part 15 spread spectrum band)

The indicated usages are illustrative and are not exhaustive.

In addition, the following bands which are designated for Fixed/Mobile communications may be appropriate for low power spread spectrum operation:

335.4-399.9 MHz (UHF satellite uplink transmission)
410-430 MHZ
890-902 MHZ

This last band is particularly interesting for a spread spectrum IVSAWS since it has enough bandwidth to support a spread bandwidths of 5-10 MHz.

Subtask 4: Transmitter Characterization.

This subtask will determine the frequency, power level, modulation technique, coding scheme, and antenna configuration for portable, sign mounted, and vehicle mounted transmitters.

Hughes review of the SHAWS report study indicates that the report is flawed in the assumption that affordable cost dictates a minimal capability system. Hughes will support this position by performing a set of tradeoffs to determine how various features affect the utility and the per unit production cost of the baseline IVSAWS system. The following tradeoffs will be performed at a minimum:

1) Range - The communication range as a function of road geometry, terrain and antenna configuration will be evaluated for selected frequency bands,
3) Overhead Content of the Transmitted Waveform - In addition to the actual data for the alert message, the transmitted message must contain certain overhead fields. A start of message preamble and a message ID field are necessary. Error detection coding is necessary to assure that only valid messages are displayed. The size of this field must be selected. The utility of forward error correction coding will be assessed. The bit error probability and bit error rate, with and without error detection and correction, will be provided.
4) Message Garbling - The probability of message garbling due to collision will be assessed.
5) Interference - The impact of co-channel interference and impulsive noise on bit error rate will be assessed and signal processing techniques that enhance channel utility will be characterized.
6) Impact of Self-Test/Fault Isolation -The mechanization of self test functions will be considered to identify when failures have occurred that would degrade the performance of the IVSAWS hardware. Fault isolation tests to be available in a

test mode will be considered to aid technicians in isolating faulty IVSAWS components.

7) Power Requirements - Transmitter current consumption and input voltage will be estimated. Battery capacity for transmitters located at fixed, remote sites will then be evaluated.

The SHAWS selection of a six pulse waveform is not well justified, even for a very limited system. Hughes has the following objections to this design:

- The amount of data is very limited
- The message structure could readily br generated by a burst of noise, leading to false alarms

By contrast, more sophisticated waveforms, such as those used in anti-jam communications, will have strong en-or correction codes to validate the message and reject almost all false alarms.

Subtask 5: Receiver Characterization.

A low cost, simple-to-operate, and ascetically low-impact receiver will be characterized. It is likely that a more capable receiver than that described in the referenced report will be required. The SHAWS receiver design targeted a low-cost receiver constructed from readily available parts. By contrast, Hughes believes affordable, multi-function receivers with much greater sophistication can be fabricated with available semiconductor technology (i.e., using Application Specific Integrated Circuits or ASICs) when the market is measured in millions of units. The large volume of units to be produced makes the non-recurring investment to develop the semiconductor masks and processes reasonable. In evaluating a more sophisticated receiver the following will be analyzed:

1) Application Specific Integrated Circuit Evaluation- The feasibility of implementing the IVSAWS RF hardware with Application Specific Integrated Circuits (ASICs) will be determined.
2) Reliability – The reliability of the IVSAWS hardware will be determined based on preliminary partitioning of the IVSAWS hardware.
3) Production Cost – The production costs of ASIC chip-based hardware will be projected based on GM-Delco's assessment of ASIC costs.
4) Antenna Configuration- An IVSAWS receiver which uses the vehicle's existing radio antenna is desirable. If this configuration is not possible, other low-impact options will be evaluated.

Subtask 6: Computer Modelling.

Much of the system parameter analysis will be performed using well known results from the field. This approach will allow us to narrow the architectural design problem to the resolution of a few key issues:

- The number of bits to be transmitted in a message, including overhead for each message type
- The burst data rate and transmit duty factor
- The appropriateness of a spread spectrum waveform
- The selection of the frequency band

These issues were discussed in Subtask 3. Only one requires a computer analysis. Namely, the issue of frequency selection is strongly determined by propagation coverage in rolling terrain. This analysis has been addressed with the Longley-Rice propagation model, which has been standard in the US Army for more than 10 years and has been carefully validated with experimental data. Hughes has extended the model to include the effects of foliage attenuation. Figure C-l shows the use of the Longley-Rice Model in a network management context. The model includes:

- A point-to-point mode, which uses a terrain profile and computes the path loss based on a series of knife-edge diffraction losses
- An area mode, based on data from the Defense Mapping Agency height data or a two dimensional random surface with a specified roughness

The output from this program gives a mean propagation loss and the expected variance in the propagation loss between any number of specified terminal pairs. The Longley-Rice model will be used in establishing the effects of excess propagation loss as a function of frequency. Additional computer analyses and simulation may be used to optimize waveform parameters as the study progresses and the baseline waveform parameters are determined.

Subtask 7: Transmitter Directionality Analysis.

Control of the alert coverage area is a key issue. A transmitter located on an overpass should alert only traffic on the overpass and not the lower road. The coverage should also be capable of being controlled to alert only vehicles approaching the hazard from one direction and not the other. The referenced report suggests two methods of limiting the dissemination of the alert to drivers: (1) control of the radiation pattern and (2) the use of inhibiting transmitters.

Hughes will assess the use of simple directive antennas such as those used for television to limit the coverage sector. Beamwidths of the order of 60 degrees are readily achievable with simple electromagnetic horns, particularly in the 900 MHz band. The use of a dual-mode antenna, as described in the referenced report, is very helpful in eliminating reception through sidelobes and backlobes, but it does require a receiver capable of making amplitude comparisons between two parts of a transmission, and a more complex transmitter. Due to budgetary constraints, the dual-mode architecture will not be considered.

The use of a flexible message structure and/or free text which allows inhibiting specific message IDs to limit the coverage, for example, to westbound traffic on an east-west highway will be investigated. The use of vehicle orientation sensors will be examined. The use of inhibiting transmitters will also be examined.

Subtask 8: Task C Report

A report summarizing the results of the previous subtasks will be generated. Requirements for the IVSAWS to support highway/driver information systems will be projected and included in the document.

FIGURE C-1. Hughes Network Management Algorithm Development Tools.

HUGHES

Section D - Task D Workplan

Based upon the results of Task C, appropriate transmitter, receivers, antennas, coders/decoders, and control processors will be procured and modified as needed in order to demonstrate key concepts from the communication system design. The transmitter(s) shall be capable of use in a wide variety of situations including fixed and movable locations. Transmitters shall be battery operated, either from internal batteries or from the 12-volt automobile battery, simple to operate, and have conuols that resist inadvertent activation. Vandal-resistant hardening of fixed, remote installations shall be considered.

Subtask 1: Communication Equipment Survey and Selection.
The demonstration communication hardware design will consist of selecting as much commercial off-the-shelf (COTS) hardware as possible. Task C requirements will be reviewed and key communication concepts will be identified. The commercial market will be examined for candidate communication equipment which can demonsnate these concepts. The candidates will be evaluated and final selections will be made.

Test vehicles supplied General Motors Corporation will be used for evaluating the IVSAWS concepts developed during this study. Demonsuation testing will be implemented using a commercially available portable personal computer (PC) for driving the demonstration hardware and software. Since the demonstration will be viewed as a concept validation only, no attempt will be made to reduce demonstration hardware cost.

Subtask 2: Communication Equipment Procurement.
A technician will be assigned to order and track the procurement of the selected hardware. Hardware for two transmitters and one receiver will be purchased (including coder/decoders and control processors). Received hardware will be marked as government property and tracked accordingly.

Subtask 3: Mechanical Design and Fabrication.
Mechanical design for mounting the subject hardware in the vehicle will be performed. The receiver and decoding electronics shall be capable of operating over the full range environmental and electrical conditions found in the test vehicle for the duration of the Task G tests. Additional housings and mounts will be designed and fabricated such that the transmitter assemblies can be fixed to a sign or pole, deployed at roadside, and mounted in a vehicle.

Subtask 4: Software Design and Generation.
The principle design task for the IVSAWS communication hardware modification consists of generating the necessary software for use in the PC. The PC communication software will include several modules including those for down-loading and storing serial data from the modem and conuol of the receiver and transmitters.

Subtask 5: Integration and Test
The equipment procured and modified in Subtasks 2 thru 5 will be bench tested at the system level in order to isolate and correct major faults. Testing will include:

- Measurement of receiver sensitivity (threshold)
- Measurement of receiver bit error rate with additive Gaussian and impulsive noise
- Observation of receiver response to near-simultaneous transmissions
- Transmitter power output

The receiver and one of the transmitters will then be installed in test vehicles and tested for proper installation via the transmission and reception of test messages.

Section E - Task E Workplan

Subtask 1: Driver-Alert Warning System Design.

The Driver-Alert Warning System represents those components (hardware and software) resident in a vehicle which are used to convey information concerning advisory, safety and hazard situations to the driver of the vehicle. One of the main objectives of the study is to determine the specific components which make up an optimum Driver-Alert Warning System. Optimization parameters include driver safety, system effectiveness, maintainability, reliability, recurring and non-recurring cost, size, power, weight, environmental characteristics, installation complexity, system expansion/growth capabilities, integration effectiveness with existing vehicle systems, usefulness by normal drivers, physically impaired drivers, and different age groups, as well as acceptance by the motoring public. Many of these parameters represent diametrically opposed implementation constraints.

Based on the recommendations from Task B, the selection of the appropriate driver display will result from joint trade studies conducted by human factors, systems engineering, electrical engineerin g, and mechanical engineering personnel. Three primary candidates include (1) instrument panel tell-tales (symbols), (2) heads-up display, and (3) touch panel CRT.

Human factors specialists will define DAWS system parameters including display position, control panel layouts, equipment arrangements, display formats, auditory alarms/alerts, accessibility, lighting, display legibility, and noise limits.

DAWS system parameters, including maintenance access to IVSAWS equipments, will be reviewed during the development of soft mockups and test bench design of the equipment, Kapid menu selection, minimum driver entry, standardization of display segments, standardization of voice and/or tone outputs and easily identified hazard/fault nomenclature will be investigated.

Subrask 2: Driver-Alert Warning System Mockup Testing.

The testing of a "mockup" Driver-Alert Warning System will be predicated on data derived during Subtask 1. The initial task data contained in Report No. FHWA/RD-81-124 will be compared to, and updated by, data contained in the study commissioned by the U.S. Department of Transportation (DOT) and the National Highway Traffic Safety Administration (NHTSA), Driver Education Task Analysis, Vol. I: Task Description. Contract No. FH-1 l-7336.

The candidate Driver Alert Warning System will be tested in a static environment in the Human Factors Laboratory at Ground System Group, Fullerton, California. Anthropomehic analysis and mockups will be used to evaluate the human-machine interface.

Two specific laboratories will be considered for initial empirical testing of the Driver-Alert Warning System. The fist is the Hughes Ground Systems Group (GSG) Human Factors/Artificial Intelligence Laboratory, Fullerton, CA. The second is the General Motors System Engineering Center (SEC) Human Factors Laboratory, Troy, MI.

The subjects used for empirical testing will be apportioned into age groups representative of the groups to be used for final system testing. That is, young (16 to 35 years of age), middle aged (36 to 65 years of age), and mature (over 65 years of age).

The population will include subjects that range in size from the fifth percentile female to the 95th percentile male.

Hughes will empirically test selected icon/symbols (tell-tales), for recognizability/appropriateness, comprehensibility and effectiveness, using monochrome and color applications. Colors will be selected based on probable hazard levels defined in Report No. FHWA/RD-81/124. The selected symbols will be tested individually as well as when paired with voice messages, tones, and voice. Primary measures of effectiveness will be accuracy/correctness of response and timeliness of response (response time).

Reach and vision analyses of the drivers in the static mockups will utilize the information provided in SAE Standards J287, "Driver Passenger Manuals for General Rules on Arm Reach," and SAE Recommended Practice 51052 (1985) "Motor Vehicle Driver and Passenger Head Position." The reach and vision analyses will be combined with platform information and the candidate warning system devices to determine optimum locations and sizes of devices within the driver reach envelope and cone of vision. This information will be used in soft mockup preparation and testing.

The mockups that will be used in Human Factors Engineering testing will be designed to simulate the volumetric interior space within the driver compartment of the test vehicle. The location of the instrument panel, console, steering wheel and other equipment impacting driver performance will be included as part of the test fixture. The mockup of the Driver-Alert Warning System will be mounted in locations within the driver compartment that will be identified in the anthropometric analysis. The mockups will then be used to test the displays and auditory signals for location, ease of use and driver error.

Candidate visual displays will be tested for optimum location, icon/symbol text selection, font and font size selection, color of display objects, intensity of display objects, bright/dark compatibility, frequency rate of warning, ease of perception, duration, advisory/alert categories, vocabulary (message content), abbreviations, and adherence to SAW, IS0 and ANSI standards. Candidate auditory messages will be tested for optimum location, intensity, tone/voice, advisory/alert category, and vocabulary. The data gathered in the static mockup testing will assist in determining superior candidate devices and configurations.

Subtask 3: Task E Report.

The Task E report will be prepared which summarizes the results of the DAWS system design and evaluation process.

Section F - Task F Workplan

Based upon the results of Task E, two proof-of-concept Driver Alert Warning Systems will be assembled which implement the key features of the baseline DAWS defined in Task E. The systems shall operate from the 12-volt automobile battery.

Subtask 1: Electrical Design

DAWS man-machine interface electrical design will be performed during this subtask. The design will include as much commercial off-the-shelf hardware (e.g. PC-drivable voice synthesizer circuit card) as possible.

Subtask 2: Component Procurement.

A technician will be assigned to order and track the procurement of DAWS components, display and/or voice synthesizer, and control devices. A locker dedicated to the storage of IVSAWS hardware will be secured.

Subtask 3: Mechanical Design and Fabrication.

Mounts, housings and connectors will be designed and fabricated for the installation of the subject hardware in the vehicle per human factors directives.

Subtask 4: DAWS Fabrication.

DAWS electronics will be assembled and bench tested in order to isolate faults prior to vehicle installation.

Subtask 5: DAWS Software Design and Generation

Software drivers for the DAWS display/voice synthesizer, user controls, and test message generation will be written. The software will execute on the same PC that runs the NSAWS receiver.

Subtask 6: Integration Installation and Test

The equipment and software fabricated and assembled in Subtasks 3, 4 and 5 will be integrated and bench tested prior to vehicle and simulator installation. The DAWS will be tested at the system level in order to isolate and correct faults. Testing will be limited to a power-on test and the reception and display/synthesis of a test message. One DAWS will then be installed in a test vehicle for the communication concept demonstration test while the other is installed in a vehicle simulator for the DAWS concept demonstration testing.

Section G - Task G Workplan

Tests will be structured and conducted in order to demonstrate the concepts developed in this study.

Subtask 1: Communication System Test Plan Development

A test plan will be developed that will, at a minimum, include the following tests:

1) Radio Propagation Test - The limits of reliable line-of-sight reception will be determined by increasing transmitter and receiver separation until the bit error rate exceeds a threshold. By knowing the receiver sensitivity, transmitter power (both measured during Task D) and antenna gains(losses), the impact of rural or urban background noise on communication range can then be estimated by comparing the resulting separation to that predicted using a free-space path loss assumption.

2) System Coverage Selectivity Test - The ability of the system to selectively alert drivers only on specific routes and in a specific direction will be tested with fixed and mobile transmitters. The transmitter will be placed on an overpass to determine if a test vehicle travelling on underpass is able to receive warning signals.

3) False Alarm Test - An acceptable false alarm rate will be observed. No false alarms should occur during execution of the test plan (Subtask 2).

4) Scenario Testing - The test plan will include the conduct of four specific scenarios, which will include various types of hazards, road conditions, environmental, and geometric situations. "Difficult" scenario communication path geometries will be selected (e.g. winding road). The test will demonstrate the reliability of the system to be selective in reporting and devoid of false alarms. The duration and amount of testing is based on the criteria of two successful tests of each type plus the possibility of rescheduling 25% of the tests because of unexpected difficulties in their conduct, i.e., equipment failure, human error. Measurements of link margin will be made at each scene.

5) Test Plan Site Survey - Candidate sites at which to conduct tests 1 thru 4, above, will be selected by examining terrain and road maps. Final selection will be made after a visual examination of the candidates.

Subtask 2: Communication System Demonstration.

The test plan developed during Subtask 1 will be executed.

Subtask 3: Driver Alert Warning Svstem Test Plan.

A test plan will be developed which, when executed, will demonstrate whether the detailed operations and maintenance of the IVSAWS can be performed effectively, reliably and safely by a wide range of drivers and that hazards are accurately recognized and safely avoided.

A population of 60 subjects will be used for the test and evaluation phase. Of these 60 subjects, 20 will be young (16 to 35 years of age), 20 will be middle aged (36 to 65 years of age) and the remaining 20 subjects will be mature (over 65 years of age). Ten subjects from each age category will be male and the other 10 will be female. For all subjects, personal information relevant to the subjects' performance and data analysis will be gathered. This information may include, but is not limited to: name, address, social security number, proof of valid driving license, level of education, current and/or former occupation, current working status (working or retired), level of driving experience, driving record (number of tickets for traffic law violations), and type of car driven. Information on the subjects' current health will also be gathered. Health information will include visual acuity determination for both distance and color vision (Corrected distance vision should be as close to 20/20 as possible.), presence of visual correction (glasses or contact lenses), auditory perception determination, presence of hearing aid(s), physical limitations, and drug or alcohol consumption.

Several forms will be created to inform the subjects about the testing conditions and to record the subjects' personal information and performance data. These forms will include: initial contact letter, letter of consent (to be signed by an adult to allow the participation of a minor), task instructions, subject information questionnaire, test conductor form, and post-test questionnaire.

A number of environmental concerns will be addressed through use of the driving simulator. The driving simulator at the General Motors System Engineering Center, Troy, Michigan, will be used. Both day and night driving situations will be evaluated. Three road conditions will be evaluated: wet, dry and icy. The weather conditions that will be tested are: sunny, fog, rain and snow. The volume of traffic will be varied to test responses in heavy, moderate and light traffic conditions. Noise levels will be varied for both internal noise (radio and engine) and external noise (traffic and wind). Terrains that will be evaluated include: flat, rolling hills, curved roads, trees present, bare and buildings present.

The subjects will complete all information and legal forms with the assistance of the experimenter. Subjects will then be instructed in the use of the displays and controls. Occupant comfort in the driving simulator will be ensured by adjusting the seat, mirror and seat belt to fit each subject. The driving course or map of the road to be driven will be reviewed so that the subjects may gain Familiarity with the test course.

Human Factors personnel will develop four scenarios to be used for both equipment and driver testing. The scenarios will cover the four most significant scenarios identified in the analysis of Task B.

Drivers' responses during the test will be recorded. Post-test questionnaires will be used to obtain drivers' subjective opinions of the warning system. Additional questions will be asked after each trial to determine each drivers' hazard alert comprehension or degree of confusion. Correct and incorrect driver responses, or correction of errors, will be tabulated in relation to the scenario depicted driver-alert. These data will be reviewed, analyzed and compared to response time data.

Subtask 4: Driver Alert Warning System Demonstration.

The test plan developed during Subtask 3 will be executed.

Section H - Task H Workplan

Subtask 1: Test Data Reduction

The results from the communication and DAWS subsystem tests will be analyzed in order to identify deficiencies in the IVSAWS system design. Analysis will include careful evaluation of the driver responsiveness and communication link reliability.

Subtask 2: Relate IVSAWS to IVHS

This task will determine how the in-vehicle safety and warning system (IVSAWS) may be incorporated into an the intelligent vehicle highway system (IVHS). The IVSAWS is envisioned to provide both dynamic and fixed hazard information pertinent to the motorist's immediate route. This type of information includes weather, dangerous intersections, slow moving vehicles, roadside emergency incidents, road repair activity, traffic alerts, available services, vehicle location, detour, route guidance, and special events.

The IVHS is envisioned to provide suitably equipped vehicle with trip planning capabilities, real time route guidance, information upon request, and special services. Information upon request includes accommodations, restaurants, weather, and special events. Special services includes reservations and emergency services. These or other driver information subsytems may require that a transmit function be built into passenger vehicles, requiring additional analysis beyond the scope of this contract.

The IVHS infrastructure must support IVSAWS so that information relevant to the motorist's immediate route is available in a timely manner. Similarly, IVSAWS may need to support the transmissions of vehicle control information such as road geometry and capacity in order to assist the vehicle for future enhancements such as lane control and automatic chauffeuring. The relationship of IVSAWS to IVHS will be documented in the IVSAWS functional specification.

Subtask 3: Generate IVSAWS functional specification.

This task will specify the functions of the in-vehicle safety and warning system (IVSAWS) based on the evaluation of the results of the system test and demonstration. The functional specification will delineate the operational concept, the architectural design, the subsystem interfaces, the subsystem performance parameters, the subsystem physical characteristics, cost, fabrication, and system test. These principle specification features are summarized in the following table. The functional specification will address operational issues, system messages, waveform design, and the RF parameters. The architectural design of the IVSAWS has three principal subsystems — the roadside or in-vehicle transmitter, the in-vehicle receiver, and the driver alert warning system. For each of these three subsystems, the functional specification will address subsystem functional requirements, interfaces to the other subsystems, physical requirements, and software / firmware requirements. The functional specification will include the method for testing . the system and the method for verifying that the system meets the specified requirements.

ITEMS IN SYSTEM FUNCTIONAL SPECIFICATION

- Operational concept
  - Significant Hazards to be Reported
  - Operation of the IVSAWS System
- Architectural Design
  - Roadside Transmitter
  - In-Vehicle Receiver
  - Waveforms and Message Structure
  - Driver Alert Warning System
- Interfaces
  - For each Architectural Element
    - Electrical
    - Mechanical
    - I/O and Controls
- Performance
  - For each Architectural Element
    - Processing
    - Software /Firmware
    - I/O Signal Definition
- Physical Characteristics
  - For each Architectural Element
    - Size
    - Weight
    - Power
    - Environment
    - Reliability
- Cost
- Fabrication
- System Test
  - Methods for testing system
  - Verification of performance to requirements

Section I - Task I Workplan

Subtask 1: Technical Summary

Hughes will prepare the four-page technical summary in accordance with the two-column format shown in Attachment 8 of the NSAWS contract. Recognizing that this document will be used to sell succeeding phases within the Federal Highway Administration, the Department of Transportation, and possibly to Congressional committees, Hughes will use its technical publications activities to ensure that the technical summary is a professional, concise summary of the effort.

Section J - Task J' Workplan

Subtask 1: Draft Final Report

The draft final report shall describe the results of Task A through Task H. The material for the draft final report will be drawn from the Engineering Notebooks which have been used to document the results of significant analysis, tradeoffs, and testing. The preparation of the draft final report should be mostly be limited to polishing and editing the material in the Engineering Notebooks to respond to previously provided suggestions from the Federal Highway Administration or to provide further clarification to the Federal Highway Administration. Tasks A, C, and E require a thorough set of documented reports. These interim reports will also be incorporated in the draft final report. Because the System Functional Specification is a separate deliverable item, this specification will not be part of the draft final report.

This report shall be prepared in accordance with the "Guidelines for Preparing Federal Highway Administration Publications" (FHWA-AD-88-001), dated January 1988, so that any revisions to the draft final report will be in regards to technical content rather than format.

The Government will review the draft final report and will furnish written comments within 30 days after receipt.

Section K - Task K Workplan

Subtask 1: Final Report.

The final report shall describe the results of Task A through Task H. This task will revise the draft final report produced in Task J to reflect the Federal Highway Administration review comments. The revision will incorporate suggestions and or provide further clarification as needed. Because the System Functional Specification is a separate deliverable item, this specification will not be part of the draft final report.

This report shall be prepared in accordance with the "Guidelines for Preparing Federal Highway Administration Publications" (FHWA-AD-88-001), dated January 1988.

The Government will review the final report and will furnish written comments within 30 days after receipt. These comments will be responded to in order to assure acceptance of the final report.

Section L - Plan A and Plan B Schedules

SECTION L

APPENDIX B: IVSAWS ENGINEERING CHANGE PROPOSAL 3 (ECP-003) OVERVIEW

This appendix outlines FHWA changes to the baseline IVSAWS workplan. Overall, these changes revised the baseline IVSAWS workplan to expand the system design work and allow for analysis of several system concepts.

IVSAWS Engineering Change Proposal 3 (ECP-003) Overview

Introduction

On September 5. 1990 Hughes Aircraft Company was awarded a contract by the Federal Highway Administration (FHWA) to identify candidate advisory, safety, and hazard situations for motorists, and provide functional specifications of an In-Vehicle Safety Advisory and Warning System (IVSAWS) in sufficient detail to permit gradual incorporation of these functions into automotive vehicles.

As a result of Task C (Communications Technology Selection), a two-way spread spectrum communication link was specified as the basis of the IVSAWS Communication Subsystem. With this architecture, a ranging function was identified for incorporation into IVSAWS such that the distance from the vehicle to the roadway hazard can be determined independent of other proposed IVHS Subsystems (e.g., Driver Navigation Aide). The rational for incorporating ranging is to minimize false driver alerts and maximize correct driver response to a valid warning by presenting the hazard alert to the driver at the optimum vehicle-to-hazard separation. The ranging function was identified as significant but not within the scope of the original contract. However, the spread spectrum approach does offers a solution that provides simultaneous communication and ranging support while enabling an integrated hardware implementation.

Near the end of the Task C Communication Architecture selection process it became clear that FCC or NTIA licensing for the proposed spread spectrum system would be difficult to obtain. Under direction from the FHWA, an evaluation of alternate approaches was performed (ECP-002) in order to identify an architecture that could meet both technical requirements and regulatory restrictions.

The examination of five candidate IVSAWS Communication Subsystem architectures indicated that a low-cost system cannot be developed which also eliminates false alarms. Also, based on IVHS comments response to several conference presentations, sufficient interest exists to justify the development of a full system description(s), rather than a single demonstration prototype. Thus, in conjunction with the FHWA IVSAWS Future Direction Memo, Hughes recommends that Task B (Advisory, Safety, and Hazardous Situation Identification) and Task C (Communications Technology Selection) be. expanded to re-examine the highway problem with respect to IVSAWS and identify alternate system concepts such that architectures with varying levels of functionality and cost can be defined. Candidate system approaches include the following:

- Narrowband communication with GPS ranging
- Wideband communication with two-way ranging
- Cellular telephone (call-in)
- Automatic Highway Advisory Radio (AHAR)
- Low-power Highway Advisory Radio (LPHAR)
- Radio Data System (RDS)
- FM subcarrier modulation
- TravTek
- Socrates

Recommendations will be developed for the optimum technical approach(es) which are applicable to IVSAWS. These recommendations will be sufficient to guide follow-on product development work.

Systems engineering required to identify candidate system concepts, derive technical requirements, predict expected concept technical performances, and document results will take approximately 15 months and require an additional funding level of $292K.

Impact of Change on Workplan

The objective of the original IVSAWS study was to identify candidate advisory, safety, and hazard situations for motorists, and develop a functional specification for an IVSAWS to permit gradual incorporation of these functions into automotive vehicles. The functional specification was to define a single "optimal" approach which could be used for urban, rural, and secondary roads. A major emphasis of the study was to develop a proof-of-concept system which would implement key subsets of the desired functionality and demonstrate functional conformance in a concept demonstration.

This ECP seeks to change this singular approach by expanding the "front-end" system design work to consider several system concepts. Communication Subsystem hardware development and test has been eliminated. Fabrication and test of the IVSAWS Driver Alert Warning System (DAWS) driver-machine interface has also been eliminated. The technical performance of candidate subsystem architectures will be derived through research, analysis, and simulation only. This change in focus impacts the IVSAWS workplan. The major changes in scope are identified below on a task-by-task basis:

Task A Develop Workplan)

This task is complete and there is no additional Task A work to be performed under this ECP. The effort spent to modify the worlcplan (i.e. generate this ECP) has been assigned a separate program management line item.

Task B (Advisor-v. Safety. and Hazardous Situation Identification)

This task is expanded to include the following work:

- An IVSAWS concept conference will be held at the FHWA Turner-Fairbanks facility in order to further define the usefulness of IVSAWS in a variety of scenarios. The goal is to bound the functionality of candidate system concepts. At the conference, new and previously identified IVSAWS hazard and advisory applications are to be examined as part of an expanded study of potential IVSAWS system applications. The various scenarios will be prioritized on a scale which estimates the relative risk of each situation to the driving public.
- An operational concept for deployment of an IVSAWS hazard warning unit will be developed for each application, which addresses the actions required of the individuals deploying the warning unit. Discussions will be held with appropriate organizations to assess practicality in terms of a willingness to adopt a system of this type, the amount of time and attention available for deployment tasks, equipment interface issues, user interface issues, reasonable system cost limits, and other system issues identified by the organizations.
- A subcontractor who specializes in the conduct of focus groups will be contracted to hold two meetings with sample cross-sections (8 - 10 qualified members per group) of the rural and urban driving public in order to predict how the IVSAWS end-user would want the system configured. Desired functionality, end-user cost limits (retrofit and "add-on"), and specific situations in which the driver would find the system useful will be predicted from group responses.
- The IVSAWS functionality required to mitigate each hazard situation will be determined. Tradeoffs will then be performed in order to identify that set of

functions which will enable IVSAWS to effectively reduce crash frequency and severity for "most" situations. Additional functional sets will be formed at logical functional-effectiveness boundaries.

TASK C: (Select Communications Technology)

This task is expanded to include the following work:

- IVSAWS system architectures with varying levels of cost and functionality will be identified. Trade-offs will be performed between the architectures and the functional sets identified in Task B. Systems which maximize the functionality-cost ratio will be identified for further study.
- For those system concepts identified as "most promising", system technical performance will be estimated for key hazard and advisory scenarios.

Task D: (Procure and Modify Communications Equipment)

This task has been deleted since a Communication Subsystem will not be built.

Task E: (Driver Alert Warning System Definition)

This task is complete and no additional work is planned.

Task F: (Driver Alert Warning System Fabrication)

This task has been deleted since a Driver Alen Warning System will not be built.

Task G: (Concept Demonstration)

This task has been deleted since neither a Communication Subsystem or Driver Alert Warning System will be built.

Task H: (Functional Specification)

This task was originally planned to allow for specification of a single IVSAWS concept with sufficient detail to facilitate procurement of next generation hardware. Given the change of focus as described herein and in the Future Direction memo, the task has been modified to allow for functional descrintions of at least two system concepts. The descriptions will be in sufficient detail to guide follow-on product development.

Task I: (Technical Summary)

This task has not been changed and, except for a schedule change, work will be performed as described in the original IVSAWS workplan.

Task J: (Draft Final Report)

The scope of this task has been increased to allow for incorporation of Task B and Task C results from both the original contract and from the results to be obtained from new work to be performed as part of this ECP.

Task K: (Final Report)

This task has not been changed and, except for a schedule change, work will be performed as described in the original IVSAWS workplan.

Detailed statements of work follow. Currently, all work is scheduled for completion by the end of June, 1993. A revised program schedule and cost to complete data are included in this ECP package.

EXHIBIT II

REVISED WORK BREAKDOWN STRUCTURE (WBS)

IVSAWS ECP-003 Rev 2 WORK BREAKDOWN STRUCTURE (WBS)

EXHIBIT III

REVISED STATEMENT OF WORK

Task A - Workplan Development (WBS A)

The purpose of Task A was to develop a workplan and schedule for the IVSAWS program. The workplan was completed and accepted by the FHWA per Department of Transportation letter dated 6 November, 1990 (Robert B. Robel - FHWA Contracts).

Task B - Advisory, Safety, and Hazardous Situation Identification (WBS B)

The purpose of Task B was to identify roadway advisory, safety, and hazardous situations. Formal approval of work was not required and Task B results were incorporated into the Task C (Communications Technology Selection) final report.

Task B Workplan (WBS B OFT AA)

The following subtasks are amendments to the original Task B Workplan which provides a base from which to develop candidate situations for the application of NSAWS and identifies candidate signalling recommendations.

This effort initiates the development of operational concepts that will be implemented by the user community. By soliciting inputs from the user community early in the design process, desired operational functions and features can be analyzed for feasibility and then be used to modify the design when applicable. Work will include meetings with members of the user community, development of enhanced operational concepts, and investigations concerning the impact of current user community equipment on the NSAWS system design.

Subtask · IVSAWS Concept Conference

A meeting will be held at the FHWA Turner-Fairbanks facility in order to further define the usefulness of IVSAWS in a variety of scenarios, so as to bound the functionality of the system and aide the assessment of deployment practicality. Prior to the conference, Hughes will prepare and distribute an information package to the attendees which describes the system, developments to date, and key system parameters. The package and presentation will be brief and geared for an audience without an electronics background. Candidate attendees include representatives from the DOT/FHWA, IVHS contractors (e.g., Mitre), school districts, law enforcement agencies, trucking companies, state transportation departments, railroad groups, public safety agencies (e.g., fire departments), private ambulatory companies, and farmer associations.

As part of the conference, IVSAWS hazard applications identified during Task B, Subtask 4 of the original IVSAWS contract will be r-e-examined as part of an expanded study of potential IVSAWS system applications. One new application to be included must be mitigation of multiple vehicle crashes in fog or dust storms. Other new applications are also to be considered. Based upon the analysis, the various application-scenario pairs (hereafter called a "situation") will be prioritized on a scale which indicates the relative risk of each situation to the driving public.

Assuming a prompt and effective deployment of a hazard transmitter for each situation, the potential of IVSAWS to reduce accident frequency and severity will be assessed.

The hours and cost allocated for this subtask are applicable to Hughes personnel only. Conference expenses for other attendees are not included in the cost.

A program review will be held at the FHWA prior to the concept conference.

Subtask 2: IVSAWS Focus Group - IVSAWS and the Driving Public.

A subcontractor who specializes in the conduct of focus groups will be contracted to hold two meetings with sample cross-sections (8 - 10 qualified members per group) of the rural and urban driving public in order to predict how the IVSAWS end-user would want the system configured. Desired functionality, driver sensitivity to false alarms, end-user cost limits (retrofit and "add-on"), and specific situations in which the driver would find the system useful will be predicted from group responses.

Subtask · Assessment of IVSAWS Deployment Practicality

An operational concept for deployment of an IVSAWS hazard warning unit will be developed for each situation, which addresses the actions required of the individuals deploying the warning unit (e.g., emergency response personnel). The system operational concept and equipment design must take into account the unique needs of each user.

A subconuactor who specializes in the conduct of focus groups will be contracted to hold sixty one-on-one meetings with representatives from the following deployment groups: law enforcement agencies, fire departments, paramedics, construction and road maintenance crews, railroad operators, and ambulance drivers. For each operational concept, the likely effectiveness and practicality of the individuals in performing the deployment task shall be characterized. Discussions will be held to assess operational concept practicality in terms of a willingness to adopt a system of this type, the amount of time and attention available for deployment tasks, user interface issues, reasonable system cost limits, and other system issues identified by the organizations. For those operational concepts in which operation of the system is performed or managed remotely by data fusion center personnel (e.g. police dispatch operators), these discussions will include meetings with members from this segment of the “deployment” community.

After conduct of the focus groups, quipment interface data will be collected from each of the five groups. The data will be reviewed and compiled. The impact of the warning-unit/agency-equipment interface on IVSAWS deployment practicality and system design will then be assessed.

Subtask 4: Functional Definition

The IVSAWS functionality required to mitigate each hazard situation will be determined. Tradeoffs will then be performed in order to identify that set of functions which will enable IVSAWS to effectively reduce crash frequency and severity for “most” situations. Additional functional sets will be formed at logical functional-effectiveness boundaries.

HUGHES

Task C - Communications Technology Selection (WBS C)

The purpose of Task C was to select an IVSAWS Communications Subsystem technology and perform subsystem definition. Work for this task was completed and accepted by the FHWA per Department of Transportation letter dated 12 July, 1991 (Robert B. Robel - FHWA Contracts).

HUGHES

Task C Workplan (WBS C OPT AA)

The following subtasks are amendments to the original Task C Workplan which identified a spread spectrum IVSAWS Communication Subsystem architecture as the basis of a system to be developed for the Task G concept demonstration. The additional work will focus on the re-examination of alternative IVSAWS system architectures based upon the results of Task B (WBS B OPT AA) and work previously performed under this contract.

Several system concepts will be identified which meet IVSAWS technical requirements to varying degrees. Candidate architecture alternatives include the foilowing:

- Narrowband communication with GPS ranging
- Wideband communication with two-way ranging
- Cellular telephone (call-in)
- Automatic Highway Advisory Radio (AHAR)
- Low-power Highway Advisory Radio (LPHAR)
- Radio Data System (RDS)
- FM subcarrier modulation
- TravTek
- Socrates

The former list may be modified based upon preliminary results of concept applicability or identification of other attractive alternatives. For each system concept identified, analysis will be performed to determine its technical performance and projected cost. Cost estimates will be limited to in-vehicle unit costs and the cost of IVSAWS-unique elements that must be supplied to or purchased by the agencies which will deploy IVSAWS. Infrastructure costs (e.g., the cost of a cellular telephone network) will not be estimated. Specific performance parameters will depend on the system approaches selected. Work will include research, analysis and simulation as appropriate.

Subtask 1: Analyze IVSAWS System Architectures with Respect to Critical Functional Requirements

IVSAWS system architectures with varying levels of cost and functionality will be identified. Trade-offs will be performed **between** the architectures and the functional sets identified in Task B (WBS B OPT AA). Systems which maximize the functionality-cost ratio will be identified for further study.

Subtask · IVSAWS Waveform Design

For each system architecture in which a dedicated transmitter is required or a modification or addition to an existing infrastructure communication protocol is needed, a communication waveform will be defined which specifies the following:

- Modulation type and emissions mask
- Transmit power
- Message length and structure

Based upon the outputs from Task B (WBS B OFT AA) and the IVSAWS Concept Conference, waveform support will be defined for those functions identified as necessary for each system concept and level of functionality.

Supplements or changes to the waveform required to support the mobile transmitter platform, if any, will be identified. Techniques used to minimize transmitter message collisions will be identified.

Subtask System Performance Analysis

For those system architectures and communication waveforms identified during Subtasks 1 and 2, system technical performance will be estimated for the following scenarios and/or conditions:

- (baseline) single transmitter environment, line of sight communication, 1.2 lan Driver Alert Distance (DAD)
- single transmitter environment, communication through dense foliage, elevation differential between warning unit and vehicle, 1.2 km DAD
- multi-transmitter environment with overlapping communication zones, communication over a flat surface

  a) 5 distinct hazards (fixed), same area of intended coverage

  b) 1 hazard, 20 transmitters (mobile), only 1 message need be received

Performance in the above scenarios will be derived through research, analysis and simulation only. No hardware will be procured, modified or tested. Simulation will be performed on Hughes' Signal Processing Workstation. Technical performance with respect to those parameters which can not be estimated through research, analysis and simulation will be identified for future experimental study.

As necessary to support future field experimentation, applications will be filed with the FCC or NTIA for experimental use of the following frequencies:

- 220-222 MHz channels designated for Government nationwide use
- 420-450 MHz or a segment thereof
- 825-845/870-890 MHz (cellular telephone)
- 902-928 MHz (license may be needed if required EIRP is greater than 4 Watts)

Subtask 4: Implement

Emerging technologies and available commercial hardware will be examined in order to project how the subsystems which comprise the identified IVSAWS system architectures might be implemented. Cost projections will be included for each subsystem implementation.

Subtask 5: Antenna Performance Analysis

For each system architecture, the adequacy of using existing vehicle antennas to implement basic communication and ranging functions will be determined. If existing antennas can not be used, the use of dual-band antennas within the same form factor will be investigated The radiation patterns of antenna architectures which can implement each of the functions will be determined.

Subtask 6: Retrofit Analysis

The impact on system performance when the in-vehicle unit is packaged as a retrofit kit rather than an integrated system will be investigated. The connections required, additional sensors needed, and what functionality would be lost in retrofit will be defmed. A display which provides two 32 character lines of text will be used as a baseline.

Subtask · Design Review and Selection of Communication Subsystem Architecture(s)

A meeting will be held at Hughes' Ground System Group in order to review Subtasks 1 through 7 results and make Communication Subsystem architecture selections. Recommendations will be made as to the optimum system approaches for varying levels of functionality.

Subtask 8: Task C Final Report

Task C results and recommendations will be included in a report deliverable to the FHWA.

Task D - Communications Equipment Procurement and Modification (WBS D)

The focus of Task D was to select and procure appropriate transmitter, receivers, antennas, coders/decoders, and control processors in order to demonstrate key concepts from the Task C specified (WBS C) communication system design. Task D work was halted per Department of Transportation Stop Work Order dated 19 September, 199 1 (Robert B. Robel - FHWA Contracts). Work was completed or in progress for the following subtasks:

Subtask 1 (completed) - Communication Equipment Survey

Subtask 2 (in progress) - Communication Equipment Procurement

No further Task D work is planned. This task has been deleted since a complete Communication Subsystem will not be built.

Task E - Driver Alert Warning System Definition (WBS E)

The purpose of Task E was to define the IVSAWS Driver Alert Warning System man-machine interface. Work for this task was completed and accepted by the FHWA per Department of Transportation letter dated 5 February, 1592 (Robert B. Robel - FHWA Contracts). No further Task E work will be performed.

Task F - DAWS Fabrication (WBS F)

The focus of Task F was to select and procure appropriate display, speech synthesizer, driver touch interface, coders/decoders, and control processors in order to demonstrate key concepts from the Task E specified (WBS E) Driver Alert Warning System design. Task F work was halted per Department of Transportation Stop Work Order dated 25 March, 1992 (Robert B. Robel - FHWA Contracts). Work was in progress for the following subtask:

Subtask 2 - Component Procurement A purchase order for the Driver Alert Warning System elements was submitted on 20 February, 1992. Per customer request, the order was cancelled 20 March, 1992. No n-stocking or cancellation costs were incurred.

No fiuther Task F work is planned. This task has been deleted since a Driver Alert Warning System will not be built.

Task G - Concept Demonstration (WBS G)

The purpose of Task G was to structure and conduct tests and demonstrations of the concepts developed in the I'VSAWS study. The tests were to include a sampling of the most critical highway hazards covering a range of environmental and geometric situations extensive enough to demonstrate the reliability of the system. One Communication Subsystem (originally planned to be built during Task D) and two Driver Alert Warning Subsystems (originally planned to be built during Task F) were to be used as the system test hardware. This task was cancelled per Department of Transportation letter dated 25 March, 1992 (Robert B. Robe1 - FHWA Contracts). No Task G work has been performed.

HUGHES

Task H Workplan - Functional Descriptions (WBS H OPT AA)

Subtask 1: Generate IVSAWS functional descriptions.

This task will describe the functions of at least two in-vehicle safety and warning system (IVSAWS) concepts. The functional descriptions will delineate the operational concept, the architectural design, the subsystem interfaces, the subsystem performance parameters, the subsystem physical characteristics and cost. These principle description features are summarized in the following table. The functional descriptions will address operational issues, system messages, waveform &sign, and the RF parameters. The architectural description of the IVSAWS system concepts has two principal subsystems — the roadside or in-vehicle transmitter and the in-vehicle receiver. For each of these three subsystems, the functional description will address subsystem functional requirements and interfaces to the other subsystems.

ITEMS IN SYSTEM CONCEPT FUNCTIONAL DESCRIPTION

Operational concept
- Significant Hazards to be Reported
- Operation of the IVSAWS System (except driver interface)

Architectural Description
- Roadside Transmitter
- In-Vehicle Receiver/Transceiver
- Waveforms and Message Structure

Interfaces
- For each Key Subsystem (except driver interface)
  - Electrical
  - I/O and Controls

Projected Performance
- For each Architectural Element (except driver interface)
  - Technical Requirements
  - I/O Signal Description

Physical Characteristics
- For each Architectural Element (except driver interface)
  - Size (est.)
  - Environment

Cost (est.)

Task I Workplan - Technical Summary (WBS I OPT AA)

Subtask Technical Summary

Hughes will prepare the four-page technical summary in accordance with the two-column format shown in Attachment 8 of the IVSAWS contract. Recognizing that this document will be used to sell succeeding phases within the Federal Highway Administration, the Department of Transportation, and possibly to Congressional committees, Hughes will use its technical publications activities to ensure that the technical summary is a professional, concise summary of the effort.

Task J Workplan - Draft Final Report (WBS I OPT AA)

Subtask 1: Draft Final Report.

The draft final report shall describe the results of Tasks B, C, and E. The material for the draft final report will be drawn from the Engineering Notebooks which have been used to document the results of significant analysis, tradeoffs, and testing. The preparation of the draft final report should be mostly be limited to polishing and editing the material in the Engineering Notebooks to respond to previously provided suggestions from the Federal Highway Administration or to provide further clarification to the Federal Highway Administration. Tasks C and E require a thorough set of documented reports. These interim reports will also be incorporated in the draft final report, Because the System Functional Specification is a separate deliverable item, this specification will not be part of the draft final report.

This report shall be prepared in accordance with the "Guidelines for Preparing Federal Highway Administration Publications" (FHWA-AD-88-001), dated January 1988, so that any revisions to the draft final report will be in regards to technical content rather than format.

The Government will review the draft final report and will furnish written comments within 30 days after receipt. A meeting will be held at Hughes Ground Systems Group in order to review the draft and customer comments. A program review will be held before the review of the draft final report.

HUGHES

Task K Workplan - Final Report (WBS I OPT AA)

Subtask 1: Final Report.

The final report shall describe the results of Tasks B, C, and E. This task will revise the draft final report produced in Task J to reflect the Federal Highway Administration review comments. The revision will incorporate suggestions and or provide further clarification as needed. Because the System Functional Specification is a separate deliverable item, this specification will not be part of the draft final report.

This report shall be prepared in accordance with the "Guidelines for Preparing Federal Highway Administration Publications" (FHWA-AD-88-001), dated January 1988.

The Government will review the final report and will furnish written comments within 30 days after receipt. These comments will be responded to in order to assure acceptance of the final report.

Engineering Change Proposal 1 Preparation (WBS L)

The purpose of Engineering Change Proposal 1 (ECP-001) was to expand the scope of the original IVSAWS contract to allow for development of a semi-custom transceiver. The FHWA instructed Hughes to examine alternatives to a full-scale prototype transceiver development and submit an ECP which would enable demonstration of the integrated communication-ranging waveform defined in the Task C (Communication Technology Selection) report.

The proposal, submitted 6 August 1991, was not exercised and the cost of ECP-001 preparation only has been included in the total cost of ECP-003.

HUGHES

Engineering Change Proposal 2 (WBS M)

The purpose of ECP-002 was to evaluate candidate IVSAWS Communication Subsystem architectures with respect to a set of evaluation criteria. The IVSAWS Communication Technology Selection (Task C) Report selected a Communication Subsystem architecture that featured a spread-spectrum waveform. The spread-spectrum approach offers a solution that provides simultaneous communication and ranging support while enabling an integrated hardware implementation. However, the five to ten megahertz bandwidth required to support the subsystem would be difficult to obtain at the desired operating frequency (i.e. below 500 MHz). Thus, alternate architectures were evaluated and results were documented in a report to the FHWA.

ECP-002 was negotiated and incorporated into the modified MAWS contract (MOD 2) per Department of Transportation letter dated 24 January, 1992 (Robert B. Robel - FHWA Contracts). The negotiated additional funds have been added to WBS CA.

Engineering Change Proposal 3 Preparation (WBS N)

The cost to prepare this Engineering Change Proposal has been assigned to a separate line item (WBS M). ECP-003 pnparation costs include that to prepare the draft ECP review the draft at the FHWA (including travel expenses), prepare financial backup, and finalize the draft.

EXHIBIT IV

REVISED PROGRAM SCHEDULES

REVISED SCHEDULE

IVSAWS ECP-003 PROGRAM SCHEDULE

IVSAWS ECP-003 TASK B SCHEDULE (WBS B)

IVSAWS ECP-003 TASK C SCHEDULE (WBS C)

APPENDIX C: INVEHICLE SAFETY ADVISORY AND WARNING SYSTEMS, TASK B-FINAL REPORT

This appendix consists of the final task B report that describes the definition and prioritization of candidate advisory, safety, and hazard situations that could be affected by IVSAWS. Included in the report are methods and rationale for situation selection, cases illustrating selected crash situations, and a privatization of identified IVSAWS application scenarios.

In-Vehicle Safety Advisory and Warning Systems (IVSAWS)
DTFH61 -90-R-0030

Task B -- Final Report

Under subcontract with:
Hughes Aircraft Company
Ground Systems Group
Fullerton, CA

Fredrick M. Streff
Robert D. Erwin
Daniel F. Blower

March 1991

The University of Michigan
Transportation Research Institute

[FHWA C-2]

TABLE OF CONTENTS

In-Vehicle Safety Advisory and Warning Systems
Task B -- Final Report

1.0 Introduction

This document constitutes the final report for the UMTRI subcontract for Task B - In-Vehicle Safety Advisory and Warning Systems (IVSAWS) (DTFH61-90-R-0030). This report describes the definition and prioritization of candidate advisory, safety, and hazard situations that could be affected by IVSAWS. Included are methods and rationale for situation selection, cases illustrating select crash situations, and a privatization of identified IVSAWS application scenarios.

2.0 Delineation of Contractor Tasks from RFP

> Identify candidate advisory, safety, and hazard situations, and using recent rural and urban highway accident data, develop ranking criteria to determine the severity of accidents; list them in a hierarchical order according to potential benefits to safety and traffic operations (i.e., operational performance and estimated relative frequency of occurrence)...Determine which situations could be helped by an IVSAWS. Refer to Chapter II, "The Highway Safety Problem" of FHWA/RD-81/124 Report for guidance.
>
> Using the Manual of Uniform Traffic Control Devices (MUTCD) as a guide, develop ranking criteria and apply them to determine which waming and regulatory signs should be replicated within a motorist's vehicle to improve safety and traffic operations. Use human factor analysis to make a realistic determination of which messages shall affect the proper response given the attention needed for the driving process. To reduce driver annoyance, a method to defeat or defer frequently repeated messages shall be found.

As stated in the Task B workplan, FHWA report FHWA/RD-81/124 ***-- Feasibility and Concept Selection of a Safety Hazard Advance Warning System*** is inadequate for determining crash situations that could be ameliorated through implementation of IVSAWS technologies. To improve the state of knowledge about possible crash scenarios that could benefit from IVSAWS we held several group discussions involving experts in intelligent vehicle-highway systems (IVHS), highway design, crash data analysis, accident investigation and reconstruction, and human behavior.

The initial discussion focused on identifying crash data that could help pinpoint and rank crash situations that could be remedied by an IVSAWS technology. This first meeting began with a brainstorming session to determine a few crash situations we believed could be affected by IVSAWS. This was done to provide sufficient background information for development of a data analysis and prioritization system. Results from the FHWA report (FHWA/RD-81/124) were reviewed and professional observations from the group members' experience were used to develop a short list of crash situations. From this discussion it was determined that identifying crash situations amenable to IVSAWS applications and subsequently ranking these applications based on the analysis of extant crash data sets was infeasible. Existing computerized crash data sets provide insufficient data detail to conduct analyses that would provide the type of information necessary to identify crash situations amenable to IVSAWS technologies with -sufficient specificity.

At this point it was determined that the best course of action was to convene group discussions to identify specific crash situations amenable to IVSAWS technologies using the experience and knowledge of the experts involved in the discussions. Once specific situation types had been identified, a review of detailed crash investigations was conducted to identify individual cases that would illustrate the general crash scenarios.

However, the use of mass statistical data was not abandoned altogether. Examination of crash data from the states of Michigan and Washington, as well as the 1988 General Estimates System (GES, a probability sample of all police-reported crashes occurring in the U.S.) was believed to be useful in helping to bound the number of crashes involving some scenarios. While insufficient detail is available in these data sets to examine all of the scenarios identified by the group discussions, scenarios represented by sufficient data were examined,

3.0 Crash Scenarios Amenable to IVSAWS Technologies

In general, it is our belief that IVSAWS technologies are best applied in situations in which the risk of a crash which is relatively high, the risk is known in advance and the situation occurs infrequently. In addition, the severity of the crash which is risked would preferably be high. Further, IVSAWS technologies are well suited for sites with relatively high travel speeds that act to both reduce reaction time available for collision avoidance and increase crash severity.

In order for IVSAWS technologies to be maximally effective they should be applied in ways that reduce driver habituation effects. That is, the systems should be activated infrequently to avoid the situation of drivers ignoring frequently occurring warnings (spurious or real). It is equally important that warnings be issued only to vehicles that can benefit from the advanced warning. Reception of warnings by drivers who are not at risk will likely act to reduce the attention paid to all IVSAWS warnings, reducing their effectiveness.

In the discussion to follow, each of the IVSAWS application scenarios identified by the group discussions is detailed. For some of the scenarios, cases of specific crashes are provided illustrating the general crash scenarios.

3.1 Accident-involved or disabled vehicles

An advanced warning of a disabled vehicle ahead could prevent drivers from crashing into the disabled vehicle from the rear or prevent drivers from having to perform a radical avoidance maneuver that could force them into oncoming traffic or into some roadside obstacle like a ditch, utility pole, or tree. Such a system could be activated automatically via crash sensors similar to those used to activate airbags or the system could be activated manually by the driver. If IVSAWS was implemented so that the automatically-generated warning (activated by a crash) also sent out a distress signal to police (augmented with a vehicle location code), the system could effect a significant reduction in death and injury outcomes by reducing the response time for emergency medical treatment. Such a "mayday" signal could perhaps be sent only in crashes having a sufficient delta-V that serious injury to vehicle occupants was likely.

Such an automatically activated system may have been of benefit to reducing the crash trauma induced in the recent chain-reaction crashes in Tennessee and Utah which were caused in part by high travel speeds and limited sight distance which obscured vehicles disabled by previous crashes. Two cases involving collisions with disabled vehicles in the roadway follow to illustrate this application'.

'Cases are taken from crashes investigated by the UMTRI crash investigation team headed by Dr. Donald Huelke and sponsored by the Motor Vehicle Manufacturers Association. Cases were selected from over 500 reviewed representing crashes occurring in Washtenaw County, Michigan from 1986 through 1990 involving late-model cars in which at least one occupant was injured.

IVSAWS Application Case 1

Accident Involved or Disabled Vehicles

Case Vehicle (A): 1985 Volkswagen
Type: GTI, 2-Dr. HB
Driver: 16-Yrs., Male

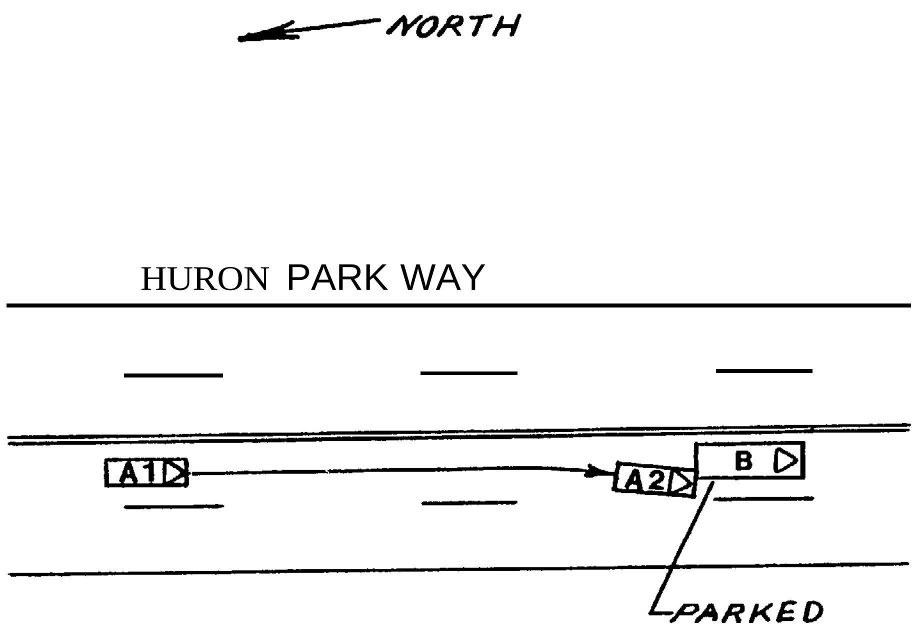
Vehicle (B): 1975 Buick
Type: Regal, 2-Dr. Sedan
Driver: Unoccupied

Situation

At about 1907 hours on Saturday, January 18,1986, case vehicle (A) was traveling at an unknown speed in the left southbound lane of Huron Parkway, a 4-lane asphalt parkway on the eastside of Ann Arbor. Vehicle (B) had run out of fuel in the left southbound lane and was left unattended with its parking lights on, but not its 4-way flashers. Perhaps due to the fog and the low visibility of the parking lights, the driver of the case vehicle (A) failed to see vehicle (B) in time to avoid a collision. Even though case vehicle (A) veered to the right at the last instant it struck the rear right comer of vehicle (B). Both vehicles then lightly slapped together, but their final positions are unknown. At the time of impact (B) was parked and the impact speed of case vehicle (A) was estimated to be 48-58 kmph.

CASE NO.: UM-2347-86
CASE VEH.(A): 1985 VOLKSWAGEN
TYPE: GTI, 2-DR. HB
DRIVER: 1 6-YRS., MALE
VEH. (B): 1975 BUICK REGAL

DATE/TIME:1 -18-86 / 1907 HRS.
WEATHER: FOG
ROAD SURFACE: WET
ROAD CONSTRUCTION: ASPHALT



(Rev. 11-83) State of Michigan
OFFICIAL TRAFFIC ACCIDENT REPORT

Department Name: ANN ARBOR POLICE
LEIN Number: 218
Department Complaint No.: 86-2638 C-20
DO NOT USE: UM-2344-86

County No.	City No.	Twp. No.	Section No.	Day of Week	Accident Date Mo/Da/Yr	Time
81	89			S M T W T F (S)	01/18/86	7:07 P.M.

Name: HURON PKWY Route No.
300 Ft. (N) S E (W) Intersection: WASHTENAW Route Nos.

WEATHER 1 Clear or Cloudy 3 Rain (2) Fog 4 Snow
LIGHT 1 Day 3 Street Lights 2 Dawn or Dusk (4) Dark
ROAD SURFACE 1 Dry 3 Snowy or Icy (2) Wet 4 Other
TOTAL LANES 4
1 Divided 2 Limited Access (3) Other
Y (N) Construction Zone
(Y) N Investigated at Scene
Total No. Vehicles: 2

Driver No. 1

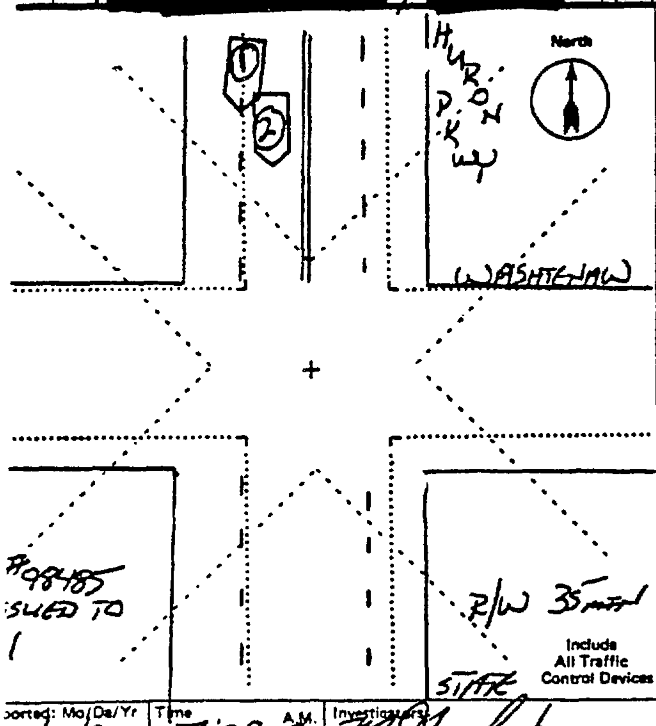
State: MI Driver's License: [redacted] DOB: Mo/Da/Yr 05/16/69 Hazardous Action Number: 8 Citation Charge: VIOL. BASIC SPEED LAW HBD: Y (N) Test: N Helmet: (N)
Driver's Name: First M. Last Address City [redacted] State Age: 16 Sex: M Inj.: C
Year: 81 Make No.: 141 Type: 1 Trailer: 0 Reg. [redacted] Yr/State: 85/MI VIN: 1VWDB0173FV047913 Removed to/by: SAKSTRUPS / SAKSTRUPS
(Y) N Haz. Citation; Y (N) Other Citation; Y (N) Driver Re-exam; Y (N) Vision Obstruct.; Y (N) Vehicle Defect; Y (N) Vehicle Drivable; Y (N) Fuel Leakage; Y (N) Vehicle Fire
Impact: 8 Severity: 5 Truck Cargo: Y N Cargo Spillage; Cargo Description: N/A Class

Occupants by occupants pos. Name Address [redacted] Pos.: 3 Age: 16 Sex: M Inj.: C Helmet: Y (N)
2 3 [redacted] ~~Golf~~ GTI Y N
5 6 Y N
Occupants: 2 Local Use/Owner, Phone: SAME / [redacted] Insurance Co.: TRANSAMERICA Agency Address: SOUTHFIELD Injured taken to/by: REFUSED

Driver No. 2

State Driver's License DOB: Mo/Da/Yr Hazardous Action Number Citation Charge HBD Y N Test Helmet Y N
Driver's Name: First M. Last Address City State Age Sex Inj.
Year: 75 Make No.: 011 Type: 1 Trailer: 0 Reg. [redacted] Yr/State: 86/MI VIN: 4J57C5H136588 Removed to/by: SAKSTRUPS / SAKSTRUPS
Y (N) Haz. Citation; Y (N) Other Citation; Y (N) Driver Re-exam; Y (N) Vision Obstruct.; Y N Vehicle Defect; Y N Vehicle Drivable; Y N Fuel Leakage; Y N Vehicle Fire
Impact: 4 Severity: 5 Truck Cargo: Y N Cargo Spillage; Cargo Description: N/A Class

Occupants by occupants pos. Name Address: Regal 2 Dr. Pos. Age Sex Inj. Helmet Y N
2 3 453-112-547 3872 07-8ZEN-4 Y N
5 6 115-284-139 1756 Y N
Occupants: 0 Local Use/Owner, Phone: [redacted] / [redacted] Insurance Co.: AAA Agency Address: ANN ARBOR Injured taken to/by: N/A



Include All Traffic Control Devices

ACCIDENT DESCRIPTION AND REMARKS (*Explain)

VEHICLE #2 HAD RAN OUT OF GAS & WAS PARKED (UNATTENDED) IN THE LEFT LANE. #2 HAD THE PARKING LIGHTS ON & DOME LIGHT. FLASHER'S DID NOT WORK
#1 WAS S-B ON HURON PKWY & AFTER COMING AROUND THE LAST CURVE PRIOR TO WASHTENAW HAD CHANGED FROM THE CURB LANE TO THE LEFT LANE & DID NOT SEE #2 IN TIME TO STOP. #1 STATED HE WAS PROBABLY GOING A LITTLE TOO FAST. WITNESS DID OBSERVE #2 WITH THE LIGHTS ON AS HE PASSED THEN HEARD THE COLLISION.

Accid. Date - Mo/Da/Yr: 01/18/86
File Class: 9220
Department Complaint No.: 86-2638 C-20

Reported: Mo/Da/Yr: 01/18/86 Time: 7:09 P.M. Investigators: M. Nowicki / D. Allison Badge No.: 025/030 Damaged Property Other Than Vehicles: N/A
Photos by: NO Comp. Disposition: Open (Closed) Reviewer: 318 Person Advised of Damaged Traffic Control Device Name: N/A Owner: N/A Address

*See "Accident Description and Remarks" area for explanation.
FORWARD COPY TO: Michigan Dep[t.] 7150 Harris [Dr.]
[FHWA C-10]
[Div]ision
AUTHORITY: Sect. 622, Act 300, P. A. of 1949
COMPLETION: Required
PENALTY: Misdemeanor

IVSAWS Application Case 2

Accident Involved or Disabled Vehicles

Case Vehicle (A): 1987 Chevrolet
Type: Celebrity, 4-Dr. NB
Driver: 33-yrs, Male

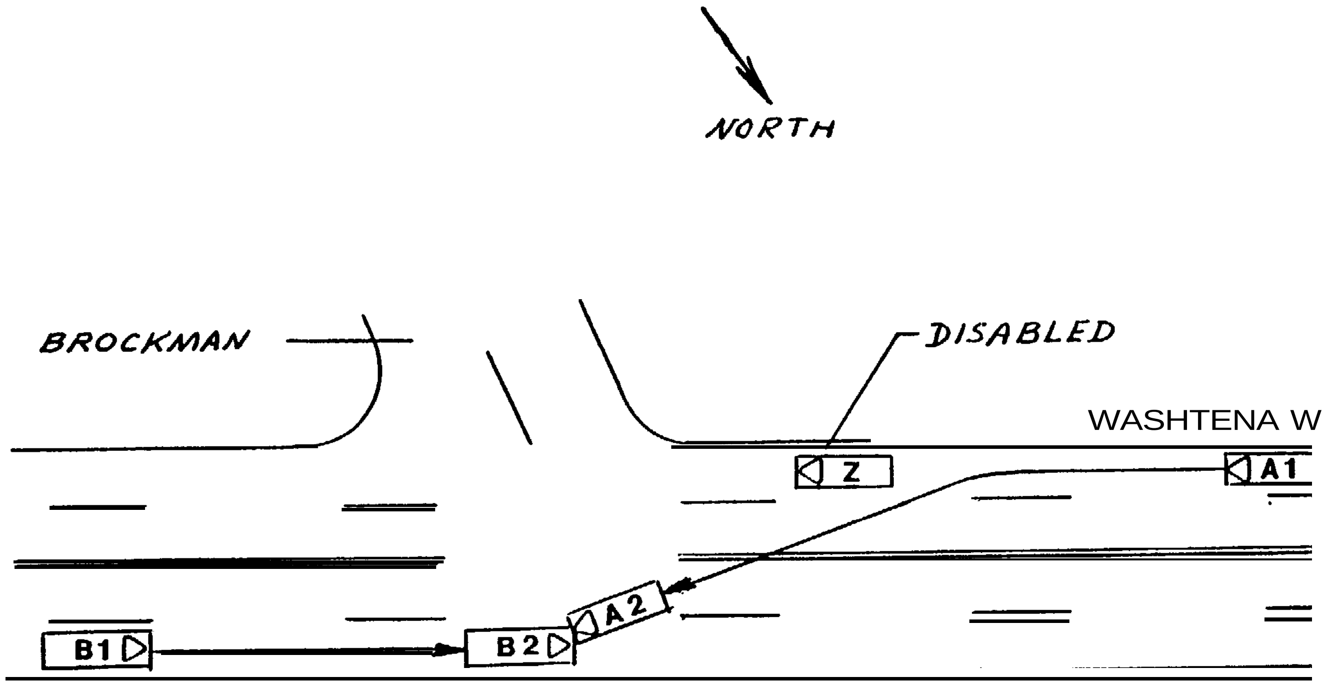
Vehicle (B): 1977 Chevrolet
Type: Impala, 2-Dr. Cpe.
Driver: 41-yrs., Male

Situation

On Friday, January 23, 1987, at about 1842 hours case vehicle (A) was southbound at a driver estimated speed of 56 kmph uphill in the curb lane of Washtenaw Avenue, a 4-lane asphalt arterial roadway through the residential area of southeast Ann Arbor, Vehicle (B) was northbound at an unknown speed in the curb lane. Just prior to the intersection with Brockman, southbound vehicle (Z) was disabled in the curb lane. As case vehicle (A) approached the intersection, the driver did not realize that vehicle (Z) was disabled until the last instant. The driver made a sharp correction to the left causing case vehicle (A) to avoid vehicle (Z). Case vehicle (A) then crossed the centerline into the path of vehicle (B) where the two struck head-on. Both vehicles came to rest locked together, but their exact position is unknown. The impact of vehicle (B) was estimated to be 24 to 32 kmph while that of case vehicle (A) was 28 to 36 kmph.

CASE NO.: UM-2447-87
CASE VEH. (A): 1987 CHEVROLET
TYPE: CELEBRITY, 4-DR. NB
DRIVER: 33-YRS., MALE
VEH. (B): 1977 CHEVROLET IMPALA

DATE/TIME: I-23-87/1 842 HRS.
WEATHER: CLEAR
ROAD SURFACE: SNOWY
ROAD CONSTRUCTION: ASPHALT



Misdemeanor

CIRCLE THE APPROPRIATE SELECTION

ORIGINAL

(9-85) State of Michigan

CIAL TRAFFIC ACCIDENT REPORT

Department Name	LEIN Number	Department Complaint No.
Ann Arbor Police	218	87-3321-E10

DO NOT USE: UM-2447-87

County No.	City No.	Twp. No.	Section No.	Day of Week	Accident Date: Mo/Da/Yr	Time
81	39			S M T W T F S	01-23-87	6:42 A.M. P.M.

Name	Route No.		Intersection	Route Nos.
Washtenaw	BLI-94 & US23	80 Ft. Mi. N S E W	Brockman	

WEATHER	LIGHT	ROAD SURFACE	TOTAL LANES			TOTAL NO. VEHICLES
1 Clear or Cloudy 3 Rain 2 Fog 4 Snow	1 Day 3 Street Lights 2 Dawn or Dusk 4 Dark	1 Dry 3 Snowy or Icy 2 Wet 4 Other	4	1 Divided 2 Limited Access 3 Other	Y N Construction Zone Y N Investigated at Scene	3

Driver No. 1

State	Driver's License	DOB: Mo/Da/Yr	Hazardous Action No.	Citation Charge	HBD	Test	Helmet
IL	[redacted]	05-26-53	5		Y N	N	Y N

Driver's Name First M Last	Address City	State	Age	Sex	Inj.
[redacted]	[redacted]		33	M	A

Make No.	Type	Trailer	Reg.	Yr/State	VIN (Make Letters Larger Than Numbers)	Removed to/by
7 0 3	1		[redacted]	87 Mi	1G1AW51R8HG155863	Saestrups/Saestrups

Haz. Citation / Other Citation	Driver Re-exam / Vision Obstruct.	Vehicle Defect / Veh. Driveable	Fuel Leakage / Vehicle Fire	Impact	Severity	Truck Cargo: Y N Cargo Spillage, Cargo Description	Class
N Haz. Citation, N Other Citation	Y N Driver Re-exam, Y N Vision Obstruct.	Y N Vehicle Defect, Y N Veh. Driveable	Y N Fuel Leakage, Y N Vehicle Fire	2/12	1/5		

Occupants by occupants pos.	Name	Address	Pos.	Age	Sex	Inj.	Helmet
	104.9 188.3 Celebrity 2 Dr NB						Y N
2 3	V 103-266-109		12	20			Y N
5 6	[redacted]						Y N

Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier)	Insurance Co.	Agency Address	Injured taken to/by
1 Avis Rent-A-Car	Undetermined		U of M Hosp / HVA

Driver No. 2

State	Driver's License	DOB: Mo/Da/Yr	Hazardous Action No.	Citation Charge	HBD	Test	Helmet
MI	[redacted]	04-13-61	0		Y N		Y N

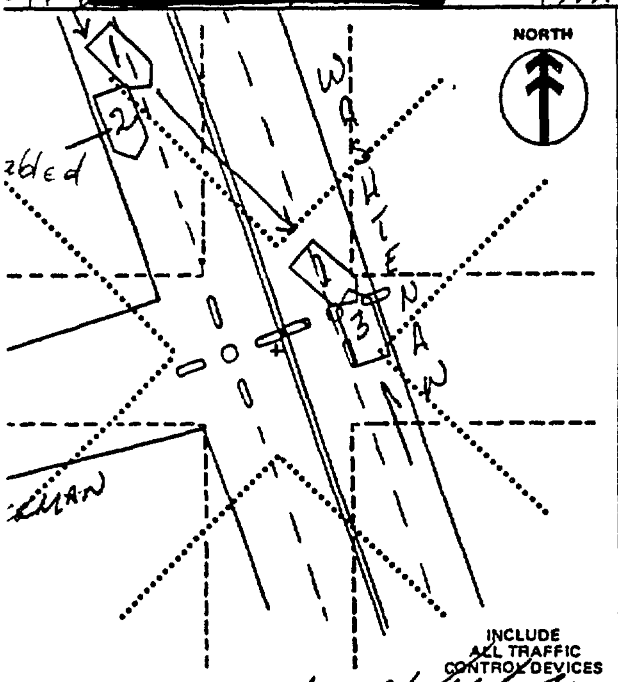
Driver's Name / Address	State	Age	Sex	Inj.
[redacted]		25	M	O

Make No.	Type	Trailer	Reg.	Yr/State	VIN (Make Letters Larger Than Numbers)	Removed to/by
4 1 2	1		[redacted]	87 Mi	VL29G4B337696	Saestrups/Saestrups

Haz. Citation / Other Citation	Driver Re-exam / Vision Obstruct.	Vehicle Defect / Veh. Driveable	Fuel Leakage / Vehicle Fire	Impact	Severity	Truck Cargo: Y N Cargo Spillage, Cargo Description	Class
N Haz. Citation, N Other Citation	Y N Driver Re-exam, Y N Vision Obstruct.	Y N Vehicle Defect, Y N Veh. Driveable	Y N Fuel Leakage, Y N Vehicle Fire	6	1		

Occupants by occupants pos.	Name	Address	Pos.	Age	Sex	Inj.	Helmet
	Ply Duster 2-Dr.						Y N
2 3							Y N
5 6	[redacted]						Y N

Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier)	Insurance Co.	Agency Address	Injured taken to/by
1 [redacted]	AAA	Ann Arbor	



ACCIDENT DESCRIPTION AND REMARKS (*Explain)

Veh #1 was SB on Washtenaw, in the right lane.

Veh #2 was disabled and dark in right lane of SB Washtenaw.

Veh #3 was NB on Washtenaw, in right lane.

Driver #2 related he had stopped at red signal (approx 3rd vehicle in line) and his vehicle had died - no power at all - no lights or flashers.

Driver #1 related he was approaching intersection and observed light change and vehicles move ahead. He then

Accid. Date - Mo/Da/Yr: 01-23-87 File Class: 4220 Department Complaint No.: 87-3321-E10

Mo/Da/Yr	Time	Investigators	Badge No.	Damaged Property Other Than Vehicle
3-87	6:44 A.M. P.M.	[signature]	009	

Comp. Disposition	Reviewer	Person Advised of Damaged Traffic C	Address
Open Closed	310	Name:	

[FHWA C-14]

dent Description and area for explanation. 1 of 2

FORWARD COPY TO: Michigan [...] 7150 Harr[...]

Division, Comm'ns [illegible]

...demeanor

CIRCLE THE APPROPRIATE SELECTION

State of Michigan

...AL TRAFFIC ACCIDENT REPORT

Department Name	LEIN Number	Department Complaint No.
Ann Arbor Police Dept	218	87-3321-E10

DO NOT USE

...y No.	City No.	Twp. No.	Section No.	Day of Week	Accident Date: Mo/Da/Yr	Time
17	89			S M T W T (F) S	01-23-87	6:42 A.M. (P.M.)

Name	Route No.		Intersection	Route Nos.
Washtenaw	BR I 94 / US 23	80 ft. Mi. (N) S E W	Brockman	

WEATHER: 1 Clear or Cloudy 3 Rain 2 Fog 4 Snow
LIGHT: 1 Day 3 Street Lights 2 Dawn or Dusk 4 Dark
ROAD SURFACE: 1 Dry 3 Snowy or Icy 2 Wet 4 Other
TOTAL LANES: 1 Divided 2 Limited Access 3 Other
Y N Construction Zone
Y N Investigated at Scene
TOTAL NO. VEHICLES

Driver No. 1

Unit	Driver's License	DOB: Mo/Da/Yr	Hazardous Action No.	Citation Charge	HBD	Test	Helmet
1	[redacted]	09-14-45	0		Y (N)		Y (N)

Driver's Name, Address, City, State	Age	Sex	Inj.
[redacted]	41	M	B

Make No.	Type	Trailer	Reg.	Yr/State	VIN (Make Letters Larger Than Numbers)	Removed to/by
03	1		[redacted]	87 Oh	1L47475336075	Saestrups/Saestrups

Y (N) Haz. Citation; Y (N) Other Citation; *Y (N) Driver Re-exam; *Y (N) Vision Obstruct.; *Y (N) Vehicle Defect; Y (N) Veh. Driveable; *Y (N) Fuel Leakage; *Y (N) Vehicle Fire

Impact: 8 Severity: 5
Truck Cargo: Y N Cargo Spillage; Cargo Description; Class

Occupants by pos.	Name / Address	Pos.	Age	Sex	Inj.	Helmet
	[redacted]	3	32	M	B	Y (N)
2 C 3	[redacted]	4	32	F	B	Y (N)
5 B 6	[redacted]	6	35	F	C	Y (N)

	Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier)	Insurance Co.	Agency Address	Injured taken to/by
4	[redacted]	State Farm	Toledo	Wash Hosp / HVA

Driver No. 2

Driver's License	DOB: Mo/Da/Yr	Hazardous Action No.	Citation Charge	HBD	Test	Helmet
				Y N		Y N

Driver's Name First	M.	Last	Address	City	State	Age	Sex	Inj.

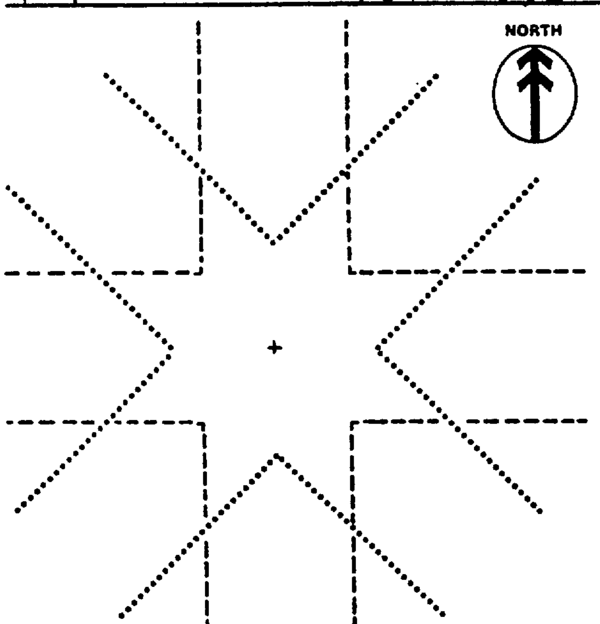
Make No.	Type	Trailer	Reg.	Yr/State	VIN (Make Letters Larger Than Numbers)	Removed to/by

N Haz. Citation; N Other Citation; *Y N Driver Re-exam; *Y N Vision Obstruct.; *Y N Vehicle Defect; Y N Veh. Driveable; *Y N Fuel Leakage; *Y N Vehicle Fire

Impact; Severity; Truck Cargo: Y N Cargo Spillage; Cargo Description; Class

Occupants by pos.	Name	Address	Pos.	Age	Sex	Inj.	Helmet
							Y N
2 3	Chev Impala 2 Dr Cpe						Y N
5 6	40 - 116 - 56.1	3643					Y N

Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier)	Insurance Co.	Agency Address	Injured taken to/by
102 - 295 - 142		1652	



ACCIDENT DESCRIPTION AND REMARKS (*Explain)

Said a vehicle in front of him swerved and he then hit a vehicle and swerved to left - he then was unclear of events.
Driver #3 related he observed an oncoming vehicle sudden swerve and come toward him at a 45° angle he attempted to turn to right and then collision took place.
Witness driving behind veh #1 (related veh #1 suddenly swerved to left around ... veh #2 and then witness also struck veh #2
Tx Driver #1 - 312-525-8196
O.U.I.L with BT sobriety on Driver #1.

Accid. Date Mo/Da/Yr: 01-23-87
File Class
Department Complaint No.: 87-3321-E10

Date: Mo/Da/Yr	Time	Investigators	Badge No.	Damaged Property Other Than Vehicle
1-23-87	6:44 A.M. (P.M.)	[signature]	204	

Comp. Disposition: Open Closed; Reviewer; Person Advised of Damaged Traffic Control D...; Name: Date:; Address

...ident Description and ...s area for explanation. 2 of 2

FORWARD COPY TO: Michigan Departme... 7150 Harris Drive,

[FHWA C-15]

3.2 Crash site -- Police Activated

This application is similar to the previous one except that the deployment of the system differs. In this application, a transmitter is programmed and placed at the crash scene by police much like flares might be deployed, currently. Police could select an appropriate message to assist with traffic control at the crash scene. Once again, secondary collisions at the crash scene and crashes caused by avoidance maneuvers are the target of this IVSAWS application.

3.3 Disabled Truck at Roadside

In ***this*** application IVSAWS warning would be activated to supplement or replace reflectors at the roadside. This application would be particularly useful on primary and interstate highways where travel speeds are high. One case involving collisions with a disabled truck at the roadside follows to illustrate this application.

IVSAWS Application Case 3

Disabled Truck at Roadside

Case Vehicle (A): 1986 Ford
Type: Escort LX, 2-Dr. HB
Driver: 55-yrs., Female

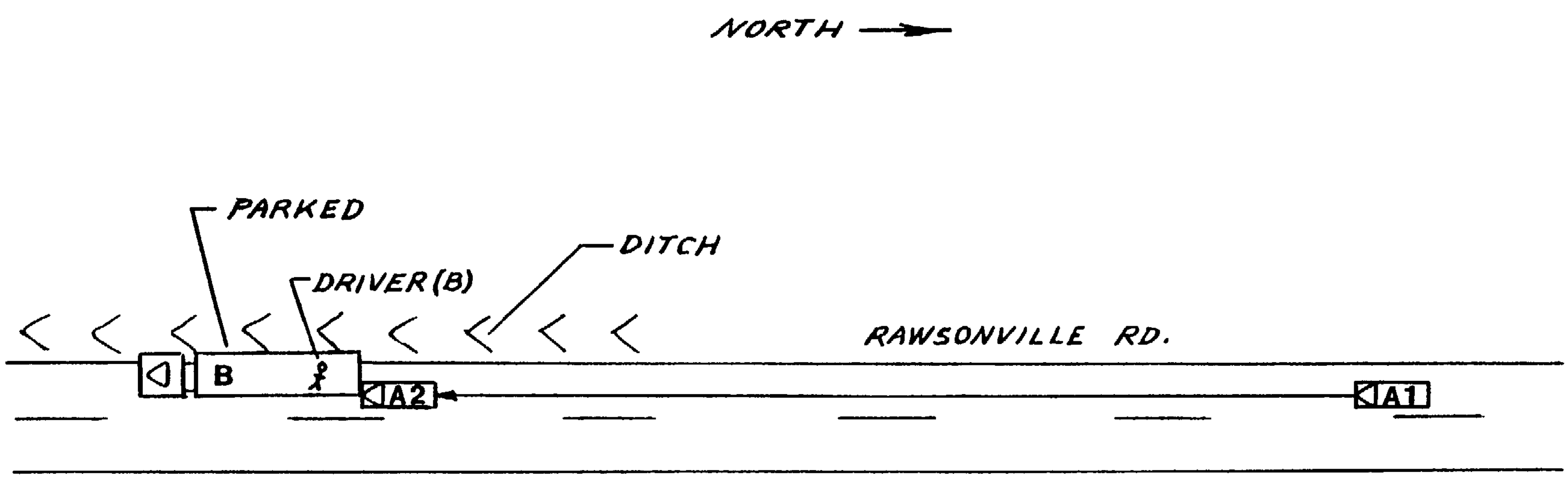
Vehicle (B): 1977 Mack
Type: DM-800ST, Tractor-Trailer
Driver: Unoccupied

Situation

At about 1310 hours on Monday, February 24, 1986, case vehicle (A) was southbound at a driver estimated speed of about 80 kmph on Rawsonville Road, a 2-lane farm area road southeast of Willis. Southbound vehicle (B) had broken down and was parked along the west side of the roadway, but well into the southbound lane because there was a ditch on the west side of the road. The driver was underneath the semitrailer working on the brakes. The driver of case vehicle (A) did not recognize that vehicle (B) was parked and case vehicle (A) struck the rear left comer and dual wheels of the vehicle (B) semitrailer. Vehicle (B) was not available for inspection, but as stated above it was stopped at the time of impact and the speed of case vehicle (A) could not be estimated. However, by assuming a barrier type of impact a delta-v was calculated using only the damage of case vehicle (A). The calculated delta-v for the assumption was 32 kmph.

CASE NO.: UM-2359-86
CASE VEH.(A): 1986 FORD
TYPE: ESCORT LX, 2-DR. HB
DRIVER: 55-YRS., FEMALE
VEH. (B): 1977 MACK TRACTOR-TRAILER

DATE/TIME: 2-24-86 / 1310 HRS.
WEATHER: CLEAR
ROAD SURFACE: DRY
ROAD CONSTRUCTION: ASPHALT



CIRCLE THE APPROPRIATE SELECTION

STATE

State of Michigan
TRAFFIC ACCIDENT REPORT

Department Name: STATE POLICE
LEIN Number: 8162600
Department Complaint No.: 26-1266-86
DO NOT USE: UM-2359-86

City No | Type | Section No. | Day of Week: S (M) T W T F S | Accident Date: Mo/Da/Yr 2 24 86 | Time 1 10 A.M. (P.M.)

Name: S. D. RAWSONVILLE | Route No. | Ft. 4 | (M) N (S) E W | Intersection: JUDD | Route Nos.

WEATHER: ...ar or Cloudy 3 Rain 4 Snow
LIGHT: (1) Day 2 Dawn or Dusk 3 Street Lights 4 Dark
ROAD SURFACE: (1) Dry 2 Wet 3 Snowy or Icy 4 Other
TOTAL LANES: 2
1 Divided (2) Limited Access 3 Other
Y (N) Construction Zone
(Y) N Investigated at Scene
TOTAL NO VEHICLES: 2

Driver No. 1

Driver's License: [redacted] | DOB: Mo/Da/Yr 3-22-30 | Hazardous Action No. 1 | Citation Charge: CARELESS | HBD Y (N) | Test | Helmet Y (N)

First M. Last: [redacted] | Address | City: YPSILANTI | State | Age 55 | Sex F | Inj. B

Type: 0 2 1 | Trailer | Reg. [redacted] | Yr/State 86 | VIN (Make Letters Larger Than Numbers): 1FABP32J5GW137548 | Removed to/by: WILLIS & BURTON SUNOCO

Haz. Citation | *Y (N) Driver Re-exam | *Y (N) Vehicle Defect | *Y (N) Fuel Leakage | Impact 1 | Severity 4 | Truck Cargo: Y (N) Cargo Spillage | Class
Other Citation | *Y (N) Vision Obstruct. | Y (N) Veh. Driveable | *Y (N) Vehicle Fire | Cargo Description

Pos.	Name	Address	Pos.	Age	Sex	Inj.	Helmet
		ESCORT,					Y N
3							Y N
6							Y N

Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier): 1 DRIVER | Insurance Co.: UNK | Agency Address | Injured taken to/by: BEYERS HOS / HVA

Driver No. 2

Driver's License | DOB: Mo/Da/Yr | Hazardous Action No. | Citation Charge | HBD Y N | Test | Helmet Y N

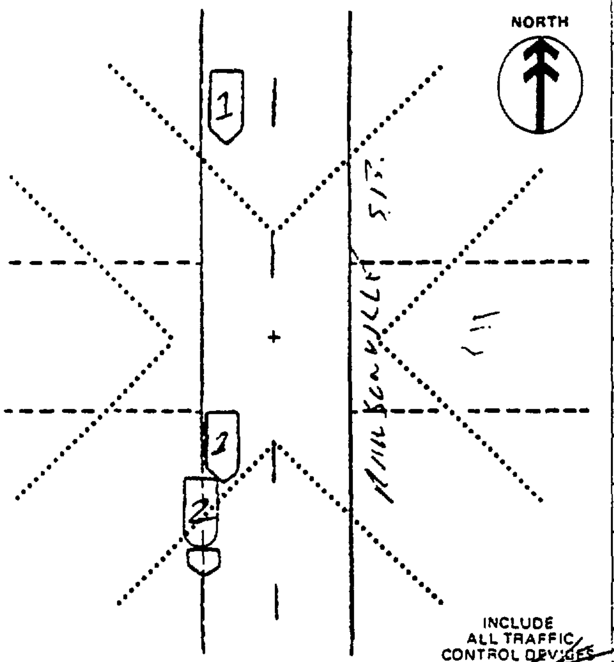
Name First M. Last: NO DRIVER | Address | City | State | Age | Sex | Inj.

Make No: 12 | Type 78 | Trailer 0 | Reg. [redacted] | Yr/State 86 MI | VIN (Make Letters Larger Than Numbers): DM687571322 | Removed to/by: KBK

Haz. Citation | *Y (N) Driver Re-exam | *Y (N) Vehicle Defect | *Y (N) Fuel Leakage | Impact 5 | Severity 2 | Truck Cargo: Y (N) Cargo Spillage | Class
Other Citation | *Y (N) Vision Obstruct. | Y (N) Veh. Driveable | *Y (N) Vehicle Fire | Cargo Description

Pos.	Name	Address	Pos.	Age	Sex	Inj.	Helmet
	[redacted]	D. Twp	P	25	M	A	Y (N)
2 3	Conventional Cab-offset 66-100,000 GWW						Y N
5 6	6x4						Y N

Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier): 0 CITY DISPOSAL [redacted] | Insurance Co.: UNK | Agency Address | Injured taken to/by: BEYERS / HVA



INCLUDE ALL TRAFFIC CONTROL DEVICES

ACCIDENT DESCRIPTION AND REMARKS (*Explain)

DRIVER #1 STATED SHE DID NOT KNOW WHAT HAPPENED

DRIVER #2 STATED HIS TRUCKS BRAKES HAD LOCKED UP, HE WAS UNDER THE VEHICLE WHEN #1 HIT IT IN THE REAR

NOTE: VEHICLE #2 HAD NO 4-WAY FLASHERS ON.

Accid. Date Mo/Da/Yr: 2-24-86
File Class: 5300-1
Department Complaint No.: 26-1266-86

Mo Da Yr Time 2 ... A.M. (P.M.) | Investigators: TPR McFARLAND | Badge No. 3... | Damaged Property Other Than Vehicle: NONE

Comp. Condition | Reviewer | Person Advised of Damaged Traffic Control De... | Name: | Date: | Address

FORWARD COPY TO: Michigan Department ...

[FHWA C-20]

3.4 School Bus or Other Special-Vehicle Hazard

Many special-use vehicles create hazards because of repeated stops or slow travel speeds relative to regular traffic. Crashes resulting from the operation of these vehicles may be the result of impacts with the special vehicle itself or with traffic backed up behind ‘the vehicle or manoeuvering around the vehicle. An IVSAWS system could provide drivers with a warning of the upcoming hazard in sufficient time to slow to react to the upcoming situation. Two cases follow to illustrate this application. One case involves a car striking a slowly moving snow-plow/salt truck on an interstate highway, the second involves a collision of a car with a civilian car used as a mail delivery vehicle.

IVSAWS Application Case 4

School Bus or Other Special-Vehicle Hazard

Sec. 622, Act 300, P.A. of 1949
Required
Misdemeanor

[redacted]

CIRCLE THE APPROPRIATE SELECTION

"X" IF CORRECTED COPY

(Rev 3-85) State of Michigan

OFFICIAL TRAFFIC ACCIDENT REPORT

Department Name	LEIN Number	Department Complaint No.
ANN ARBOR POLICE	218	90 - 57004 B20

DO NOT USE

County No.	City No.	Twp. No.	Section No.	Day of Week	Accident Date Mo/Da/Yr	Time
81	89	—	—	S M T W T F S (F circled)	12/28/90	6:45 A.M.

Name	Route No.	Ft.		Intersection	Route Nos.
I-94 (W/B)		.20 (MI)	N S E W	ANN ARBOR - SALINE RD.	

WEATHER	LIGHT	ROAD SURFACE	TOTAL LANES			TOTAL NO. VEHICLES
1 Clear or Cloudy 2 Fog 3 Rain 4 Snow	1 Day 2 Dawn or Dusk 3 Street Lights 4 Dark (circled)	1 Dry 2 Wet 3 Snowy or Icy (circled) 4 Other	2	1 Divided (circled) 2 Limited Access 3 Other	Y N Construction Zone (N circled); Y N Investigated at Scene (Y circled)	2

Driver No. 1

State	Driver's License	DOB: Mo/Da/Yr	Hazardous Action No.	Citation Charge	HBD	Test	Helmet
MI	[redacted]	4/21/61	1	VIOLATION BASIC SPEED	Y N	N	Y N

Driver's Name First M. Last	Address	City	State	Age	Sex	Inj.
[redacted]				29	M	B

Year	Make No.	Type	Trailer	Reg.	Yr/State	VIN (Make Letters Larger Than Numbers)	Removed to/by
86	06	1	0	[redacted]	90/MI	2FADP22S2GB225924	GLEN ANN/GLEN ANN

				Impact	Severity	Truck Cargo:	Class
3 Haz. Citation; 3 Other Citation	Y N Driver Re-exam; Y N Vision Obstruct.	Y N Vehicle Defect; Y N Veh. Driveable	Y N Fuel Leakage; Y N Vehicle Fire	1	5	Y N Cargo Spillage; Cargo Description	—

Restraints by occupants pos.	Name	Address	Pos.	Age	Sex	Inj.	Helmet
	[redacted]		3	28	F	A	Y N
2 3	[redacted]		6	2	F	B	Y N
5 3	- FORD Tempo GL 4-dr Sdn						Y N

	Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier)	Insurance Co.	Agency Address	Injured taken to/by
3	[redacted]	NONE	N/A	U of M / HVA

Driver No. 2

State	Driver's License	DOB: Mo/Da/Yr	Hazardous Action No.	Citation Charge	HBD	Test	Helmet
MI	[redacted]	11/2/45	0	—	Y N	N	Y N

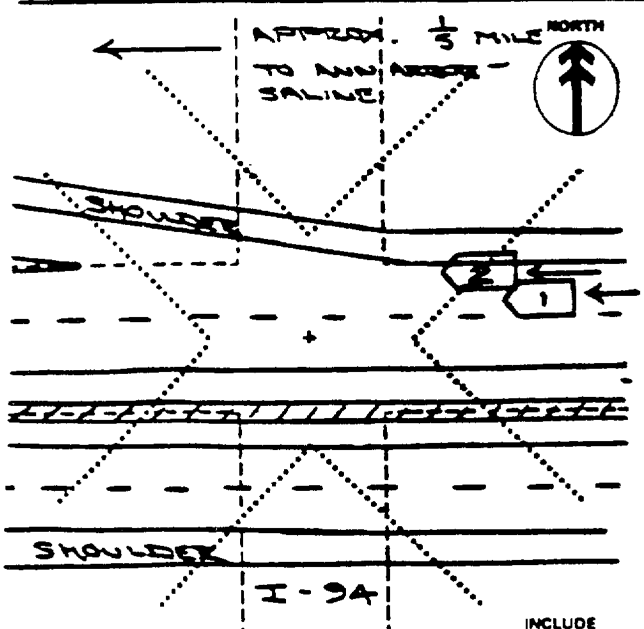
Driver's Name First M. Last	Address	City	State	Age	Sex	Inj.
[redacted]				45	M	O

Year	Make No.	Type	Trailer	Reg.	Yr/State	VIN (Make Letters Larger Than Numbers)	Removed to/by
80	26	7	0	[redacted]	91/MI	CA 257KGB15477	STREET / DRIVER.

				Impact	Severity	Truck Cargo:	Class
Y N Haz. Citation; Y N Other Citation	Y N Driver Re-exam; Y N Vision Obstruct.	Y N Vehicle Defect; Y N Veh. Driveable	Y N Fuel Leakage; Y N Vehicle Fire	5	1	Y N Cargo Spillage; Cargo Description	—

Restraints by occupants pos.	Name	Address	Pos.	Age	Sex	Inj.	Helmet
							Y N
2 3							Y N
6 6							Y N

	Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier)	Insurance Co.	Agency Address	Injured taken to/by
1	[redacted] / WASHTENAW CO.	SELF-INSURED	ANN ARBOR	N/A



INCLUDE ALL TRAFFIC CONTROL DEVICES

ACCIDENT DESCRIPTION AND REMARKS (*Explain)

VEHICLE NO. 2, A WASHTENAW CO. SALT TRUCK, WAS TRAVELING W/B ON I-94 NEAR THE ANN ARBOR-SALINE RD. EXIT RAMP. VEH. NO. 2 HAD BEEN PARTIALLY ON THE SHOULDER AND PARTIALLY ON THE ROADWAY, SCRAPING SNOW ONTO THE SHOULDER ALONG THE NORTH SIDE.

VEHICLE NO. 1 STRUCK THE REAR OF VEHICLE NO. 2 AS NO. 1 STARTED TO ENTER THE EXIT RAMP.

DRIVER NO. 2 ESTIMATED HIS SPEED AT 25-30 M.P.H. AT THE TIME OF IMPACT. HE STATED THAT HE

Accid. Date Mo/Da/Yr 12/28/90 | File Copy 0720 | Department Complaint No. 90-57004 B20

Reported Mo/Da/Yr	Time	Investigators	Badge No.	Damaged Property Other Than Vehicle
12/28/90	0649 A.M.	Ofc. D. Monroe	136	

Notes by | Comp. Disposition: Open Closed (circled) | Reviewer 211 | Public Advised of Damaged Traffic Control Dev. Name: Date: | Address

FORWARD COPY TO: Michigan Department

[FHWA C-23]

(OVER) PAGE

GENERAL INCIDENT FOLLOW-UP NARRATIVE CONTINUATION

ANN ARBOR POLICE DEPARTMENT

☐ FOLLOW-UP
☐ CHANGE

[redacted]

REPORTING OFFICER		INCIDENT TYPE
	[redacted]	

NAME	R/S	AGE OR D.O.B./ INVOLVEMENT	ARREST DISPOSITION	HOME ADDRESS/ PLACE OF EMPLOYMENT & SHIFT	TX HOME/BUSS.
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]		C V R W S O			
[redacted]		[redacted]	[redacted]	[redacted]	
[redacted]		C V R W S O			

ACCIDENT (CONT): DID OBSERVE VEHICLE NO. 1 APPROACHING AT AN EXTREME SPEED. HE STATED THAT HE DID HAVE THE VEHICLE'S OPERATING LIGHTS ACTIVATED.

DRIVER NO. 1 STATED THAT HE HAD PLANNED TO EXIT AT ANN ARBOR-SALINE RD. HE STATED THAT HE HAD OBSERVED VEHICLE NO. 2 BUT HAD STARTED TO SLIDE ON THE SNOWY PAVEMENT AND COULD NOT AVOID IMPACT. HE ESTIMATED HIS SPEED AT 40 M.P.H.

INJURIES: ALL THREE SUBJECTS FROM VEHICLE NO. 1 WERE TRANSPORTED TO U OF M ER. DRIVER NO. 1 SUSTAINED A CUT TO HIS CHIN AND HIS UPPER LIP. PASSENGER C. BARNES-YOUNG SUSTAINED A CUT TO THE RT. SIDE OF HER FOREHEAD AND COMPLAINED OF NECK PAIN. PASSENGER J. YOUNG SUSTAINED A CUT TO HER UPPER LIP.

DISPOSITION: DRIVER NO. 1 ISSUED VR KIZAZ1 FOR "VIOLATION BASIC SPEED LAW." VIOLATIONS KIZAZZ AND KIZ423 ALSO ISSUED FOR D.W.L.S (CR 90-57022) AND NO INSURANCE.

NOTE: ACCIDENT INVESTIGATORS (SGT. MILBY AND OFC. ZABODNY) HAD RESPONDED TO THE SCENE OF THE ACCIDENT.

PAGE	OF	DICTATION	R.W. TIME	REVIEWED BY	
2	2	☐			[redacted]

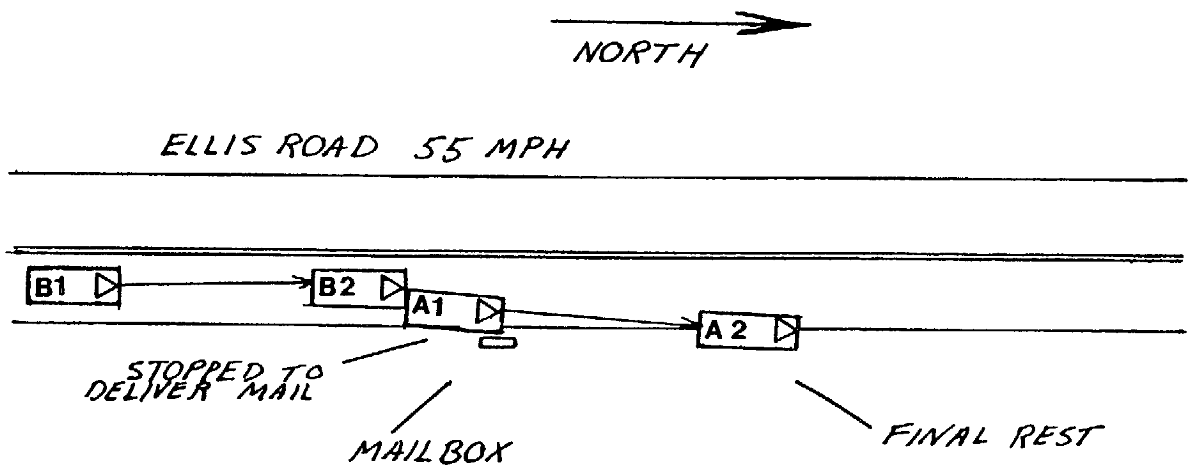
STOLEN $	RECOVERED $	DAMAGED $		BADGE	SEC	DATE	RE-CLASS
		[redacted]	[FHWA C-24]	[redacted]		[redacted]	[redacted]

IVSAWS Application Case 5

School Bus or Other Special-Vehicle Hazard

CASE NO.: UM-2812-90
CASE VEH. (A): 1989 OLDSMOBILE
TYPE: CUTLASS CIERA 4-DR. SEDAN
DRIVER: 64-YRS., FE MALE
VEH.(B): 1987 DODGE RAM PICKUP 4X2

DATE / TIME: 07-17-90 /1300 HRS.
WEATHER: CLEAR
ROAD SURFACE: DRY
ROAD CONSTRUCTION: ASPHALT



TRAFFIC ACCIDENT REPORT

Washtenaw County Sheriff 101

UM-2812-90

City No. | Twp. No. 20 | Section No. 19 | Day of Week S M T W T F S (T circled) | Accident Date: Mo/Da/Yr 7-17-90 | Time 1:00 A.M. P.M. (P.M. circled)

Name: Ellis Road | Route No. | Ft. 1/10 Mi N S E W | Intersection: Morgan Road | Route Nos.

WEATHER: Clear or Cloudy 3 Rain / Fog 4 Snow
LIGHT: 1 Day 3 Street Lights / 2 Dawn or Dusk 4 Dark
ROAD SURFACE: 1 Dry 3 Snowy or Icy / 2 Wet 4 Other
TOTAL LANES: 2 — 1 Divided 2 Limited Access 3 Other
Y N Construction Zone — Y N Investigated at Scene
TOTAL NO. VEHICLES: 2

Driver No. 1

Driver's License: [redacted] | DOB: Mo/Da/Yr 5-23-17 | Hazardous Action No. 8 | Citation Charge 78-61245 Unable to Stop ACD | HBD Y N | Test N | Helmet Y N

Name First M. Last Address City State: [redacted] | Age 73 | Sex M | Inj. C

Make No. 2 | Type 6 | Trailer 0 | Reg. [redacted] | Yr/State 90/Mich | VIN (Make Letters Larger Than Numbers) 1B7FD14H9HS369153 | Removed to/by Willis Thom Sunoco/Hwy

Haz. Citation / Other Citation | Y N Driver Re-exam | Y N Vision Obstruct. | Y N Vehicle Defect | Y N Veh. Drivable | Y N Fuel Leakage | Y N Vehicle Fire | Impact 2 | Severity 3 | Truck Cargo: Y N Cargo Spillage | Cargo Description None | Class

Occupants by pos.	Name	Address	Pos.	Age	Sex	Inj.	Helmet
1 2 3							Y N
4 5 6		[redacted]					Y N
							Y N

Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier): 1 Same as driver | Insurance Co. State Farm Ins | Agency Address Ypsilanti, Mich | Injured taken to/by Refused

Driver No. 2

Driver's License: [redacted] | DOB: Mo/Da/Yr 9-18-25 | Hazardous Action No. 0 | Citation Charge None | HBD Y N | Test N | Helmet Y N

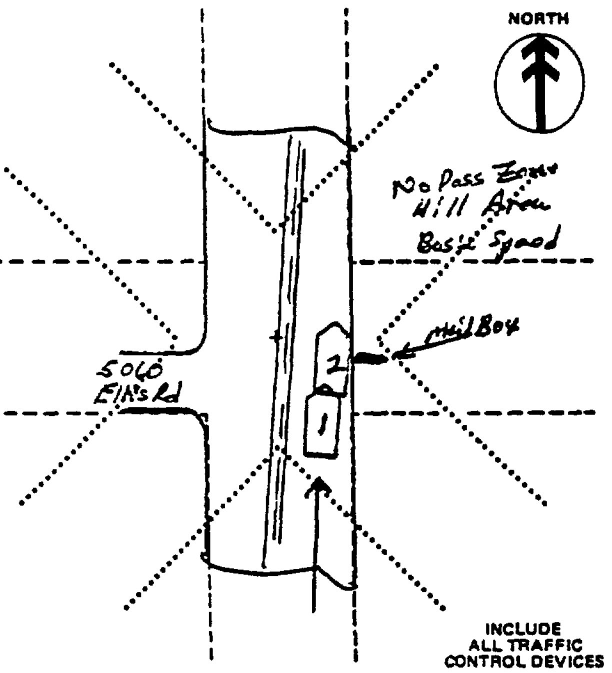
Name First M. Last Address City State: [redacted] | Age 64 | Sex F | Inj. B

Make No. 1 | Type 1 | Trailer 0 | Reg. [redacted] | Yr/State 90/Mich | VIN (Make Letters Larger Than Numbers) 2G3AJ51W7K2341656 | Removed to/by Sakstrups Towing/Wreck

N Haz. Citation / N Other Citation | Y N Driver Re-exam | Y N Vision Obstruct. | Y N Vehicle Defect | Y N Veh. Drivable | Y N Fuel Leakage | Y N Vehicle Fire | Impact 5 | Severity 5 | Truck Cargo: Y N Cargo Spillage | Cargo Description N/A | Class

Occupants by pos.	Name	Address	Pos.	Age	Sex	Inj.	Helmet
1 2 C 3		CUTLASS Ciera 4-DR SDN	V6				Y N
4 5 6		[redacted]					Y N
							Y N

Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier): 1 Same as driver | Insurance Co. AAA | Agency Address A2, Mich | Injured taken to/by St. Joseph Hosp/HVA



INCLUDE ALL TRAFFIC CONTROL DEVICES

ACCIDENT DESCRIPTION AND REMARKS (*Explain)

Vehicle #1: Was going north on Ellis Road, and didn't see #2 stopped. He struck her vehicle pushing it down the road.

Vehicle #2: Was stopped making a mail deliver in a marked postal vehicle w/sign. This was a private car used for mails.

Accid. Date - Mo/Da/Yr 7-17-90 | File Class 3155 | Department Complaint No. 90-21531

Reported: Mo/Da/Yr 7-17-90 | Time 1:04 A.M. P.M. | Investigators R. Hill / E. Swope | Badge No. 99/692 | Damaged Property Other Than Vehicle: Mail Box

Reported by | Comp. Disposition Open Closed (Closed circled) | Reviewer | Person Advised of Damaged Traffic Control Device Name: | Date: | Time: | Owner Address: Nasreen Panahi, 5060 Ellis Rd, Ypsi

Accident Description and Remarks area for explanation. | FORWARD COPY TO: Michigan ... 7150 Ha... Division.

[FHWA C-27]

3.5 *Highway Construction Zones*

IVSAWS transmitters could be deployed to accurately reflect the changing conditions at and around construction zones. Work crews could change the transmitted message to reflect current road conditions as work progresses and changes in character. In this way, drivers would be presented with the most timely information, reducing the likelihood that they will dismiss messages as not being pertinent.

3.6 *Traffic Backups*

IVSAWS transmitters could be deployed to notify drivers of impending traffic backups. This may not be practical for some recurrent traffic congestion problems. In recurrent situations the message may be so repetitive as to cause driver habituation, thus diminishing the value of the message. However, this application may be more practical in nonrecurrent traffic backup situations.

Traffic may backup as a result of a crash or other roadside or off-road event (via lane blockage or “gapers block”). In these cases, police or other emergency personnel may set up IVSAWS transmitters to inform up-stream traffic of the upcoming blockage. Another likely application is at locations on the highway where traffic backups are frequent, but are not so regular in occurrence that driver habituation becomes an issue. Such a location is at or near construction zones. A case describing a crash that occurred up-stream of a construction zone where traffic had backed up well in advance of the construction zone is described on the following pages.

IVSAWS Application Case 6

Traffic Backups

Case Vehicle (A): 1988 Dodge
Type: Ram Raider, 3-Dr. MPV
Driver: 18-yrs, Male

Vehicle (B): 1985 Freightliner
Type: COE 6 x 4 Tractor-Trailer
Driver: 49-yrs., Male

Vehicle (C): 1981 Pontiac
Type: Phoenix LJ, 5-Dr. HB
Driver: 51-yrs, Male

Vehicle (D): 1976 Chevrolet
Type: Camaro, 2-Dr. Coupe
Driver: 32-yrs., Female

Vehicle (E): 1986 Buick
Type: Electra Park Avenue, 4-Dr. NB
Driver: 46-yrs., Male

Vehicle (F): 1973 Dodge
Type: Motorhome
Driver: 64-yrs., Male

This is a multiple vehicle fatal crash with fire.

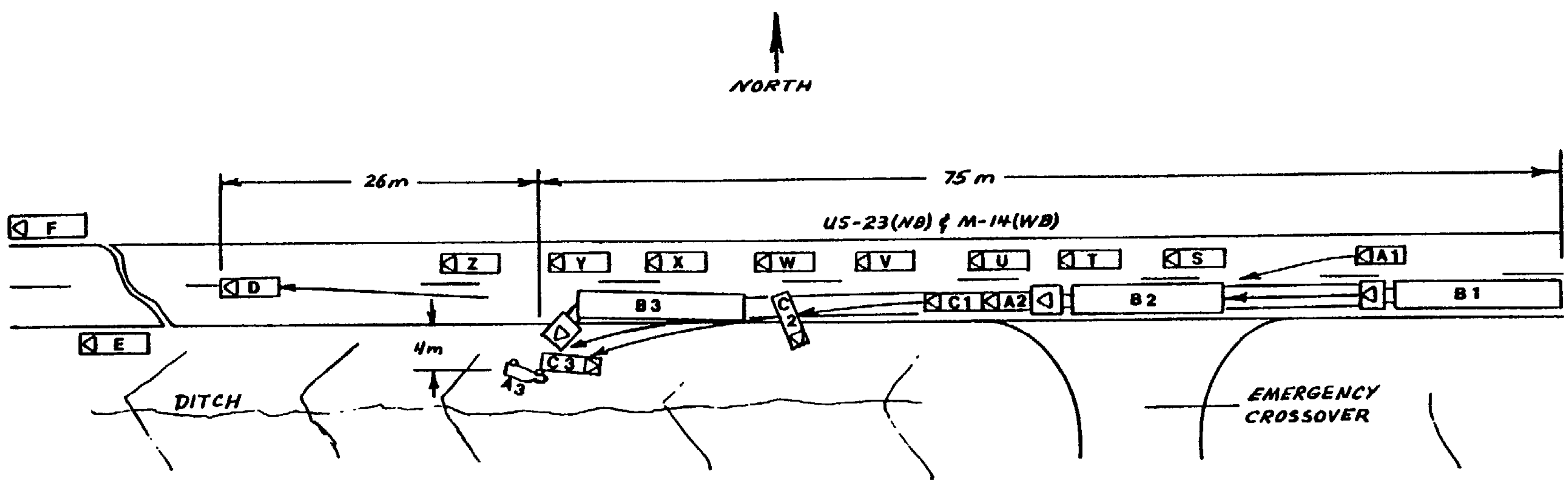
Situation

At about 0850 hours on Thursday, August 11, 1988, case vehicle (A) was reported to be traveling at an unknown speed in the right lane of US-23(NB)/M-14(WB), a 4-lane divided concrete expressway north of Ann Arbor. Vehicles (E), (D), (C) and (B) were westbound at unknown speeds in the left lane while vehicle (F) and other traffic (S) thru (Z) were westbound in the right lane. Due to construction ahead all traffic was stop-and-go except case vehicle (A) and vehicle (B). As case vehicle (A) approached this situation, it reportedly switched lanes abruptly in front of vehicle (B) and then had to slow down, but the driver of vehicle (B) was apparently not attentive enough and could not stop in time. Vehicle (B) struck the rear of case vehicle (A), which in turn struck the rear of stopped vehicle (C). Following the impact, vehicle (C) yawed to the left into the median while case vehicle (A) bounced into the air and ran off the median and rolled onto its right side. Both case vehicle (A) and vehicle (C) burst into flames and were consumed. Case vehicle (A) came to rest on its right side headed easterly about 4 meters into the median while vehicle (C) was on its wheels headed easterly just ahead of case vehicle (A) about 3 meters into the median. Following the initial impact, vehicle (B) began to jackknife and then struck the rear of stopped vehicle (D). Vehicle (B) then slid to a stop with the front of the tractor just into the median headed southwesterly at the rear of vehicle (C). Vehicle (B) left about 75 meters of skid marks. Following impact, the left front of vehicle (D) struck vehicle (E) and bounced to the right where its left front comer was struck by vehicle (F) and then sideswiped by vehicle (F). Vehicle (D) came to rest headed west astride the center of the westbound lanes and 26 meters west of vehicle (B). Meanwhile, vehicle (E) came to a stop on the median shoulder and vehicle (F) stopped on the right shoulder; both an unknown distance west of vehicle (D). It is unknown whether or not vehicles (E) and (F) were moving at the time of impact, but it was reported that vehicle (D) was stopped at the time that it was struck. The impact speeds of vehicles (B), (C) or case vehicle (A) could not be determined.

CASE NO.: UM-2613-88
CASE VEH. (A): 1988 DODGE
TYPE: RAM RAIDER, MPV
DRIVER: 18-YRS., MALE
VEH. (B): 1985 FREIGHTLINER SEMI
VEH. (C): 1981 PONTIAC PHOENIX
VEH. (D): 1976 CHEVROLET CAMARO

DATE / TIME: 8-11-88 / 0850HRS.
WEATHER: CLEAR
ROAD SURFACE: DRY
ROAD CONSTRUCTION: CONCRETE

VEH. (E): 1986 BUICK ELECTRA
VEH. (F): 1976 DODGE MOTOR HOME



MULTIPLE VEHICLE FATAL CRASH WITH FIRE

OFFICIAL TRAFFIC ACCIDENT REPORT

3.7 "Mini-zones" *Involving Roadside Work*

Crashes may occur at roadside "mini-zones"--areas where roadside work is in progress for limited periods of time. Examples of these mini-zones include utility construction sites where utility vehicles are present in the roadway while work is in progress at or near the roadway itself. Presence of these zones could be announced to up-stream traffic via IVSAWS. We should note that conversations with the corporate safety directors of several Michigan utilities have suggested that crashes involving roadside utility crews and/or their vehicles are extremely rare events. However, further research into the number and nature of such crashes may shed more light on IVSAWS applicability in these situations. Unfortunately, available crash data are unsuitable for this level of detailed analysis.

3.8 Temporary Detour Routes

The IVSAWS applications on temporary detour routes take two basic forms. First, IVSAWS could serve to warn of special hazards that may be encountered on the detour. An example of this application can be found on the following pages describing a crash of a semi-trailer truck as it tried to negotiate a curve at excessive speed on an interstate highway detour. The second possible application deviates from IVSAWS as a safety warning system and, instead, serves to provide route guidance. Transmitters could be placed along a detour path (created because of construction, a massive accident, or other special event) to direct traffic so that drivers do not get lost. While this application deviates from the hazard warning application of IVSAWS, it capitalizes on an IVSAWS installation to obtain greater functionality as a public service.

IVSAWS Application Case 7

Temporary Detour Routes

Case vehicle (A): 1978 International

Type: CO-4070B, Tractor-Trailer

Driver: 40-yrs, Male

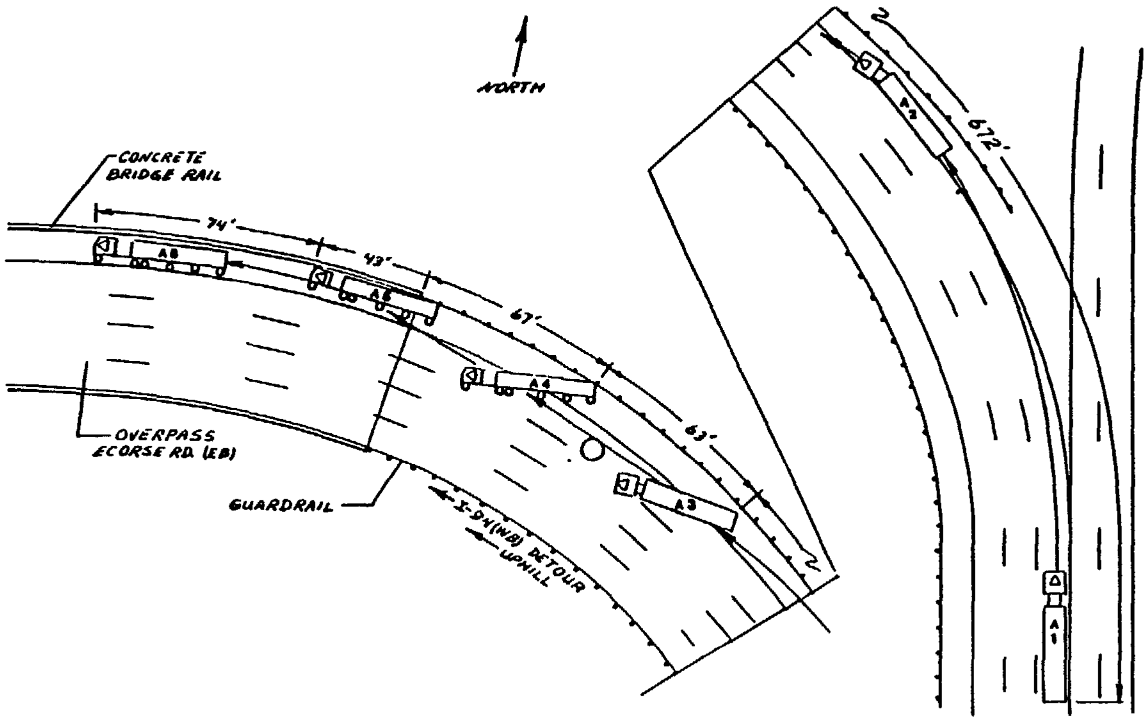
Situation

This is a fatal crash.

At about 0055 hours on Wednesday, February 4, 1987, case vehicle (A) was traveling at an unknown speed in the right lane of the 3-lane westbound I-94 detour route. There were two other lanes on the right than continued on to Ecorse Road. On a fairly sharp uphill curve to the left that went across an overpass, the case vehicle (A) was apparently traveling too fast and ran off the driving lane onto the right shoulder. The driver apparently attempted to return to the roadway too abruptly causing the case vehicle (A) to roll onto its right side. It then slid on its right side up the pavement and onto the right shoulder where it struck the guardrail. It was then directed on up along the guardrail where it struck the concrete rail of the overpass. The case vehicle (A) came to rest on its right side on the north shoulder near the center of the overpass. The rollover speed of the case vehicle (A) is unknown. The semitrailer contained two moderate (23,770 lbs total) weight rolls and one heavy (27,430 lbs) roll of stainless steel. The two smaller rolls remained in the semitrailer while the larger roll broke loose and came to rest in the center of the roadway.

CASE NO.: UM-2455-87
CASE VEH. (A): 1978 INTERNATIONAL
TYPE: CO-4070B, TRACTOR-TRAILER
DRIVER: 40-YRS., MALE

DATE/TIME: 2-4-87/0055 HRS.
WEATHER: CLOUDY
ROAD SURFACE: DRY
ROAD CONSTRUCTION: ASPHALT



UM-2455-87

STATE

PENALTY: Misdemeanor

CIRCLE THE APPROPRIATE SELECTION

(Rev. 9-85) State of Michigan

OFFICIAL TRAFFIC ACCIDENT REPORT

Department Name: Michigan State Police

LEIN Number: 026

Department Complaint No.: DO NOT 26-766-87

County No.	City No.	Twp. No.	Section No.	Day of Week	Accident Date, Mo/Da/Yr	Time
81		20	11	S M T (W) T F S	2-4-87	12:55 A.M. P.M. XX

Name: Temp. I-94 W/B N/B Willow Run Fwy. Route No. — 1/4 Ft. Mi. N S E W — Intersection: Tyler Rd. — Route Nos

WEATHER: (1) Clear or Cloudy 3 Rain 2 Fog 4 Snow — LIGHT: 1 Day 2 Dawn or Dusk 3. Street Lights (4) Dark — ROAD SURFACE: (1) Dry 2 Wet 3 Snowy or Icy 4 Other — TOTAL LANES: 3 — (1) Divided 2 Limited Access 3 Other — Y (N) Construction Zone, Y (N) Investigated at Scene — TOTAL NO VEHICLES: 1

Driver No. 1

State: MI — Driver's License: [redacted] — DOB Mo/Da/Yr: 10-17-46 — Hazardous Action No.: 1 — Citation Charge: None — HBD Test: Y (N) — Helmet: Y (N)

Driver's Name First M.I. Last Address City State Age Sex Inj.: [redacted] — 40 M K

Year: 78 — Make No.: 2 6 — Type: 8 — Trailer: 3 — Reg.: [redacted] — Yr/State: 87 MI — VIN (Make Letters Larger Than Numbers): E0327H3419760 — Removed to/by: ... — Class: #1

Y (N) Haz. Citation, Y (N) Other Citation, Y (N) Driver Re-exam, Y (N) Vision Obstruct., (Y) N Vehicle Defect, Y (N) Ven. Driveable, (Y) N Fuel Leakage, Y (N) Vehicle Fire — Impact: 0 — Severity: 7 — Truck Cargo: (Y) N Cargo Spillage — Cargo Description: COIL STEEL — Class: 5

Occupants by seating pos. — Name — Address — Pos. — Age — Sex — Inj. — Helmet

		Name	Address	Pos.	Age	Sex	Inj.	Helmet
								Y N
2	3							Y N
5	6							Y N

Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier): 1 [redacted] — Insurance Co.: Mich. Mutual — Agency Address: Oak Park, MI — Injured taken to/by: UofM/Wis-Fontana

Driver No. 2

State — Driver's License — DOB: Mo/Da/Yr — Hazardous Action No. — Citation Charge — HBD Test Y N — Helmet Y N

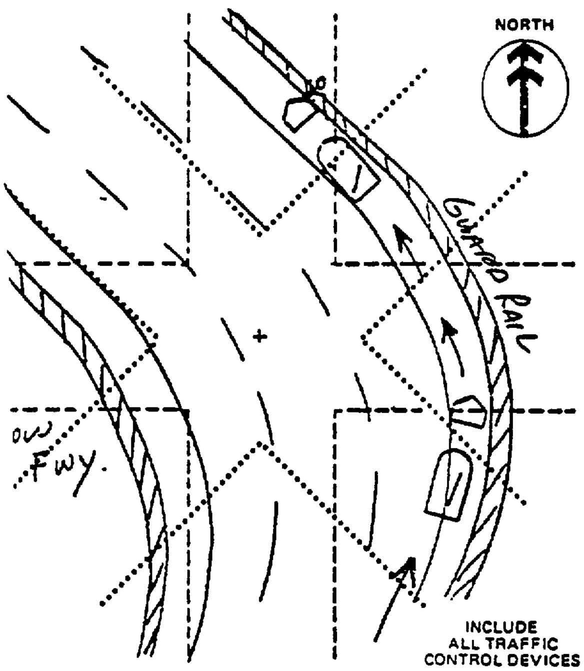
Driver's Name First M.I. Last Address City State Age Sex Inj.

Year Make No. Type Trailer Reg. Yr/State VIN (Make Letters Larger Than Numbers) Removed to/by

Y N Haz. Citation, Y N Other Citation, Y N Driver Re-exam, Y N Vision Obstruct., Y N Vehicle Defect, Y N Ven. Driveable, Y N Fuel Leakage, Y N Vehicle Fire — Impact — Severity — Truck Cargo Y N Cargo Spillage — Cargo Description — Class

		Name	Address	Pos.	Age	Sex	Inj.	Helmet
								Y N
2	3							Y N
5	6							Y N

Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier) — Insurance Co. — Agency Address — Injured taken to/by



INCLUDE ALL TRAFFIC CONTROL DEVICES

ACCIDENT DESCRIPTION AND REMARKS (Explain)

REPORTS A FATAL TRAFFIC ACCIDENT

Vehicle #1 was travelling on N/B Willow Run Freeway at the Ward Ramp. Vehicle #1 was entering a curve, with a posted 45mph speed. This area is temporary I-94 W/B. Due to the speed of vehicle #1 and the Load of Coil Steel, Vehicle #1 tipped onto its right side upon entering into the curve. #1 then struck the guard rail, and continued to travel along the right side guard rail until coming to rest on the right shoulder. Driver of #1 was not wearing a seatbelt and partially left the cab. In leaving the cab, the driver of #1 struck his head causing death. Preliminary exam. of the vehicle shows that the trailer had defective brakes. There was a slight spill of fuel and oil. The slower speed is posted well in advance of the construction zone.

Accid. Date Mo/Da/Yr: 2-4-87 — File Class: 9300-1 — Department Complaint No.: 26-766-87

[FHWA C-51]

Mo/Da/Yr — Time: 1:05 A.M. P.M. XXX — Investigators: Larry H. Gorzinski #412, James Cameron #657 — Vehicle: Guard Rail

Comp. Disposition — Reviewer — Person Advised of Damaged Traffic Control Device

3.9 Multiple (Compounding) Hazardous Conditions

IVSAWS applications could be useful in reducing the problems caused by multiple hazards. Take the example of the semi-trailer truck crash while traveling at excessive speed through the curve. The curve was not a significant hazard when traveled at the posted speed, but became hazardous to a vehicle traveling at excessive speed. A system could be designed to relay a “slow-down” message to vehicles traveling at an excessive speed through a curve. The vehicle message system could monitor vehicle speed, and the message would be signalled only to drivers in vehicles which are traveling over a predetermined speed.

Systems which could take advantage of environmental sensors may signal drivers at sites (e.g., curves, bridges) which have become particularly hazardous because of changes in the coriditions of the roadway (e.g., wet, ice, snow) or atmospheric conditions (e.g., fog). The increased reaction time afforded drivers by IVSAWS technologies may be especially helpful in these conditions where stopping distance or decision sight distance is reduced by weather or road conditions.

Other multiple-hazards involve road features which are somehow hidden from the driver because of horizontal or vertical curvature of the road or other obstacles. The case presented on the following pages describes a crash in which a car encountered a rough railroad grade after coming out of a curve at an excessive speed.

IVSAWS Application Case 8

Multiple (Compounding) Hazardous Conditions

Case Vehicle (A): 1989 For:
Type: Probe GT 2-Dr. HB
Driver: 42-yrs., Female

This is a fatal crash. The driver had been drinking and a chemical test was given; however, no results were obtained.

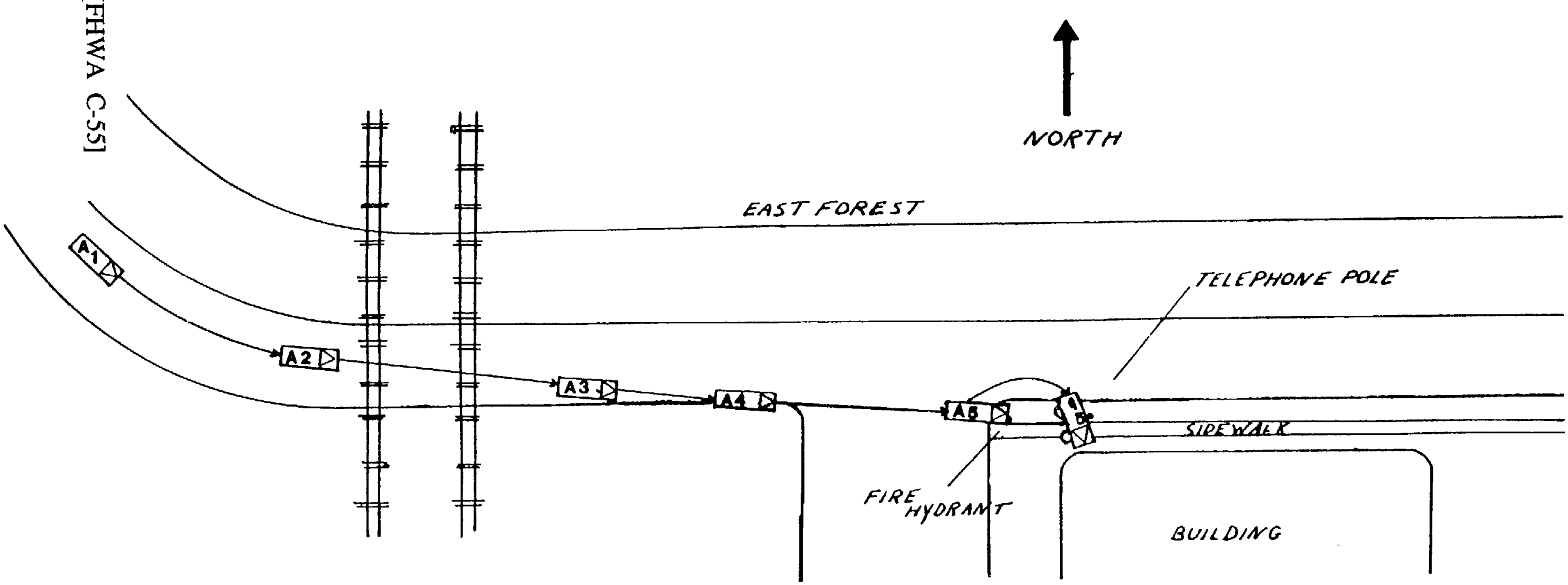
Situation

At about 0513 hours on Sunday, August 5, 1990, case vehicle (A) was eastbound at a high rate of speed on East Forest, a 2-lane asphalt roadway through a commercial area of Ypsilanti. When case vehicle A) crossed two sets of very bumpy railroad tracks it went our of control, went up the curb and left the south edge of the roadway. It traveled off the road about 17 meters where it struck a first hydrant head-on, The hydrant was broken off at the ground and flew about 5 meters where it struck the side of the building. Following the impact with the fire hydrant, case vehicle (A) rotated clockwise becoming partially airborne and struck a utility pole on the left side and roof. The case vehicle (A) rolled upwards with the roof contacting the pole seven feet above ground. The car came to rest at an angle against the pole.

CASE NO: UM-2820-90
CASE VEH. (A): 1989 FORD
TYPE: PROBE GT Z-DR. HB
DRIVER: 42-YRS., FEMALE

DATE / TIME: 08-05-90 /0513 HRS.
WEATHER: CLEAR
ROAD SURFACE: DRY
ROAD CONSTRUCTION: ASPHALT

[FHWA C-55]



AUTHORITY Sec. 322, Act 300 P.A. of 1949
COMPLETION Required
PENALTY Misdemeanor

CIRCLE THE APPROPRIATE SELECTION

X IF CORRECTED COPY

UD-10 (Rev 9-85)
State of Michigan
OFFICIAL TRAFFIC ACCIDENT REPORT

Department Name: Ypsilanti PD
LEIN Number: 836
Department Complaint No: 90-12783
DO NOT USE: 2820-90

ACCIDENT LOCATION
County No: 81 | City No: 80 | Twp. No.: — | Section No.: — | Day of Week: S M T W T F S | Accident Date Mo/Da/Yr: 8-5-90 | Time: 5:13 AM PM
Name: ON E. Forest | Route No. | Ft.: 170 Mi. N S E W | Intersection: MArket Pl. | Route Nos

ACCIDENT COND
WEATHER: 1 Clear or Cloudy 3 Rain 2 Fog 4 Snow
LIGHT: 1 Day 2 Dawn or Dusk 3 Street Lights 4 Dark
ROAD SURFACE: 1 Dry 2 Wet 3 Snowy or Icy 4 Other
TOTAL LANES: 2
1 Divided 2 Limited Access 3 Other
Y N Construction Zone
Y N Investigated at Scene
TOTAL NO VEHICLES: 1

VEHICLE DRIVER NO 1
State: MI | Driver's License: [redacted] | DOB Mo/Da/Yr: 10-8-47 | Hazardous Action No: 8 | Citation Charge | HBD Y N | Test | Helmet Y N
Driver's Name First M. Last Address City State: [redacted] | Age: 42 | Sex: F | Inj: K
Year: 89 | Make No: 06 | Type: 1 | Trailer: -- | Reg.: [redacted] | Yr/State: 90/MI | VIN (Make Letters Larger Than Numbers): 1ZVBT22LXK5265966 | Removed to/by: 41 Water St./Ypsi Tow
Y N Haz Citation | Y N Other Citation | *Y N Driver Re-exam | *Y N Vision Obstruct. | *Y N Vehicle Defect | Y N Veh Driveable | *Y N Fuel Leakage | *Y N Vehicle Fire | Impact: 1 | Severity: 7 | Truck Cargo Y N Cargo Spillage | Cargo Description: N/A | Class

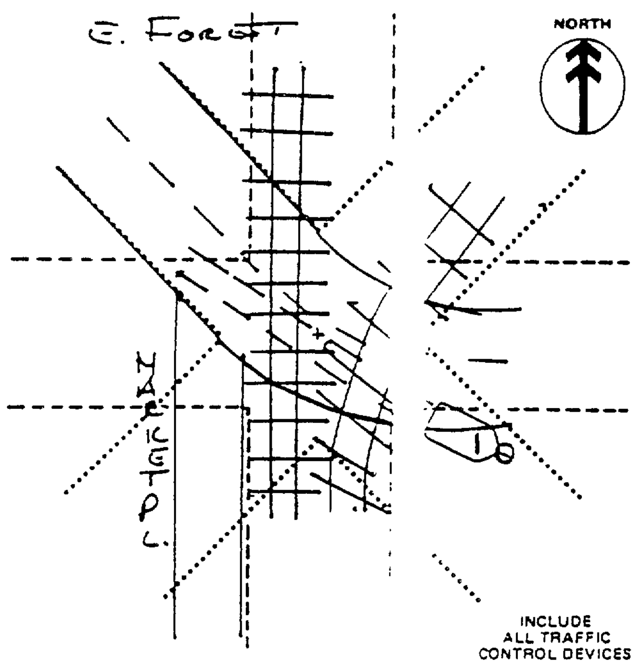
Restraints by occupants pos | Name | Address | Pos. | Age | Sex | Inj | Helmet
[redacted] | 3 | 31 | M | A | Y N
C 1 2 C 3 | | | | | | | Y N
4 5 6 | | | | | | | Y N
Total Occupants: 2 | Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier): [redacted] | Insurance Co. | Agency Address | Injured taken to/by: St. Joe's/HVA

Driver No. 1

VEHICLE DRIVER NO 2
State | Driver's License | DOB Mo/Da/Yr | Hazardous Action No. | Citation Charge | HBD Y N | Test | Helmet Y N
Driver's Name First M Last | Address | City | State | Age | Sex | Inj
Year | Make No | Type | Trailer | Reg. | Yr/State | VIN (Make Letters Larger Than Numbers) | Removed to/by
Y N Haz Citation | Y N Other Citation | *Y N Driver Re-exam | *Y N Vision Obstruct. | *Y N Vehicle Defect | Y N Veh Driveable | *Y N Fuel Leakage | *Y N Vehicle Fire | Impact | Severity | Truck Cargo Y N Cargo Spillage | Cargo Description | Class

Restraints by occupants pos. | Name | Address | Pos. | Age | Sex | Inj | Helmet Y N
1 2 3 | | | | | | | Y N
4 5 6 | | | | | | | Y N
Total Occupants | Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier) | Insurance Co. | Agency Address | Injured taken to/by

Driver No. 2



INCLUDE ALL TRAFFIC CONTROL DEVICES

ACCIDENT DESCRIPTION AND REMARKS (*Explain)

Vehicle #1 was going E/B on E. Forest at a high rate of speed. Vehicle became airborn while crossing the railroad tracks at E. Forest/Market Pl. and driver lost control of vehicle.

Vehicle first hit south curb and left the roadway and struck a fire hydrant. Hydrant was broken off the ground along with 4½' of iron pipe, (underground piping). Fire hydrant hit building and vehicle rolled roof first into telephone pole at a height of 7½'. Vehicle rotated counter-clockwise around pole and fell to ground at rest.
See supplemental drawing * PENDING MSP ANALYSIS

Accid. Date Mo/Da/Yr | File Class | Department Complaint No.

Reported Mo/Da/Yr Time: 8-5-90 5:15 AM | Investigators: Yek/Brschnieder | Badge No: 123/176 | Damaged Property Other Than Vehicle: building (12 E. Forest) Fire Hydrant
Photos by: 123 | Comp Disposition: Open Closed | Reviewer | Person Advised Name: N/ | Owner: MI Ladder/City of Ypsilanti | Address

Use Accident Description and Remarks area for explanation
FORWARD C...
[FHWA C-56]
...raffic Services Division.

3.10 Supplemental Traffic Control Device

Changes in traffic control devices may surprise drivers who travel through the site very frequently, thus contributing to crashes. Changes may result from engineering initiatives (e.g., replacing a yield with a stop sign, removing a stop sign) or because of some unplanned event (e.g., traffic light maintenance, power failure at a traffic signal). IVSAWS technologies could be applied to inform drivers of changes in traffic control devices before they arrive at the area where driving decisions based on the changed traffic control device would be required.

3 .11 Railroad Grade Crossings

Railroad grade crossings can be hazardous. Drivers often have difficulty judging the speed of the oncoming train, or may be unaware of the existence of the crossing. This is particularly true at night, in rural areas, at crossings without lights or gates. IVSAWS could be applied to remedy this hazard by mounting IVSAWS equipment on the engine, itself, signalling ahead to vehicles approaching the nearby crossing.

3.12 Signalling Emergency Vehicle Presence

IVSAWS could be applied to increase drivers' awareness of approaching emergency vehicles. While these vehicles are already equipped with auditory and visual signals (i.e., sirens and lights), IVSAWS technologies could be applied to increase drivers' awareness of the approach of such vehicles. These technologies might be best used in high density areas where there are many distractions obscuring the emergency vehicles' lights or sirens.

4.0 Hierarchy Development for IVSAWS Application Situations

The IVSAWS applications described in the previous section were ranked using a two-phase scheme. First, crash data were analyzed to determine the number and relative injury severity of crashes that occur involving each scenario. Because crash data were unavailable for six of the scenarios, this step was supplemented by a prioritization based on issues of practicality and perceived benefits that may be derived from each IVSAWS application situation.

3.1 *Crash data analysis*

Three crash-data sets were used to estimate frequencies of crash types that may be affected by the NSAWS application scenarios. These data sets were the 1989 crash files from Michigan and Washington state, and the 1988 General Estimates System (GES) data produced by the National Highway Traffic Safety Administration, National Center for Statistics and Analysis. The Michigan and Washington state data sets are census files of police-reported crashes in the respective states. The reporting threshold for Michigan is property damage of at least $200. For Washington, the reporting threshold is $300. GES is a probability-based sample of crashes from the U.S. intended to be representative of all crashes nationwide.

The objective of the crash-data analyses was to generate accident and injury frequencies of accident types that are represented in the 12 IVSAWS applications described in the previous section. Data necessary to isolate many of these crash scenarios are not currently available. Much of the information required for this objective concerns the precrash situation, nut the focus of most crash-data files has been on the crash itself and its outcome. Data collection in the past has focussed on crashworthiness, not crash avoidance. Consequently, it is not possible to estimate even broad crash frequencies for some crash types. Excluded crash types include "mini-zones," temporary detour routes, traffic backups, crashes which may be related to changes in traffic control devices, and for the most part, crashes related to previous crashes. For the others, it has been possible to isolate crash scenarios which are either a subset or super-set of the crash scenarios described earlier. These analyses are described in the following sections.

4.1.1 Accident involved or disabled vehicles

For this scenario, the analysis subset consisted of crashes in which a vehicle was stopped or disabled which were not intersection- or driveway-related. The purpose of the latter constraint was to eliminate crashes where a vehicle was stopped for a traffic light or stop sign. This subset identifies crashes involving vehicles stopped on the roadway where they would normally be expected to be moving.

In Michigan, there were 26,776 such crashes (6.4% of the 417,252 crashes in 1989). This subset had a lower proportion of fatal, A-level (serious), and B-level (moderate) injuries, and a higher proportion of C-level (minor) injuries than the crash data overall. Overall in Michigan, 13.9% of crashes involve C-level injuries as the worst injury in the crash. For this subset, 23.4% involved C-level injury as the worst injury. This crash scenario was overinvolved on limited-access, U.S., and State-numbered routes compared to all crashes.

Similar analyses were conducted for Washington state data. Although the specific code values used to generate the subset differed from those used for Michigan, roughly the same crash subset was isolated. For Washington, subset crashes consisted of those where one vehicle was stopped on the roadway and was struck by another traveling in the same direction. Intersection- and driveway-related crashes were again excluded. In Washington, there were 6,335 such crashes in 1989, 4.9% of the 128,000 total crashes. As in Michigan, C-level injuries were overrepresented and more serious injuries were underrepresented.

4.1.2 School-bus Involved

Michigan includes a data code for school-bus involved or influenced crashes. In 1989, there were 2,182 such crashes, 0.5% of the total. The school-bus itself was physically involved in 1,606 of the crashes. In 54 crashes, a person boarding or exiting the bus was injured by another vehicle. The remaining 522 did not physically involve the bus, but the bus was reported to have influenced the crash by its stop. The profile of crash severity for school-bus crashes was vary similar to that of all crashes. Interestingly, school-bus crashes were more likely to have occurred at an intersection than crashes overall. Over 60% (1,318) occurred at an intersection or driveway, compared to 53.3% for crashes overall.

School-bus involvement is also coded in the 1988 GES data. GES is designed to yield national estimates for different crash types, but 1988 was the first year of GES availability, and frequency estimates should be used with caution. For example, the GES estimate for the total number of fatal crashes in 1988 is 30,922. The census number from the Fatal Accident Reporting System (FARS) is 42,119. While the FARS figure is within the 95% confidence interval for the GES estimate, these differences illustrate the fact that there is a good deal of variance associated with GES estimates. The proportion of crashes involving school buses in the GES data is 0.58%, virtually the same as in Michigan. Crash severities are again similar to those in crashes overall.

4.1.3 Highway Construction Zones

The coding for highway construction zones in the Michigan data are widely considered to be unreliable, even within the Michigan Department of Transportation. Review of hard copies of police crash reports has shown that in many cases the construction zone was inactive or even nonexistent. With that caveat, there were 6,755 crashes (1.6% of the total) coded as occurring in construction zones. These crashes closely matched the severity profile of crashes overall. Daylight crashes, when a construction zone is typically active, were overrepresented compared to crashes overall (74.5% versus 61.4%).

4.1.4 Multiple (compounding) hazardous conditions

This is a particularly difficult set of crash scenarios to isolate in computerized crash data. In most cases, identifying such a crash requires detailed information about a sequence of events and/or the relationship between roadway features. The combination of hazards and their sequence are critical for meaningful analysis, but such information is not generally available in current crash data that focus more o crash worthiness rather than crash avoidance. Nevertheless, it is possible to isolate some broad categories of crashes that might fit this IVSAWS application. The first discussed is snowy or icy roads in combination with curves and/or grades (horizontal and vertical curves).

In Washington state there were 12,475 crashes (9.7% of the total) on snowy/icy roads in 1989. Crashes on curves were overrepresented, and the combination of a grade and curve was the worst, having twice the proportion of snowy/icy crashes than crashes overall. Specifically, 15.2% (1,900) of the snowy/icy crashes occurred on mad segments with both curves and grades, while only 7.5% of all crashes in Washington state were on such road segments. The proportion of property-damage crashes for this crash scenario was higher than the proportion for crashes overall (64.0% versus 55.7%).

Another application of IVSAWS technology fitting this general scenario is to provide warnings at bridges when roads are snowy or icy. In Washington, 410 such crashes occurred (coding for Michigan on this scenario has been inconsistent and thus is not detailed). Although the overall crash risk is low, there could be payoff in identifying specific bridges with particularly hazardous conditions that would warrant an IVSAWS signalling application.

Fog is another weather hazard that can be compounded by road alignment. There were 2,868 crashes (6.8% of the total) occurring in foggy conditions in Michigan in 1989. Serious crashes were somewhat overrepresented among fog crashes. Fog crashes were found to occur more often on a curved portion of the road than crashes overall (7.4% versus 5.2%). IVSAWS application should probably focus on areas with severe recurrent fog problems.

4.1.5 Railroad grade crossings

Although car-train collisions are relatively infrequent events, they are usually more severe than other crashes. There were 279 such crashes in Michigan in 1989 (0.07% of the total). However, 26 (9.3%) resulted in at least one fatality compared to 0.4% for crashes overall. Although the rural-urban distinction is not captured with great precision in Michigan, it appears that rural areas are overrepresented, as are crashes in darkness.

In Washington state in 1989, there were 98 car-train collisions (0.08% of the total). As was the case in Michigan, these crashes tended to be more sever than average (6.1% involving at least one death versus 0.3% for all crashes). The urban-rural coding is better in Washington state data, and again rural areas were overrepresented. Almost 35% of car-train crashes occurred in rural areas compared to 21.4% for crashes overall.

4.1.6 Emergency vehicles

Michigan crash data includes a code for crashes involving emergency vehicles. In 1989, there were 1,679 crashes (0.4% of the total) involving ambulance, fire, or police vehicles. These crashes tended to be more severe than the average crash. The same proportion of crashes resulted in death, but nonfatal-injury crashes were overrepresented (34.8% versus 25%). Almost 75% of crashes involving emergency vehicles were coded as intersection crashes compared to 55.6% for crashes overall. Interestingly, almost 45% of emergency-vehicle-involved crashes were at intersection with both vehicles traveling in the same direction. Only 22.1% of crashes overall had that configuration. Another 34.1% of the emergency-vehicle-involved crashes were same direction, non-intersection.

*4.2 Hierarchy **of** IVSAWS Application Situations*

These analyses show that there is much we do know about crashes that might be prevented by IVSAWS application, but there is still more that remains unknown about these crashes. The following table provides ranks of the 12 IVSAWS situations detailed in this report according to the crash data and a final hierarchical ranking based on the crash data, professional estimates of crash occurrence (based on experience rather than hard data), and an understanding of how IVSAWS technologies might be implemented and used in the field. Following the table is a brief discussion of the rationale for the final IVSAWS application rankings.

Rankings of Possible IVSAWS Applications

IVSAWS Application	Crash Data Rank		Overall Rank
	Crash Freq.	Injury severity	
Signalling emergency vehicle presence	5	2-3	1
Railroad grade crossings	6	1	2
Multiple (compounding) hazardous conditions	3	2-3	2
Highway construction zones	2	5-6	3
Supplemental traffic control device	NA	NA	4
Crash site -- Police Activated	NA	NA	4
School bus or other special vehicle hazard	4	4	5
Temporary detour routes	NA	NA	5
Disabled truck at roadside	NA	NA	6
"Mini-zones" involving roadside work	NA	NA	7
Traffic backups	NA	NA	7
Accident-involved or disabled vehicles	1	5-6	8

IVSAWS applications were ranked based on actual crash exposure and overall utility of the IVSAWS application. The “overall” utility ranking was based on the number and severity of crashes, the number of transmitters that would need to be deployed, and the general applicability and utility of IVSAWS technology for affecting crashes in each scenario. Obviously, this final ranking criterion is subjective. The specific rationale for the ranking of each scenario is provided in the following section.

Rank 1: Signalling emergency vehicle presence. Crash data show this scenario represents a very small proportion of all crashes, but that injury severity from these crashes is greater than for crashes overall. The configurations of the crashes in the data analysis (i.e., predominately same direction-intersection, and same direction-nonintersection) suggests that drivers may not be aware of the presence of these vehicles as they approach, despite the lights and sirens. Thus, an IVSAWS message may provide them with additional information necessary to prevent a crash. The number of vehicles that would require IVSAWS transmitters is limited to the number of emergency vehicles in the population (presumably a manageable number). Full penetration of IVSAWS transmitters and/or receivers is not necessary for benefits of this application to accrue because these systems would provide a supplementary warning to sirens and lights. In addition, benefits of preventing emergency vehicle crashes go beyond the crash incident itself. That is, when an emergency vehicle is involved in a crash, some emergency need is not met in a prompr manner, perhaps resulting in unnecessary property loss or additional personal injury.

Rank 2: Railroad grade crossings. The probability of a car-train crash is quite low; however, the results of such crashes are disproportionately severe. The crash data also show that car-train crashes occur disproportionately at night in rural areas (many of which are probably unguarded crossings). This suggests that a supplemental warning could be effective in preventing these crashes. IVSAWS transmitters would only have to be installed on the lead engine of each train. This should not pose an unreasonably large burden. Messages transmitted from the trains could be totally unambiguous and standardized. There are also probable benefits on the train-side of the crash situation, especially when hazardous cargos are involved (i.e., special hazardous commodity codes could be encrypted onto the transmitted message).

Rank 2: Multiple (compounding) hazardous conditions. Crash data are not available for the majority of situations that fit this scenario, but the data that are available (i.e., fog, slippery conditions and vertical or horizontal curvature) are compelling. It is certain that there are many more crashes that involve multiple hazardous conditions than could be readily identified by the crash data. This is a rich domain for safety-and-traffic engineers who could tailor IVSAWS messages to suit the local problems. The number of sites for transmitter deployment need not be excessively high. In fact, not every potential site should be instrumented. Sites should be selected based on identified needs from crash experience (of course, this would require adequate record keeping). Many of the multiple hazard scenarios are likely to include excessive speed as one of the compounding conditions. An IVSAWS system that relayed a warning only to vehicles traveling over some predetermined “safe” speed seem to constitute a valuable and practical application of IVSAWS deployment.

Rank 3: Highway construction zones. This is a valuable application of IVSAWS because construction zone crashes present a hazard not only to vehicles traveling through the zone, but also to workers in the zone. A significant number of crashes are reported to occur in construction zones, but not so many zones that transmitter deployment should be overly burdensome. Construction zones also present an ideal IVSAWS application opportunity because we know precisely where the site is, we know much about the hazards associated with the site, and the zone is not permanent, thus reducing possible habituation effects. In fact, as the characteristics of the zone change, it should be possible to change the characteristics of applicable warning messages, further reducing habituation.

Rank 4: Supplemental traffic control device. No crash data were available to describe the extent of the hazard these situations cause. However, it is not difficult to think of situations where signals or signs have been changed or disabled for one reason or another that have the potential for creating traffic conflicts. IVSAWS would serve as a supplement to existing signals, and thus it would represent an additional safety message to equipped vehicles. Unequipped vehicles should not be negatively affected by the lack of an IVSAWS warning. The safety value of such a system cannot be determined precisely in the absence of crash data, but the value for crash prevention is probably quite low.

Rank 4: Crash site -- Police activated. There are little to no crash data available to describe the potential for this application to prevent crashes. However, the potential for such a system to inform drivers of an upcoming crash site (and possible lane blockage, debris, etc.) is appealing. Such a system may involve the active deployment by officers in the field to select the message, signal direction and strength, transmitter placement in the roadway, and perhaps other features. If the system was burdensome to the officers, they may not be prone to use the system. Such a system may be combined with the emergency vehicle alert system mentioned previously. If this was feasible, the utility of the total system would be enhanced. If this system required a separate transmitter, it would represent perhaps a doubling of the cost of IVSAWS installation to police agencies.

Rank 5: School-bus or other special vehicle hazard. Crash data showed that school bus crashes are relatively rare events, and it is unclear if additional signalling would be beneficial in preventing the few that do occur. Given the large number of busses that would have to be equipped, it is unclear if the cost (and problem with frequent and redundant signalling) are worth the benefit that may be derived. For other special vehicles such as rural mail carriers (see example in previous section), the utility of a IVSAWS system is less sure.

Rank 5: Temporary detour routes. No crash data are available to determine the threat to safety that is presented by temporary detour routes. In fact, temporary detours are themselves not threatening, but the conditions they create may be. Thus, these threats may be conceived as fitting into more specific IVSAWS applications. On the other hand, IVSAWS applications as markers for a temporary detour could be useful as temporary route-guidance technology. Until there is 100% market penetration, these IVSAWS route markers would have to be used as supplements to traditional detour markers.

Rank 6: Disabled truck at roadside. Specific data on the hazard created by disabled trucks at the roadside are not available. The most significant problem with this application is the large number of vehicles that would have to be equipped with a transmitter. In addition, IVSAWS information would only supplement existing use of flares and reflective triangles. It is unlikely that the benefits derived from the system would approach or exceed the costs of deployment.

Rank 7: "Mini-zones" involving roadside work. Through conversations with several utility companies it was determined that "mini-zones" do not create any special crash hazard. Therefore, IVSAWS application is unwarranted.

Rank 7: Traffic backups. No crash data are available describing the extent to which traffic backups create a significant traffic safety hazard. At best, this application is a subset of the construction zone or police-activated systems. Recurrent traffic backups are not suitable for IVSAWS application because of the potential for habituation effects.

Rank 8: Accident-involved or disabled vehicles. Although a large number of crashes seem to involve vehicles stopped in the roadway for some reason, the crash data are unclear on the reason why these vehicles were stopped. It is likely that many were stopped for reasons other than a crash or the vehicle being disabled. Even if all of these crashes did fit the original scenario, the cost of deploying an IVSAWS transmitter and receiver in every vehicle is likely to exceed the benefits derived from such deployment. This negative conclusion is strengthened when one considers that a higher than expected proportion of crashes involving vehicles stopped in the roadway involve minor injuries and a lower proportion of these crashes involve serious injuries.

4.3 Summary

In sum, it may be most useful to consider the 12 IVSAWS application situations described in this report as fitting into one of three priority categories. The highest priority category includes IVSAWS applications for:

- signalling emergency vehicle presence,
- railroad grade crossings,
- multiple (compounding) hazardous conditions, and
- highway construction zones.

These applications are most likely to provide a significant safety benefit and reasonably fit the IVSAWS application concept. The second tier of IVSAWS applications includes IVSAWS as:

- a supplemental traffic control device,
- police-activated crash site IVSAWS,
- school-bus or other special vehicle hazard signalling, and
- signalling at temporary detour routes.

These applications have only limited and highly speculative crash reduction potential. The lowest priority category includes IVSAWS for:

- disabled trucks at the roadside,
- traffic backups,
- "mini-zones", and
- accident-involved or disabled vehicles.

Each of these applications has even more limited or speculative crash reduction potential than the second priority situations, and the costs associated with equipping all heavy trucks and passenger vehicles are prohibitively high.

5.0 Signalling Recommendations

Replication of Manual of Uniform Traffic Control Devices (MUTCD) roadside signing is not a feasible signalling strategy for most of the IVSAWS applications identified in this report. There are only two cases in which existing MUTCD road signs might be reproduced directly in the vehicle (i.e., railroad grade crossings and supplemental traffic control devices). The use of icons similar to those used in MUTCD signs is clearly one strategy for IVSAWS signalling, and new icons could be developed to identify IVSAWS situations for which MUTCD icons do not currently exist. However, drivers would have to become acquainted with these new icons for them to be effective. It is probable that many drivers would not take the time necessary to become fully acquainted with the new icons prior to the time they may encounter them on the road. It is also probable that the drivers who could use the hazard information most (i.e., risky drivers) would be the least likely to learn icon meanings prior to driving. In this case, these drivers would only learn the new icon meanings while driving and encountering the hazardous situations, severely diminishing the value of the icons during the “learning trials.” In addition, IVSAWS situations should be relatively infrequent events, thus drivers would have few occasions to become acquainted with the new icons and their meaning. The IVSAWS message system should also be sufficiently flexible that it could be incorporated into developing driver information systems. These broader driver information systems will probably utilize information systems more sophisticated than icon replication, and the IVSAWS system should be developed with these upcoming technologies in mind. For these reasons, we do not recommend MUTCD replication or the development of similar icons for the IVSAWS situations identified earlier.

Signalling of IVSAWS situations should be based on thorough human factors research on both auditory and visual information transmission systems. It is recommended that in addition to somehow describing the hazardous situation ahead, signals should provide specific information on the behaviors drivers should employ or be prepared to employ to avoid a crash, rather than simply informing drivers of an upcoming hazard. This is still another reason why simple icon use is not a recommended strategy for IVSAWS signalling.

While messages could be conveyed via auditory systems only (e.g., voice synthesis), there may be a benefit to using an auditory signal to alert drivers of an upcoming IVSAWS message that would be transmitted visually. A visual message could remain available for the driver to attend to in his/her own time, and remain available for repeated reference. On the other hand, auditory transmission of IVSAWS warnings would be less visually distracting, permitting drivers to keep their eye on the road. An auditory system could also be developed which would be able to repeat messages upon driver request. The pros and cons of visual versus auditory systems or their combination are speculative at this point and the selection of the signalling system must be based on rigorous human factors and behavioral testing.

APPENDIX D:
DRIVER ALERT DISTANCE ANALYSIS SCENARIO SELECTION

This appendix presents the selection of the four most significant signaling and hazardous roadway situations from the scenarios identified as part of the IVSAWS task B effort.

1. Abstract. The purpose of this ENB entry is to present the selection of the four most significant signalling and hazardous roadway situations from the twelve scenarios identified during Task B (see ENB B-3-1). The four scenarios which are identified are to be used in subsequent determination of the required Driver Alert Distance Analysis. The selection is based upon inputs from Dr. Fred Streff (UMTRI), Dr. Bob Ervin (UMTRI), and Anthony Yonik (General Motors Research Environmental Activities - Safety).

2. Scenarios. The twelve candidate scenarios as identified in the Task B Preliminary Report are listed in Table 1. Streff, Ervin, and Yonik have ranked the scenarios based upon relative crash frequency, relative injury severity, and an empirical estimate of the applicability of IVSAWS technologies towards crash reduction. The crash frequency and injury severity were derived from three databases: 1) the 1989 accident files from the state of Michigan, 2) the 1989 accident files from the state of Washington, and 3) the 1988 General Estimates System (GES) file produced by the National Center for Statistics and Analysis (NCSA) of the National Highway Traffic Safety Administration(NHTSA).

Table 1. Streff. Ervin and Yonik Scenario Rankings.

IVSAWS Application	Streff Rank	Ervin Rank	Yonik Rank	Σ Ranks	Overall Rank
Accident involved or disabled vehicles	8.5	10	1	19.5	7
Crash sites - police activated transmitter	8.5	6	1	15.5	4
Disabled truck at roadside	8.5	8	10	26.5	12
School bus, farm vehicle, or other special hazard vehicle	2.5	7	7	16.5	5
Highway construction zones	5	3	2	10	3
Traffic backups	5	9	7	21	8
"Mini-zones" involving roadside work	9.5	9	7	25.5	11
Temporary detour routes	9.5	7	7	23.5	10
Permanent hazardous roadway locations	9.5	2	10	21.5	9
Supplemental traffic control device	5	6	7	18	6
Railroad grade crossings	1	2	3	6	1
Signalling emergency vehicle presence	2.5	1	4	6.5	2

3. Results. Based upon the overall rankings from Table 1, the following four scenarios have been identified as situations to be used to determine IVSAWS Driver Alert Distances:

- Railroad grade crossings
- Signalling emergency vehicle presence
- Highway construction zones
- Crash sites - police activated transmitter

In addition, due to its relative high rank and the significant volume of farm vehicle traffic on the rural highway system (IVSAWS' principle client), signalling the presence of school buses and farm vehicles has been incorporated into the list of situations to be analyzed. Technically, this situation is very similar to the emergency vehicle problem and therefore does not represent a increase in scope. The refined list is presented below:

- Railroad grade crossings
- Signalling emergency vehicle/farm vehicle/special vehicle presence
- Highway construction zones
- Crash sites - police activated transmitter

APPENDIX E:
DRIVER ALERT DISTANCE ANALYSIS

This appendix presents the analysis/results of the IVSAWS Driver Alert Distance (DAD) evaluation and preliminary results for the time required to perform a corrective-action lane change.

1. Abstract. The purpose of this ENB entry, C-2-1, is to present the analysis and results for IVSAWS Task C, Subtask 2, Driver Alert Distance (DAD) Analysis. The SHAWS report [1] shows that the distance required to alert a driver to a hazard via an IVSAWS warning(the Driver-Alert Distance) exceeds the Decision Sight Distance (DSD) (see Figure 1). The report also tabulates preliminary results for the time required to perform a corrective-action lane change. The DSD is defined as the distance travelled during the period of time required for a driver to detect and recognize a hazard (from the time the hazard first enters the driver's field of vision), decide upon a hazard avoidance response, initiate the response, and perform the maneuver. A worst-case IVSAWS Driver Alert Distance was evaluated in ENB C-l- 1, Communication Geometry Analysis. Since the release of the C-l- 1 ENB, scenarios have been identified (ENB C-2-2) which are "most significant" with respect to the IVSAWS applique. Given this new information, Driver Alert Distances will be re-examined using the scenario data and by verifying or correcting assumptions made in the SHAWS report with respect to driver hazard identification and response times, AWTs, and hazard avoidance maneuver times.

2. Assumptions. Engineering notebook C-l-l derived a Driver Alert Distance based upon a hypothetical scenario involving an emergency vehicle equipped with an IVSAWS transmitter approaching a IVSAWS-receiver-equipped vehicle head on. This scenario is worst-case with respect to DAD and the required communication range of the transmitter. Under these conditions the required communication range was determined to be 2.7 kilometers. Since the release of ENB C-l-l, the hazardous situation analysis task of the IVSAWS study (Task B) has been completed and the Driver Alert Distance needs to be re-evaluated for the following reasons:

a) Task B shows that less than 0.2% of all traffic accidents involve an emergency vehicle approaching another vehicle head-on. Due to the statistical insignificance, designing a system that will provide coverage for this scenario while both vehicles are travelling at 99th percentile speed will result in an over-designed system since it nearly doubles the required IVSAWS communication range (at significant increased cost) with respect to providing coverage for all other roadway hazards .

b) More data relevant to Decision Sight Distance has been collected since the release of ENB C-l-l.

In re-evaluating the DSD, the following assumptions have been made:

a) Scenario - The hazard situation will involve a receiver-equipped commercial truck or car approaching a stationary transmitter. Margin will be added to the calculated DSD in order to compensate for scenarios involving mobile transmitters approaching at modest speeds.

STEP	TIME	VEHICLE ACTIONS	DRIVER ACTIONS	IVSAWS RECEIVER	HUMAN FACTORS
1	t0	Vehicle approaches hazard	Driver uses normal driving skills	No Action - signal not yet detected	
2	t0			Signal is detected, analyzed and warning selected	DETECTION AVOIDANCE DISTANCE TIME
3	t1			Warning is generated by visual and/or aural synthesizers	
4	t2		Driver detects warning signal		WARNING EFFECTIVENESS PERIOD
5	t3		Driver understands warning		
6	t4		Driver decides warning action		
7	t5		Driver begins warning response		
8	t6	Vehicle is in line-of-sight of hazard			DECISION SIGHT DISTANCE TIME
9	t7		Driver detects hazard		
10	t8		Driver recognizes hazard		
11	t9		Driver decides on hazard avoidance response		
12	t10		Driver begins hazard avoidance response		
13	t11	Vehicle avoids hazard	Driver continues normal driving		

Figure 1. Detection-avoidance distance (DAD) timeline.

b) Vehicle speeds - DSD will be evaluated for vehicle speeds of 40,50,60,70 and 80 miles per hour. Eighty miles per hour is the 98th percentile speed for interstate and rural arterial highways based upon measurements made by Olsen, et al. [2]

c) Hazard avoidance maneuvers - DSD will be evaluated for the following hazard avoidance maneuvers: Complete stop prior to reaching hazard, lane change and increased driver attention.

2. Identification and evaluation of general DSD time parameters. The DSD time can be sub divided into two intervals, 1) the perception-response time and 2) the hazard avoidance maneuver time. Paragraphs 2.1 and 2.2 evaluate these parameters for the hazard avoidance maneuvers under consideration.

2.1 Evaluation of perception-response time. Current literature based upon experimentation with subjects performing hazard avoidance maneuvers in response to simulated roadway hazards specify the perception-response time to be 1.6 seconds.[3],[4] However,much literature exists on the topic of perception-response times and estimates of a design value range from 0.9 second to 4 seconds, depending on road geometry and author opinion. The American Association of State Highway and Transportation Officials (AASHTO) recommends a design value of 2.5 second[5]. Since it is not the purpose of the IVSAWS study to be an exhaustive study of driver perception and reaction, the 2.5 second value has been selected as a baseline for the evaluation of DSD and DAD.

2.2 Evaluation of hazard avoidance maneuver time. Hazard avoidance distances for the three maneuvers outlined above are listed in Table 1 for vehicle speeds of 40,50,60,70 and 80 miles per hour. Increased driver attention requires no vehicle maneuver and is assumed to be instantaneous upon driver perception of the hazard. The braking maneuver is assumed to be a controlled stop on worn tires (2/32 inch tread), over a wet paved surface, and does not involve wheel lock up.

TABLE 1. HAZARD AVOIDANCE MANEUVER DISTANCES

	Maneuver Distance (feet)			
			Full Stop [7]	
Vehicle Speed (mph)	Increased Attention	Lane Change[6]	Car	Heavy truck
40	0	260	220	380
50	0	300	380	650
60	0	340	620	990
70	0	380	940	1410
80	0	420	1370	1890

2.3 DSD Summary. In order to estimate DSD, the perception-response distances corresponding to the 2.5 second perception-response time need to be added to the Table 1 values. The results are listed in Table 2.

TABLE 2. DECISION SIGHT DISTANCES

Vehicle Speed (mph)	Perception-Response Distance (feet)	Decision Sight Distance (feet)			
		Increased Attention	Lane Change	Full Stop Car	Full Stop Heavy truck
40	150	150	410	370	530
50	180	180	480	560	825
60	220	220	560	840	1210
70	260	260	640	1200	1670
80	290	290	710	1560	2180

3. Warning: Effectiveness Period (WEP) and message repeat rate. In order for an IVSAWS warning to be effective the driver should understand the warning and be attentive to the impending hazard prior to the DSD. However, the driver should not be alerted so early that he or she disregards or forgets the warning before the hazard presents itself. Thus, the WEP is the period of time during which a driver can initiate a warning response (e.g., increased attention, removal of foot from accelerator) that will increase the probability of a successful hazard avoidance maneuver. If it is assumed that the WEP for in-vehicle and roadway electronic warnings are similar, the duration of the amber phase of traffic signals might be usable as a baseline for IVSAWS warning effectiveness. Olsen and Rothery[8] show that an amber period of 6 seconds is appropriate to warn drivers of an impending red light for vehicles travelling less than 50 miles per hour. Extending their analysis to vehicle speeds of 80 miles per hour yields an amber duration of slightly over 6 seconds. It should be noted that the analogy between amber phase duration and IVSAWS WEP may not be entirely appropriate. Firstly, the amber period includes time for a hazard avoidance maneuver (full stop prior to intersection); hazard avoidance is not part of the IVSAWS WEP. Secondly, extending the amber phase beyond 6 seconds may not result in an ineffective warning although it is a popular hypothesis that drivers treat an extension of the amber beyond what is normally needed as an extension of the green. Thus, the IVSAWS WEP may be shorter or longer in duration. However, a 6 second IVSAWS WEP seems like a reasonable initial estimate to be verified or corrected during the subject testing phase of the study when considering the sparse nature of literature about warning effectiveness periods for electronically generated in-vehicle warnings.. Given this estimate, the IVSAWS roadway transmitter units must repeat their broadcasts at least once every six seconds to ensure that drivers respond to IVSAWS warnings in a timely manner.

4. Detection Avoidance Distance (DAD) and IVSAWS communication range. The detection avoidance distance is composed of 1) the DSD, 2) the distance travelled during the WEP, and 3) the distance travelled by the vehicle from the point of message reception by the in-vehicle IVSAWS receiver up to driver comprehension of the warning. The latter two DAD intervals may or may not be mutually exclusive, depending upon the point of message reception relative to the location of the roadway hazard. Worst case, the hazard warning will be received, processed, and presented to the driver such that a warning response is inititated at the very beginning of the WEP. This requires that distance be built into the DAD to cover message processing by the in-vehicle receiver, warning generation, and driver detection and recognition of the warning (steps t0 though t4, Figure 1). Message processing will be nearly instantaneous. Message generation could take several seconds if speech synthesis is used. A two sentence English message could consume 5 seconds. Driver detection and perception of the hazard message is assumed (again, due to lack of relevant literature) to be equal to the 2.5 second hazard perception-response time described in paragraph 2.5. Table 3 lists the resulting DAD as a function of vehicle speed.

TABLE 3. DETECTION AVOIDANCE DISTANCES

				Detection Avoidance Distance (feet)			
Vehicle speed (mph)	WEP distance (feet)	Message generation distance (feet)	Warning perception-response distance (feet)	Increased Attention	Lane Change	Full Stop Car	Full Stop Heavy truck
40	350	290	150	940	1200	1160	1320
50	440	370	180	1170	1470	1550	1815
60	530	440	220	1410	1750	2030	2400
70	620	520	260	1660	2040	2600	3070
80	710	590	290	1880	2300	3150	3770

The corresponding required IVSAWS communication range is 3770 feet (1150 meters) when vehicle and hazard are separated by a straight, flat road. As road curvature increases, the required communication range will decrease due to geometry.

5. IVSAWS communication range versus scenario link losses. The IVSAWS system design under consideration has a link budget of 136 dB. The link loss corresponding to a receiver-transmitter separation of 3770 feet over a straight, flat road has been estimated to be 107 dB at 425 MHz (see ENB C-4-2). Thus, the design under consideration has a link margin of 29 dB in near worst-case conditions (98th percentile speed, wet road, heavy vehicle, etc.) for the straight road scenario. Figures 2 through 5 show the system link margin as a function of vehicle speed for the three hazard avoidance manuevers considered herein and the four communication scenarios

identified during Task C, Subtask 1. Positive link margins are maintained in all cases except when dropouts occur due to mountain peaks intersecting the line-of-sight between the roadway transmitter and vehicle (Scenario D), and when the required DAD requires the signal to propagate through more than 2000 feet of trees. With the specified design, transmitter-vehicle communication paths within the DAD with negative link margins will occur less than 1 percent of the time.

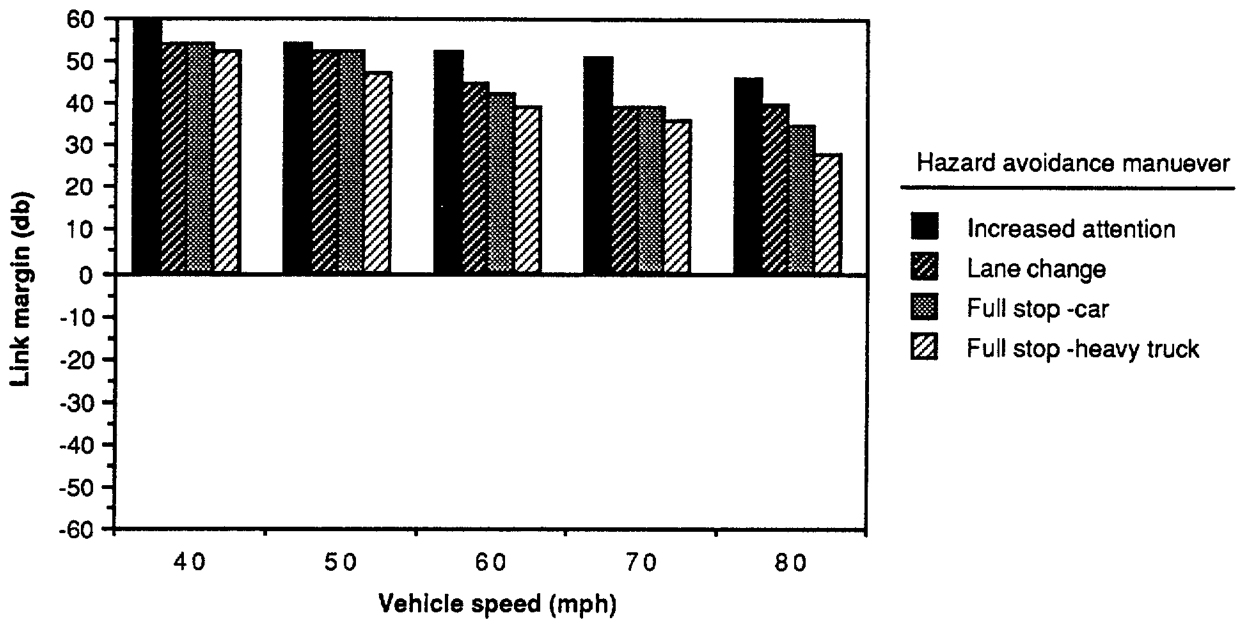


Figure 2. Scenario A link margins versus vehicle speed and hazard avoidance manuever.

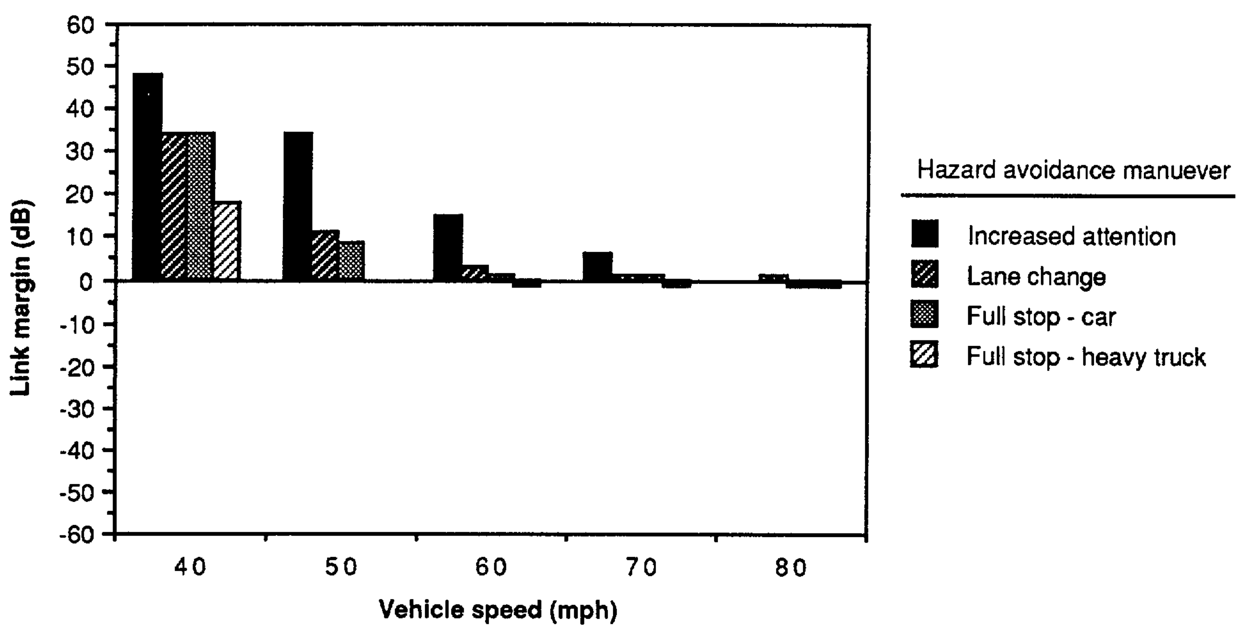


Figure 3. Scenario B link margins versus vehicle speed and hazard avoidance manuever.

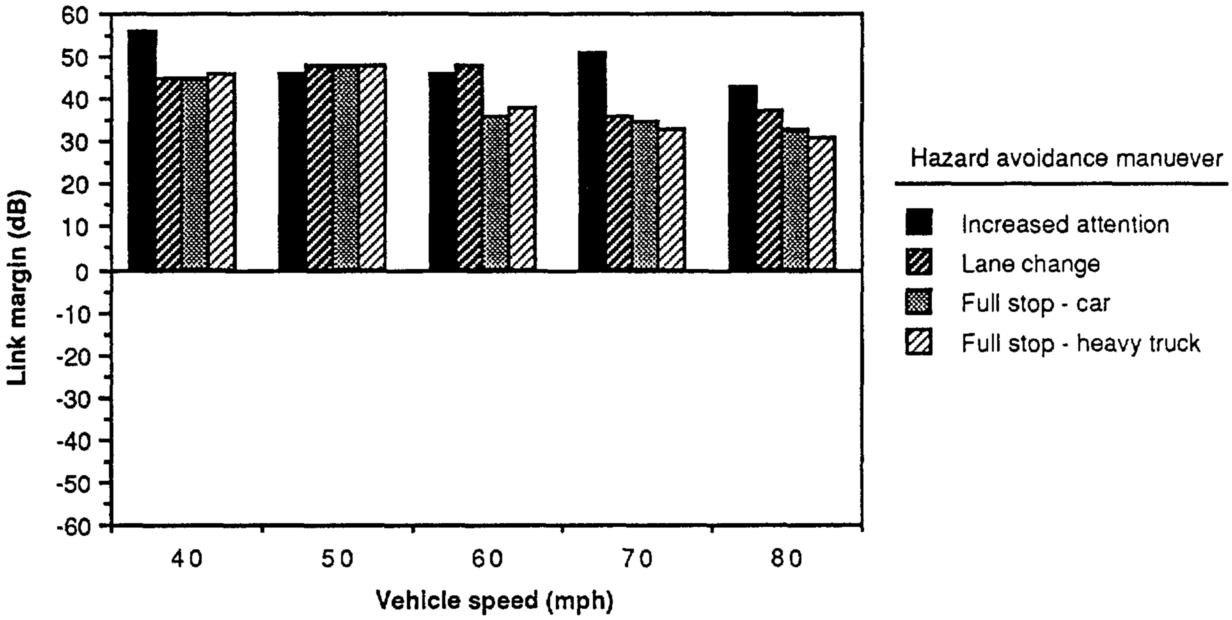


Figure 4. Scenario C link margins versus vehicle speed and hazard avoidance manuever.

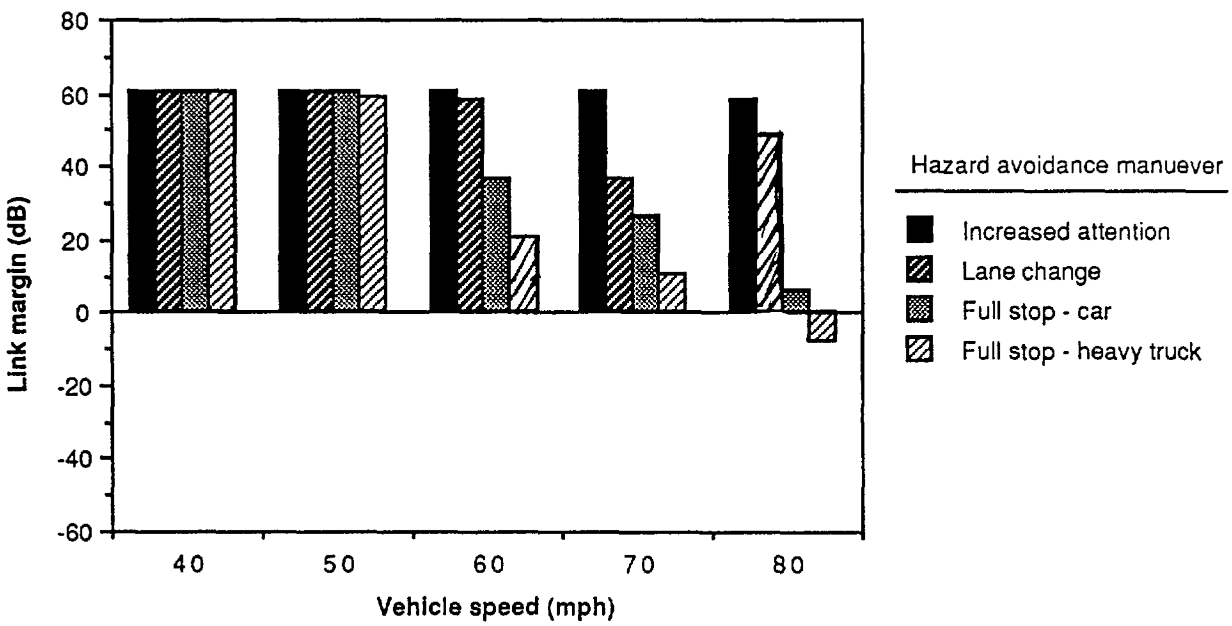


Figure 5. Scenario D link margins versus vehicle speed and hazard avoidance manuever.

6. References.

[1] Federal Highway Administration, "Feasibility and Concept Selection of a Safety Hazard Advance Warning System (SHAWS) - Volume II - Technical Report," Washington, D.C., Report No. FHWA/RD-81/124, April 1982, pp. 3-8,9.

[2] Transportation Research Board, "Parameters Affecting Stopping Sight Distance," Washington, DC., Report No. PB86-186905, June 1984, pp. 24-27, 125.

[3] Wilson, F.R., Sinclair, J.A., and Bisson, B.G., "Evaluation of Driver/Vehicle Accident Reactions", Review draft report, 1984, pp. 1,27.

[4] Olson, P.L. and Sivak, M., "Perception-Response Time to Unexpected Roadway Hazards", Human Factors, 1986, vol. 28(l), pp. 91-96.

[5] Transportation Research Board, p. 28.

[6] Federal Highway Administration, p. 3-9.

[7] Transportation Research Board, p. 22.

[8] Olson, P.L. and Rothery, R., "Driver Response to Amber Phase of Traffic Signals," Highway Research Board, Bulletin 330, Washington, D.C., 1962, p. 48.

APPENDIX F: COMMUNICATION PATH GEOMETRY ANALYSIS

This appendix presents the analysis and results for IVSAWS task C, subtask 1, Communication Path Geometry Analysis. The geometry of four IVSAWS-related communication paths are identified with link parameters summarized for computer simulation and estimation of total path loss.

1. Abstract.The purpose of this ENB entry is to present the analysis and results for IVSAWS Task C, Subtask 1, Communication Path Geometry Analysis. As described in the IVSAWS workplan, the geometry of communication paths for four significant signing and hazardous roadway situations be identified, including as applicable, those situations identified in Task B, Subtask 3, CARDfile Data Analysis. In this context, "significant" means those situations with geometries which will make communication most difficult, such as through dense foliage or over a large obstacle. As applicable, geometry will be analyzed for transmitters placed on fixed-permanent, mobile and temporarily-deployed platforms.

2. The primary input to this subtask is the Task B Preliminary Report prepared by theInputs. University of Michigan Transportation Research Institute under subcontract to Hughes as part the IVSAWS contract. The report identifies twelve traffic scenarios which have proved to be hazardous and have remained hazardous despite application of traditional crash reduction treatments. For each scenario, a case study is provided. Other documents used as references for this subtask are listed in Paragraph 7 of this ENB. Information from the literature will be supplemented with empirical data, primarily those parameters not identified in the texts which affect communication path geometries.

3. Processing. Firstly, those key parameters which shape communication paths will be identified and their relevance to IVSAWS communication paths will be analyzed. Secondly, candidate IVSAWS-applicable situations will be identified and analyzed in order to bound the parameters. The situations will be selected such that the identified parameters will be set to a value or condition which will stress the communication link. Where possible, the case study geometries identified in the Task B report will be utilized. However, if it appears that none of case studies provided will adequately bound a particular parameter a hypothetical situation will be substituted.

4. Outputs. The bounded parameters and hypothetical situations will be incorporated into the development of a set of four road geometries with corresponding terrain information. The road geometries and surrounding terrain will be selected such that each key parameter will be set to its "worst case" condition (relative to the IVSAWS application) in one or more of the geometries. The goal is to identify a set of highway/terrain architectures which will stress the communication link between the transmitter and in-vehicle receiver such that upper bounds on the required transmitter power, receiver processing gain, etc. can be evaluated. For each geometry, a real-world example of a highway/terrain geometry which approximates the hypothetical case will be identified. The approximations and bounded parameters will serve as inputs to the computer modelling effort (Task C, Subtask 6) which will estimate total propagation loss and probability of communication statistics.

5. Analysis.

5.1 Communication Path Loss Models.

5.1.1 Free-space Path Loss Model. With respect to the IVSAWS communication link, the communication path geometry will affect the path loss between the transmitter and receiver. Path loss is part of the range equation which relates received power (P_r) to transmitted power (P_t) as[1]

$$P_r = P_t G_r G_t \lambda^2/(4\pi R)^2 \qquad (1)$$

where R is the transmission range, λ is the free-space wavelength, and G_r and G_t are the receiver and transmitter gains (losses), respectively, including antenna gains and coupling losses. This equation can be converted to the form[2]

$$P_r = P_{amp} L_t L_a L_f g_t g_r \qquad (2)$$

where P_{amp} is the carrier power at the amplifier output, L_t is the antenna coupling loss at the transmitter, L_a is channel loss due to atmosphere (e.g. absorption, rainfall), L_f is the free space propagation loss, and g_t and g_r are the transmitter and receiver antenna gains, respectively. L_f can be evaluated using the equation[3]

$$L_f(\mathrm{dB}) = 32.5 + 20 \log_{10}(f) + 20 \log_{10}(R) \qquad (3)$$

where f is the frequency in megahertz and R is the range in kilometers. Equation (3) is based upon the free space propagation model which assumes a straight-line communication path between the transmitter and receiver in vacuum. This model is inappropriate for use when simulating the rural mobile-communication environment since the ground, trees and other obstacles will modify or attenuate the communication path.

5.1.2 Free-space Okumura Model. In addition to the free-space model, Sklar, et al[4] have researched four other communication path-loss models, two of which, the Free-space Okumura and Longley-Rice, are applicable to the IVSAWS study. Okumura carried out propagation tests in the VHF and UHF frequency bands for a wide variety of natural terrain and environmental clutter. The experimental data led to a set of charts for predicting propagation loss above free-space loss (L_o). The charts were curve-fit in order to develop an empirical expression for Lo:

$$Lo(dB) = 37.10 + 6.16 \log10(f) - 13.82 \log10(HR) - a(HT) + (24.9 - 6.55 \log10 HR)\log10(R) \quad (4)$$

The equation identifies two additional parameters which are affect the communication path geometry, HT and HR, the height of the transmit and receive antennas above ground level.

5.1.3 Longley-Rice Model. The Longley-Rice model was designed to predict mean values of path attenuation relative to the free-space loss. It is particularly useful in predicting link propagation losses over long-range irregular terrain for which for knife-edge diffraction losses are significant. The irregular contours and diffractions are characteristic of hilly and mountainous environments in which the IVSAWS will have to operate. In addition to the parameters previously identified in 5.1.1 and 5.1.2, inputs to the model include terrain descriptions (contour and foliage).

5.2 Parameter Identification. The following is a list of parameters which affect point-to-point (transmitter output to receiver input) communication connectivity:

- Carrier power at the amplifier output
- Antenna coupling loss at the transmitter
- Carrier frequency
- Transmission range
- Channel loss due to atmospheric effects
- Transmitter and receiver antenna gains
- Transmitter and receiver antenna heights above ground level
- Surface reflectivity
- Contour
- Foliage

Surface reflectivity, not mentioned in the models described above, has a major impact on connectivity and has been added to the list. Not all of the above parameters are a function of communication path geometry. Carrier power, antenna coupling loss, and carrier frequency are independent of link geometries and will not be examined in the subsequent parameter analysis.

5.3 Parameter analysis.

5.3.1 Transmission Range. Empirically, the required transmission range will be maximum when the closing rate between the hazard transmitter and in-vehicle receiver is greatest. Such a scenario would involve a transmitter-equipped vehicle and receiver-equipped vehicle travelling in opposite directions on a highway which supports high-speed transportation. A worst-case example could involve a police vehicle travelling at about 200 kph (120 mph), in pursuit of a threat in front of it, and approaching a large vehicle (e.g. commercial long-haul truck) with a long stopping distance which itself is travelling at high velocity, for example 130 kph (80 mph) on a slick highway. The closing rate between the transmitter and receiver would be 330 kph (200 mph). In this context, a successful hazard avoidance maneuver would result in the truck moving to the side of the road and stopping before the threat reaches it. Here, it is assumed the threat is 400 meters in front of the police vehicle. It is also assumed that the IVSAWS transmitters will be repeating the "get the heck out of the way" message at least once a second. The SHAWS report[5] shows that the hazard avoidance maneuver is a multi-step process. This process is illustrated in Figure 1 and described below:

a) The transmitter must send the message to the receiver. Here, it could take up to a second if the truck was out of communication range just prior to the last transmission.

b) The receiver must generate a warning message for the truck driver. Worst case, the warning would be an audible message of the form, "Emergency vehicle approaching. Please pull the side of the road and stop". A message of this type could take 5 seconds to synthesize.

c) The driver must recognize the warning. The SHAWS report indicates recognition could take up to 2 seconds.

d) The driver must decide upon a warning action and initiate a hazard avoidance maneuver. The time required to perform this step is difficult to bound and is largely dependent upon the driver's interpretation of the urgency attached to the hazard warning. The driver may initiate the maneuver without any external confirmation of the hazard. However, the driver may seek visual or aural confirmation of the hazard before slowing. If so, and if due to an obstacle or turn in the road confirmation arrives at a truck-to-threat separation which is less than the Decision Sight Distance required to avoid the hazard, the maneuver will be unsuccessful.[1] Presupposing that the driver initiates a successful response based upon the IVSAWS warning (whether or not the threat is visually detectable) upper bound estimates of the decision-initiation time are between 7 and 8 seconds.

1 The Decision Sight Distance is the distance required in order to perform a hazard avoidance maneuver when visual notification is the only means of threat detection.

STEP	TIME	VEHICLE ACTIONS	DRIVER ACTIONS	IVSAWS RECEIVER	HUMAN FACTORS
1	t0	Vehicle approaches hazard	Driver uses normal driving skills	No Action - signal not yet detected	WARNING EFFECTIVENESS PERIOD
2	t0			Signal is detected, analyzed and warning selected	
3	t1			Warning is generated by visual and/or aural synthesizers	
4	t2		Driver detects warning signal		ADVANCED WARNING TIME
5	t3		Driver recognizes warning		
6	t4		Driver decides warning action		
7	t5		Driver begins warning response		
8	t6	Vehicle is in line-of-sight of hazard			DECISION SIGHT DISTANCE TIME
9	t7		Driver detects hazard		
10	t8		Driver recognizes hazard		
11	t9		Driver decides on hazard avoidance response		
12	t10		Driver begins hazard avoidance response		
13	t11	Vehicle avoids hazard	Driver continues normal driving		

Scenario: Driver is driving, using normal driving skills, and is unknowingly approaching a hazard. The hazard may be unseen and, even assuming ideal driving conditions, is situated such that there is insufficient decision-sight distance to avoid emergency maneuvers and/or accident.

Figure 1. Generalized Hazard Avoidance Time Line Using IVSAWS[6].

e) The maneuver must complete. Similar to step (d), the time (distance) to complete the maneuver is dependent upon driver judgement. Given advance warning, the driver should not initiate a panic maneuver. That is, the stopping distance will greater than the minimum. On a slick highway the driver might apply especially light brake pedal pressure in order to avoid a potential skid. For this report the stopping distance has been assigned an upper bound of 800 meters. This estimate will be changed if reports ordered relevant to heavy truck braking performance warrant such a modification. The former analysis and Equation 5, below, yield an upper bound transmission range (R) of 2.7 kilometers (1.7 miles).

R=	1 second	[step (a)]	(5)
	5 seconds	[step (b)]	
	2 seconds	[step (c)]	
+	8 seconds	[step (d)]	
	16 seconds x 92 meters/sec closing rate = 1500 meters		
		800 meters [step (e)]	
		+ 400 meters [threat-transmitter separation]	
		2700 meters	

The transmission range is largely a linear function of the transmitter-receiver closing rate. Thus, the required transmission range for permanent fixed-site and temporarily-deployed transmitters will be considerably less since the velocity of these platforms is zero. Using assumptions similar to those above, the required ranges for fixed and temporary transmitters are both 1.4 kilometers (0.9 mile).

5.3.2 Channel Loss Due to Atmospheric Effects. With respect to the IVSAWS application, atmospheric effects are negligible. The frequency band utilized by the IVSAWS will be under 2.5 GHz. Atmospheric effects are insignificant at frequencies below 3 GHz. For example, at 3 GHz rain falling at a rate of 100 millimeters per hour (4 inches per hour) will cause 0.04 dB/km excess path attenuation. Thus, channel losses due to atmospheric effects will be ignored.

5.3.3 Transmitter and receiver antenna gains. The communication path geometry will affect the transmitter and receiver antenna gains achieved. Communication will be most difficult if the receiving and transmitting antenna beam patterns are tightly focused and the beams point in directions which are perpendicular to each other. However, this extreme case will not be encountered in an IVSAWS application since the in-vehicle receiver will utilize an omni-directional antenna in order to provide 360° coverage. Transmitters located at fixed-permanent locations might utilize directional antennas. However, “beam pointing” losses can be ignored since the topography is known in advance and stationary: If necessary, the transmit beam pattern can be shaped to fit the required communication path geometry. In fixed-transmitter scenarios where a single transmitter can not provide adequate coverage multiple transmitters or repeaters can be used. Conversely, antennas mounted on temporarily-deployed transmitters should be omni-directional; in some deployments an omni pattern will be desirable and the deployable transmitters must be able to cover this general case; omni-directional antennas are also more compact and rugged (e.g. short dipole "rubber duckie" antenna) than directional antennas and are therefore well suited to the abuse temporarily-deployed transmitters must endure. Similarly, mobile transmitters are likely to use some form of dipole in order to provide omni-directional coverage when necessary. Thus, with respect to communication path geometry and IVSAWS-relevant antenna directionality characteristics, worst case will involve an "omni-to-omni" link at a high elevation angle (see Figure 2, below).

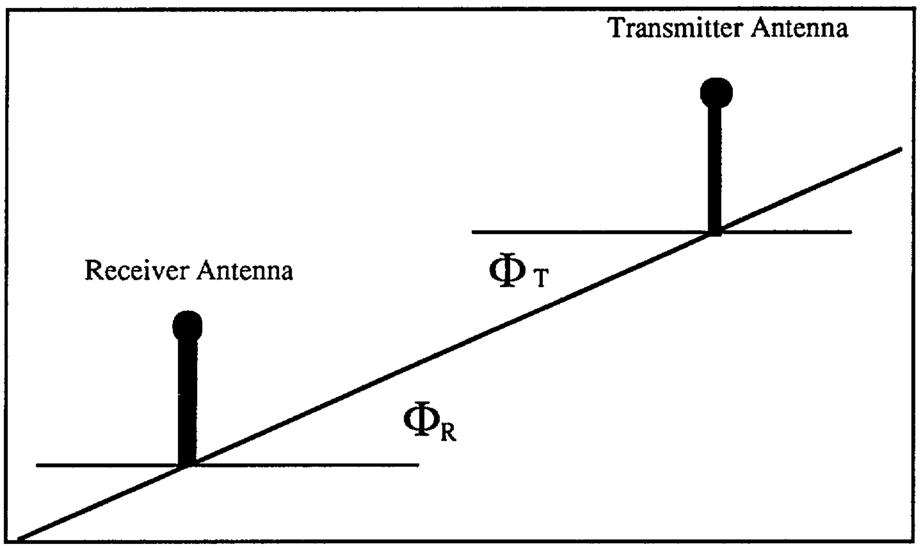


Figure 2. Two-Dimensional Transmitter and Receiver Antenna Elevation Angles.

For example, if the transmitter and receiver where located on different legs of a switchback highway, the angles ϕ_T and ϕ_R might, worst case, approach 60 degrees. In this case, and assuming short dipoles (length << λ; g = 1.5) are used at both receiver and transmitter, the effective gains of the antennas will each be reduced to .38 by the equation[7]

$$\text{Effective gain} = g \cos^2 \phi \qquad (6)$$

This can be modelled by assuming a flat road condition and inserting an additional 12 dB worth of path loss. However, on steep and curved highways the maximum closing rate between the receiver and transmitter, and thus the required transmission range, will be less than that on a flat high-speed roadway. Empirically, closing rates should not exceed 190 kph (120 mph). The required transmission range (2.0 km using Equation 5) will be further reduced due to geometry: The communication path between the transmitter and receiver will still be a straight line yet the length of highway that the vehicles must travel until they meet will be considerably longer. A precursory examination indicates that in order to provide warning at a receiver-to-transmitter separation of 2.0 kilometers, the required communication range will not exceed 1.0 km. An examination of topographical maps covering three well-travelled highways with corresponding steep communication elevation angles will be used to confirm this initial estimate and be incorporated into the first revision of this ENB. Thus, due to reduced vehicle speeds and the geometry of mountainous highways, the free-space path loss will be reduced by 10 dB (using Equations 4 and 5). Again, this can be modelled by assuming a flat road condition and subtracting 10 dB worth of path loss. Thus, worst case, a maximum net loss of 2 dB will be incurred due to communication path geometries with steep antenna elevation angles. In short, as long as mobile transmitters and IVSAWS receivers utilize low-gain antennas with wide half-power beamwidths, losses incurred by the geometry of the antenna beam patterns will be largely offset by a decrease in propagation loss due to a decrease in the required transmission range. As the elevation angles decrease, path loss due to increasing required transmission range will grow, but the effective transmitter and receiver antenna gains will increase more rapidly. Net communication degradation in environments with large elevation separations between the transmitter and receiver should be less than 2 dB.

5.3.4 Transmitter and receiver antenna heights above around level. According to Equation 4, transmission losses due to antenna height will be maximum when the antenna is closest to the ground. Paragraphs 5.3.4.1 through 5.3.4.4 estimate the minimum antenna heights for each of the IVSAWS platforms. The minimum estimates will serve as inputs to the computer modelling task which, as described in Paragraph 4, will compute the excess mean path loss as a function of antenna height.

5.3.4.1 IVSAWS-equipued vehicles. Ideally, in-vehicle receivers should have their antennas mounted at the roofline. However, due to cost and aesthetic considerations this may not be desirable: Most vehicles come equipped with a long dipole antenna (AM/FM) located at the hoodline and utilization of this asset must considered. The height of this antenna is seldom less than 1 meter. Thus, HR will be set to 1.0 meter when modelling the effects of receiver antenna height (Task C, Subtask 6, Computer Modelling).

5.3.4.2 Deplovable transmitters. In most situations transmitters deployed from emergency or maintenance vehicles will sit on the ground. An antenna extension (boom) of some type will be needed in order to avoid excessive losses. At a minimum, a 1.5 meter boom should be storable in the trunk of an emergency vehicle (assuming the transmitter, boom, and antenna could be stored as separate assemblies). Thus, HT will be set to 1.5 meters when modelling the effects of deployable transmitter antenna height.

5.3.4.3 Mobile transmitters. Unlike passenger vehicles, aesthetic concerns are not a major issue for emergency vehicles, buses, farm vehicles, etc.. Mounting an antenna at the roofline is desirable in order to minimize losses. Of the vehicles which are candidates for mobile transmitter installation, police cars and other modified passenger vehicles have the lowest rooflines; approximately 1.5 meters. Thus, HT will be set to 1.5 meters when modelling the effects of mobile transmitter antenna height.

5.3.4.4 Fixed transmitters. At fixed transmitter sites (e.g. hazardous turn, railroad crossing, icy bridge) it will be possible to elevate the antenna. In most situations a sign post, bridge trestle or other fixed object will be available on which to mount the antenna. If not, a pole can be sunk to provide adequate elevation. In any case, it should be possible to elevate the antenna at least 4 meters. Thus, HT will be set to 4.0 meters when modelling the effects of fixed transmitter antenna height.

5.3.5 Surface reflectivity. In the IVSAWS environment radio waves will reflect off of many sources including hills, roads, aircraft and buildings. The primary effect of the reflections will be to introduce multipath fading. The multipath fading will be worst when a reflected signal and the desired signal arrive at the receiver 180^{o} out of phase and destructively interfere with each other. If the amplitude of the reflected and desired signal are nearly equal, a deep fade will occur and communication will be effectively blocked. This type of multipath fading is called Rayleigh fading and is "far and away the most difficult challenge of the mobile (radio) environment[181]". The effect of multipath fading is most pronounced in environments with a large number of reflectors (e.g. city street with tall buildings). Yet even in the rural environment, aircraft, road surfaces, canyon walls and signs will produce numerous and significant fades. At frequencies above 100 MHz, the maximum fades will occur hundreds of times per second when the receiving vehicle is travelling at modest speeds. Even in a static environment the location and depth of multipath fades is difficult to predict; objects that seem to be unlikely reflectors will reflect; an apparently insignificant reflection path will bounce off another reflector and become significant. The use of omni-directional transmitter antennas further complicates the problem by increasing the number of possible reflection paths with respect to narrow-beam point-to-point communication. Due to the imprecision and complexity associated with analyzing this problem, the geometry (location) of multipath fades will not be predicted or computer modelled. Rather, it will be assumed that frequent and severe fades will occur in the IVSAWS environment and waveform design (Subtask 4) will be used to minimize the impact of fading on communication performance.

5.3.6 Contour. The losses due to non line-of-sight communication over an ideal knife edge can be calculated as a function of frequency, distance from the transmitter to the edge, distance from the receiver to the edge, and height of the edge. However, the mountains, hills, and other obstacles likely to be encountered in an IVSAWS application will diverge considerably from the ideal case. Losses over real-world edges are typically 10 to 20 dB greater than the ideal case[9]. The effects of hills, mountains, and knife-edges with respect to excess mean path loss will be simulated by Hughes' Longley-Rice computer model for at least two IVSAWS-relevant scenarios with such topography.

5.3.7 Foliage. In general, foliage will act as an attenuator between the receiver and transmitter. Wooded areas are particularly strong attenuators[10]. The effects of trees with respect to excess mean path loss will be simulated by Hughes' Longley-Rice computer model for at least one IVSAWS-relevant scenario with such topography.

6. Scenario Selection. Based upon the previous parameter analysis, four scenarios have been identified for computer simulation and estimation of total path loss. The scenarios and associated link parameters are summarized in Table I:

Table I. Scenario Selection

Scenario	Parameter Stressed by Scenario
Straight, flat high-speed highway	Communication range
Curved highway through trees	Foliage attenuation, antenna elevation angles
Highway through rolling hills	Diffraction loss due to contour
Curved road with interleaving mountains	Diffraction loss due to contour

For each scenario, three cases will be modelled: mobile transmitter, temporarily-deployed transmitter, and fixed-site transmitter. Thus, the effects of transmitter and receiver antenna heights will be modelled for each IVSAWS deployment option. As mentioned previously, the geometry (location) of multipath fades due to surface reflections will not be modelled.

6.1 Straight flat high-speed highway scenario (Scenario A). Site selection for this scenario is somewhat arbitrary since straight and flat stretches of highway are numerous. Case #6 from the IVSAWS Task B preliminary report was chosen to model this geometry (see Figure 3).

The stretch of road involved is U.S. Highway 23 near its intersection with Michigan Highway 14. The parameters for this scenario are listed in Table II.

6.2 Curved highway through trees (Scenario B). U.S. Highway 89 Alternate, approximately 13 miles north of Sedona, Arizona was selected to emulate this scenario (see Figure 4). At the northern end of Oak Creek Canyon, the highway has sharp curves and covers a significant elevation differential (approximately 700 ft differential in 2 miles). Through this region, posted speed limits drop to 15 mph. Foliage along this route is dominated by dense oak and pine woods. The parameters for this scenario are listed in Table III.

6.3 Highway through rolling hills (Scenario C). U.S. Highway 385, approximately 1 mile south of Hot Springs, South Dakota was selected to emulate this scenario. Figure 5 shows the heights of the hills over which the radio waves must propagate. A topographic map like those shown in Figures 4 and 6 has been ordered and will replace the sketch in a subsequent revision of this ENB. The parameters for this scenario are listed in Table IV.

6.4 Curved road with interleaving mountains (Scenario D). Interstate 90, through Snoqualmie Pass, Washington was selected to emulate this scenario. Figure 6 shows the mountain over which the radio waves must propagate. The parameters for this scenario are listed in Table V.

SCENARIOS

1. TABLE II. Scenario A Parameters. Straight and flat highway. Line of sight communication between transmitter and receivers. Communication range is maximized in this scenario.

2. TABLE III. Scenario B Parameters. Curved highway through dense woods. Significant antenna elevation angle

3. TABLE IV. Scenario C Parameters. Curved highway through dense woods. Significant antenna elevation angle.

4. TABLE V. Scenario D Parameters. Curved highway with interleaving mountains.

5. FIGURE 3. Scenario A – Straight, flat high-speed highway

6. FIGURE 4. Scenario B – Curved highway through trees.

7. FIGURE 5. Scenario C – Highway through rolling hills.

8. FIGURE 6. Curved road with interleaving mountains.

7. References.

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[2] R.M. Gagliardi, Introduction to Communications Engineering, John Wiley & Sons, Inc., New York, New York, 1988, p. 146.

[3] J.R. Sklar, et. al., "Masking for Covert Communications," Lincoln Laboratory, MIT, Lexington, Massachusetts, Project Report TST-83,4 December 1987, pp. 5-6.

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[5] Federal Highway Administration, "Feasibility and Concept Selection of a Safety Hazard Advance Warning System (SHAWS) - Volume II - Technical Report," Washington, D.C., Report No. FHWA/RD-81/124, April 1982, pp. 3-8, 9.

[6] Federal Highway Administration.

[7] Gagliardi, p. 110.

[8] G. Calhoun, Digital Cellular Radio, Artech House, Inc., Nor-wood, Massachusetts, 1988, p. 218.

[9] Jordan, p. 33-24.

[10] Calhoun, p. 211.

APPENDIX G: INVEHICLE SAFETY ADVISORY AND WARNING SYSTEM (IVSAWS) TASK E REPORT, RESULTS OF THE DRIVER ALERT WARNING SYSTEM DESIGN MOCKUP TESTING AND EVALUATION

This appendix describes the human factors approach, methods, and conclusions for the survey and analysis of the candidate Driver Alert Warning System (DAWS). Empirical testing of selected symbols and candidate auditory messages were evaluated using a foam-core mockup environment. Driver symbol recognition, understanding, and responses are analyzed.

Task E Report for the In-Vehicle Safety Advisory and Warning System (IVSAWS) Driver-Alert Warning System Design Mockup Testing

1.0 Introduction

As identified in the Workplan for IVSAWS, Task E was performed by Hughes GSG Human Factors using a static mockup environment. Hughes created a minimum foamcore mockup environment and conducted empirical testing of selected symbols, or telltales, for driver recognizability, comprehensibility and effectiveness. Symbols were presented using both limited monochrome and color applications. Colors were selected based on probable hazard levels defined in Report No. FHWA/RD-81/124 and in IVSAWS Task B University of Michigan Transportation Research Institute (UMTRI) Report. The selected symbols were tested individually as well as paired with blink, audio tone, voice and text messages. The number of symbols and the various modes of presentation were limited due to time and cost constraints. From the 12 hazard situations identified by UMTRI's report, eight symbols were developed and tested.

Reach and vision analysis of the drivers in the static mockup utilized the information provided in SAE standards J287, "Driver Passenger Manuals for General Rules on Arm Reach", SAE Recommended Practice J1052 (1985) "Motor Vehicle Driver and Passenger Head Position", as well as information derived from General Motors and GM Hughes Electronics publications. The volumetric interior space within the driver compartment and the positioning of the DAWS were simulated in the mockup.

Candidate visual text displays and candidate auditory messages were selected based on Tasks B, C and D data. These candidate text and visual messages will assist in determining the superior candidate messages and configuration that will be evaluated during Tasks F, Proof-of-Concept Driver-Alert Warning System and G, System Concept Test and Demonstration.

This Task E Report describes the approach, method and conclusions for the survey and analysis of the candidate DAWS system. The Report defines the analyses for driver symbol recognition, understanding and responses for driver reach and vision in separate sections of this report. The results of both analyses are summarized in this report.

2.0 Background and Task Interrelationships

As part of the Hughes system engineering approach to the development of a comprehensive assessment and baseline design for the IVSAWS concept, Task E, within the multi-phase study, provides an initial evaluation of the basic research and data developed during the preceding Tasks A through D. Task B, Subtasks 1 through 5, provided the data for hazard situation identification and prioritization of the situations as developed by UMTRI. Table 2 - 1 shows the hazard situations and the prioritization developed by UMTRI and applied to IVSAWS applications. In addition, analysis by Hughes GSG Human Factor Task B, Subtask 6, included recommendations for telltales and the context for driver visual and auditory messages. Tasks C and D reviewed and selected an appropriate communications technology for alerting drivers to advisory and safety signing, and roadway hazards. These data were based on analyses of worst-case situations and on signal propagation distances.

The key areas that provided input to Task E were focused upon four signalling categories and parameters, these were:

1. The use of visual mode displays and indicators presenting combinations of graphic symbols (icons), color and text.

2. The use of audio mode presenting tones, audio symbols and/or synthesized speech.

3. Driver control of alert signalling parameters and modes, including driver override, message acknowledgement, and/or message repetition commands.

4. The length and signalling intensity of messages to be presented to the driver.

Task E was concerned with the application of the first two signalling categories and with the combined human factors and communications engineering results of the

Table 2 - 1. UMTRI Ranking of IVSAWS Applications

IVSAWS Applicatior	Crash Data Ranl		Overall Rank
	Crash Freq.	Injury Severity	
Signalling emergency vehicle presence	5	2–3	1
Railroad grade crossings	6	1	2
Multiple (compounding) hazardous conditions	3	2–3	2
Highway construction zones	2	5–6	3
Supplemental traffic control device	NA	NA	4
Crash site — police activated	NA	NA	4
School bus or other special vehicle hazard	4	4	5
Temporary detour routes	NA	NA	5
Disabled truck at roadside	NA	NA	6
"Mini-zones" involving roadside work	NA	NA	7
Traffic Backups	NA	NA	7
Accident-involved or disabled vehicles	1	5–6	8

third and fourth category. The Hughes Human Factors signalling presentation analysis resulting from Task B, Subtask 6, shown in Table 2-2, provided the basis for signal and message enumeration. Within Table 2-2, the IVSAWS Applications column identifies those situations that UMTRI categorized and ranked based upon analyses of crash data and driver information needs implied by crash documentation.

The columns entitled Alerting Messages and Action Advisories provided the basis for text and audio messages used in Task E analysis. These messages formed a portion of the final recommendations of Task B, Subtask 6. Additional recommendations included; sensory format, to present advisory messages in a bi-sensory format to minimize driver attention and visual workload, and to carefully consider special or unique symbols for presentation to the driver. In addition to the concern for presentation of unique symbols, careful consideration for the positioning of a vehicle's primary control suite was recommended.

The concern for positioning of the Driver Advisory Warning System (DAWS), within Task E, required not only consideration of the above Task B recommendations for message formats and special symbols, but also the provision for estimated driver workload. Task C analyses combined the data from Task B with the analysis of radio transmission and receiver characteristics and with estimated driver reception and response times.

Task C analysis provided analytic evaluation for IVSAWS Driver Alert Distances (DAD). The Driver Alert Distance is the distance from a hazard that a driver must be warned so that the driver can perceive the situation and respond accordingly. The SHAWS report showed that the DAD exceeds the distance at which the hazard first enters the driver's field of vision . As shown in Figure 2-1, the DAD is composed of a warning generation time, a warning effectiveness period (Wp), and a Decision Sight Distance (DSD). The DSD is defined as the distance travelled during the period of time required for a driver to detect and recognize a hazard , decide upon a hazard avoidance response, initiate the response, and perform the maneuver. The time required and the distance covered depends on the type of maneuver and the type of vehicle. The three types of maneuvers were designated as: increased attention, a lane change, and a full stop. The SHAWS report also tabulated preliminary results for the time required to perform a corrective lane change. The two types

Table 2-2. Task B IVSAWS Alerting Messages (Derived from Analyses of UMTRI Subtasks 3 and 4.)

IVSAWS Applications	Alerting Messages	Action Advisory
Emergency Vehicle (EV) Presence	EV ahead/stopped EV approaching EV near, location unknown	Slow down Stop Pull over to right & stop
Railroad Grade Crossings	RR grade crossings ahead	Prepare to stop
Multiple (Compounding) Hazardous Conditions	Hazard situation ahead Hazard situation in area, location diffuse	Slow down Slow to xx mph Stop Merge right Merge left Pull over to right & stop Pull over to left & stop Change lane 8 slow Accelerate to x x mph Turn on headlights Turn off headlights Remain in vehicle Leave/abandon vehicle
Highway Construction Zones	Construction zone ahead	Slow down Prepare to stop Stop
Supplemental Traffic Control Device (STCD)	STCD ahead STCD in area, location is uncertain	Be alert to unusual traffic control signals/devices
Crash Site - Police Activated	Crash site ahead Crash site in area	Slow down stop Change lanes (right or left) Turn (right/left) at next intersection
School Bus or Other Special Vehicle (OSV) Hazard	Bus or OSV ahead Bus or OSV in area	Slow down Prepare to Stop stop
Temporary Detour Routes	Detour(s) ahead	Slow and take notice of detour instructions
Disabled Truck (DT) at Roadside	DT ahead at roadside on the right DT ahead at roadside on the left	Slow and avoid right side of road Slow and avoid left side of road
Mini-Zones Involving Roadside work	Roadside work ahead	Slow down Prepare to stop stop
Traffic Backups	Traffic queue ahead Traffic queue in area	Be alert Slow down Turn to alternate route (xxx)
Accident Involved or Disabled Vehicle(s)	Accident or disabled vehicle ahead	Be alert Slow down Turn to alternate route (xxx)

STEP	TIME	VEHICLE ACTIONS	DRIVER ACTIONS	IVSAWS UNIT	HUMAN FACTORS
1	t_0	Vehicle approaches hazard	Driver uses normal driving skills	No Action. Signal not yet detected	
2	t_0			Signal detected Signal analyzed Warning selected	DRIVER ALERT DISTANCE TIME
3	t_1			Warning generated by visual and aural synthesizers	
4	t_2		Driver detects warning signal		WARNING EFFECTIVENESS PERIOD
5	t_3		Driver understands warning		
6	t_4		Driver decides warning response		
7	t_5		Driver begins warning response		
8	t_6	Vehicle in sight of hazard			DECISION SIGHT DISTANCE TIME
9	t_7		Driver detects hazard		
10	t_8		Driver recognizes hazard		
11	t_9		Driver decides hazard avoidance response		
12	t_{10}		Driver begins hazard avoidance response		
13	t_{11}	Vehicle avoids hazard	Driver continues normal driving		

Figure 2-1. Driver Alert Distance Timeline

of vehicles considered were passenger vehicles and commercial trucks. Combining the various factors yields an overall distance which is then the IVSAWS communication range.

As Task C reported, the DSD time was sub-divided into two intervals: 1) the perception-response time and 2) the hazard avoidance maneuver time. These two parameters were evaluated for the hazard avoidance maneuvers under consideration.

Task C identified that perception response times are determined through experimentation. Subjects perform hazard avoidance maneuvers in response to simulated roadway hazards and the elapsed time is measured. Current literature from these experiments specify the perception-response time to be 1.6 seconds. However, much literature exists on the topic of perception-response times and estimates of a design value range from 0.9 second to 4 seconds, depending on road geometry and author opinion. The American Association of State Highway and Transportation Officials (AASHTO) recommends a design value of 2.5 seconds. Because the purpose of the IVSAWS study is not an exhaustive study of driver perception and reaction, the 2.5 second value was selected as a baseline for the evaluation of DSD and DAD.

Hazard avoidance distances for the three maneuvers outlined above are listed in Table 2 - 3 for vehicle speeds of 40, 50, 60 ,70 and 80 miles per hour. Increased driver attention requires no vehicle maneuver and is assumed to be instantaneous upon driver perception of the hazard. The braking maneuver is assumed to be a controlled stop on worn tires (2/32 inch tread) over a wet paved surface without wheel lock up.

Table 2 - 3. Hazard Avoidance Maneuver Distances

Vehicle Speed (mph)	Maneuver Distance (feet)			
	Increased Attention	Lane Chanae	Full Stop Car	Full Stop Heavy truck
40	0	260	220	380
50	0	300	380	650
60	0	340	620	990
70	0	380	940	1410
80	0	420	1370	1890

The DSD estimates are obtained by adding the 2.5 second perception-response time to the hazard avoidance maneuver distances in Table 2 -3. The additional elapsed time for the perception-response translates into additional distance as a function of vehicle speed. The resulting DSD are shown in Table 2 - 4.

Table 2 - 4. Decision Sight Distances

Vehicle Speed (mph)	Perception-Response Distance (feet)	Decision Sight Distance (feet)			
		Increased Attention	Lane Change	Full Stop Car	Full Stop Heavy truck
40	150	150	410	370	530
50	180	180	480	560	825
60	220	220	560	840	1210
70	260	260	640	1200	1670
80	290	290	710	1560	2180

Task C concluded that, considering the sparse nature of literature about warning effectiveness periods for electronically generated in-vehicle warnings, a six second IVSAWS warning effectiveness period was a reasonable initial estimate. This could be verified or corrected during the subject testing phase of the study. Given this estimate, the

IVSAWS warning units must repeat their broadcasts at least once every six seconds to ensure that drivers respond to IVSAWS warnings in a timely manner.

The overall conclusions and recommendations derived from Tasks A through Task C, formed the database for the initiation of Task E. Task B provided the identification and prioritization of vehicle crash and hazardous situations. It also provided the initial identification and recommendations of symbols/pictograms and the audio and text warning messages for the prioritized crash situations. Task C identified critical warning effectiveness time-frames and driver alert distances. Additional data provided by Task D included the identification of the type of equipment necessary to demonstrate the communication architecture. For the preliminary design, the driver alert module recommended includes a symbol/icon display on the instrument panel, a speech synthesis unit with speaker and a CRT display.

3.0 Objective

The primary objective of the Task E study is to evaluate alternative signalling presentations, codes and symbologies for driver alerting and to evaluate the Driver- Alert Warning System (DAWS) positioning within the vehicle. The DAWS represents those components (hardware and software) resident in a vehicle which are used to convey information concerning advisory, safety and hazard situations to the driver of the vehicle.

Tasks C and D evaluated the relative importance of the human factors attributes in relation to the hardware/software aspects of the DAWS. For the purposes of the Task E study, these human factors attributes were considered more important than the specific hardware/software attributes. Specifically, comprehensibility (understanding/interpretation), relative effectiveness (correctness of response, accuracy), human reliability (error control) and signalling format (voice, tone, text, symbol) were considered to be of prime importance. Consideration of accessibility/location (ease of access) and physical attributes (size of buttons, character size) were secondary, but important to the overall concept of the DAWS. For these reasons a static mockup to evaluate the DAWS, although not conducive to accurate driver anthropometric measurements and to the establishment of an appropriate driver mind-set, was considered adequate for the establishment of Task F and Task G baselines. Empirical measurement and evaluation of driver reaction time and accuracy of driver physical responses will await Task G simulation and test.

4.0 Methodology/Procedure and Subtasks

The testing of a static mockup DAWS was predicated on data derived from Tasks A through D. The candidate DAWS was tested in a static environment in the Human Factors Laboratory at Ground Systems Group, Fullerton, California. Figure 4-1 shows a representative sketch of the mockup used for the testing of the DAWS. The Task E Workplan established three specific subtasks to be performed during Task E. These subtasks provided the baseline for the equipment used during testing, the populations sampled as well as the methods and procedures for the DAWS test and evaluation. The subtasks involved DAWS design, DAWS testing and preparation of a Task E report. The details of these subtasks were:

A. Driver-Alert Warning System Design

1. Selection of appropriate driver display; tell-tales/pictograms, Head-up display, CRT monitor
2. Define system parameters; display format and position, equipment arrangement, legibility, auditory alerts, voice output, accessibility
3. Soft mockup for test-bench design; standardization of display segments and voice/audio tone output, identification of hazard nomenclature

B. DAWS Mockup Testing

1. Review driver task data; FHWA/RD-81-24, NHTSA Task Analysis
2. Test DAWS in static environment
    - Anthropometric analysis
    - Three subject groups; young, middle-aged and mature
    - Test selected pictograms for recognizability, appropriateness, comprehensibility and effectiveness
    - Reach and vision analysis
    - Evaluate candidate visual displays
    - Evaluate auditory messages

C. Prepare Task E Report

1. Summary of test and evaluation design
2. Report of evaluation process and results

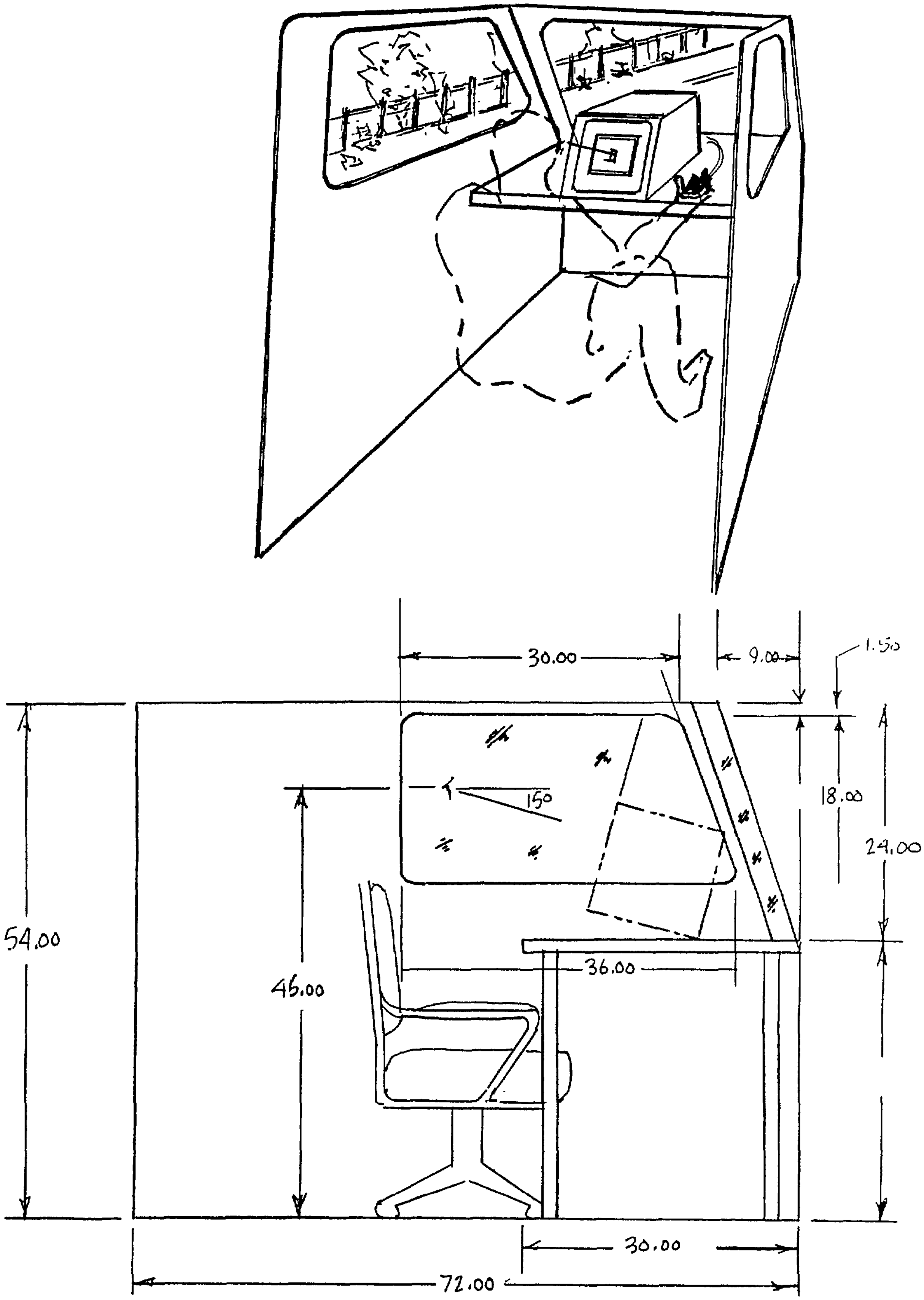

Figure 4 - 1. Mockup Construction and Dimensions

4.1 Establishment of mockup and test methods

Based on the Task E subtasks and tests to be conducted within a static mockup, an environment using a mockup constructed of soft foamcore and standard office furniture were used as the driver enclosure. This provided a designated "driver" area. The data provided by Tasks C and D identified the use of a CRT display as the driver receiver and interface. Within Task E, the use of a head-up display was not amenable to a static mockup. Therefore, a Macintosh II display was selected. The Macintosh permitted the use of visual text as well as auditory tones and text using Supercard software. By careful software programming, the Macintosh mouse was able to be used as illustrative of a DAWS "turn-on" button for voice and displayed text messages.

The selected DAWS pictograms/symbols were programmed into the Supercard software as the test questionnaire was developed. The pictograms are shown in Attachment A and the developed questionnaire is enclosed as Attachment B. Pre-test trials identified corrections to the questionnaire prior to its use in the established test. Figure 4 - 2, shows the format used for the majority of the questionnaire. Each presentation of eight different pictograms to the tested subjects, involved six different formats (subsets A through F), that used pictograms presented in monochrome then color, then associated with flash (four per second), audio tone, long voice and text messages and finally short voice and text messages. The pictograms used depicted;

- Fire Vehicle
- Farm Vehicle
- Police Vehicle
- Emergency Vehicle
- Rail Road Crossing
- Construction Zone
- Accident/Crash Site
- Hazard Alert

Each of the eight pictograms were presented to the subjects using the six different presentation formats described above. (A video tape showing the presentations will be submitted to the FHWA). A final set of presentations with alternating flash/blink between "Hazard Alert" and a selected pictogram was used for the presentation set 9, 10 and 11.

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:________________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
1.A Mono.	___________	________________	_______________
1.B. Color	___________	________________	_______________
1.C. Color Flash	___________	________________	_______________
1.D. Color Tone	___________	________________	_______________
1.E. Color Tone Text (long)	___________	________________	_______________
Voice	___________	________________	_______________
1.F. Color Tone Text (short)	___________	________________	_______________
Voice	___________	________________	_______________

Which one of the above do you prefer? ________

Why? ____

What would you change or add?______________________________

____

Figure 4 - 2. Questionnaire Format for Pictogram 1 - 8

The pictograms that alternated with the Hazard Alert pictogram were; Emergency Vehicle, Rail Road Crossing and Farm Vehicle. This form of presentation had been suggested by Mr. Tony Yanik, Environmental Activities Staff of General Motors. Mr. Yanik is a leading authority in regard to mature drivers and their driving behavior and driving limitations.

The test subjects were selected from Hughes Ground Systems personnel. The subjects were asked to identify sex, age group and physical height. Educational level was not requested, however, the subjects were drawn from different levels within Hughes including clerical, hourly and engineering. The 13 total subjects with representation in three age groups of young, 16 - 30 (four persons), middle-aged, 31 - 50 (six persons) and mature, 51 and over (three persons).

4.2 Test procedures

At the onset of Task E, it was recognized that a static mockup would provide minimal automotive fidelity and that the DAWS would be a new system not within the experience of the test subjects. For this reason the introduction to the test questionnaire provided a description of the IVSAWS Program and an introduction to the Task E DAWS evaluation (Attachment B). In addition, only two of the eight pictograms presented, Rail Road Crossing and Construction Zone, were expected to be familiar to the subjects. For these reasons a subjective, free-text response questionnaire was used.

Pre-test trials identified that subjects completing their own questionnaire while viewing the presentations would transcribe their comments in detail for each subset of pictograms. The time for completion for the pre-test group ranged from one hour to one and one/half hours when allowed to pause, verbalize and then write their comments or answers. During actual testing, subjects were allowed the choice of completing their questionnaire or to allow the test monitor to transcribe their answers and comments. In both cases, ditto marks (") were permitted for similar responses rather than completion of repetitive comments.

Test subjects were brought into the Human Factors Laboratory on a scheduled basis and introduced to the DAWS mockup. Each subject was first asked about their computer familiarity. Although the interface with the DAWS test required minimum action on the part of each subject, a common set on instructions were used during the introduction phase. (Reference page 2 of Attachment B). To change the presentation the subject was required to press the “RETURN” key. During the fifth and sixth sub-set (subsets E and F), of each presentation, the subjects was required to reach for, and press, the “MOUSE BUTTON.” The last page of the questionnaire was always completed by the subject. This page provided the subject with the opportunity to summarize reactions and understanding of the DAWS presentation and to rank the presentations based upon the subject’s preference.

The test procedure followed the following sequence:

1. Introduction to the soft foamcore mockup and equipment.

2. Introduction to IVSAWS.

3. Introduction to the process for responding to the presentation.

4. Test monitor gives the subject the questionnaire and requests the subject to read and complete the first page and to continue on to the second page.

5. Test monitor answers to any questions asked by the subject.

6. Test monitor reinforces each subject to consider the potential rural or urban setting during testing and for the use of the DAWS.

6. Test monitor asks subject if he/she will complete the questionnaire. If the test monitor is to transcribe the subject’s responses, the subject is told that some clarification may be required to assure accuracy of response.

7. Test monitor reinforces that presentations will be number 1 through 11. That sequences 1 through 8 contain sub-sets alphabetized A through F and that sequences D and F will require and added action, the use of the mouse button to obtain the complete signal presentation.

8. Test is initiated by subject.

9. At completion of presentation 11 the subject is given the questionnaire, or is asked to complete the last, summary page

The above sequence was followed for each subject. No subject appeared to be confused by either the use of the Macintosh computer or of the purpose of the test. Each subject provided a complete set of responses and no data were nullified. The time of completion for the thirteen subjects ranged from 35 minutes to one hour. The test monitor responded identically to similar questions asked by various subjects.

5.0 DAWS Positioning Analysis

Since the static mockup contained minimal automotive fidelity, only subjective reach data could be obtained. In this regard, summary question Number 4 (last page - page 14 - of Appendix B), requested the subjects to respond to the effect upon the driver, “to have to reach for and press a key for additional information.” Further questions refined the response by asking if the additional information was worth the added effort. In 10 of the 13 responses, the subjects felt that the effort were worth the effort. The three negative responses were from males, two in the 51 and over group and one in the 16-30 group. The three negatives would reconsider if the “messages were more direct” or if the “button” was located on the steering wheel hub.

The analysis of the DAWS positioning required that existing automotive and military standards be reviewed to determine the causal anthropometric factors for appropriate human interface with the DAWS. In this regard two primary factors must be considered; visual angle and reach distances. Each of these factors is somewhat dependent on driver positioning (the automotive term is “seat reference point” - SgRP- in the design realm of “occupant packaging”), within the vehicle. For visual angle considerations MIL-STD-1477A, Military Standard - Symbols for Army Air Defense System Displays, and MIL-STD-14720, Human Engineering Criteria for Military Systems, Equipment, and Facilities, and Campbell, J. L., Analysis of Alphanumeric Symbology Requirements for Automotive Displays, 1989, were used to provide a baseline for establishing DAWS requirements.

There is minimal disparity between the data. For visual acquisition and recognition of alphanumeric characters, a minimum subtended visual angle of not less than 15 - 16 minutes of arc when measured from the driver’s eye in its normal viewing location. For symbology, the recommendation approximates a visual angle of not less than 25 minutes of arc . Distance considerations indicate that the viewing distance is 20 inches. Therefore, symbols 24 inches in distance from the driver would be a minimum of 0.174 inches in height and for a distance of 36 inches the symbol height would be 0.261 inches in height. These recommendations must also consider luminance, contrast ratios and color usage.

For positioning purposes, the preferred downward, vertical angle for driver viewing would be 15 minutes of arc, not to exceed 30 minutes of arc, from the driver’s normal seated position. Within this context, the mature driver differs from the younger driver in terms of visual perception. For legibility purposes, concern for the mature driver must also consider accommodation, acuity, and glare sensitivity in addition to illumination requirements, contrast sensitivity and color sensitivity. Each of these factors must be studied in relation to the ambient conditions, vehicle adjustment capabilities as well as the DAWS visual presentation medium. These factors could not be studied in a static mockup environment.

The positioning of the DAWS also requires consideration of existing automotive standards and designs. SAE J287, Driver Hand Control Reach (1981) provides detailed numeric and location considerations within the automotive industry (refer to Attachment C, for illustration of the initial pages of J287). This current SAE driver packaging model is depicted in Figure 5 - 1. However, recent data studied by General Motor (R. Roe, unpublished, 1991) and UMTRI have identified that these data may require updating. Their preliminary data indicates that drivers are sitting more erect thereby raising the eye range and moving the reach distances closer to the instrument panel. Current positioning data (Attachment C), indicates that for a CRT placed within the onboard driver information center, a maximum distance of 26 to 28 inches from the restrained driver’s, non-extended shoulder, provides the 95% boundry.

To further confound the ease of locating the DAWS, the majority of the automotive manufacturers have established an area to the right of the driver’s instrument panel, near the vehicle centerline, that has become known as the Driver Information Center (DIC). This area, in some vehicles, contains an existing CRT or flat panel display, used to present the driver with vehicular indications and controls for the radio, air conditioning and various status displays. The head-up display, in addition to the CRT, can also provide this capability. Limitations, such as cost, may preclude acceptance or validation since the head-up display is still being evaluated.

To provide recommendations that are germane to the DAWS, all the above factors should be evaluated in depth. For the purposes of this study, limited by the static mockup, a few indications derived from test subject comments are apparent. The alert symbology/pictogram should be located within the drivers normal visual angles, the controls for display of text and audio messages should be proximic to the vehicle steering wheel hub but no further than the established vehicle DIC and the visual text messages should be either within the DIC area or on a proposed head-up display.

CURRENT SAE DRIVER PACKAGING MODEL

- THE SPATIAL RELATIONSHIP BETWEEN THE SEAT, PEDALS AND STEERING WHEEL AND THE RESULTING DRIVER SEAT, EYE AND HEAD LOCATION ARE CRITICAL IN DEFINING DRIVER VISION, SEATING ACCOMMODATION AND COMFORT.

  - EYE AND HEAD LOCATION
  - STEERING WHEEL LOCATION
  - SELECTED SEAT POSITION
  - CONTROLS REACH

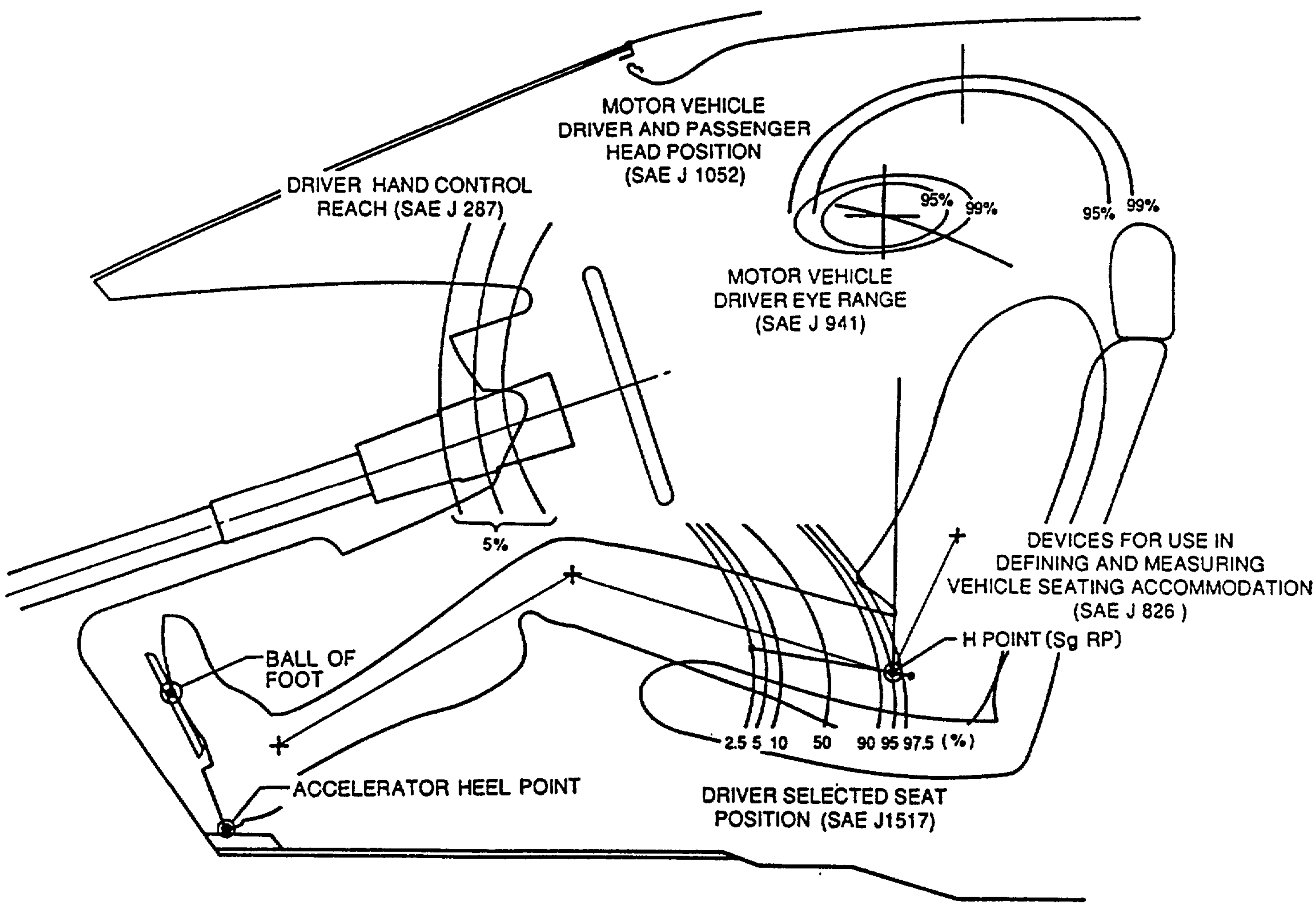

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FIGURE 5 - 1. Current SAE Driver Packaging Model

6.0 Results

This section of the report presents the results of the data derived by analysis of the test questionnaires as well as the subjective data provided by the test subjects. Positioning results were included in the previous section and are summated in Section 7, Conclusions/Remarks, of this report. The following paragraphs and figures summarize the results of the IVSAWS DAWS Task E symbol signalling tests and provide test data definition and interpretation.

Test data were of two metric categories, nominal and ordinal. The tables reflect the numerical analysis of the ordinal data (rank order judgements of the test subjects). The nominal data, including all commentaries and opinions, were reviewed for general impressions and for cues to better understanding of the ordinal data.

6.1 Analysis of preferences for signalling options

At the end of the test sequence each subject was instructed to rank the seven options in order of preference. Rankings were scaled from 1 to 7 with 1 being the most preferred. Results of these rankings were summed across all test subjects and averaged to obtain a mean rank preference value for each option. Standard deviations (S.D.s) of rankings were automatically calculated for each mean value obtained. Mean rankings were then numerically transformed to obtain "Preference Index" (P.I.) values (P.I. = reciprocal of mean rank value=1/Avg Rank). The P.I. metric has the advantage over the rank order in that the larger values reflect the stronger preferences. The below definitions provide the basis necessary for the interpretation of the preference figures that follow:

- Mean Rank - Each mean rank value is interpreted as the best estimate of the group's preferential ranking of each option.

- Standard Deviation of Rank Values - The standard deviation of rank value for each option is a mathematically inappropriate parameter but , since it was available as part of the data reduction software, it was calculated as a crude indication of the reliability of each mean ranking. As such, it provides an indication of the relative concordance of the group with regard to the ranking of each option. Larger S.D.s indicate less group agreement and smaller S.D.s are suggestive of more group agreement.

• Preference Index Values - The P.I. value for each option is interpreted as the test group's relative preference for that option. These preference values have no practical comparative meaning beyond the context of this study, i.e., they cannot be extrapolated to, or compared with, symbology experiments or surveys done in other contexts. They do genuinely reflect the test group preferences among the 7 options in this static mock-up study. As such, these data represent a practical basis for screening out some of the least preferred options and for narrowing the scope of any future testing of this set of options.

• Within Group Differences - Mean values and S.D.s of sub-group data indicate that there may be significant differences in preference associated with gender and age level. Confirmation of these differences would require a more detailed study, with a larger and more strategically selected subject sample.

Although the population sample is small and not fully representative of the larger driver population, further analysis of the current data may be warranted. Data from the current study could be subjected to several additional calculations, some of which might confirm correlations between subgroup identity and certain preferences. These possibilities are currently under review.

6.2 Preference ranking and average values for signalling options

The overall preference index of the subject group is shown in Figure 6 - 1. The categories labeled CTTVM (Color, Audio Tone, Text, Visual Message), were predominantly prefered by the subject group. The category Color + Blink, indicates a preference by the four female subjects. Of interest is the fact that except for these three categories, there was little disparity between among the gender groups. The explanations offered by the female subjects in free text and conversation was that the blink or flash was interpreted to be the presence of a more immediate danger, that is, the blinking pictogram represented a danger closer in proximity to their vehicle and would require more immediate action. The male population believed that more information would be worthwhile thereby allowing the driver to take the most appropriate action. The selection of the voice and text message options were interpreted to mean that the DAWS system would provide accurate advance information and thereby permit the driver to take the most appropriate action for the given option.

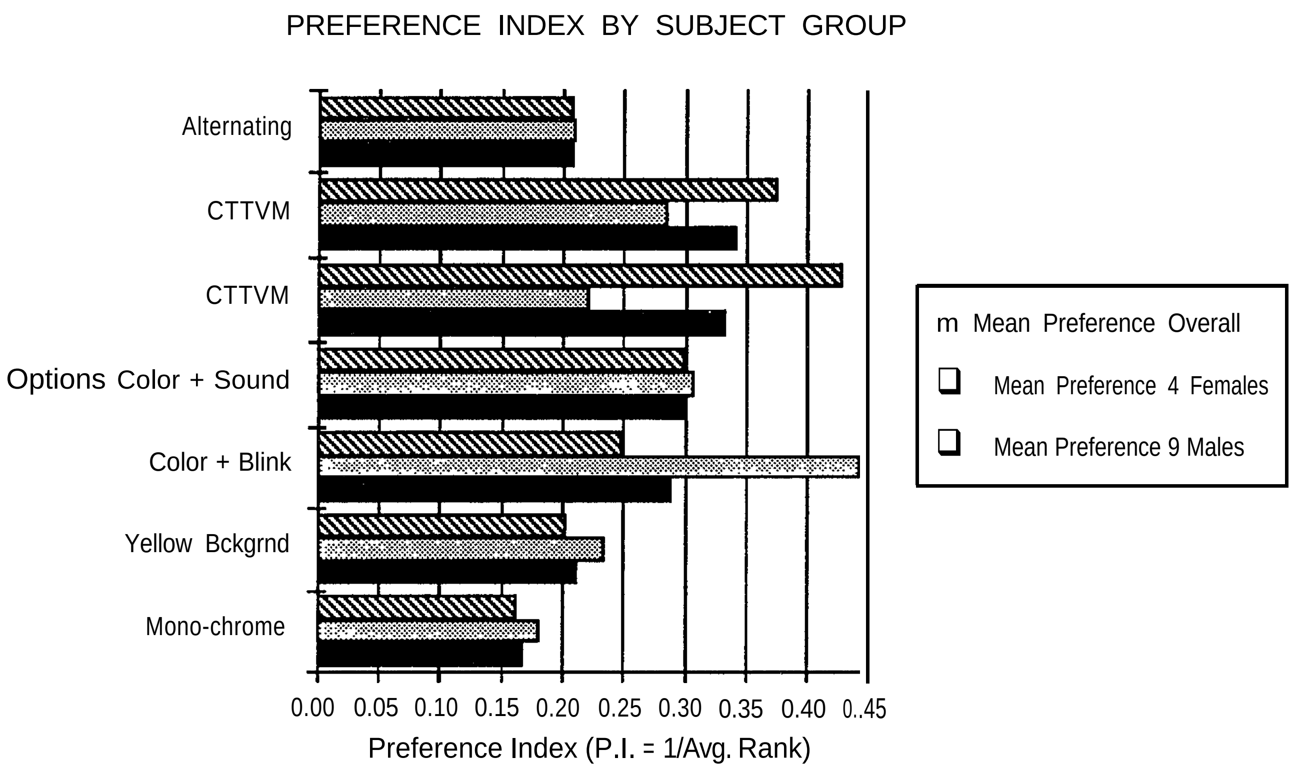

Figure 6 - 1. Preference Index by Subject Group

Figure 6 - 2 shows the mean ranking and standard deviation for the subject group's preferences between the different signal options. In ranking the preference, a ranking of 1 indicated first choice while a ranking of 7 indicated the least prefered. As defined earlier, the smaller the S.D. the more the agreement of the group for the given option. Again, the Long Message and Short Message text and voice options ranked higher than the other options. The S.D.s for these two options also show a relatively low deviation of agreement.

Figure 6 - 3 shows the preference by age group. This figure clearly shows that the preference for text and voice messages was more highly prefered by the 16-30 (Young) group followed by the 51 and over (Mature) group. When compared to Figure 6 - 4, preference by subject group, it can be identified that the larger male population contributed to the overall average. Within Figure 6 - 4, the concurrence within the female population is shown by the high preference index for the color and blink option. This was verified as shown in Figure 6 - 5 where only the female population distribution was considered.

In general the results showed a preference for the voice and text message associated with each pictogram. The variance accorded the female population group should be considered if a blinking or flashing pictogram is to be used. The free text entries identified the rationale used by the subjects in their selections. Those comments most relevant to this study included the following:

A. Blink/flash provided an inference that the hazard situation was in the immediate vicinity of the driver's vehicle.

B. Message content should provide information not available from the pictogram presentation in and of itself.

C. All pictograms were recognizable by the subjects.

D. Several subjects indicated that they were more likely to pull over for a police vehicle due to the potential of receiving traffic citations.

E. The majority of the subjects felt that they knew what action to take based upon pictogram presentation and an understanding if IVSAWS.

F. The most confusing pictogram was the farm vehicle. Due to the profile depiction, subjects thought it represented a vehicle entering from a side road.

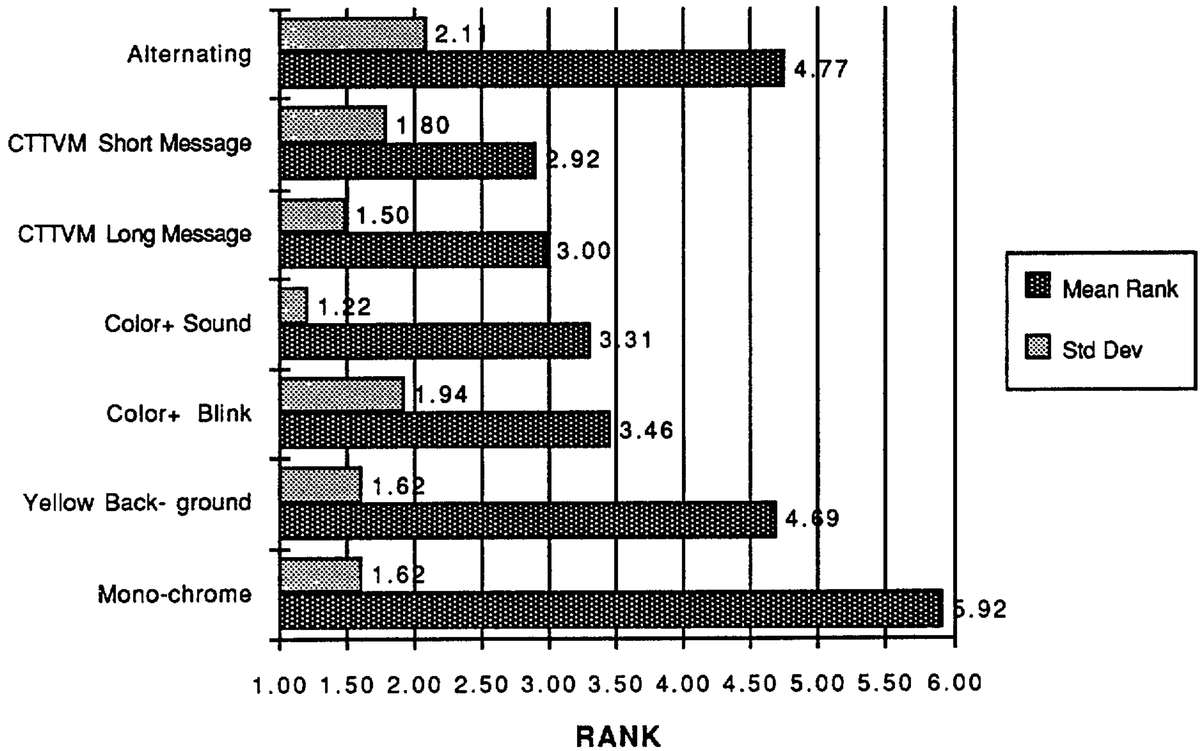

Figure 6 - 2. Mean Rank and Standard Deviation of Signal Options

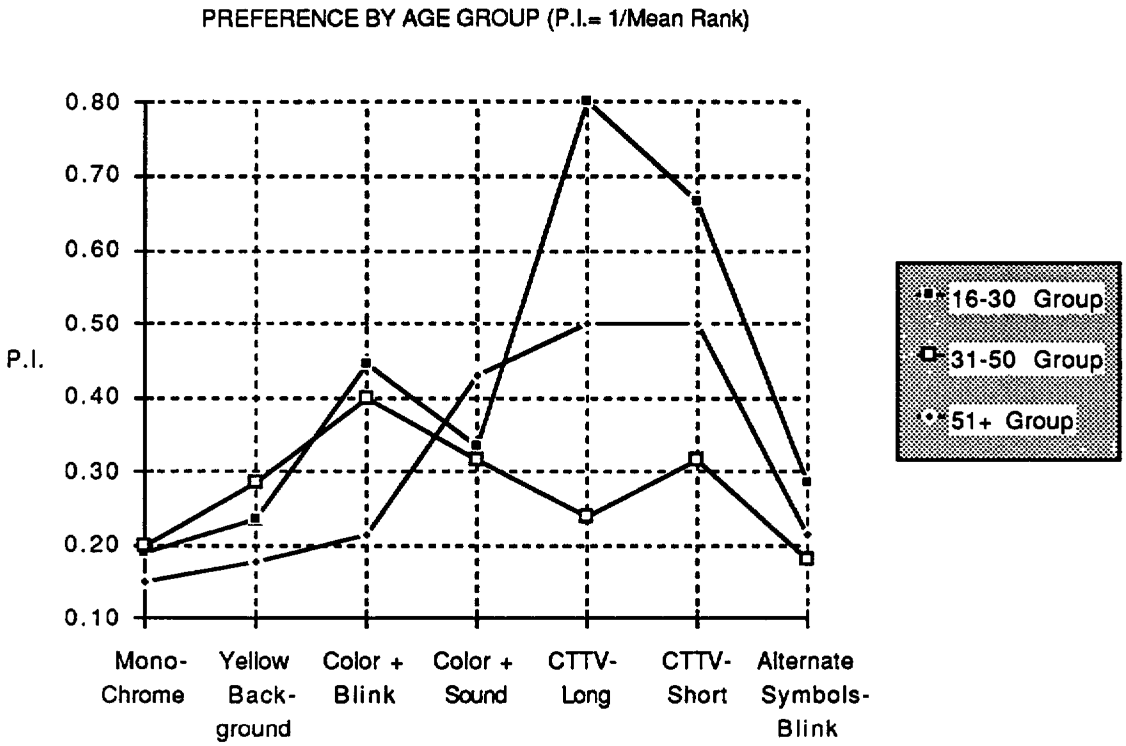

Figure 6 - 3. Preference by Age Group

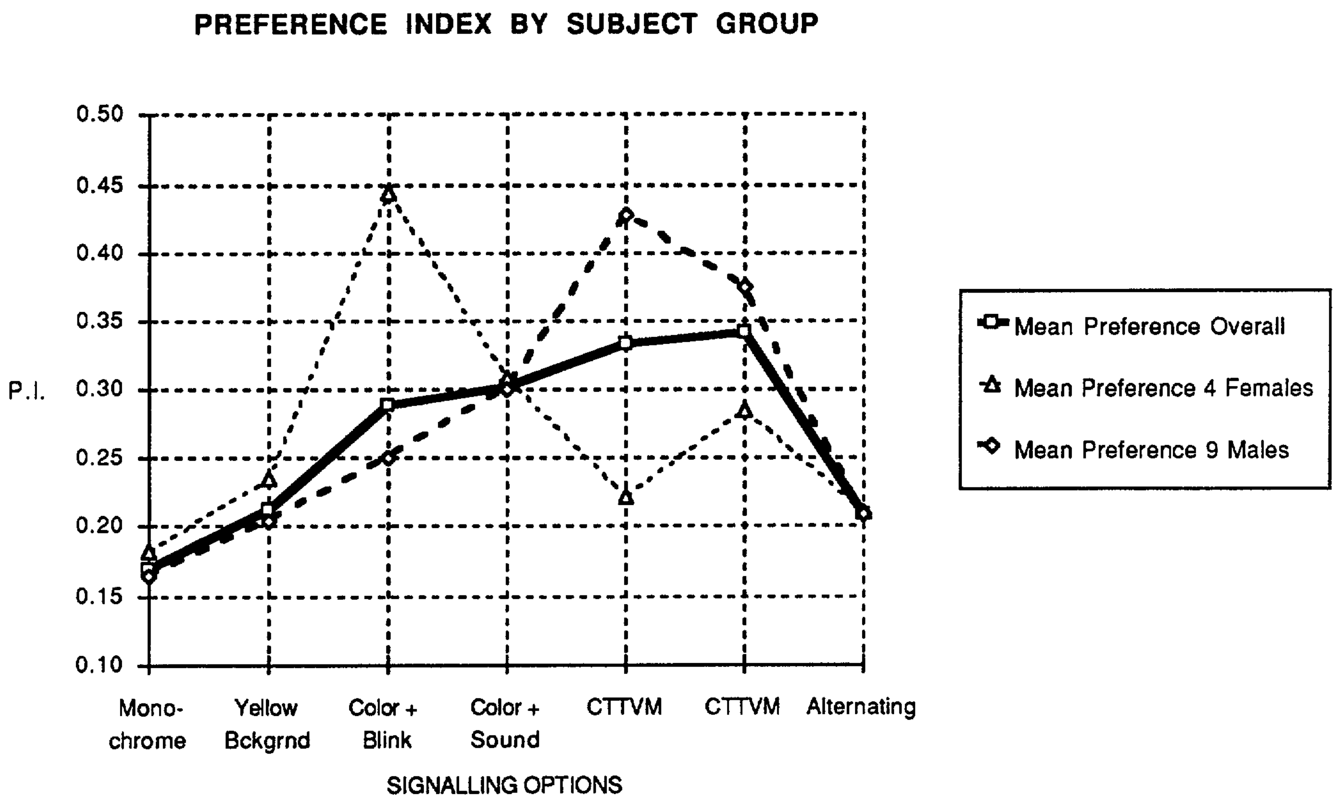

Figure 6 - 4. Mean Preference by Subject Group

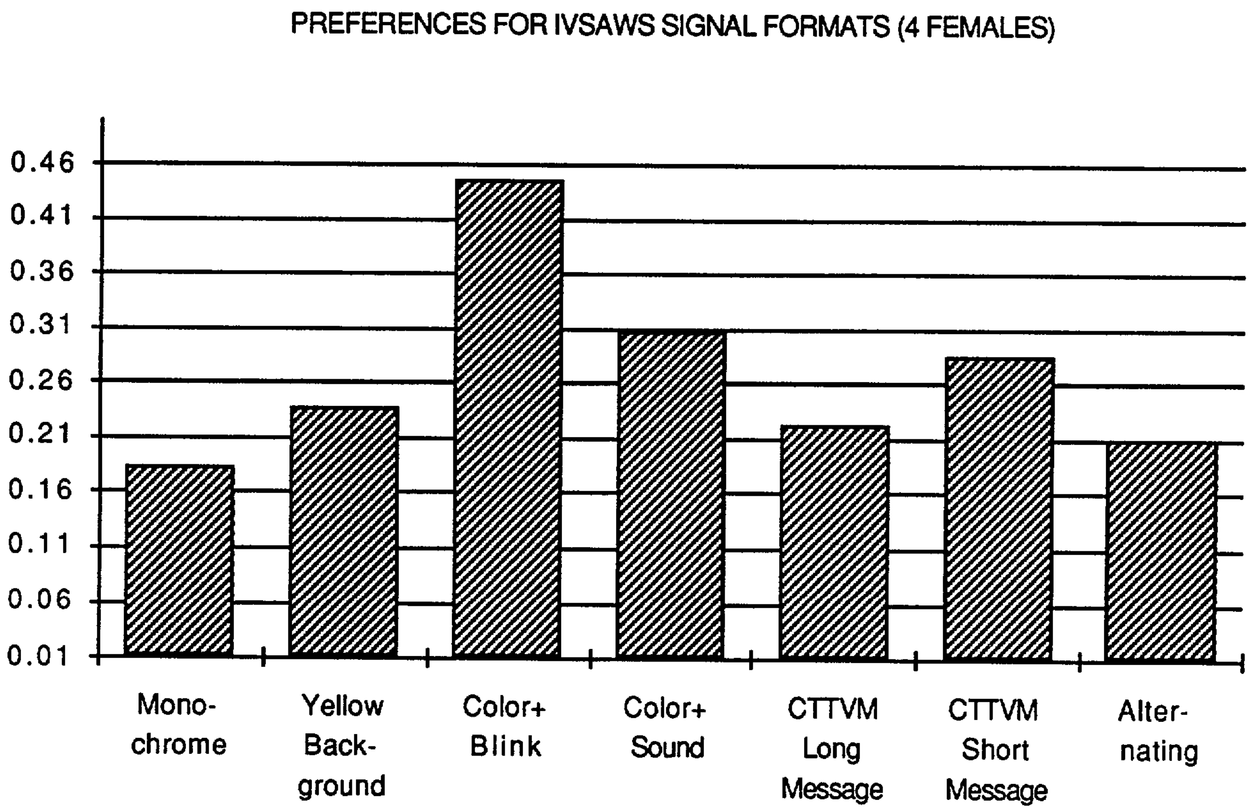

Figure 6- 5. Preference Index for Female Population Group

7.0 Conclusions/Remarks

As stated earlier, this study employed new pictograms in a static mockup with minimal automotive fidelity. In addition, the DAWS system, as a new system, was not within the tested subject's experience. The latter point did appear to deter the subjects full participation and understanding of the test. The results have indicated that the Task E study efforts will contribute to a more full definition of the basic design for the IVSAWS DAWS. The following major conclusions will be used to establish the baseline for continued validation and evaluation within Tasks F and especially within Task G. These conclusions are:

A. Overall, the subjects agreed that IVSAWS would be a substantial aid to the driver.

B. There is general accord that the combined signals using color, text, audio tone and voice messages would be most beneficial.

C. There is general accord that voice and text messages that provide meaningful hazard/traffic recommendations (e.g., alternative routes, distance to the hazard), would be more readily acceptable to the driver.

D. The subject's felt that reaching for an operational "button" would be acceptable if added information was provided beyond that presented by the pictogram.

E. Individual pictograms were recognizable, but could be confusing. Special attention should be given to standardizing the symbols, especially if side and front views are mixed.

F. Audio tone would be more meaningful if they represented the sounds associated with the expected emergency vehicle. In general, audio tones were associated with a need to attend to a function and therefore, should not be eliminated.

G. DAWS positioning within a vehicle should be guided by the extensive studies conducted by the SAE and the automotive industry.

The Task E study provided sufficient data to initiate Tasks F and G. Although further study is recommended to insure a more representative sample of driver's age and gender groupings, this can be partially alleviated within Task G. The selection of appropriate symbols/pictograms should be studied further with some support from the membership of the International Standards Organisation (ISO).

The placement of the DAWS system must also consider current vehicle designs and state-of-the-art options available in newer vehicles. As described earlier, newer data has shown a change in driver positioning and seat reference point (SgRP). This must be considered in relationship to options such as the head-up display and to vision enhancement systems. It is recommended that one or more of these options be considered during Task G and during actual driver field testing.

In conclusion, due to dynamic changes in vehicle styling and state-of-the-art electronic advancements, the IVSAWS program must stay aware of these new and changing options in order to provide a viable and cost effective product.

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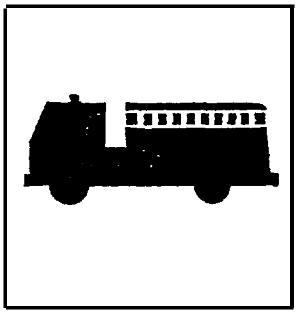
ATTACHMENT A

SAMPLE DAWS PICTOGRAMS/SYMBOLS



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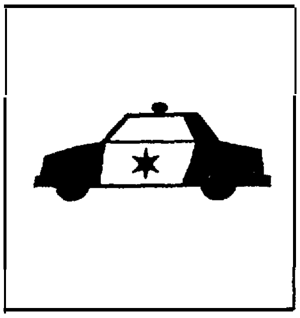

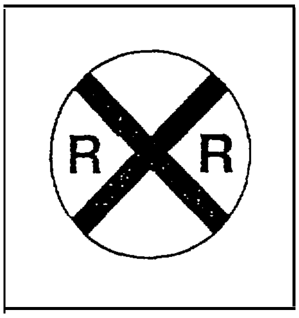
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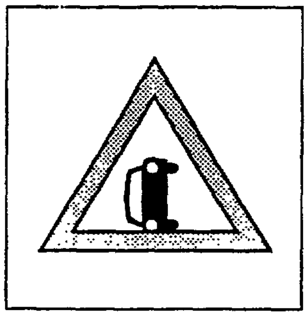
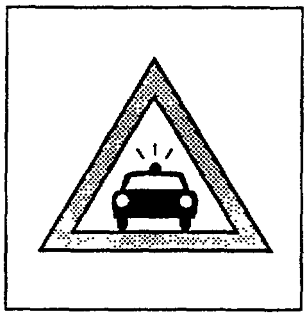




ATTACHMENT B

TASK E FREE TEXT QUESTIONNAIRE

IN-VEHICLE SAFETY ADVISORY AND WARNING SYSTEM (IVSAWS): A Study of Driver Alert Options

The In-Vehicle Safety and Warning System (IVSAWS) is a Federal Highway Administration funded study. The intent of the system is to provide the vehicle driver with appropriate advisory and warning alerts related to hazardous road situations. The system will operate using a transmitter that can be positioned at stationary locations as well as in mobile vehicles/units. The driver of a vehicle containing IVSAWS would receive a signal presentation that alerts the driver to potentially hazardous or dangerous rural or urban road conditions or situations. The situations can include crash sites as well as approaching emergency vehicles.

Your participation in this presentation will allow us to define a baseline for the actual Driver Alert Warning System (DAWS) to be located in future vehicles. The presentation will test for recognition, comprehension and effectiveness.

You will be shown eight different symbols. Each symbol will be shown individually as well as in paired configurations with different attributes. You will be asked to identify the meaning, and to evaluate your understanding, of each set of symbols. At the end of this presentation you will be asked to rank the presented symbol sets based upon their individual value and their paired attributes.

After you have read this introduction, complete the questions at the bottom of the page and inform the test monitor that you are prepared for the presentation.

Please Check one:

( ) Female ( ) Male

My Age Group is:

( ) 16-30, ( ) 31 -50, ( ) 51 -Over

My Height is:

_____Ft. _____ inches

IVSAWS TASK E - PRESENTATION INSTRUCTIONS

During this presentation, you are asked to respond to a variety of driver advisory symbols and messages. The IVSAWS system, when fully developed, will provide warning and advisory information to drivers who are in rural (country), or urban settings.

The visual presentation of driving through the countryside, or streets, will not be used during this survey. However, please consider this real-time aspect when responding to the various presentations.

Each presentation sequence is numbered 1 through 11. The sequences 1 through 8 contain sub-sets that are alphabetically coded A through F (e.g. 1.A, 1.B, 1.C,. . . . . 8.F). During the sequences A through D (e.g. 1.A, 1.B., 1.C, 1.D), after responding to the associated questions, you may move to the next screen sequence by pressing the return key. That is, 1 .A, depress return, 1.B, depress return, etc.

The presentations that are alpha-coded “E” and “F” require a different action. You will receive the presented symbol and then must reach for and activate the **mouse button** to obtain the complete signal presentation. This action simulates the physical action that must be taken in the planned Driver Advisory and Warning System design.

If you have any questions, the presentation monitor will provide the answers as appropriate. Otherwise, inform the monitor that you are ready to begin. Thank you.

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:________________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
1.A Mono.	____________	__________________	________________
1.B. Color	____________	__________________	________________
1.C. Color Flash	____________	__________________	________________
1.D. Color Tone	____________	__________________	________________
1.E. Color Tone Text (long)	____________	__________________	________________
Voice	____________	__________________	________________
1.F. Color Tone Text (short)	____________	__________________	________________
Voice	____________	__________________	________________

Which one of the above do you prefer? _________

Why? ____

What would you change or add?_________________________________

____

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:_______________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
2.A Mono.	___________	_______________	_______________
2.B. Color	___________	_______________	_______________
2.C. Color Flash	___________	_______________	_______________
2.D. Color Tone	___________	_______________	_______________
2.E. Color Tone Text (long)	___________	_______________	_______________
Voice	___________	_______________	_______________
2.F. Color Tone Text (short)	___________	_______________	_______________
Voice	___________	_______________	_______________

Which one of the above do you prefer? ________

Why? ____

What would you change or add?___________________________

____

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:________________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
3.A Mono.	___________	________________	_______________
3.B. Color	___________	________________	_______________
3.C. Color Flash	___________	_________________	_______________
3.D. Color Tone	___________	_________________	_______________
3.E. Color Tone Text (long)	___________	_________________	________________
Voice	___________	_________________	________________
3.F. Color Tone Text (short)	___________	_________________	________________
Voice	___________	_________________	________________

Which one of the above do you prefer? ________

Why? ____

What would you change or add?______________________________

____

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:________________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
4.A Mono.			
4.B. Color			
4.C. Color Flash			
4.D. Color Tone			
4.E. Color Tone Text (long)			
Voice			
4.F. Color Tone Text (short)			
Voice			

Which one of the above do you prefer? ________

Why? ____

What would you change or add?______________________________

____

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:________________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
5.A Mono.	___________	________________	_______________
5.B. Color	___________	________________	_______________
5.C. Color Flash	___________	________________	_______________
5.D. Color Tone	___________	________________	_______________
5.E. Color Tone Text (long)	___________	________________	_______________
Voice	___________	________________	_______________
5.F. Color Tone Text (short)	___________	________________	_______________
Voice	___________	________________	_______________

Which one of the above do you prefer? _________

Why? ____

What would you change or add?_________________________________

____

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:________________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
6.A Mono.	___________	________________	_______________
6.B. Color	___________	________________	_______________
6.C. Color Flash	___________	________________	_______________
6.D. Color Tone	___________	________________	_______________
6.E. Color Tone Text (long)	___________	________________	_______________
Voice	___________	________________	_______________
6.F. Color Tone Text (short)	___________	________________	_______________
Voice	___________	________________	_______________

Which one of the above do you prefer? ________

Why? ____

What would you change or add?____________________________

____

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:________________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
7.A Mono.	___________	________________	_______________
7.B. Color	___________	________________	_______________
7.C. Color Flash	___________	________________	_______________
7.D. Color Tone	___________	________________	_______________
7.E. Color Tone Text (long)	___________	________________	_______________
Voice	___________	________________	_______________
7.F. Color Tone Text (short)	___________	________________	_______________
Voice	___________	________________	_______________

Which one of the above do you prefer? ________

Why? ____

What would you change or add?____________________________

____

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:________________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
8.A Mono.	____________	__________________	________________
8.B. Color	____________	__________________	________________
8.C. Color Flash	____________	___________________	________________
8.D. Color Tone	____________	___________________	________________
8.E. Color Tone Text (long)	____________	___________________	_________________
Voice	____________	___________________	_________________
8.F. Color Tone Text (short)	____________	___________________	_________________
Voice	____________	___________________	_________________

Which one of the above do you prefer? _________

Why? ____

What would you change or add?________________________________

____

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:________________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
9.A. Color	___________	________________	_______________
9.B. Color Flash Hazard	___________	________________	_______________

Does the alternating symbols convey a message? _______________

Why? ____

What would you change or add?____________________________

____

How does the alternating symbols compare to the prior single symbol presentations?____

____

Does it convey sufficient information?_________________________

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:______________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
10.A. Color	___________	_______________	______________
10.B. Color Flash Hazard	___________	_______________	______________

Does the alternating symbols convey a message? ______________

Why? ____

What would you change or add?______________________________

____

How does the alternating symbols compare to the prior single symbol presentations?____

____

Does it convey sufficient information?________________________

IVSAWS TASK E SYMBOL SIGNALLING TEST

Symbol:_______________

Screen Frame No.	Do you Recognize it?	What meaning does it have for you?	What action would you take?
11.A. Color	__________	_______________	______________
11.B. Color Flash Hazard	__________	_______________	______________

Does the alternating symbols convey a message? _______________

Why? ____

What would you change or add?____________________________

____

How does the alternating symbols compare to the prior single symbol presentations?____

____

Does it convey sufficient information?_________________________

IVSAWS TASK E - SYMBOL SIGNALLING TEST
SUMMARY

1. What do you think of the system in general? ____________________

- -

- -

2. Are there any symbols that were less or more meaningful to you?

- -

3. Are there some symbols or messages that you would like to eliminate, combine, add-to, change, etc? ____________________

- -

4. What was the effect to you, as a driver, to have to reach for and press a key (mouse), for additional information? ____________________

- -

5. Was the additional information worth the added effort? ____________

- -

6. Do you believe this system would be an added safety benefit or an added distraction for the driver? ____________________

- -

7. Please RANK your preference, using the numbers 1 through 7, for each functional presentation:

____ One Color (Monochrome)
____ Color (Yellow Background)
____ Color and Blink/Flash
____ Color and Sound-Tone
____ Color/Tone/Text/Voice Message - Long
____ Color/Tone/Text/Voice Message - Short
____ Alternating Symbols with Hazard - Blink

ATTACHMENT C

SELECTED SAE J287 PAGES AND TABLES

Driver Hand Control Reach

-SAE J287 FEB80

SAE Recommended Practice
Completely Revised February 1980

THIS IS A PREPRINT WHICH IS SUBJECT TO REVISIONS AND CORRECTIONS. THE FINAL VERSION WILL APPEAR IN THE 1981 EDITION OF THE SAE HANDBOOK.

Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE. WARRENDALE. PA 15096

PREPRINT

[FHWA G-52]

:port of the Human Factors Engineering Committee, approved July 1976, completely revised February 1980.

1. Introduction—The description of driver hand control reach envelopes was developed using data acquired from test subjects performing reach tasks in test fixtures simulating a range of actual vehicle configurations (Ref. 1 and 2): The test subjects included equal numbers of men and women selected to represent the (United States) driving population on the basis of stature and age, and were tested both with and without upper torso three-point restraint (a diagonal non-extending shoulder strap attached separately to the lap belt, i.e., not a continuous loop). The envelopes constructed using the non-extending shoulder and lap belt are meant to define a restrained reach and the envelopes constructed using the lap belt only will describe an unrestrained upper torso hand reach. The hand reach envelopes are three-dimensional surfaces described in table form and can be referenced to a particular vehicle seating configuration according to procedures described in Sections 5 and 6. Only the 95% boundaries are presented in the tables.

2. Scope—This recommended practice describes boundaries of hand control locations that can be reached by desired proportions of different driver populations in passenger cars, multi-purpose passenger vehicles, and light and medium trucks. This practice is not applicable to heavy trucks.

3. Field of Application

3.1 This practice is primarily directed towards the initial design stages of a new vehicle program, where reference to H-point or Rearmost H-point implies Rearmost Design H-point or Seating Reference Point (SgRP). Its application for checking purposes in actual vehicles and prototype seat models will take into account an allowable tolerance for actual H-point.

3.2 The hand reach envelopes are directly applicable to left hand drive motor vehicles designed for seated operators in full width or single width seats having fore and aft seat adjustment approximately horizontal. Application to right hand drive vehicles is assumed to be symmetrically opposite.

3.3 The hand reach envelopes are directly applicable for a three-finger grasping reach to a forward mounted control knob of 25 mm diameter maneuvered horizontally in the fore-aft direction. The hand reach envelopes also applicable to other types of reach to forward controls by using an ,propriate adjustment factor that will account for the mode of operation of the control (Ref. 3).

3.3.1 Extended Finger Operated Control—An adjustment factor of 50 mm is added to the tabled values of the reach envelope in order to describe the center of the finger pad contact surface which will be within the reach of drivers.

3.3.2 Full Hand Grasped Control—An adjustment factor of 50 mm is subtracted from the tabled values of the reach envelope in order to describe the center of the face of the control knob which will be within the reach of drivers.

4. Definitions

4.1 Driver Hand Reach Capability—The maximum reach capability of drivers in a simulated driving situation with the non-reaching hand on the steering wheel and the right foot on the accelerator pedal.

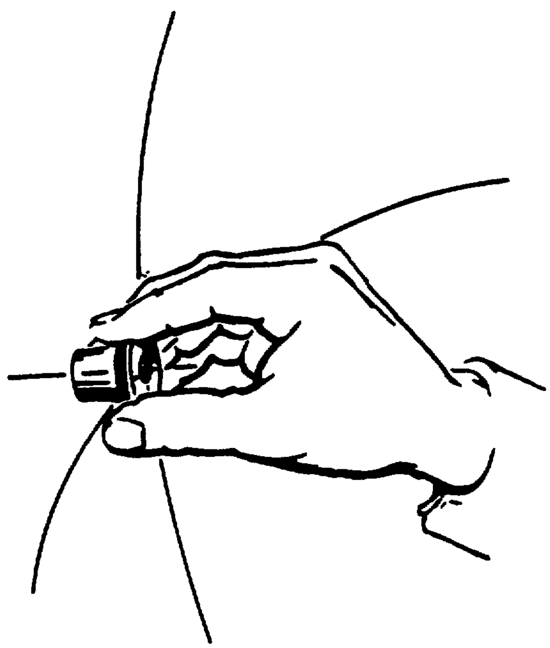
4.2 Basic Reach Task—The hand reach to a forward mounted control with the control held in a three-finger grasp. See Fig. 1.

4.3 Hand Reach Envelopes—Geometric description of the hand reach capability for a specified proportion of a driver population and type of torso restraint system. The contour of the hand reach envelope refers to the geometric center of the control knob face. If the control knob face is at, or rearward of, the contour, it is estimated that at least the specified proportion of the indicated driver population can reach and operate the control.

4.4 Hand Reach Reference Plane (HR Plane)—A vertical reference plane extending laterally across the vehicle used to properly position the hand reach envelopes with respect to the geometry of the vehicle seating configuration. The horizontal location of the HR plane rearward of the Accelerator Heel Point is determined by application of the General Package Factor (G) as shown below:

$$HR = 786 - (99)\,G,\ \text{mm}$$

4.5 Interior Dimensions—All interior dimensions referred to in this ommended practice, except where noted, are defined in SAE Recom-.nded Practice, J1100a, Motor Vehicle Dimensions. All dimensions are



This diagram represents a three-finger grasping reach to a 25 mm (1.0 in.) diameter control knob. All measurements for the hand-reach envelope are referenced to the centre of the control knob face.

FIG. 1—THREE-FINGER GRASPING REACH

defined normal to the three-dimensional reference system of the vehicle loaded to design load weight and oriented to a ground reference plane using fiducial marks as described in SAE Recommended Practice, J182a, Vehicle Fiducial Marks.

The characteristics of seat geometry are described in terms of the two- and three-dimensional H-point devices with 95 percentile leg length adjustments as described in SAE Recommended Practice, J826b, Devices for Use in Defining and Measuring Vehicle Seating Accommodation. The interior dimensions are measured with the front seat in the rearmost normal driving position as specified by the manufacturer. All other adjustable features, such as steering wheel, seat height, or tilt adjustment for the seat back or seat cushion, are also located as specified by the manufacturer, and if not specified will be positioned at a normal driving position.

4.5.1 General Package Factor (G)—An algebraic equation that expresses and summarizes the geometry of a particular vehicle seating configuration in terms of a single index value. See Figs. 2 and 3. The range of package dimensions for which this recommended practice is applicable is shown below:

L40	Back angle-front	9.0 deg	33.0 deg
H30	Vertical SgRP to heel pt	130 mm	to 520 mm
L23	Horizontal Hpt travel, SgRP	130 mm	nominal
W9	Steering wheel diameter	330 mm	to 600 mm
H18	Steering wheel angle	10.0 deg	to 70.0 deg
L11	Horizontal steering wheel center	660 mm	to 152 mm
H17	Vertical steering wheel center	530 mm	to 838 mm

4.5.2 Centerline of Occupant (C/LO)—Centerline of occupant is the "Y" coordinate of the H-point and is represented by the centerplane of the occupant or H-point machine in each designated seating position.

4.5.3 Accelerator Heel Point (AHP)—Accelerator heel point is located at the intersection of the two- or three-dimensional device heel point and the depressed floor covering with the shoe on the undepressed accelerator pedal and the foot angle at a minimum of 87 deg. For vehicles with SgRP

The ϕ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

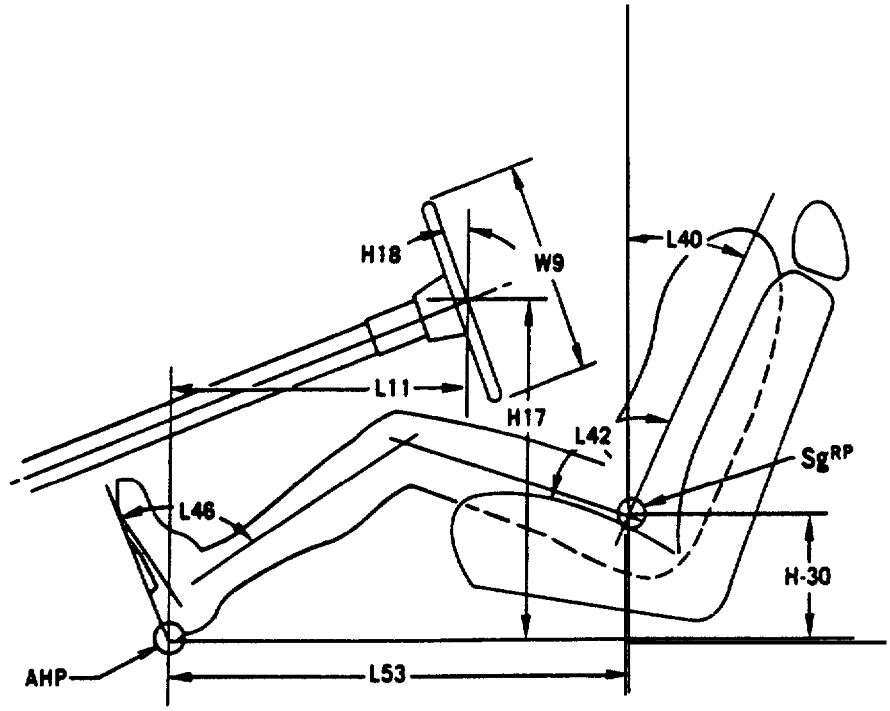


FIG. Z-VEHICLE SEATING CONFIGURATION

The General Package Factor(G) is a synthesized variable that provides a quantitative index of a vehicle's workspace geometry. The G value for a vehicle can be calculated by substituting the principal package dimensions in millimeters into the equation shown below.

G = 0.0018 (H30) – 0.0197 (L40) + 0.0027 (W9) + 0.0106 (HI8) – 0.0011 (L11) + 0.0024 (H17) + 0.0027 (L42) – 03.0853

FIG. S-GENERAL PACKAGE FACTOR (G)

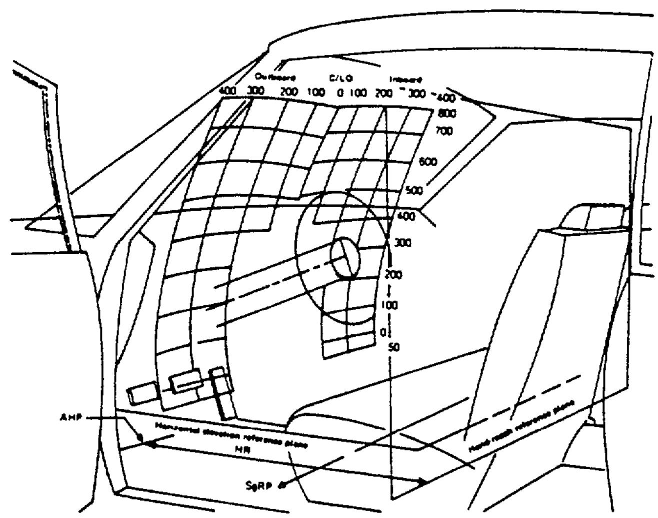


FIG. 4-HAND REACH ENVELOPES IN VEHICLE POSITION

to heel (H30) greater than 457 mm, the accelerator pedal may be depressed as specified by the manufacturer. If the depressed pedal is used. the foot must be flat on the accelerator pedal

5. Required Characteristics

5.1 The ranges of the interior dimensions for which this recommended practice is applicable is described in paragraph 4.5.

5.2 The envelopes describe the boundaries of control locations that can be reached by at least 95% of certain driver populations that include mixtures of 50/50, 75/25, and 90/10 male to female driver population ratios. The envelopes for each of these categories arc described as referenced in a fore and aft diction to specified seating coordinates. The envelopes extend from 400 mm outboard to 600 mm inboard of operator centerline and from -100 mm below H-point to 800 mm above H-point See Fig. 4.

5.9 Hand reach envelopes arc provided in the attached tasks for seven different seating configurations, three male to female driver population ratios and two types of restraint systems which account for drivers wearing a lap belt only permitting a free upper torso and unrestrained reach; and secondly, both lap and shoulder belt permitting only a restrained reach. The selection of an envelope for a vehicle is based on the calculated value of the General Package Factor(G). identification of the male to female driver population appropriate for the vehicle, and the identification of the appropriate restraint system. The General Package Factor(G) is calculated using the dimensions describing the vehicle seating configuration as shown in Figs. 2 and 3.

5.4 The Hand Reach Envelope is located in the vehicle by employing a relationship that utilizes the value of the General Package Factor(G). The horizontal component of the envelope is measurcd as a distance forward of a Hand Reach Reference Plane. The fore and aft location of this plane rearward from the Accelerator Heel Point is determined from the value of the General Package Factor (G) as shown in paragraph 4.4.

6. Procedure for Using the Hand Reach Envelopes

6.1 The envelopes arc located in the vehicle according to a set of orthogonal reference planes: A horizontal elevation reference plane through the H-point of the rearmost normal driving position, the lateral HR plane, and a vertical plane extending along the C/LO. See Fig. 4.

6.1.1 Establish a reference origin.

6. X.1.1 Specify the dimensions describing the geometry of the vehic' seating configuration and calculate the value of the General Package Facto. (G) as described in Fig. 3.

6.1.1.2 Calculate HR from the value of the General Package Factor (G) as shown in paragraph 4.4. Determine the longitudinal location of the hand reach reference plane by comparing HR to L53, the horizontal distance from SgRP to Accelerator Heel Point.

6.1.1.2.1 If (HR-L53) is less than zero, then the hand reach reference ane is located longitudinally at a distance (HR) rearward of the Accelerator el Point.

6.1.1.2.2 If (HR-L53) is greater than zero, the hand reach reference plane is located longitudinally at the H-point of the rearmost normal driving position.

6.1.2 Identify the appropriate hand reach envelope.

6.1.2.1 Referring to the attached tables, identify the hand reach envelope appropriate for the value of the General Package Factor (G) calculated for this vehicle, the specified driver population, and the appropriate type of restraint system.

6.1.2.2 Determine the lateral locations of the controls of interest. These locations will be described as lateral locations from the (C/LO). Determine the height of the control above the horizontal elevation reference plane described in paragraph 6.1.

6.1.3 Determine if the control is within reach[1].

[1] The blank areas in the hand reach tables are regions where hand reach was not measured or where design limit values could not be established. The gray areas are regions where the difference between the hand reach model and the observed design limit values exceeded 25 mm. The reach values shown in these areas should be used cautiously.

6.1.3.1 The limiting value of reach can be read from the appropriate table at the designated elevation and station locations. Interpolation may be required if the necessary locations are not included in the table. Interpolate laterally first before interpolating vertically. Curvilinear interpolations should be made using two locations on either side of the desired control.

7. References

1. D. Hammond and R. Roe, "SAE Controls Reach Study." Paper 720199 presented at SAE Automotive Engineering Congress and Exposition, Detroit, January 1972.

2. D. Hammond, D. Maurer, and L. Razgunas, "Controls Reach—The Hand Reach of Drivers." Paper 750357 presented at SAE Automotive Congress and Exposition, Detroit, February 1975.

3. R. W. Roe, "Reach to Other Types of Controls." Minutes of meeting of Design Devices Subcommittee, SAE Human Factors Engineering Committee, April 18, 1972.

TABLE 1

HAND REACH-RESTRAINED VEHICLE RANGE: (G LESS THAN -1.25) POPULATION MIX: 50/50 MALES-TO-FEMALES

(INCH)

HORIZONTAL REACH FORWARD OF THE HR REFERENCE PLANE AT STATIONS LOCATED LATERALLY FROM THE CENTERLINE OF OPERATOR (C L/O) AND AT ELEVATIONS ABOVE THE REARMOST H POINT. THE ENVELOPE DESCRIBES A 95% LEVEL OF PERFORMANCE OF A DRIVER POPULATION COMPOSED OF 50% MALE AND 50% FEMALE DRIVERS WEARING A TYPE 2a RESTRAINT.

ELEVATION ABOVE H PT (inch)	STATIONS OUTBOARD OF C L/O (inch)						
	15.0	12.5	10.0	7.5	5.0	2.5	0.0
35.0	12.4	13.8	15.0	15.9	16.5	16.9	17.0
32.5	14.8	16.1	17.1	17.9	18.4	18.8	19.1
30.0	16.9	18.1	18.9	19.6	20.0	20.4	20.7
27.5	18.7	19.7	20.5	21.0	21.4	21.7	21.9
25.0	20.1	21.0	21.7	22.2	22.5	22.7	22.7
22.5	21.2	22.1	22.7	23.1	23.4	23.4	23.2
20.0	22.0	22.8	23.4	23.8	24.0	23.8	23.8
17.5	22.6	23.3	23.9	24.3	24.4	23.9	22.9
15.0	22.8	23.5	24.1	24.5	24.5	23.8	22.3
12.5	22.8	23.4	24.1	24.6	24.4	23.4	21.3
10.0	22.4	23.0	23.8	24.3	24.2		
7.5	21.9	22.4	23.3	23.9	23.6		
5.0	21.0	21.6	22.6	23.3			
2.5	19.9	20.5	21.6	22.4			
0.0	18.6	19.2					
-2.5	17.0	17.6					

ELEVATION ABOVE H PT (inch)	STATIONS INBOARD OF C L/O (inch)									
	0.0	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5
35.0	16.9	17.0	17.1	16.9	16.3	15.4	14.2	18.2	11.8	
32.5	18.7	19.0	19.1	18.8	18.3	17.4	[illegible]	15.1	13.6	
30.0	20.3	20.8	20.8	20.5	20.0	19.2	[illegible]	[illegible]	[illegible]	
27.5	21.7	22.2	22.3	22.0	21.5	20.8	19.9	19.0	17.8	16.4
25.0	22.7	23.4	23.5	23.3	22.8	22.1	21.4	20.5	19.4	17.9
22.5	23.6	24.3	24.4	24.3	23.9	23.3	22.6	21.7	20.6	19.0
20.0	24.1	24.9	25.1	25.0	24.7	24.2	23.6	22.7	21.5	19.9
17.5	24.4	25.2	25.5	25.6	25.4	24.9	24.3	23.3	22.1	20.5
15.0	24.4	25.2	25.7	25.9	25.8	25.4	24.7	23.7	22.4	20.8
12.5	24.2	24.9	25.5	26.0	26.1	25.7	25.0	23.8	22.4	20.8
10.0			25.1	25.8	26.1	25.8	24.9	23.6	22.0	20.5
7.5			24.4	25.4	25.9	25.6	24.7	23.1	21.4	19.9
5.0				24.7	25.4	25.3	24.2	22.3	20.4	19.0
2.5				23.9	24.8	24.7	23.4	21.3	19.0	17.8
0.0				22.7	23.9	23.8	22.4	19.9	17.4	16.2
-2.5				21.4	22.9	22.8	21.1	18.3	15.4	14.4

TABLE 2

HAND REACH-RESTRAINED VEHICLE RANGE: (G LESS THAN -1.25) POPULATION MIX: 75/25 MALES-TO-FEMALES

(INCH)

HORIZONTAL REACH FORWARD OF THE HR REFERENCE PLANE AT STATIONS LOCATED LATERALLY FROM THE CENTERLINE OF OPERATOR (C L/O) AND AT ELEVATIONS ABOVE THE REARMOST H POINT. THE ENVELOPE DESCRIBES A 95% LEVEL OF PERFORMANCE OF A DRIVER POPULATION COMPOSED OF 75% MALE AND 25% FEMALE DRIVERS WEARING A TYPE 2a RESTRAINT.

ELEVATION ABOVE H PT (inch)	STATIONS OUTBOARD OF C L/O (inch)							STATIONS INBOARD OF C L/O (inch)									
	15.0	12.5	10.0	7.5	5.0	2.5	0.0	0.0	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5
35.0	13.8	15.2	16.4	17.2	17.5	18.1	18.2	18.5	19.7	18.7	18.5	17.9	17.0	15.8	14.5	13.1	
32.5	16.2	17.4	18.4	19.1	19.6	20.0	20.3	20.2	20.6	20.6	20.3	19.8	18.9	17.9	16.7	15.5	
30.0	18.2	19.3	20.2	20.8	21.2	21.5	21.9	21.7	22.2	22.2	21.9	21.4	20.6	19.7	18.7	17.5	
27.5	19.9	20.9	21.7	22.2	22.5	22.8	23.0	22.9	23.5	23.6	23.3	22.8	22.1	21.3	20.4	19.2	17.8
25.0	21.3	22.2	22.9	23.3	23.6	23.7	[illegible]	[illegible]	24.6	24.7	24.5	24.0	23.4	22.7	21.8	20.7	19.1
22.5	22.4	23.2	23.8	24.2	24.4	24.4	[illegible]	[illegible]	25.4	25.6	25.4	25.0	24.5	23.8	22.9	21.8	20.2
20.0	23.2	23.9	24.5	24.9	25.0	24.7	[illegible]	[illegible]	25.8	26.1	26.1	25.8	25.3	24.7	23.8	22.6	21.0
17.5	23.6	24.3	24.9	25.3	25.3	24.8	23.6	25.3	26.0	26.4	26.5	26.4	26.0	25.3	24.3	23.1	21.5
15.0	23.8	24.5	25.1	25.5	25.4	24.6	22.9	25.2	25.9	26.5	26.8	26.7	26.4	25.7	24.6	23.2	21.6
12.5	23.7	24.4	25.1	25.5	25.3	24.1	21.7	24.9	25.5	26.2	26.8	26.9	26.6	25.8	24.6	23.1	21.5
10.0	23.4	24.0	24.8	25.3	25.0					[illegible]	26.5	26.8	26.6	25.7	24.3	22.6	21.1
7.5	22.7	23.4	24.3	24.8	24.4					[illegible]	26.0	26.5	26.3	25.3	23.7	21.8	20.4
5.0	21.9	22.5	23.5	24.2							25.3	26.0	25.9	24.7	22.8	20.7	19.4
2.5	20.7	21.4	22.6	23.3							24.3	25.3	25.2	23.8	21.6	19.2	18.0
0.0	19.3	20.1									23.1	24.4	24.3	22.7	20.1	17.5	16.4
-2.5	17.7	18.5									21.6	23.2	23.1	21.3	18.3	15.4	14.4

TABLE 3

HAND REACH-RESTRAINED VEHICLE RANGE:(G LESS THAN -1.25) POPULATION MIX: 90/10 MALES-TO-FEMALES

(INCH)

HORIZONTAL REACH FORWARD OF THE HR REFERENCE PLANE AT STATIONS LOCATED LATERALLY FROM THE CENTERLINE OF OPERATOR (C L/O) AND AT ELEVATIONS ABOVE THE REARMOST H POINT. THE ENVELOPE DESCRIBES A 95% LEVEL OF PERFORMANCE OF A DRIVER POPULATION COMPOSED OF 90% MALE AND 10% FEMALE DRIVERS WEARING A TYPE 2a RESTRAINT.

ELEVATION ABOVE H PT (inch)	STATIONS OUTBOARD OF C L/O) (inch)							STATIONS INBOARD OF C L/O (inch)									
	15.0	12.5	10.0	7.5	5.0	2.5	0.0	0.0	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5
35.0	14.7	16.1	17.1	18.0	18.5	18.9	19.0	19.4	19.6	19.7	19.4	18.9	18.0	16.8	15.5	14.2	
32.5	17.0	18.2	19.2	19.9	20.3	20.7	21.0	21.1	21.5	21.5	21.2	20.7	19.8	18.4	17.7	16.4	
30.0	19.0	20.1	20.9	21.5	21.9	22.2	22.5	22.5	23.0	23.1	22.8	22.2	21.5	20.6	19.6	18.4	
27.5	20.7	21.7	22.4	22.8	23.2	23.4	23.7	23.7	24.3	24.4	24.1	23.6	22.9	22.1	21.2	20.1	18.6
25.0	22.0	22.9	23.5	24.0	24.2	24.3	24.4	[illegible]	25.3	25.4	25.2	24.8	24.2	23.4	22.6	21.4	19.9
22.5	23.1	23.9	24.5	24.9	25.0	24.9	24.6	[illegible]	26.0	26.2	26.1	25.7	25.2	24.5	23.6	22.5	20.9
20.0	23.8	24.6	25.2	25.5	25.6	25.3	24.5	[illegible]	26.4	26.7	26.7	26.4	26.0	25.3	24.4	23.2	21.6
17.5	24.3	25.0	25.6	25.9	25.9	25.3	24.0	25.8	26.5	27.0	27.1	27.0	26.6	25.9	24.9	23.6	22.0
15.0	24.4	25.1	25.8	26.1	26.0	[illegible]	[illegible]	25.7	26.4	26.9	27.3	27.3	26.9	26.2	25.1	23.7	22.1
12.5	24.3	25.0	25.7	26.1	25.8	[illegible]	[illegible]	25.3	25.9	26.7	27.2	27.4	27.1	26.3	25.0	23.5	21.9
10.0	23.9	24.6	25.4	25.8	25.4					[illegible]	26.9	27.3	27.0	26.1	24.6	22.9	21.4
7.5	23.3	24.0	24.9	25.4	24.8					[illegible]	26.4	26.9	26.7	25.7	24.0	22.1	20.7
5.0	22.4	23.1	24.1	24.7							25.6	26.4	26.2	25.0	23.0	20.9	19.6
2.5	21.2	22.0	23.1	23.8							24.5	25.6	25.5	24.0	21.7	19.3	18.2
0.0	19.8	20.6									23.3	24.6	24.5	22.9	20.8	17.5	16.5
-2.5	18.2	19.0									21.8	23.4	23.3	21.4	18.3	15.3	14.4

TABLE 20

HAND REACH-RESTRAINED VEHICLE RANGE: (G GREATER THAN 1.25) POPULATION MIX: 75/25 MALES-TO-FEMALES

(INCH)

HORIZONTAL REACH FORWARD OF THE HR REFERENCE PLANE AT STATIONS LOCATED LATERALLY FROM THE CENTERLINE OF OPERATOR (C L/O) AND AT ELEVATIONS ABOVE THE REARMOST H POINT. THE ENVELOPE DESCRIBES A 95% LEVEL OF PERFORMANCE OF A DRIVER POPULATION COMPOSED OF 75% MALE AND 25% FEMALE DRIVERS WEARING A TYPE 2a RESTRAINT.

ELEVATION ABOVE H PT (inch)	STATIONS OUTBOARD OF C L/O (inch)							STATIONS INBOARD OF C L/O (inch)									
	15.0	12.5	10.0	7.5	5.0	2.5	0.0	0.0	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5
35.0	15.1	16.6	17.8	18.7	19.3	19.7	19.9	20.0	20.3	20.4	20.1	19.5	18.6	17.5	16.2	14.8	
32.5	17.3	18.6	19.7	20.4	21.0	21.4	21.7	21.7	22.2	22.3	22.0	21.4	20.6	19.7	18.5	17.3	
30.0	19.2	20.4	21.3	22.0	22.4	22.8	23.1	23.2	23.8	23.9	23.6	23.1	22.4	21.5	20.5	19.3	
27.5	20.8	21.9	22.7	23.3	23.7	24.0	24.2	24.4	25.1	25.2	25.0	24.5	23.9	23.1	22.2	21.0	19.5
25.0	22.1	23.1	23.8	24.3	24.7	24.9	25.1	25.3	26.1	26.3	26.1	25.7	25.2	24.5	23.6	22.4	20.8
22.5	23.1	24.0	24.7	25.2	25.4	25.5	25.4	25.9	26.7	27.0	27.0	26.7	26.2	25.5	24.6	23.4	21.8
20.0	23.9	24.7	25.3	25.8	26.0	25.9	25.5	26.3	27.1	27.5	27.6	27.4	27.0	26.3	25.4	24.1	22.5
17.5	24.3	25.0	25.7	26.1	26.3	26.0	25.2	26.4	27.1	27.7	28.0	28.0	27.6	26.9	25.8	24.4	22.9
15.0	24.5	25.1	25.8	26.3	26.4					27.6	28.1	28.3	28.0	27.2	26.0	24.5	22.9
12.5	24.4	25.0	25.7	26.2	26.2					27.2	28.0	28.3	28.1	27.2	25.8	24.2	22.7
10.0	24.0	24.5	25.2	25.7						26.6	27.7	28.2	28.0	27.0	25.4	23.6	22.2
7.5	23.3	23.8	24.7	25.3						25.7	27.1	27.9	27.7	26.6	24.7	22.7	21.4
5.0	22.4	22.8	23.8	24.6							26.3	27.3	27.2	25.9	23.7	21.5	20.3
2.5	21.2	21.5	22.7	23.6							25.3	26.6	26.5	25.0	22.5	20.0	18.9
0.0	19.7	20.0	21.3	22.4							24.0	25.6	25.6	23.8	21.0	18.2	17.3
-2.5	17.9	18.3	19.7	21.0							22.6	24.4	24.4	22.5	19.2	16.2	15.4

TABLE 21

HAND REACH-RESTRAINED VEHICLE RANGE: (G GREATER THAN 1.25) POPULATION MIX: 90/10 MALES-TO-FEMALES

(INCH)

HORIZONTAL REACH FORWARD OF THE HR REFERENCE PLANE AT STATIONS LOCATED LATERALLY FROM THE CENTERLINE OF OPERATOR (C L/O) AND AT ELEVATIONS ABOVE THE REARMOST H POINT. THE ENVELOPE DESCRIBES A 95% LEVEL OF PERFORMANCE OF A DRIVER POPULATION COMPOSED OF 90% MALE AND 10% FEMALE DRIVERS WEARING A TYPE 2a RESTRAINT.

ELEVATION ABOVE H PT (inch)	STATIONS OUTBOARD OF C L/O (inch)							STATIONS INBOARD OF C L/O (inch)									
	15.0	12.5	10.0	7.5	5.0	2.5	0.0	0.0	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5
35.0	16.2	17.6	18.7	19.6	20.3	20.7	20.8	20.8	21.2	21.2	20.9	20.3	19.5	18.4	17.1	15.7	
32.5	18.3	19.6	20.6	21.4	21.9	22.3	22.6	22.5	23.0	23.1	22.8	22.2	21.4	20.5	19.4	18.1	
30.0	20.1	21.3	22.2	22.9	23.3	23.7	24.0	24.0	24.6	24.7	24.4	23.9	23.2	22.3	21.3	20.1	
27.5	21.7	22.8	23.5	24.1	24.5	24.8	25.1	25.1	25.8	26.0	25.7	25.3	24.6	23.9	23.0	21.8	20.2
25.0	23.0	23.9	24.6	25.1	25.5	25.7	25.8	26.0	26.8	27.0	26.8	26.4	25.9	25.2	24.3	23.1	21.5
22.5	23.9	24.8	25.5	25.9	26.2	26.3	26.2	26.6	27.4	27.7	27.7	27.4	26.9	26.2	25.3	24.1	22.5
20.0	24.6	25.4	26.1	26.5	26.7	26.6	26.2	27.0	27.7	28.1	28.3	28.1	27.7	27.0	26.0	24.8	23.1
17.5	25.1	25.8	26.4	26.9	27.0	26.7	25.9	27.0	27.8	28.3	28.6	28.6	28.2	27.5	26.4	25.1	23.5
15.0	25.2	25.9	26.5	27.0	27.1					28.2	28.7	28.9	28.6	27.8	26.6	25.1	23.5
12.5	25.1	25.6	26.4	26.9	26.9					27.8	28.6	28.9	28.7	27.8	26.4	24.8	23.3
10.0	24.6	25.2	26.0	26.5						27.2	28.2	28.8	28.6	27.6	26.0	24.2	22.7
7.5	23.9	24.4	25.3	26.0						26.3	27.7	28.4	28.3	27.1	25.2	23.2	21.9
5.0	21.0	23.4	24.4	25.2							26.8	27.9	27.7	26.4	24.2	22.0	20.8
2.5	21.7	22.1	23.3	24.2							25.3	27.1	27.0	25.5	23.0	20.5	19.4
0.0	20.2	20.6	21.9	22.9							24.5	26.1	26.0	24.3	21.4	19.7	17.7
-2.5	19.4	18.8	20.2	21.5							23.1	24.9	24.9	22.9	19.6	16.6	15.8

APPENDIX H:
PROPOSAL FOR THE INVEHICLE ADVISORY AND WARNING SYSTEM (IVSAWS)

This appendix outlines an industry proposal submitted to FHWA in response to Request for Proposal DTFH6 1-90-R-0030 for an Invehicle Safety Advisory and Warning System (IVSAWS).

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2. Overview of the Technical Approach

R.FP Ref: SOW Tasks A-K; Section L.I.A.

The In-Vehicle Safety Advisory and Warning System (IVSAWS) Program requires **a multi-discipline systems analysis approach to identify and help resolve the key issues in configuring a viable system design. Hughes approach** assumes **that the RF communications and the In-Vehicle Driver Alert System designs must** support **evolutionary capabilities for multiple highway information distribution systems.**

The IVSAWS Study Program is a multi-phase study intended to provide the Government with an assessment of the IVSAWS concept, a baseline design for the development of operational NSAWS hardware, and preliminary testing of all aspects of the IVSAWS system. These aspects include the RF communications, the in-vehicle man machine interface, and the measured responses of a scientifically selected population of mixed ages to the utility of the hazard alert warnings.

An example of such evolutionary requirements, directly applicable to this study, is Hughes role as the TRAVTEK system engineer in a partnership with the American Automobile Association, the City of Orlando, Florida, the Florida Depamnent of Transportation, and the Federal Highway Administration. TRAVTEK is a proof of concept test program involving a finite quantity of vehicles within a specific geographical area, which is a highly urban environment. Its purpose is to aid the driver of the vehicle in the selection of the best route to a designated destination, taking into consideration current traffic conditions. The major functions of this project are navigation and location of vehicles, real-time traffic information, route selection and guidance, and two-way communications. Hughes has studied the data radio communications requirements with the intent of defining technical approaches that meet the requirements of the program.

The phases of the IVSAWS study and the key issues or outputs of each phase are summarized in Table A.l-1. Tasks C and E require careful systems engineering effort to determine the optimum design for the RF communications equipment and message structure (Task C) and the man-machine interface (Task E). Rather than designing these systems for the IVSAWS scenarios, Hughes recommends expanding the task so that the architecture will support evolutionary growth in the capability to display/announce data to the driver.

The key issue in Task C is that the communications equipment must support a variety of message types and ensure that they are received properly with a low probability of false message acceptance and without garbling in a multiple transmitter environment. To support evolutionary requirements, the IVSAWS baseline receiver design must also be sufficiently flexible to support other services such as reception of data from intelligent highways and status data at freeway on ramps. The selection of the link bandwidth and modulation must, therefore, support these evolutionary capabilities.

The use of low power spread spectrum modulation services has been given approval by the FCC. Spread spectrum modulation allows receivers to separate interfering signals on a common RF channel. Because the complexity of such a receiver is enormous in terms of conventional lumped element techniques, Hughes is working with Delco to develop an all-digital radio with A/D conversion directly in the AM/FM frequency band This development will allow direct application of the semiconductor chip technology to the design of a sophisticated receiver. This type of chip is called an Application Specific Integrated Circuit (ASIC).

ASICs with a complexity of 100,000 transistors are currently within the state of the art, and the level of economically achievable complexity is growing logarithmically with time. Of course, the availability of a market of five to ten million units per year is ideal to cover the large non-recurring engineering cost associated with the development of a complex ASIC-based receiver.

TABLE Al-l.
HIGHLIGHTS AND KEY ISSUES OF THE IVSAWS PROGRAM

Task A Establish a plan for the whole study and obtain written COTR approval.

Task B Define a prioritized list of hazards together with likely road geometries, terrain, speed, and other factors. Human factors and traffic engineers must reach a consensus on the amount and type of information that will provide adequate warning without distracting or annoying the driver.

Task C Define the baseline IVSAWS RF link and Man Machine Interface to support reliable, timely, and unambiguous distribution and announcing of hazard alert information. Obtain written approval of results by COTR. The communications engineers must define a communications architecture to support general evolutionary services and to support reliable message transmission with sufficient flexibility to allow processing of inhibit and multi-mode antenna message overhead. The choice of frequency, bandwidth, and modulation structure must suppon an affordable design.

Task D Select readily available, affordable radio, digital modem equipment and display/announcing equipment to demonstrate key features of the baseline IVSAWS design.

Task E Select equipment to announce IVSAWS hazard alert message for the test program. Obtain written approval of the COTR. Human factors engineers must look at the range of available and projected man-machine interface technologies to ensure that the architecture will support evolutionary changes.

Task F Design and fabricate test program equipment and install it in test vehicles and for roadside operation.

Task G Test IVSAWS equipment using a mix of young, middle aged, and over age 65 drivers to determine the utility of the key design features. The test must be designed to allow a clear validation of the baseline architecture and to support the development plans for subsequent phases.

Task H Develop a system level specification for the baseline IVSAWS design to support a later development phase.

Task I Provide a four-page technical summary of the key results in the selected two-column format.

Task J Prepare and deliver Draft Technical Report for COTR approval.

Task K Prepare and deliver Final Technical Report.

3. Application of the SHAWS Feasibility Report in the Hughes Approach

RFP Ref: SOW Task B; Section L.1.A

The SHAWS feasibility report is an excellent piece of technical work and makes a substantial contribution toward the development of an IVSAWS system. The Hughes approach improves the future growth and robustness deficiencies of the SHAW approach with an alternate design, which supports a more flexible communication architecture that can be built inexpensively using advanced semiconductor chip designs to incorporate capabilities in support of future highway information distribution systems.

The report, "Feasibility and Concept Selection of a Safety Hazard Advance Warning System (SHAWS) (Report No. FHWA-B1/124) by the Commonwealth Research Corporation is excellent and delineates most of the key issues associated with the development and deployment of an IVSAWS system. The discussions of scenarios for the deployment of IVSAWS transmitters are very useful. The concept of using multiple transmitters to provide signal inhibiting is quite good. The concept of a multilobe transmitter for limiting coverage is also a god adaptation of a well-proven radar technique. In general, the overall discussion of traffic analysis, human factors and RF propagation analyses are helpful in delimiting the approach to an IVSAWS system.

The selection of a six pulse waveform, however, is not well justified, even for a very limited capability system. Hughes has the following objections to this design:

- The amount of data is very limited
- The message structure could readily be generated by burst of noise, leading to false alarms that will cause the driver to question the validity of each message
- The cost assumptions ignore the possibility of a multi-function receiver based on advanced semiconductor technology

The limited message structure provides only the most rudimentary indication of the type of hazard. It ignores the need for a more flexible structure to support message exchange with other systems. The result is a single function unit that is of questionable value to most urban automobile owners.

The selected waveform could easily be replicated by a noise burst. Using a receiver with a bandwidth matched to a 500 microsecond pulse, each of the six pulses would be received as a pair of 500 microsecond pulses with a 500 microsecond gap for a "zero" spacing and a one millisecond gap for **a** "one" spacing. The duration of the pulse nain will last between 8.5 milliseconds for a message with four "ones" and one "zero". This pattern has at most 20 degrees of freedom. Since the receiver must make 2000 tests a second for 24 messages (not all 32 are allowed), lightning strobes or spark plug ignition could create an intolerably high false alarm rate.

By contrast, more sophisticated waveforms, such as those used in anti-jam communications, will have strong error detection codes to validate the message and reject almost all false alarms (typically one in one million may be accepted).

Even without a false alarm problem, however, the problems of low signal to noise ratio are not addressed. Propogation conditions will, at times, suppon much longer ranges than intended, and receiver noise bursts will frequently transform the transmitted message into a different received message, confusing the driver and reducing his reliance on the system.

Finally, there is the issue of how the receiver recognizes the start of a message burst without any apriori means of bit synchronization. It will be necessary to include a start of message preamble to identify the message.

The whole rationale for this design is a low-cost receiver constructed from readily available parts. By contrast, Hughes believes affordable, multi-function receivers with much greater sophistication can be fabricated with available semiconductor technology (i.e., using Application Specific Integrated Circuits or ASICs) when the market is measured in millions of units. The large volume of units to be produced makes the non-recurring investment to develop the semiconductor masks and processes reasonable.

Just as microprocessors have revolutionized the computing industry, putting incredible processing power within the budget of the masses, so too will the ASIC-based all-digital receivers make wideband, high data rate communications affordable to all automotive owners.

4. Strawman Communication System

RFP Ref: SOW Task C; Section L.1.A

The proposed Hughes strawman communication system and waveform solves the SHAWS report technical approach weaknesses with a robust, high data rate, flexible communications architecture. It is also affordable, since it uses a subset of the commercially available Advanced Radio Local Area Net (ARLAN) system used by Hughes to implement the Chevrolet Racing Team telemetry system.

Through extensive tradeoffs to be accomplished during the study, the Hughes strawman design is presented to highlight how Hughes visualizes the needed communications architecture requirements versus the very limited architecture recommended in the SHAWS report.

The message structure of the communication architecture in the report, "Feasibility and Concept Selection of a Safety Hazard Advance Warning System" is too limited to be useful for anything but a minimal rural system. It is also vulnerable to false alarms.

Hughes envisions a state-of-the-art communication waveform with a start of message preamble, message ID field, a data field of perhaps 1000 bits and powerful error detection codes to validate the message and avoid alerting the driver with false alarms or erroneous message data. A strawman design for such a waveform is shown in Table A.4-1. Hughes will evaluate the need for error correction coding. The data modulation will be Differential Phase Shift Keying (DPSK), a modification to conventional Bi-Phase Shift Keyed (BPSK) modulation that avoids the need for a carrier reference by using phase comparison between adjacent received bits.

To minimize the likelihood of contention, a short message burst, say 10 milliseconds duration, will be used. The burst transmission rate during this burst will be 100 kb/s.

Based on Hughes' successful experience with the ARLAN system for the Chevrolet Racing Team secure telemetry system, a 900 MHz system could be used. This system is described in Section E of this volume. If spread spectrum operation provides useful, a 10 MHz instantaneous bandwidth would be used, with a 100:1 spreading rate. Multiple receive channels operating from a single preamble detector would support simultaneous demodulation of more than one message without garbling.

Although this design is intended only as a strawman to reveal Hughes' thought processes and to show how such a receiver could be usable with a variety of highway information distribution systems, it is based upon the Advance Radio Local Area Net (ARLAN) system (produced by Telesystems of Ontario, Canada) as a commercially available package. Even if the functionality of this strawman exceeds that of the baseline system selected during the study, the cost of an ASIC-based design is expected to be compatible with the cost goals of an affordable IVSAWS receiver.

TABLE A.4-I
HUGHES IVSAWS STRAWMAN COMMUNICATION SYSTEM

Operating Frequency	900 MHz
Burst Communication Rate	100 Kb/s
Message Block Size	1000 bits
Receiver Bandwidth	100 kHz (nom.)
Data Modulation	DPSK
Preamble Duration	20 bits
Message ID Field	10 bits
Error Detection code Size	20 bits
Inhibit Message Field	5 bits
Antenna Sidelobe Inhibit Field	20 bits

5. Overview of Management Approach

RFP Ref: SOW; Section L.I.A

Hughes has broad experience in bringing together and managing diverse organizations to solve complex problems. In managing the IVSAWS program, Hughes will use well-established management procedures and tools to ensure program success.

In executing this study, Hughes will selectively draw from expertise within the Hughes organizations, GM, and Delco Electronics Corp. In addition, Hughes will be supported by personnel from the University of Michigan and from Michigan's Department of Transportation. The management challenge is to effectively and efficiently use the best qualified individuals and organizations that can focus on the pertinent efforts of the assigned tasks and coordinate the synthesis of all tasks so that the required objectives of the program are met. In dealing with similar challenges in the past, Hughes has established policies and procedures for program management for the control of projects of various types and size. The goal of these procedures is to achieve uniformity and efficiency of each project while allowing some degree of management flexibility within the context of the specific project. Management attention at all levels is of paramount importance, and the management techniques used ensure this attention. Some of the tools by which effective management of the IVSAWS project will be accomplished are described below.

Several management issues need to be addressed in executing a program such as IVSAWS. Attention must be focused on the program objectives as a whole rather than the individual task or subtask. The challenge is therefore to make sure all efforts required to meet the objective are dealt with at the same relative technical depth. Another management challenge is to ensure efforts required to produce results for subsequent tasks are completed on time and in sufficient depth to allow the subsequent tasks and program to be completed within cost and schedule. Also of importance is the sharing of intermediate results and decisions so that there are no surprises when a given task is completed with products usable by subsequent tasks. These and many other management challenges are greatly mitigated through the use of a master program plan, which establishes the flow and continuity of tasks. Work Authorization and Delegation agreements ensure that each contributing organization understands the scope of work, schedule of tasks to be performed, products required, and the budget to perform the efforts. Formal and informal meetings/reviews are the means by which progress, intermediate decisions, and designs are measured. The engineering notebook is the means used to convey initial, intermediate and final information, decisions, and data to all participating organizations and individuals so all endeavors can proceed with synergism. Hughes will use these tools as depicted in Figure AS-l, along with other management tools used for each of its programs.

Master Program Plan – The Master Program Plan translates the contract requirements and tasks into subtasks, each with an associated cost, schedule, and expected output in terms of study results, tradeoffs, design decisions, equipment procurement and modification or test results. The plan, as established, is monitored against the milestone achievement and the budget associated with each item of the Work Breakdown Structure. When deviations from the plan occur, solutions must be generated, reported to the appropriate levels of management, and the corrective action taken,

Cost/Schedule Control System Criteria – Since the anticipated contract is cost reimbursable with an award fee, Hughes will use the DOD validated C/SCSC system of financial tracking. This system is based on Hughes cost information system (CIS) augmented by Hughes project reporting system (PRS). The Hughes C/SCSC is a uniform system for documenting and tracking the delegation of tasks and recording and reporting actuals vs. planned cost/schedule. This system allows the project manager to not only check charges to the contract, but also to evaluate cost/schedule variances along with technical milestone performance and then take any necessary corrective action in a timely fashion. For the IVSAWS Program C/SCSC tracking will be accomplished at the task level.

Work Authorization Delegation - CIS ensures that each task delegation is supported by the work definition and cost-planning documentation needed to control the task. The Work authorization and Delegation (WAD) package requires a statement of work which flows down from and expands upon (if necessary) the SOW supplied by the Government. The WAD also contains a statement of objectives, schedule, cost summary number and total budget. The WAD package is effectively a contractual agreement between the Hughes Program Manager and the performing organization. Such agreements will be consummated between the Hughes IVSAWS Program Manager and the performing organizations that will participate in the program.

Coordination Meetings - For development programs like IVSAWS, weekly or biweekly meetings conducted by the Program Manager or the Principal Investigator with the participating personnel for coordination and communications is critical to the success of the program. For those individuals at remote locations, a teleconference tie-in works extremely well. During these meetings problems of mutual interest are discussed, along with the dissemination of results and information pertinent to the participants. The

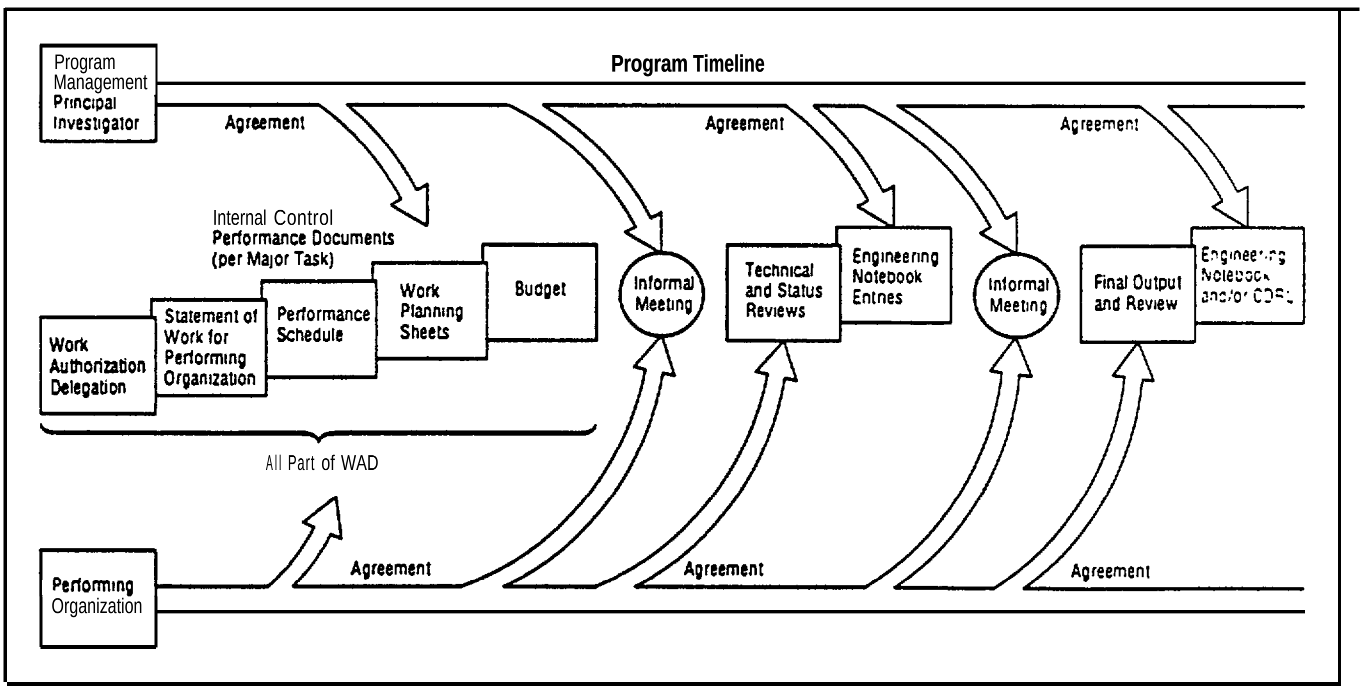

Figure A.5- 1. Approach to Managing Diverse Performing Organizations. The program manager and principal investigator control and monitor the program through agreement with the performing organization on scope of work, schedule, technical output and budget and then formal and informal review of progress, intermediate outputs, and final products.

5. Overview of Management Approach (Continued)

Program Manager reports monthly the status of the program to upper management. More regular reviews of the program occur if warranted.

Informal Meetings - Besides the more formal means of program communications described above, the Project Manager and the Principal Investigator engage in informal program meetings with the project personnel. For a study demonstration effort such as IVSAWS, these meetings provide an excellent means of reaffirming, one-on-one, the program objectives and ensuring that the project goals are met. These meetings also provide a means of getting feedback on difficult design decisions and tradeoffs.

Design Reviews - The Principal Investigator and the Project Manager will use the internal design review process as a management tool to assess the overall technical progress, the technical approach/soundness, and the quality of the effort. During the design review of a given task, the task leader describes the approach taken, rationale, and associated results. This method of review not only subjects the task/design to critical review by experienced personnel, but also provides vital communication of the ideas and decisions to the other members of the team. The results of the design review will also be documented and distributed to all members of the project team.

Engineering Notebook - Another key means of managing the project effort is the documentation of such items as tradeoffs, decisions, designs, and test results. All members of the team are required to record pertinent program information, such as that noted above, in a Project Engineering Notebook. This notebook is the means for all project participants to communicate important issues, decision methodology and decisions, designs, design review documentation, test results, etc. to all other project personnel.

PART I
TECHNICAL

SECTION B
ASSUMPTIONS, DEVIATIONS, AND EXCEPTIONS

1. Assumptions

RFP Ref: Section L.I.B

The IVSAWS system requires a thorough review of the assumptions of the referenced report including the receive-only assumption and the cost assumptions to determine the system requirements and architecture, The IVSAWS system fits into the multi-band all-digital radio architecture being developed by Hughes/GM, which will include both transmit and receive functions.

The referenced report "Feasibility and Concept Selection of a Safety Hazard Advance Warning System" makes several key assumptions that must be reviewed before the requirements for an IVSAWS architecture can be determined. In addition, Hughes makes the following assumptions:

The IVSAWS communication architecture should support other distribution systems – The receiver envisioned for IVSAWS must operate both in a rural environment and in an urban environment, where the density of message traffic may be much higher. The five bit message structure is not adequate to support these services, even if the messages were properly protected against transmission errors and false alarms. The other services supported by the IVSAWS system may require transmit capability and not just a receive-only capability.

The IVSAWS cost basis should be determined on five to ten million units per year – The referenced report emphasizes the very low cost of the small, simple receiver. It assumes that the receiver must be fabricated with lumped element components. By contrast, substantially more complex implementations using an all-digital system will still be affordable when the non-recurring development costs are amortized over a large market. The automotive public will support the use of these systems because of the larger value added.

The Driver Alert Display Subsystem tradeoffs should include the projected developments in displays – The selected architecture should be sufficiently flexible to take advantage of evolutionary changes in the car/driver interface systems including the adaptation of cockpit Heads Up Display (HUD). Hughes Human Factors engineers are currently working on the adaptation of both dashboard displays and HUDs to enhance the drivers awareness of his situation. The alert message display interface should be flexible enough to include a variety of displays, including rudimentary icon displays or buzzer alerts to sophisticated systems in which the driver can acknowledge the display and request additional information.

A state-of-the-art spread spectrum waveform will be useful and affordable for the extended IVSAWS **communication architecture** -The IVSAWS receiver will require a start of message preamble, a message ID, and a powerful error detection code to reject false alarms or messages with transmission errors. Hughes will incorporate these features in the message and assess the utility of also including error correction coding. Furthermore, the receiver will often be subjected to a multiple transmitter environment, particularly in an urban environment or when low loss propagation conditions apply. Hughes will assess the utility of short bursts and pseudo-random delays before repeating the message to resolve multiple access contention (i.e., message garbling). Alternatively, spread spectrum modulation using a receiver with a single common start of message preamble and multiple demod channels will be assessed to resolve multiple access contention.

In addition to these general assumptions, the following specific assumptions are also made.

- During feasibility testing, Hughes will test the various warning systems in a controlled environment
- Actual rain, snow, sleet, accident, or other hazard will not need to occur or be environmentally active for system test purposes
- The size of test groups may be increased, especially for the older (over 65 years of age) group. This would allow consideration of visual variations brought about by corrective lenses, including bifocals and trifocals
- Based on recent rural and urban highway accident data obtained during the performance of Task B, the hierarchical order of ranking may differ from FHWA/RD-81/124
- Geographical location for testing is not a major factor as long as sufficient urban, rural, and secondary roads exist

University of Michigan Traffic Research Institute (UMTRI) experts in experimental psychology applied to drivers and in the study of accident causation have sufficient grasp of the driving task to formulate a package of scenarios and driver message constituting a suitable IVSAWS design list.

- The accident record compiled over many years within the State of Michigan, and supplemented by the geographic locator system called MALI, "Michigan Accident Locator Index," constitutes a suitable resource for identification of fixed-place hazards associated with roadway features
- The operating experience of the Michigan Department of Transportation plus the safety research expertise of UMTRI staff provides a suitable experimental base which to identify temporary hazards at the roadside, such as those resulting from construction, maintenance, and traffic control at an accident site.
- The Michigan Department of Transportation, having a working knowledge of the Manual on Uniform Traffic Control Devices, is able to identify those warning and regulatory signs that should be replicated within an IVSAWS application

2. Deviations and Exceptions

RFP Ref: Section L.1.B

With the exception of the following, Hughes takes no exceptions and requires no deviations from the statement of work or contract requirements.

FAR Clause 52.209-5 is contained in the RFP. In order to further clarify the intent of this FAR clause, Hughes Aircraft Company requests the following notes be added to the contract terms and conditions:

A. The following note should be keyed to paragraph 52.209-5(a)(l)(i);

“The term ‘offerer’ means Hughes Aircraft Company exclusive of its wholly or partially owned subsidiaries.”

B. The following note should keyed to paragraph 52.209-5(a)(l)(i)(B) and (a)(1)(i)(c);

“Matters described in this subparagraph do not include citations, complaints or allegations issued by governmental environmental protection agencies.”

PART I
TECHNICAL

SECTION C
TECHNICAL UNCERTAINTIES

1. Tradeoffs

RFP Ref: Section L.1.C

Hughes envisions performing extensive tradeoffs to determine the requirements and baseline implementation of the IVSAWS system. It is anticipated that a substantially more capable system may result while maintaining an affordable per unit cost.

Hughes review of the Shaws report study indicates that the report is flawed in the assumption that affordable cost dictates a minimal capability system. Hughes will support this position by performing a set of tradeoffs to determine how various features affect the utility and the per unit production cost of the baseline IVSAWS system. The following tradeoffs will be performed at a minimum:

1) **The Alert Message Content -** The message size must be determined based on the utility of the data to aid the driver. This tradeoff will identify how much additional data is of interest to the driver beyond the minimal hazard alert. A second factor to be considered is the utility of sending a minimal message identifier (e.g., message No. 43) when message No. 43 is stored in the receiver in a more extensive form to be displayed or announced to the driver.
2) **The Overhead Content of the Transmitted Waveform -** In addition to the actual data for the alert message, the transmitted message must contain certain overhead fields. A start of message preamble and a message ID field are necessary. Error detection coding is necessary to assure that only valid messages are displayed. The size of this field must be selected. The utility of forward error correction coding will be assessed. Overhead for amplitude comparison is required for multimode transmit antenna systems.
3) **The Center Frequency and Bandwidth of the Signal -** The frequency band will have to be selected to provide minimum interference with other systems. FCC regulations restrict this choice to limited bands. The bandwidth of the signal will be dictated by the number of transmitted bits and the burst duration. Short-burst durations are dictated by the need to avoid message contention resulting from nearly simultaneous transmissions.
4) **Transmit/Receive Configuration –** Although the referenced report assumes a receive-only configuration, other systems which might use the receiver consider half duplex operation for ranging and other functions. Since even the IVSAWS operation may be improved by having a transmit capability, this tradeoff will determine its utility.
5) **Techniques for Providing Coverage Control –** Hughes will assess the use of dual mode (i.e., directive beam + omnidirectional coverage) antennas, inhibitor transmitters, and position information derived from an intelligent highway to determine when an alert message applies to the automobile.
6) **Assess Various Driver Display and Acoustic Interface Technologies –** Hughes will assess the utility of various display and announcing systems to alert the driver to a hazard. The utility of special features, such as driver acknowledge and the ability to request expanded information, will be assessed.
7) **Physical Partioning of the IVSAWS RF hardware –** Assuming that the IVSAWS RF hardware is implemented as Application Specific Integrated Circuits (ASICs), the optimum partitioning into one or more ASICs for performance and production cost w-ill be determined.

8) **Reliability Assessment** – The reliability of the IVSAWS hardware will be determined based on preliminary and final partitioning of the IVSAWS hardware. Design techniques to maximize the mean time between failures (MTBF) will be provided to the design team.
9) **Impact of Self-Test/Fault Isolation** – The mechanization of self test functions will be considered to identify when failures have occurred that would degrade the performance of the NSAWS hardware. Fault isolation tests to be available in a test mode will be considered to aid technicians in isolating faulty IVSAWS components.
10) **Production Cost Studies** -The production costs of the baseline ASIC chip-based hardware will be projected based on GM-Delco's assessment of ASIC costs.
11) **Applicability of Spread Spectrum** – An assessment of spread spectrum modulation techniques will be accomplished, including signal excision in the presence of interference and the separation of multiple simultaneous received messages.
12) **Drive Impairment** – As identified in Report No. FHWA/RD-8 l/124, alcohol, drug abuse and fatigue will have direct effects on attention, judgment, reaction time, and lockout. The degree to which any of these can be incorporated into IVSAWS testing is questionable. Obviously drug abuse cannot be included. Does the Federal Highway administration anticipate:

    a. the use of alcohol to establish a level of in attention, lack of judgement , etc. on the part of test drivers? If so, what level of blood alcohol is acceptable? 0.05, 0.08, 0.10?
    b. the use of fatigue to establish a level of in attention, etc.? If so, what level or criteria is acceptable? 24 hours sleep deprivation?, 36 hours sleep deprivation?, a combination of sleep deprivation and exercise?

13) **Display Technology** – The state of the art of vehicle design has expanded to include not only instrument panel indicators/symbols, but also driver control stations that provide touch-screen CRT/displays as well as Heads Up Displays (HUD). Currently HUDs and EL/CRT displays are potential options to the buyer/driver, however in the near future the EL/CRT display will be broadly available. Does the FHA exclude either of these two display options from consideration in the study?
14) **Vehicle Type** – The type of vehicle was not expressly identified in Report No. FHWA/RD-81/124. Consider vehicle type in relation to driver age. Review data to determine most likely vehicle type (e.g. sports, 2-door, 4-door, pickup, etc.), for use in the study.
15) **Alert Messages** -Based upon University of Michigan felt experience it is felt that Task B has significant issues relative to the selection of alert messages and their content:

    1). The messages should relate to "significant" hazards so that a hazard alert warning gives the driver cause for serious concern. He should not be given so many warnings that he routinely dismisses them, nor so few that he does not get information on real hazards to his safety.
    2) The information presented to the driver should be sufficient to understand appreciate the message.
    3) The selection of data presented should lead the driver over a period of time to form an opinion that such alerts provide valuable information to him.

PART I
TECHNICAL

SECTION D
ORGANIZATION OF THE WORKPLAN

1. Overview of the Task Flow

RFP Ref SOW Tasks A - K; Section L.I.D

A key factor in the performance of the task sequence will be a thorough review of the communications requirements to account for a multifunction system and the inclusion of advanced display/announcing technologies in the assessment of the driver/warning alert subsystem

Figure D. 1.1-1 shows the task flow envisioned by Hughes. Its structure agrees with that specified in the RFP SOW. Hughes will observe all the required COTR approvals.

Hughes recommends several changes to the scope of the study to enhance the utility of the effort. Task C will incorporate a projection of other requirements for the in-vehicle receiver to support highway/driver information systems. These projected requirements will be supplied from other Hughes highway safety contracts and programs and from the GM organization. Hughes believes this will expand the market base for IVSAWS.

In Task E, advanced technologies for displaying or announcing data to drivers will be included in the assessment of the driver alert warning subsystem, as well as conventional acoustic and flashing icon warnings. Hughes is familiar with the liability requirements to provide the driver with sufficient data while not distracting him from his current situation.

Hughes will draw on its experience and simulation facilities in devising displays and alert systems for pilots as well as the GM experience in this area. Hughes four-year participation in the FAA Advanced Automated Air Traffic Control System resultedin advanced color touch display operating in real time. The Hughes Driver Simulator provides a dynamic, driver-in-the-loop automobile simulator used for development of the automotive Heads-Up Display (HUD).

Hughes will use GM vehicles with specially modified displays and announcing systems for the test program. The availability of these vehicles through GM at no cost to the program allows much more sophisticated display/announcing strategies to be tested.

Hughes will provide a detailed final report together with a plan for developing a state-of-the-art, all-digital receiver using the semiconductor technology base to develop Application Specific Integrated Circuit (ASIC) components. This development will include self-test features to complement the already high reliability inherent in the semicondutor based chips.

The proposed IVSAWS program schedule is shown in Figure D. 1.1-2.

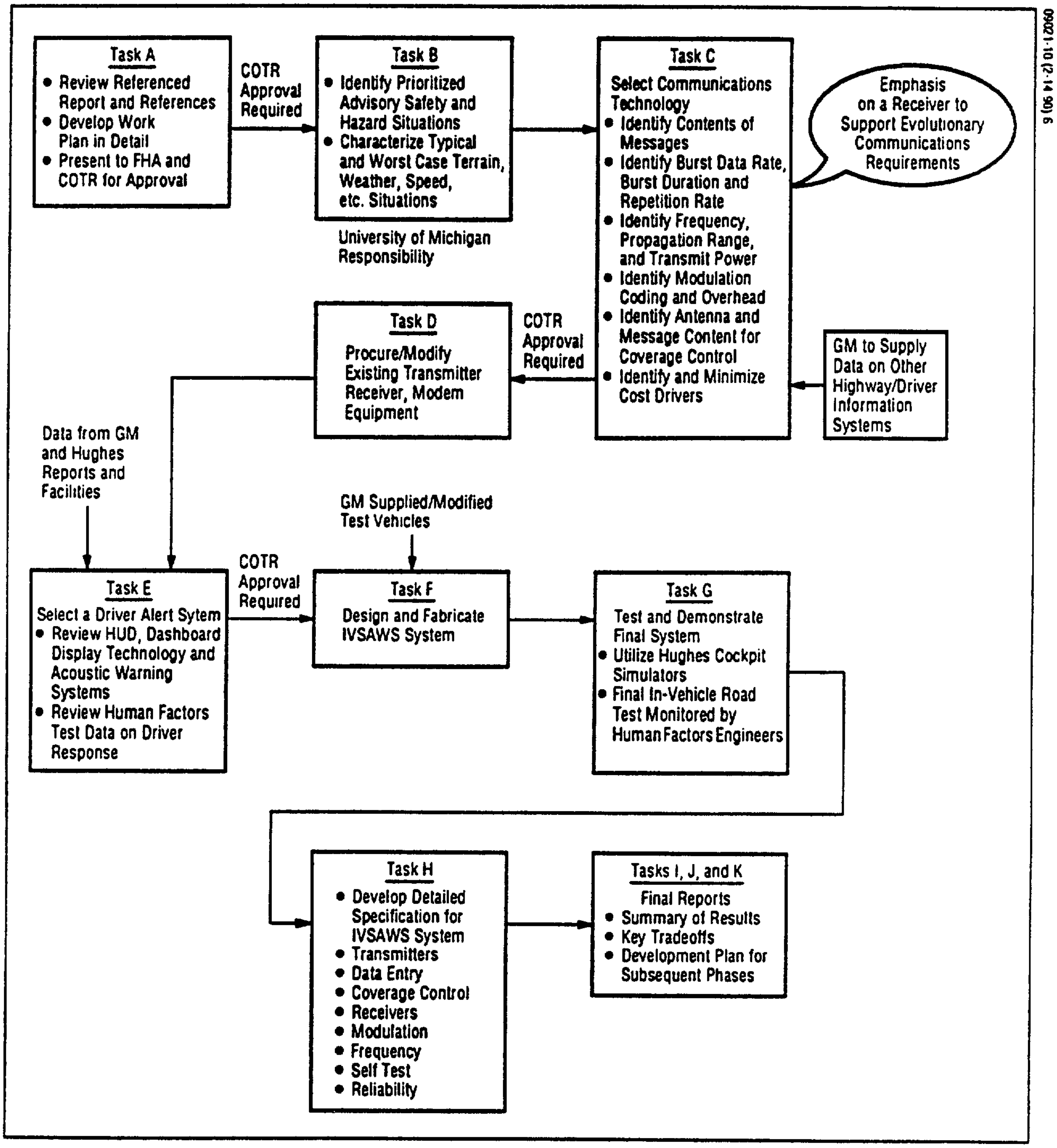

Figure D.1.1-1. Task Flow for the IVSAWS Study. Hughes will develop an architecture based on an assessment of IVSAWS and other requirements so that IVSAWS hardware has a broader market base.

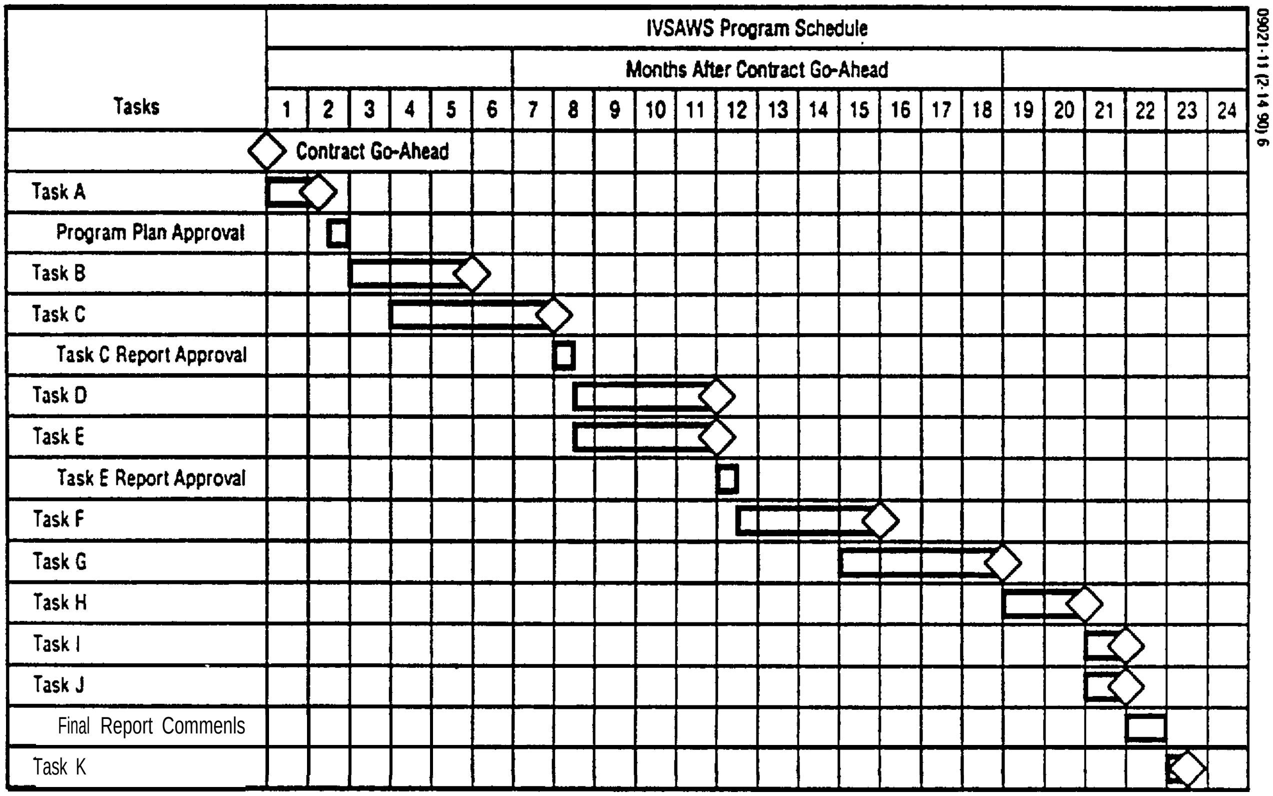

Figure D.l.l-2. IVSAWS Program Schedule. The program schedule establishes the task flow, start and completion dates, and the time frames for approval as called out in the contract.

2. The Development Plan

RFP Ref: SOW Task A; Section L.1.D

The Hughes plan will concentrate on the requirements for a more flexible communications architecture and an affordable implementation based on state-of-the-art semiconductor chip designs.

Hughes has made a preliminary review of the SHAWS report, "Feasibility and Concept Selection of a Safety Hazard Advance Warning System." This assessment leads to the conclusion that the baseline waveform and receiver is too limited to be of interest to the automotive market. The report contains useful data and concepts for deployment and control of the IVSAWS system. The Principal Investigator and the lead Human Factors and Communications Engineers will further review this report during their preparation of the development plan.

The development plan will be worked out in concert with traffic engineering specialists at the University of Michigan, who will help the Hughes team assess the optimum information content to minimize the probability of an accident. The key issues in this discussion will be (1) the amount of data to be be transmitted by the RF communication subsystem and (2) the techniques for displaying/announcing this data to the driver. (See Figure 0.1.2-l.)

Hughes believes the five-bit message presented in the referenced report is too limited and too vulnerable to false alarms to be useful, and will devise a much more capable message structure to support IVSAWS receiver functionality.

The Hughes team will pursue an all-digital design using the Application Specific Integrated Circuit (ASIC) approach to devise a low production cost receiver that can support multiple data distribution systems. The production cost of such a device can be held to reasonable levels because the development cost would be spread over a market expected to run five to ten million units per year. Furthermore, properly designed ASIC components can provide high inherent reliability in the specified operating conditions and can readily include the required self-test features.

The development plan will also utilize the specialized Human Factors engineering facilities of Hughes Aircraft and the availability of the latest display technologies on specially modified GM test cars. This will have the effect of extending the scope of the program to include a variety of future technologies at virtually no cost to the FHA.

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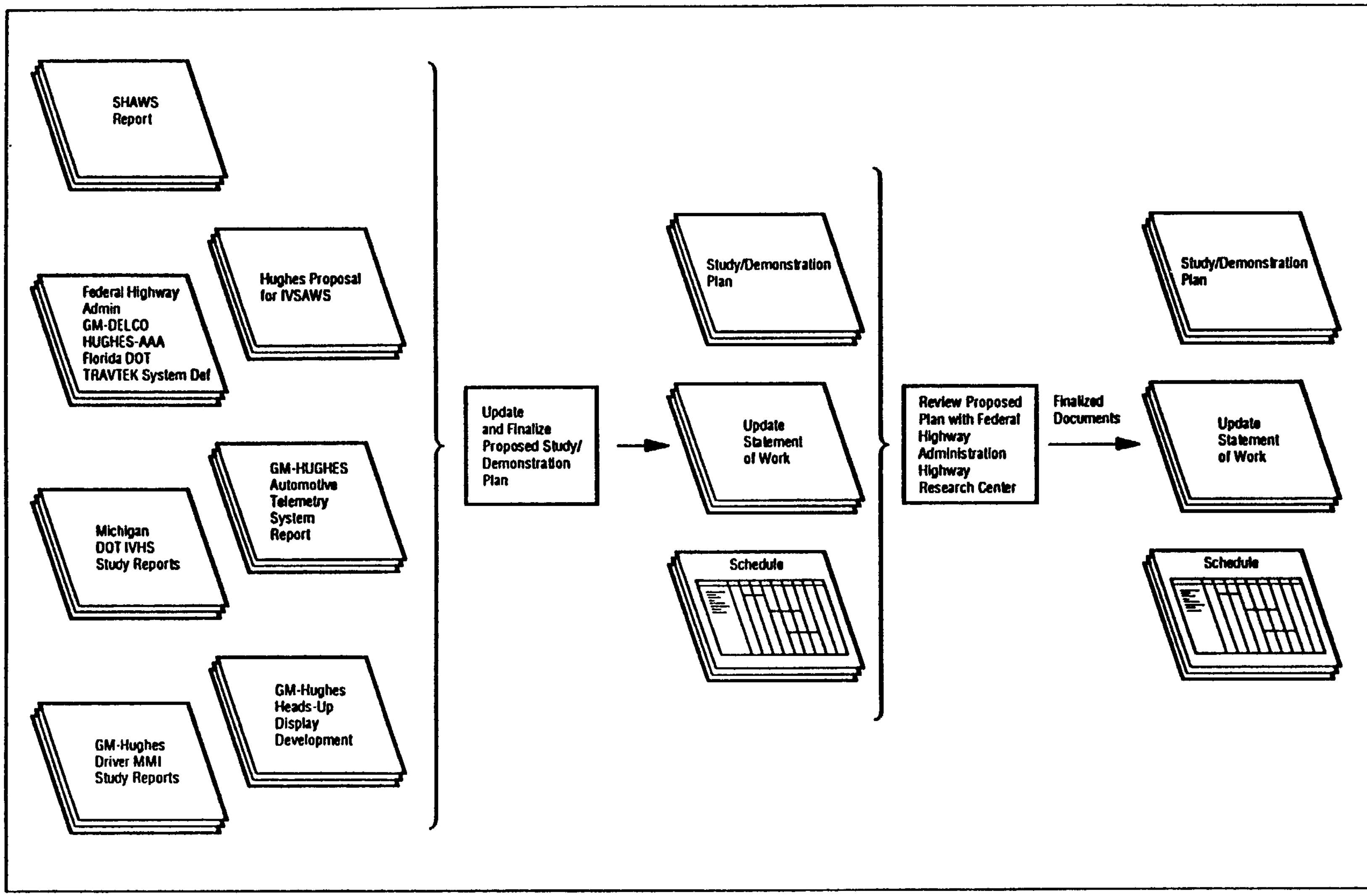

Figure D.1.2-1. Establishment of Study Demonstration Plan. Hughes will draw from related program documentation, the SHAWS Report and other pertinent documentation that may be made available by the Federal Highway Administration in updating the proposed plan set forth in the proposal. The update plan will then be reviewed as required by the contract prior to finalizing the plan and proceeding.

1. Assumptions and Technical Issues Involved in Implementation of the IVSAWS Concept

RFP Ref: SOW Task B; Section L.1.D

The IVSAWS concept is based on the assumption that drivers will enjoy reduced accident risk if effectively advised of upcoming hazards on the highway, The issues posed by this concept, addressed in Task B of the Statement of Work, pertain to the "effectiveness" of the advice.

In the Hughes/UMI approach to Task B of the Statement of Work, the following assumptions are used to identify advisory, safety, and hazard situations and the types of driver messages needed to address such situations:

- The accident record compiled over many years within the State of Michigan, and supplemented by the geographic locator system called MALI, "Michigan Accident Locator Index," constitutes a suitable resource for identification of fixed-place hazards associated with roadway features.
- The operating experience of the Michigan Department of Transportation, plus the safety research expertise of UMTRI staff, provides a suitable experiential base upon which to identify temporal hazards at the roadside, e.g., hazards caused by construction, maintenance, and traffic control at an accident site.
- The Michigan Department of Transportation, having a working knowledge of the Manual on Uniform Traffic Control Devices, is able to identify those warning and regulatory signs that should be replicated within an IVSAWS application,
- UMTRIs experts in experimental psychology applied to drivers and in the study of accident causation have sufficient grasp of the driving task to formulate a package of scenarios and driver messages constituting a suitable IVSAWS design list.

Technical Issues – Key issues involve (a) the significance or risk level posed by the qualifying hazards, (b) the ability of drivers to understand and appreciate the message intended to portray each hazard, and (c) the conduciveness of the message system, over time, to belief by drivers and thus to corresponding decisions/behavior.

The tradeoffs posed by each issue are as follows:

1. Concerning the significance of risk level, clearly the tradeoff has to do with the contextual setting for message presentation. On the one hand drivers do not want to hear a continuous stream of messages that address all extant hazards; on the other hand, the confinement of messages only to highly infrequent hazards posing enormous hazard (e.g., propane tanker about to explode on the highway) would minimize the value of a message system. Accordingly, there is a need to prioritize the overall set of candidate hazards to single out those few that occur relatively rarely but currently exact a high accident toll.
2. Concerning the ability of drivers to understand and appreciate IVSAWS messages, the tradeoff is between various elements in the message formulation. The "understanding" part is simply the question of cognition, once a perceivable voice or visual display is engaged. The "appreciation" matter pertains to the deduced importance or instruction value of the message, once its information content has been understood. The tradeoff is among informational content, attention-getting, and the implied risk-level communicated through the message. The total length of a message string is clearly also pertinent to cognition. In addition, string length is associated with highway length over which the message

is communicated and, thus, spatial clearance between the receiving vehicle and the transmitter.

3. Concerning conduciveness to belief, the complex arena of human judgment, learning, and conditioning will govern the utility of IVSAWS, as people gain experience with such a system over time. Over relatively short periods, such as a few hours, the driver will be conditioned simply by the frequency and annoyance factor with which any messages might be heard, as mentioned above. For example, drivers will tend to disbelieve that a given situation constitutes a significant hazard if messages advising of this situation arrive frequently. Over the longer term, measured in weeks to years, drivers will remember the correspondence, or lack thereof, between advisory messages and their own observations as they proceeded along the road. Thus, the tradeoff is between delivering all of the messages that seem warranted, given a careful prioritization, and risking the credibility of the system by presenting too many message or messages, the validity of which (either informationally, or in implied risk level) is not readily confirmable by drivers.

2. Approach to Resolving the IVSAWS Tradeoffs

RFP Ref: SOW Task B; Section L.I.D.

Three key issues have been identified: (1) the significance or risk level posed by the qualifying hazards, (2) the ability of drivers to understand and appreciate the message intended to portray each hazard, and (3) the credibility of the message system to drivers. The Hughes-UMTRI approach to these issues is to prioritize hazards from modeled data and refine the ensuing list in accordance with IVSAWS applicability.

Hazard Risk Level – Hughes proposes to adapt the IVSAWS concept to specific hazard scenarios according to an assessment of risk. That is, the overall set of candidate hazards will be prioritized to single out those that occur relatively rarely but exact a high accident toll. The risk assessment effort of Task B will be focused on the use of Michigan's MIDAS and MALI statistical databases. Addressing the entire Michigan road system, the Michigan Dimensional Analysis Surveillance system (MIDAS), and the Michigan Accident Location Index (MALI) constitutes powerful analysis tools that can be used to (1) identify the types of situations that have the highest potential payoff and (2) select candidate locations for treatment.

The MIDAS model uses the roadway geometrics and environmental inventory to analyze accidents by such criteria as laneage, degree of curve, speed limit, and passing/no passing zone. The MALI system allows for location of each accident site. Data from policing agencies throughout the state are processed to locate the accident on roadway, X a distance, Y, from intersection **Z,** covering a system of over 100,000 miles of roads and streets. The two tools enable peer group comparisons by which one can rank high accident locations with their geometric and environmental peers so that true outliers can be isolated as candidates for corrective action. The characteristics of outlying road sections can then be examined for identification of features requiring hazard warning.

Although an overall ranking of hazard situations will be developed from the Michigan data, identification of perhaps six to ten specific candidate locations for treatment will also be very informative. Such specific problem locations will be examined to challenge the selection of accident scenarios and messages with test cases that are known to be hazardous, despite traditional treatments in the past.

The statistical and specific-site examination will then provide a prioritized list of candidate scenarios and nominal hazard descriptions. Subsequent effort in this task will then entail a refinement of this list according to the particular issues posed by the interaction between IVSAWS and drivers.

Refining the Hazard List – The candidate list will be refined through a process that classifies the various scenarios/messages according to their suitability for IVSAWS treatment, per se. The methodology is as follows:

1. Statistical data will be used to characterize each scenario by its frequency of occurrence, per mile of vehicle travel.
2. The tradeoff between importance and frequency will then be examined in light of the desire to avoid the human problem with frequently repeated warning.
3. Messages will then be formulated with special sensitivity to the matter of cognition on the part of the driving population.
4. Cognition concerns in the development of highway signage will be reviewed for guidance on the tailoring of message content.

If feasible, a scale of perceived importance in the hierarchy of IVSAWS messages will be developed through the selected phraseology so that drivers will be more capable of realizing the risk level in a given message. As stated earlier, there will be a tradeoff between informational content, attention-getting, and the communication of risk-level by means of the message presentation.

System Credibility - The third level of activity for determining suitable scenarios and messages for the IVSAWS application concerns the credibility of the system. Two such problems of credibility were discussed in some detail in the SHWS report of 198 1. One is a failure to warn when a hazard exists. This is referred to in the SHAWS report as a Type 1 error. Another is false alarms or false warning where no hazard actually exists (called a Type 2 error in the SHAWS report).

The SHAWS report regards a Type 1 error as particularly serious, since it may cause a collision. However, given that, for the foreseeable future, IVSAWS technology will be used as a supplement to conventional warnings, a Type 1 error can cause a collision only if the other warnings fail as well. In view of this, it may be that Type 2 errors are, in the long run, more detrimental to overall safety because they will promote disbelief of warning messages. In the near term, before the driver has become unresponsive to warnings, false alarms may cause collisions when warned drivers brake unexpectedly in anticipation of a nonexistent condition, thus raising the spectre of liability issues.

In a situation where the operators can be fully informed of the shortcomings of the system (e.g., as with commercial pilots), false alarms can be tolerated to some degree, if the value of the warning is perceived as being high. For example, an andcollision warning might be much appreciated by pilots, even if they know that 90% of the time it means nothing more than an aircraft nearby, simply because of the seriousness of the situation on the 10% of the occasions when the warning is valid.

Unfortunately, there is no way to reliably ensure that the driving public is fully informed about operational characteristics that may result in frequent false alarms. No matter what efforts are made, a significant number of drivers will only know that the system frequently tells them falsely that a hazard exists. This "cry wolf' phenomenon will diminish the effectiveness of that warning and perhaps that of the entire spectrum of warnings provided. This says that any system that may result from the planned research or future efforts must produce very few false alarms. Even further, scenarios must be selected and messaging approaches designed so that the hazard is readily confirmable by the driver. Treatment of these design issues will require concentrated effort from experimental psychologists and those who have carefully studied the roadside hazard environment.

1. Analysis of Geometry Versus Communications Paths Alert Distance and Direction

RFP Ref SOW Task C: Section L.1.D

Hughes will determine the propagation range, minimum update rate, and required signal-to-noise ratio to alert the driver to the assumed hazard and will assess the use of inhibiting transmitters and multimode antennas as a means of controlling the coverage.

Hughes communications engineers will review the scenarios evaluated by the University of Michigan in Task B to determine how the geometry and worst-case speed of the automobile determines the minimum coverage range for receiving the alert and the corresponding minimum time to repeat the message. For example, if a teenager were racing his car at 120 mph, a four-mile coverage and a repeat time of once per minute would be required to guarantee that the driver would be alerted one minute before encountering the hazard.

Conuol of the alert coverage area is a key issue. As the RFP point out, a transmitter located on an overpass should alert only traffic on the overpass and not the lower road. the coverage should also be capable of being controlled to alert only vehicles approaching the hazard from one direction and not the other. The referenced report suggests two methods of limiting the dissemination of the alert to drivers: (1) control of the radiation pattern and (2) the use of inhibiting transmitters.

Hughes will assess the use of simple directive antennas such as those used for television to limit the coverage sector. Beamwidths of the order of 60 degrees are readily achievable with simple electromagnetic horns, particularly in the 900 MHz band. The use of a dual-mode antenna, as described in the referenced report, is very helpful in eliminating reception through sidelobes and backlobes, but it does require a receiver capable of making amplitude comparisons between two parts of a transmission, and a more complex transmitter. Figure D.3.1-1 shows the use of a dual mode antenna to control the direction of coverage. The availability of a flexible message structure allows inhibiting specific message IDs to limit the coverage, for example, to westbound traffic on an east-west highway. The inhibiting transmitter is placed to the east of the obstacle, and the receivers on eastbound automobiles are alerted to inhibit display of the alert message intended for westbound cars.

These techniques impose additional requirements on the message structure to support higher data rates for the overhead and to allow multiple access without garbling the individual messages. These concepts further support Hughes assessment of the need for a more capable message structure and receiver. It is Hughes belief that the need for these capabilities should be included in the assessment of the requirements of the IVSAWS communication system

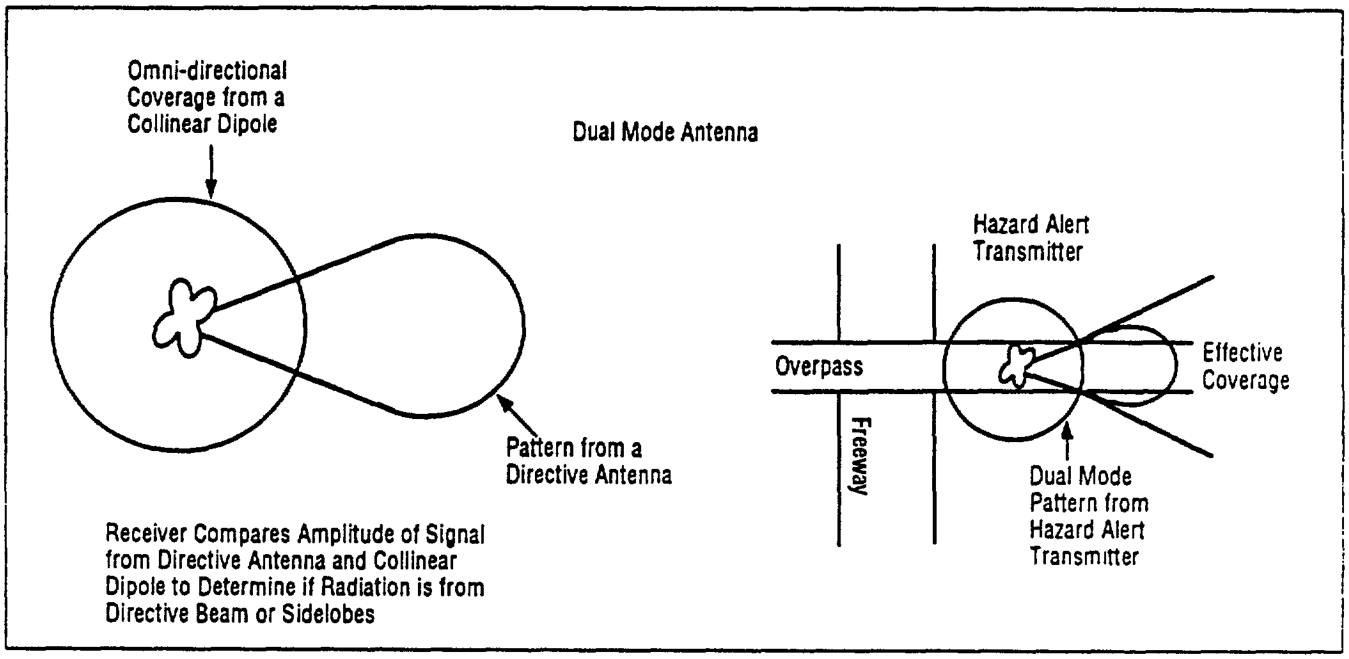

Figure D.3.1-1. Dual-Mode Antenna Usage. Amplitude comparison circuitry rejects message if signal level radiant from dipole is greater than that from the directive antenna.

2. Determination of Communications Architecture

RFP Ref:

Hughes will develop a communication link design based on broad experience with multiple access radio systems, the Position Location and Reporting System (PLRS) and the Joint Tactical Information Distribution System (JTIDS), and on experience in human factors acquired while working with GM on advanced concept information and display systems.

The communications architecture must be selected along with the message content and the message display/announcing function. The Hughes Communication Systems Division is at the forefront of the state of the art in the development of advanced communications systems, including the PLRS for the Army, JTIDS for the Air Force, and the new Advanced Anti-Air Engagement System for the Navy (NAVAIR). Hughes human factors engineers are working closely with GM to develop advanced display concepts including adaptation of the pilot's Heads Up Display (HUD) to projecting information directly into the driver's field of view so he does not have to take his eyes off the road.

The IVSAWS team includes engineers who have played key roles in all of these developments, ensuring that the Government will have access to both the high technology and to the latest concepts in vehicle automation.

The methodology for this task is summarized in Figure D.3.2-1. It assumes a list of hazards prioritized according to their frequency of occurrence, together with data on typical and worst case roadway layout and terrain obstructions. This database will be provided by the University of Michigan, which will also provide guidance on the frequency of message repeats based on the time between the first reception of the message and the time at which the hazard is encountered, based on the automobile speed.

In addition, the architectural task will include inputs from the man-machine interface technologies (i.e., displays and voice announcers). Human factors will provide guidance as to the optimum amount of information to be displayed or announced and which techniques should be used for which part of the information.

FCC regulations on frequency usage will be another input to the frequency selection part of the study, Preliminary identification of bands include the MF band from 550 KHz to 1600 KHz, the 300 MHz band, and the 900 MHz mobile telephone band. An assessment of co-channel interference level will be made, particularly if a spread spectrum system is used.

The choice of frequency will be heavily driven by the propagation losses and the background noise, which together determine the available signal-to-noise ratio. Figure D.3.2-2 shows how the available signal-to-noise ratio margin varies with frequency for a link with the following parameters:

1 **watt** transmitter
3 mile line of sight path loss (l/R2 loss)
Omnidirectional antennas
Urban, suburban, and rural noise environments
100 Kb/s data rate
Differential Phase Shift Keyed (DPSK) Modulation

As figure D.3.2-2 shows, the link margin is strongly affected by background noise and that, with the exception of the excess path loss resulting from buildings, terrain, and foliage, the margins are not strongly frequency dependent.

The link margin determines how much additional propagation loss caused by buildings, terrain obstacles, and foliage attenuation can be accommodated.

The methodology shown in Figure D.4.B-1 shows three major subtasks. The first subtask will involve assessing the list of prioritized hazards together with the available display and announcing technologies to determine the information and method of display to be presented to the driver. The Human Factors Personnel involved in Task E will participate in this task to provide guidance on optimal methods of alerting the driver without annoying or distracting him. They will also provide guidance for alerting drivers with disabilities such as hearing impairment, or who might be momentarily distracted.

The result of this subtask will be several sets of candidate message contents for each prioritized hazard. A range of candidate messages will be needed to determine how the data rate requirement varies with the amount of data. For example, one set of candidates might use a stored dictionary of words to compose the message in the receiver. The message would then consist of a sequence of words selected by a limited number of bits. This option would lead to very low data rate communication requirements but at the cost of a very inflexible architecture. This assessment will have to include the effect of data entry in the IVSAWS transmitter. A set of "canned" messages might be desirable to a police officer setting up an IVSAWS transmitter at an accident site.

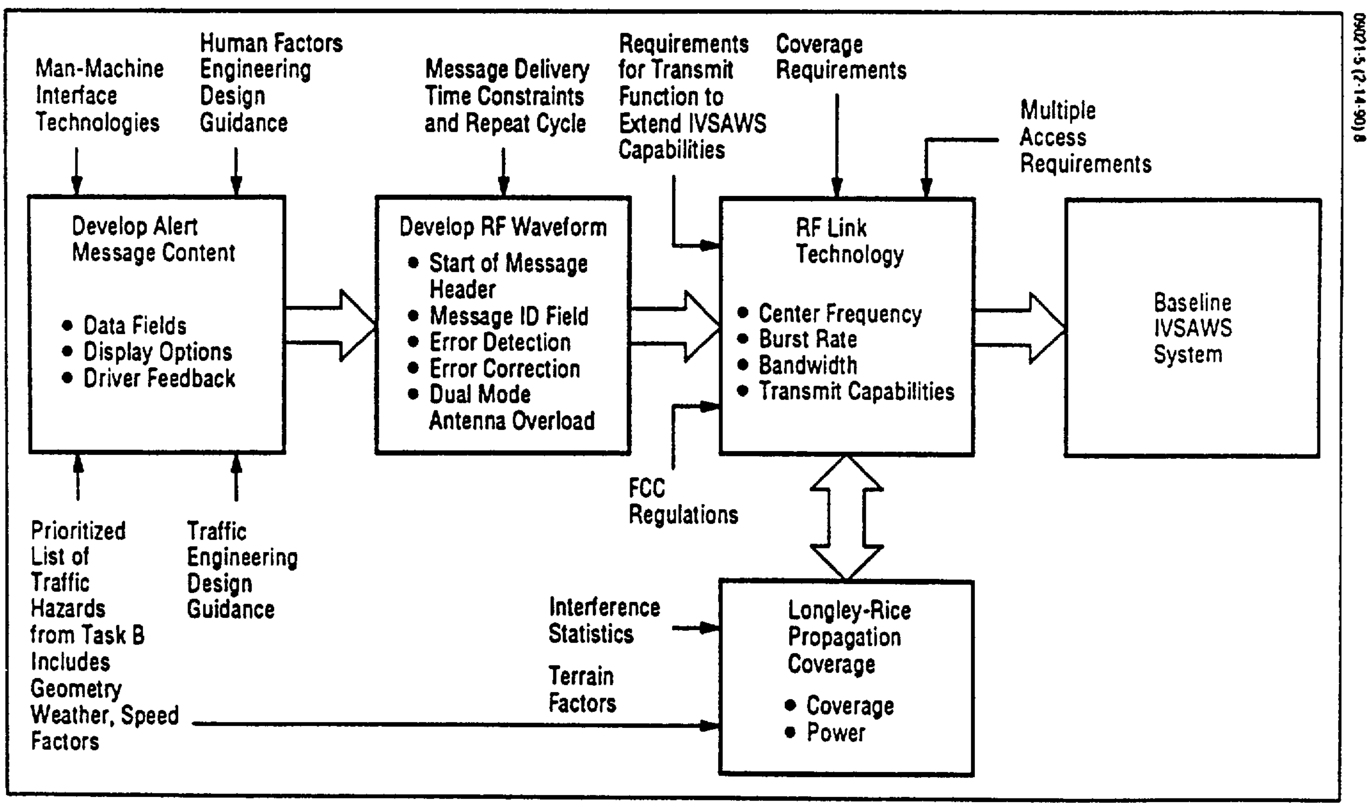

Figure D.3.2-1. Communications Architecture Selection Methodology. Hughes will review and incorporate all potential requirements before selecting the baseline IVSAWS communication architecture.

2. Determination of Communications Architecture (Continued)

The next study will determine the overhead and overall data rate and bandwidth needed to meet the message duration and repeat cycle constraints established in Task B for the example hazard. This study will include the effects of start of message preamble, message ID and error detection coding overhead as well as the bandwidth expansion of error correction encoding. If a dual-mode antenna system is involved, then it will be necessary to include system overhead to make an amplitude comparison between the directive and the omnidirectional antenna modes.

Finally, the frequency and data modulation must be selected. Hughes has considerable background in determing propagation losses as a function of frequency and various excess loss mechanisms, including undulating terrain, buildings in urban and suburban environments, and foliage on deciduous trees. One tool used to characterize propagation loss and coverage is the Langley-Rice computer model, which has been validated for application in Army programs. This model is installed on the Communication Systems Division VAX computer and is immediately available for application to this task. Hughes is very familiar with the effects of multipath fading in an urban environment, particularly on UHF frequencies (300-3000 MHz).

In addition to selecting the center frequency of the transmission, it is necessary to select the burst data rate and, possibly, the spread spectrum bandwidth. Short high rate burst transmission is probably needed to minimize the effects of simultaneous multiple transmissions. The message will be digital and a simple noncoherent data modulation, such as Differential Phase Shift Keying (DPSK), will be used. Spread spectrum waveforms are a possibility to overcome multipath fading and co-channel interference.

Spread spectrum waveforms provide an ideal method of separating transmissions that overlap in time. With sufficient spread spectrum processing gain (approximately 100: 1 spreading ratio), two overlapping signals of equal power can be easily separated. A single channel receiver will respond to the first preamble and reject the second message since it is not synchronized. A dual or multiple channel receiver with a common preamble detector can process the overlapping messages without any garbling.

Depending on the expected worst case interference level, the need to include narrowband interference excision in the receiver will be considered. Interference excision is readily achievable with a digital receiver and Fast Fourier Transform (FFT) processing.

The three subtasks will have significant feedback to account for the interactions between the data rate and frequency selection effects. These paths are not shown in Figure D.3.2-2 to simplify the appearance of the diagram.

The result of this task will be a baseline IVSAWS link design, including both the digital data transmitter with data entry interface as required and a receiver with digital message storing and message processing.

This type of system can be implemented in an affordable package by using ASIC technology to develop a low per unit cost, all-digital production design.

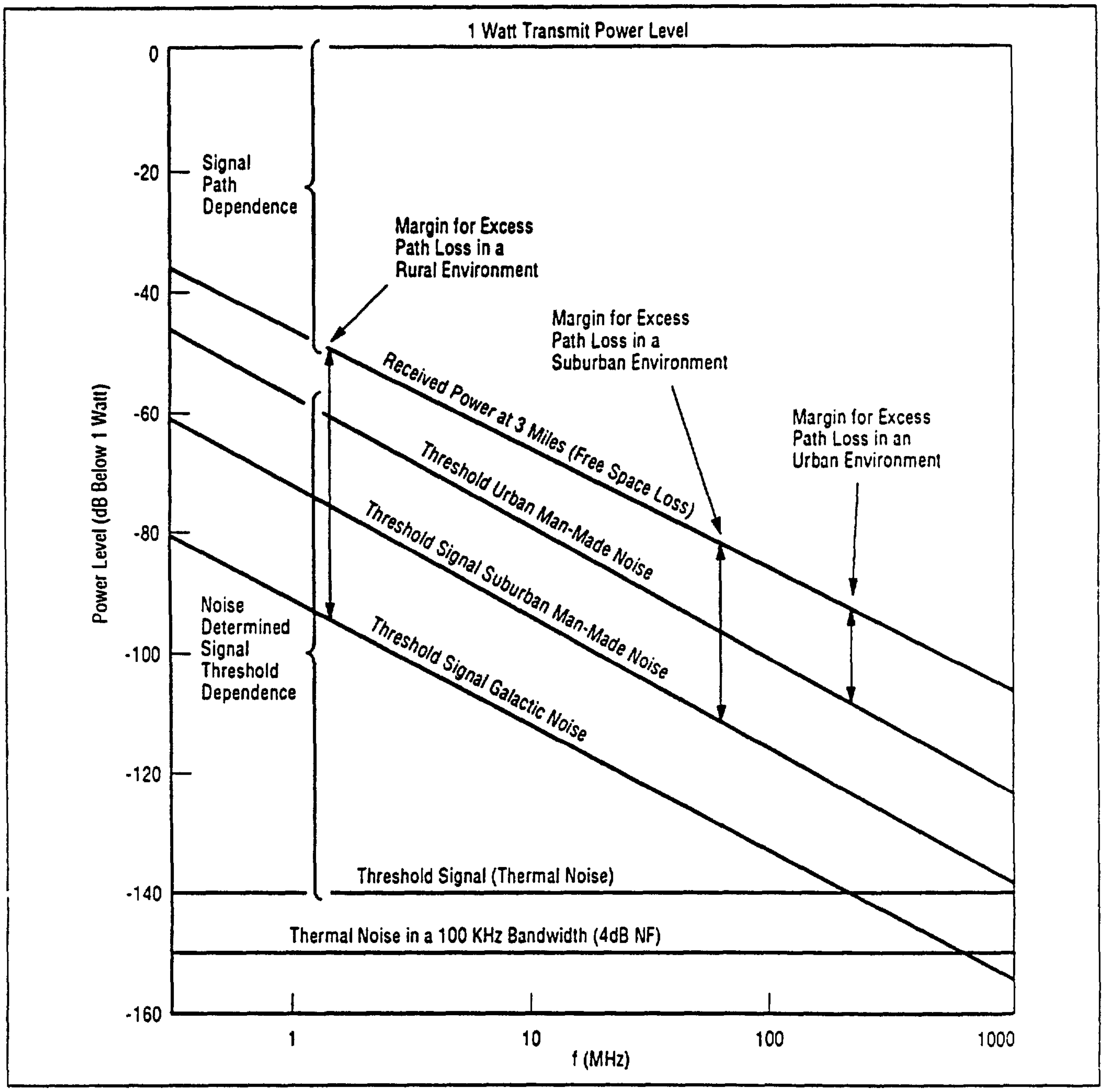

Figure D.3.2-2. Effect of Frequency Selection of Margin for Excess Path Loss. The effects of background noise minimizes the impact of frequency selection on link margin.

3. Definition of Communication Elements

RFP Ref: SOW Task C: Section L.I.D

To meet the low cost required to make this system feasible, the transmitter and receiver designs chosen for the ultimate baseline system will be implemented using a minimum number of MMIC and ASIC circuits. The flexibility of this design will support user-friendly operation and control.

Hughes believes that a transmit/receive system will be available as part of other automobile information systems. With this assumption, Hughes recommends consideration of both receive-only and transmit receive systems.

Considerable effort remains before foal determination can be made of the frequency of operation and the modulation waveforms and information content for the ultimate IVSAWS system. As indicated in the SHAWS Study Report, there are significant advantages to a two-way link capability. Through the use of Application Specific Integrated Circuits and Microwave Monolithic Integrated Circuits (ASICs and MMICs), significantly greater complexity can be achieved without greater costs, thereby making such a twoway system worth considering in these tradeoffs.

Most of the waveforms being considered for the ultimate system allow the transmitter and receiver to have a high degree of commonality with the receiver being the more complex of the two. The receiver consists of two primary functions: a message and signal processor, and an RF/analog section. With modem MMIC technology, the addition of the parts needed to provide the automobile with a transmitter and therefore a two-way link might have little or no impact on the cost of the overall unit.

The message and signal processor will consist of a modem chip (or chip set) and special processing logic. The modem chip will be used for converting (analog to digital) sampled data from the RF subassembly to a serial bit stream for subsequent processing by the message processor unit. The modem chip set will provide the required bit time tracking loop requirements. Since cost will be a driving factor for the receiver system, non-coherent signal processing will be used to eliminate costly phase tracking circuitry. The modem logic will also include some type of simple forward error correction decoding and preamble/ID recognition logic.

The demodulated output data from the modem will be saved in memory and used to control and drive both the voice synthesizer chip and visual display modulator. The approach for voice synthesis will be determined during the course of the IVSAWS study, but both canned messages and real-time messages may be required for successful system operation. If this is the case, resident memory will be included in the IVSAWS Driver Alert Warning System (DAWS) to store not only canned hazard messages, but real-time digital voice. In this manner, if the vehicle occupants request a repeat of the last received message, they need only request a retransmission from the buffered data in the vehicle's DAWS memory, as opposed to requesting a retransmission from the distant transmitter. An automatic timeout function will be included to clear DAWS memory if and when periodic updates are not received from the transmitter. The visual display modulator will be used to drive and refresh the color display monitor.

The message and signal processor requirements lend themselves to the use of Application Specific Integrated Circuit (ASIC) devices. Hughes is experienced in developing chip sets with microprocessor embedded dies. This approach allows for low recurring cost implementations. The availability of a microprocessor component in the Driver Alert Warning System will add extremely efficient flexibility to the IVSAWS system by providing ease in reprogramming both stored voice synthesis and display driver graphics. The microprocessor software will include self-test diagnostic routines to test the DAWS electronics during both initial power turn-on and actual operation. Microprocessor CPU utilization is expected to be very low, thereby allowing for system self-test functions in a so-called non interrupt background mode. The basic design can also (if required) provide fault isolation to allow technicians to identify the failed module. The receipt of a hazard message will generate a vectored interrupt to the microprocessor, which will initiate audio synthesis and/or visual display. It is expected that in some cases (depending on the priority of the hazard) the microprocessor outputs will automatically interrupt/override existing audio (car stereo) within the car for urgent hazard warnings. The combination of automatic override, interactive use of the system (voice synthesis retransmission request), combinations of voice synthesis and visual displays and human factors studies are all aimed at an IVSAWS DAWS characterized by user-friendly controls, high reliability, dependability, and low recurring cost.

The RF section must provide all the analog and RF signals necessary to generate or receive the over the air waveforms. It will contain circuits operating from low frequency analog (such as the controls driving the modulator) to high speed RF (such as the PLL generating the RF carrier). Currently available RF/Analog ASIC and MMIC technologies include fairly complex circuits such as multi-bit analog to digital and digital to analog converters. Advances are being made in the state of the art, allowing much higher speed, higher density silicon processes.

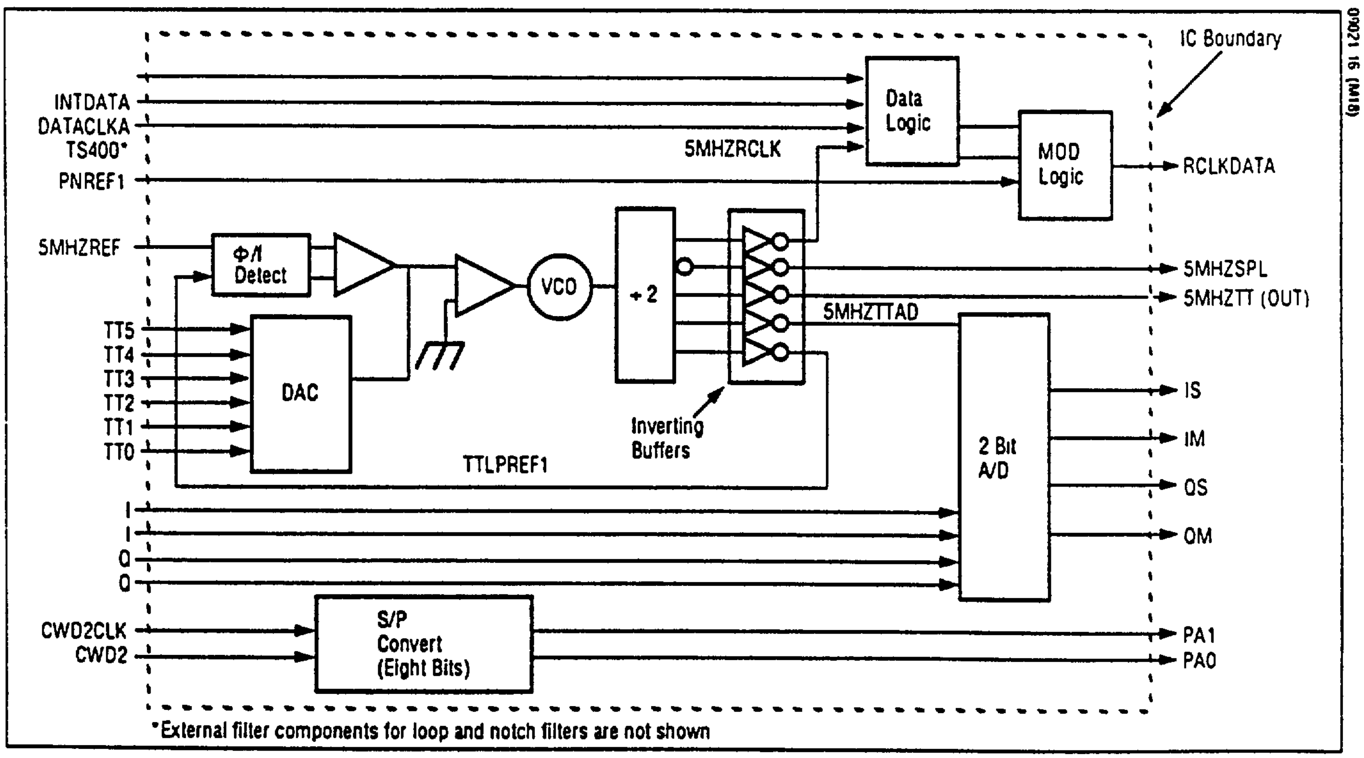

Figure D.3.3-1. Typical Mixed Mode Digital/Analog ASIC currently in development at Hughes. With the 50% reduction in production costs resulting from this IR&D effort and the quantities expected for the IVSAWS, the cost for the ASIC is expected to be about $ 5.

4. Use of Computer Models for Communications Analysis

RFP Ref: SOW Task C; Section L.1.D

Hughes communications specialists are trained in digital waveform design and optimization in marginal signal conditions, including low signal to noise ratio and fading signals. Supplementing this experience are Hughes sophisticated computer models to analyze propagation loss and other signal processing designs to give a high degree of confidence in the selected design.

The Hughes Communications System Division (CSD) engineering staff is intimately familiar with the problems of designing a system to work under marginal conditions. Hughes CSD has pioneered the use of spread-spectrum modulation and error correction encoding to counter the effects of noise, impulsive interference and fading signals. Supplementing this experience are Hughes sophisticated computer models to analyze propagation loss and other signal processing designs to give a high degree of confidence in the selected design.

The Hughes Communication Systems Division (CSD) engineering staff is intimately familiar with the problems of designing a system to work under marginal conditions. Hughes CSD has pioneered the use of spread-spectrum modulation and error correction encoding to counter the effects of noise, impulsive interference and fading signals. Much of the analysis will be performed using well known results from the field. This approach will allow us to narrow the architectural design problem to the resolution of a few key issues:

- The number of bits to be transmitted in a message, including overhead for each message type
- The burst data rate and transmit duty factor
- The appropriateness of a spread spectrum waveform
- The selection of the frequency band

These issues were discussed in the preceding topic. Only one requires a computer analysis. Namely, the issue of frequency selection is strongly determined by propagation coverage in rolling terrain. This analysis has been addressed with the Langley-Rice propagation model, which has been standard in the US Army for more than 10 years and has been carefully validated with experimental data. Hughes has extended the model to include the effects of foliage attenuation. Figure D.3.4- 1 shows the use of the Longley-Rice Model in a rework management context.

- **A** point-to-point mode, which uses a terrain profile and computes the path loss based on a series of knife-edge diffraction losses
- An area mode, based on data from the Defense Mapping Agency height data or a two dimensional random surface with a specified roughness

The output from this program gives a mean propagation loss and the expected variance in the propagation loss between any number of specified terminal pairs.

The Longley-Rice model will be used extensively in establishing the effects of excess propagation loss as a function of frequency.

Additional computer analyses and simulation may be used to optimize waveform parameters as the study progresses and the baseline waveform parameters are determined.

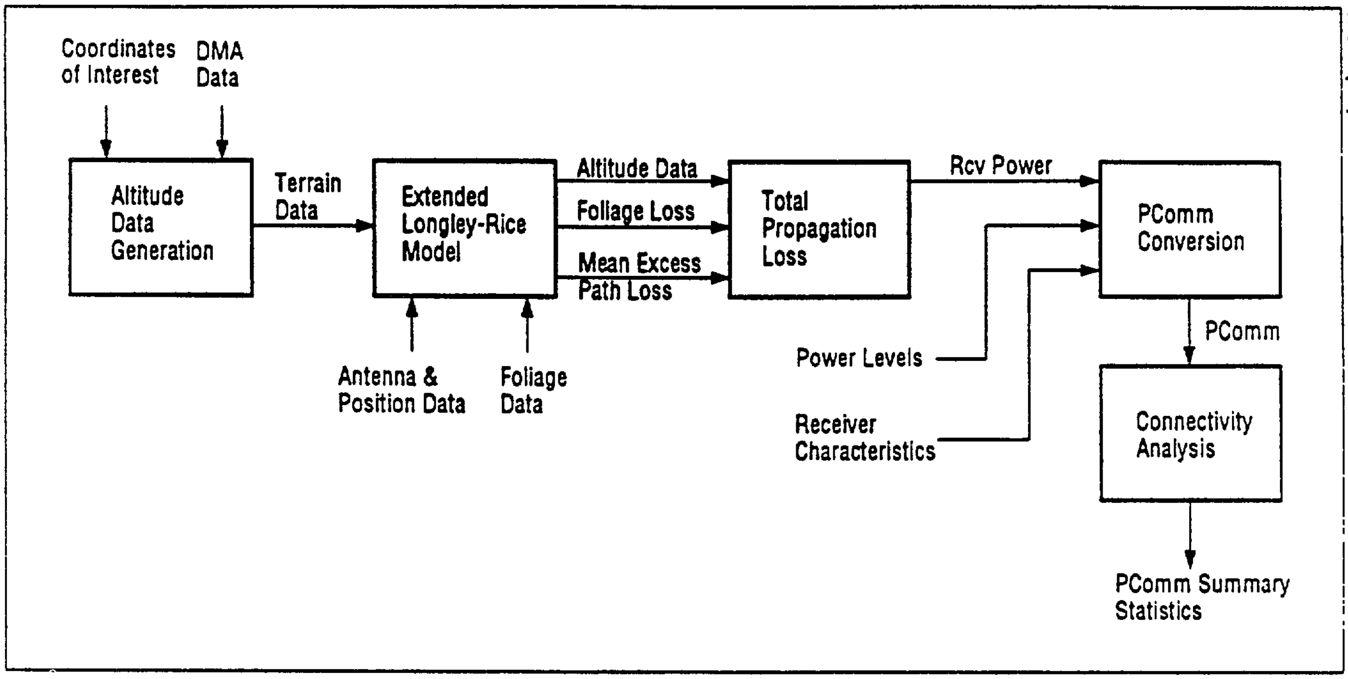

Figure D.3.4-1. Hughes Network Management Algorithm Development Tools Software. Hughes will use its highly refined communications connecivity analysis tools to assure an effective communication systems architecture and accurate modeling of communication performance.

5. Definition of Method of Alerting Drivers

RFP Ref: SOW Task C; Section L.I.D

Using past experience and current research, Hughes human factors and systems engineering personnel will determine a practical method for alerting drivers to hazards, at a distance appropriate to allow corrective action.

Hughes has had considerable experience over the last 30 years designing display-intensive user-interface systems that require rapid operator understanding and reaction. This experience has ranged fiom early monochrome displays for U.S. Navy Tactical Data Systems (NTDS) to current full-color air traffic control systems. As both military and commercial systems have become more complex, the need for effective human factors has grown. Human operators or drivers must assimilate information rapidly, identify the need for action or inaction, decide on an appropriate action, and respond correctly. In nearly all cases this response must be 100 percent accurate to avoid a hazard, system damage, mission failure or the death of many persons. For this reason Hughes takes the IVSAWS study very seriously and has identified prior studies and programs that provide **a** strong basis for selecting an appropriate method for alerting drivers of varying ages and degrees of attention.

Two recent activities provide relevant data toward the selection of methods for alerting automotive drivers. The first provides the results of the Federal Aviation Administration/Advanced Automation System (FAA/AAS), System Design Trade Study reported in March of 1986. Within this four-year study are relevant trade studies that will contribute to an effective means of alerting drivers. These include the following:

- Effects of task difficulty on performance of simulated tasks as a function of color coding
- Effect of display density, color and exposure time on operator accuracy
- Effect of color as a function of display density
- Angular limits for color detection with head and eye fixed
- Expanded angular limits for color sensing, assuming freedom to move head and eyes
- Effects of display and density exposure time on accuracy of target location
- Recommended symbol size as a function of the number of colors used on the display
- Reading accuracy as a function of symbol color
- Response time as a function of misregistration

The overall effect of these studies, combined with additional design development, has provided a means for air traffic controllers to accurately, safely, and effectively perform their tasks within highly time-critical parameters. The FAA judged Hughes' design technically superior. An example of FAA/AAS Candidate color application to potential hazardous situations is shown in Table D.3.5I

The second study is currently ongoing with the direct involvement of the City of Orlando, Florida, General Motors, AAA, and the University of Idaho. Hughes will develop a Driver Interface Specification that describes in detail the operational, functional and performance requirements necessary to design, develop and test the interface for TRAVTEK. The mission of the TRAVTEK Driver Interface is to provide displays and controls to aid the driver in the selection of the best route to a designated destination, given current traffic conditions. In addition, the driver is supplied with information on

TABLE D.3.5-I. MAJOR BENEFITS OF COLOR TO AIR TRAFFIC CONTROL

Display Functions	Advantage of Color
• Flight Specific Data	
Hazardous	
Conflict Alert	Quick Location of incident and causal factors
Minimum Safe Altitude	Quick location of aircraft
Emergency	Quick location of aircraft
Airspace Encroachment	Quick location of aircraft and airspace impacted
Handoff Rejection	Reduce coordination communications
Potentially Hazardous	
Handoff/Pointout Status	Identifies need for controller action
Track Deviations	Early identification could preclude hazard
Spill Outs/Spill Ins	Early identification could preclude hazard
Unusual Maneuvers Rate of Climb - Descent	Controller bases action on anticipated aircraft behavior
Excessive or Abnormal Speed in Terminal Environment	Early identification could preclude hazard
Altitude Nonconformance	Early identification could preclude hazard
Area Probes	Early discrimination of probe
Flow Control Violations	Quick location of aircraft and type of violations
Non-Hazardous	
Track Update	Quickly seen as normal operation
• Dynamic	
Weather Graphics	Various weather products and intensities discernible
Special Use Airspace Status	Status always readily visible
Special Activities - Parachuting, etc.	Information always readily visible

local events and with a cellular phone connection for further information and emergency use.

Hughes is currently developing the prototype color display, icons/symbols, and graphics, and is supporting voice output and audible alerts. Hughes Human Factors responsibility is the Driver Interface that provides the inputs and outputs between the vehicle subsystem of TRAVTEK and the vehicle driver.

Participation in these studies, combined with ongoing General Motors activity, permit Hughes Human Factors to be aware of the various factors that influence the selection of a driver alerting method. Additional data, relevant to the older driver, is provided by Hughes General Motors association with the University of Southern California, Institute of Safety and Systems Management. A March 31,1989 report (No. PB276626), addresses the age-specific needs as well as physical, sensory-motor and motivational characteristics of elderly drivers with regard to comfort/performance, safety and confidence in the effective operation and usage of a motor vehicle. This nport made evident several factors influencing a design for those over 50 years of age, and that must be considered for an effective alerting method:

- Body size and shape
- Range of motion and joint flexibility
- Strength and force
- Biomechanical injury
- Sensitivity to glare
- Visual field
- Acuity and contrast sensitivity
- Cognitive changes (attention, speed of decisions, judgment)

Based on the above studies, Hughes does not propose a single method of alerting drivers, but anticipates the use of multiple alerting capabilities. Hughes Human Factors will investigate a combination of visual and auditory alerting capabilities that include the following;

- In-dash touch-panel color display
- Heads-up color display
- Instrument panel indicator displays
- Voice output
- Tone/signal output

Hughes Human Factors believes that a combination of visual and auditory alerting is necessary to obtain the attention of drivers who are hearing impaired, require corrective lenses, or are elderly. This combination, with some visual or auditory enhancement, should also accommodate drivers with reduced attention.

Upon conclusion of this research supported by the laboratory facility described in D.5.2, it is anticipated that, based on cost and availability, one visual system will be selected, in combination with one or two auditory systems, as the report recommendations submitted to the COTR for approval, procurement and test.

1. Selecting Available Equipment for the Demo

RFP Ref: SOW Task D; Section L. I. D

The demonstration will be conducted with available off-the-shelf equipment as the core of the transmitter/receiver subsystem. Hughes is developing a low-cost spread spectrum transmitter/receiver for a vehicle location system that will be evaluated as alternative evaluation equipment.

Hughes is one of the leading companies in the world in the development of communications systems, including spread spectrum systems. One such system developed by Hughes is the Position Location and Reporting System (PLRS). This system uses a spread spectrum waveform very similar in nature to the DPSK format being considered for IVSAWS. Laboratory and field tests have shown that the PLRS/EPLRS system is capable of receiving a DPSK signal. If commercially available equipment proves unsuitable for use as the demonstration units, it may be possible to use the hardware developed for an offshoot of PLRS known as the Vehicle Location System (VLS). This system uses modified PLRS receivers and a small DPSK transmitter to achieve point to point communications of digital messages.

While Hughes expertise in the development of spread spectrum systems is very critical to the development of the final configuration units, the demonsnation is expected to be carried out using a commercially available system. One commercial system currently being considered for use in the demonstration system is based on the Advanced Rapid Local Area Net (ARLAN) System developed by Telesystems SLW Inc. of Ontario, Canada. This system is designed as a wireless intraoffice communications system to allow personal computers to communicate. It was used by Hughes in 1989 to outfit a race car for General Motors. The system was configured to relay data from various onboard systems to a central location. The tests were highly successful and prove the applicability of ARLAN **to** a test like that envisioned for IVSAWS.

The ARLAN unit uses a DPSK spread spectrum format to provide communication of digital messages. The system operates at a center frequency of 915 MHz with a spreading bandwidth of 26 MHz. It can maintain data rates of up to 19200 baud rate. It is designed to be controlled by a personal computer, and has a standard RS-232C interface. Because it is designed for intraoffice communications its range is limited. An external power amplifier, low noise preamplifier, and a modified antenna would be required to meet the needs of this demonstration. Table D.4.1-1 summarizes some of the important operating parameters of the ARLAN unit.

An interface box would be built containing the ARLAN unit, a power supply, power amplifier, low noise preamplifier, and bandpass filters configured to reduce susceptibility to undesired interference from normal broadcast and other sources. The power supply will be capable of generating all voltages required for the ARLAN and other units from either automotive or fixed site battery sources. A standard voice synthesizer chip will be used as required to support announcing alert messages to the driver. This device will be driven from a limited vocabulary dictionary with digitally addressed entries.

An analysis of transmission power levels required to meet link margins will be made and a power amplifier of sufficient level will be chosen accordingly. Similarly, the gain and noise figure for the LNA will be determined and a unit chosen. One area of particular concern is the type and configuration of the antenna or antennas required to provide desired transmission and reception coverages. Significant effort will be required to determine suitable antennas and antenna placement on both the transmit and receive platforms.

Hughes will select an installation package in the car which will assure simplicity of operation, freedom from inadvertant activation and will be secure from vandals.

TABLE D.4. l- 1. OPERATING PARAMETERS OF THE ARLAN SYSTEM

User Interface	
Type:	Serial RS-232C, full duplex
Speed and Format:	Asynchronous, 7 or 8 **bit ASCII,** even, odd or no parity, 1 stop bit 300, 1200, 2400, 4800, 9600, or 19200 baud.
Radio	
Frequency:	915 MHz (center of band)
Modulation:	Spread spectrum over a 26 MHz bandwidth
Power Output:	1 watt maximum
FCC Regulations:	Operates license-free under FCC Part 15 as a low power spread spectrum system.
Data Link Format	
Multiplexing:	Packet Radio
Rate:	**200** kb/s
Media access:	Multiple access and adaptive polling
Addressing:	Virtually unlimited (open addressing)
Encryption:	User-programmable soft-key
Physical	
Size:	2.5 x 4.75 x 10 inches
Weight:	**2.2** lb

1. Definition of Driver Alert Warning System

RFP Rcf: SOW Task E; Section L.I.D.

Hughes will evaluate both available and projected state of the art displays and voice announcing devices to select a Driver Alert Warning System Baseline. Selection criteria will include driver reactions, the limited availability of space for display, and the needs of physically impaired drivers.

The Driver Alert Warning System (DAWS) represents those components (hardware and software) resident in a vehicle which are used to convey information concerning advisory, safety and hazard situations to the driver of the vehicle. One of the main purposes of the proposed study is to determine the specific components which make up an optimum DAWS. Optimization parameters include driver safety, system effectiveness, producibility, maintainability, reliability, recurring and non-recurring cost, size, power, weight, environmental characteristics, installation complexity, system expansion/growth capabilities, integration effectiveness with existing vehicle systems, usefulness by normal drivers, physically impaired drivers, and different age groups, as well as acceptance by the motoring public. Obviously, many of these parameters represent diametrically opposed implementation constraints. The IVSAWS study will address and weight each DAWS parameter for determining an optimum Driver Alert Warning System.

The Hughes approach to developing the IVSAWS DAWS is to provide a base for a fully integrated audible and visual display system, which not only satisfies the IVSAWS requirements, but also provides for integration of existing (odometer, tachometer, fuel status, oil pressure, engine temperature, climate control, diagnostic reports, warning systems, radio, direction signals, etc.) as well as future (Intelligent Vehicle Highway System IVHS), Radio Determination Satellite System (RDSS), Vehicle Location System (VLS), etc.) automotive systems. This approach is considered necessary because of the extremely limited amount of usable instrumentation panel space and human factors constraints.

Hughes has recently conducted an extensive acoustic study for General Motors related to the measurement of noise generated within the passenger compartment of moving vehicles. Although this study was conducted to determine the frequency spectrum and levels of noise sources at various speeds for the purpose of developing noise cancelling headsets for vehicle drivers, the study does provide valuable assistance for determining the type and level of audible/voice synthesis methods required for effectively alerting automotive occupants. To provide optimization as well as coverage for hearing impaired drivers, it is expected that visual display requirements will also evolve from the IVSAWS study. Assuming the use of a combination of both audible and visual display technology, the driver alert warning system must be designed to assure simple, non-confusing effective operation. The method of warning the driver via DAWS represents a key technical challenge to the IVSAWS study.

Although it is anticipated that a fully integrated DAWS voice synthesis/display system will be required, human factors studies will be used to determine the amount, overlap and effectiveness of audible/visual display technology required for normal, hearing impaired and visually impaired drivers.

The hardware expected to be used during the demonstration part of the IVSAWS program to emulate the DAWS system is expected to consist of the following main components:

1. An antenna receiver, and digital demodulator
2. Dash-board mounted Color display unit (4” to 7” diagonal)
3. Portable PC
4. Voice synthesizer card for portable PC

The personal computer will be used to process digital data output from the spread-spectrum modem for appropriate formatting of symbols and messages. It is envisioned that for the demonstration a subset of the ultimate programs icons/pictograms/symbols (tell-tales) will be used. In addition a plug-in voice synthesizer card will be used in the PC for generating audible tones and/or messages for the driver. These components will be installed into a vehicle provided by General Motors. General Motors currently has several vehicles loaned to the Hughes Fullerton facility which will be used for testing and evaluating the IVSAWS DAWS system. The above quipment will be instrumented with test equipment required to perform human factors engineering studies (refer to next section) and communications throughput/processing tests.

2. Human Factors Testing of Driver-Alert Warning System

RFP Ref: Sow Task E; Section L.I.D

Hughes will confirm the feasibility of a selected Driver-Alert Warning System interface through state-of-the-art empirical human factors laboratory testing. Preliminary measures of effectiveness will be established and refined taking into consideration the needs of older drivers as well as impaired drivers.

The testing of a Driver-Alert Warning System will be predicated on data derived during the human factors engineering analysis phase of this study as well as data obtained during selection trade studies. The initial task data contained in Report No. FHWA/RD-8 1-124 will be compared to, and updated by, data contained in the study commissioned by the U.S. Department of Transportation (DOT) and the National Highway Traffic Safety Administration (NHTSA), Driver Education Task Analysis Vol. I. Task Description. Contract No, FH-1 l-7336. The University of Southern California, Institute of Safety and Systems Management, further refined the task data in Report No. PB276626, for a General Motors study involving mature drivers over 50 years of age. These data, task analyses, and functional allocations will provide the bases for the development of a critical task analysis and scenario relevant to the testing of the driver-alert warning system.

The selection of the appropriate driver display will be the result of joint trade studies conducted by human factors, systems engineering, electrical engineering, and mechanical engineering personnel. Three primary candidates include (1) instrument panel tell-tales (symbols), (2) heads-up display, and (3) touch panel CRT. Prior to selecting of a candidate or candidates, a number of visual factors will require resolution.These factors include:

- Appropriateness of screen icon/pictogram/symbol
- Comprehensibility of icon/pictogram/symbol
- Effectiveness of icon/pictogram/symbol
- Appropriateness of voice/tone output
- Comprehensibility of voice/tone output
- Effectiveness of voice/tone output
- Advantage/disadvantage of color
- Useful number of colors
- Color discriminability

In regard to the first three factors, the International Standardisation Organization (ISO) has developed a standardization procedure to ascertain the comprehensibility of graphic symbols intended for the presentation of public information. The standard is, in fact, a design brief. Crucial in the standardization procedure is that objective proof be provided that the symbol used for the standard image description be understood by the potential users. IS0 uses an acceptance criterion of 67% correct responses.

The American National Standards Institute (ANSI) standard 2535.3 (ANSI, 1987) recommends an 85% recognition rate for a pictogram to be considered acceptable for general use. It is incumbent on Hughes to carefully and empirically test the use of any symbol or icon independent of the Driver-Alert Warning System.

In regard to voice technology, Hughes Radar Systems Group, Automotive Programs, recently completed a GM restricted report, Speech Recognition Technology ev, June

1989, Report No. 89-07/G7690-001, that provided certain tentative conclusions applicable to this study. The abridged conclusions follow.

1. Speech technology, for the foreseeable future is not a panacea for automotive control/display designers. Natural speech input is unlikely as is highly accurate performance for all speakers.
2. Nevertheless, upwards of 95 percent recognition should be achievable for small but useful vocabularies if they are properly designed. This accuracy should be relatively independent of normal automotive noise levels. . .
3. Most current systems that do not require training of individual users employ small, specialized vocabularies. . .
4. . . . With integrated circuits continuing to be improved as they have been, an inexpensive, completely self-contained automotive speech recognizer is also a distinct near-term possibility."

As with symbol selection, voice input/output must be tested to ensure comprehensibility and understanding. Driver preferences for speech versus tone as well as message content will be reviewed during laboratory testing.

The last three factors deal with color application applicable to symbol/pictogram/icon as well as with the specific display device used. Table D.5.2-I identifies some major factors to be considered in the selection of colors as well as the design-sensitive factors that relate to their usage. These factors will be considered during Hughes empirical laboratory testing.

Two specific laboratories at Hughes will be considered for initial empirical testing of the Driver-Alert Warning System. The first is the Hughes Ground Systems Group (GSG) Human Factors/Artificial Intelligence Laboratory, Fullerton, CA. The second is the Hughes Radar Systems Group (RSG) Display Systems Laboratory, Culver City, CA. The Hughes GSG Lab has been used most recently for the graphic display prototyping of color screens in support of the TRAVTEK, FAA/Advanced Automation System (FAA/AAS) for air traffic control, Canadian Advanced Automation Traffic Control System (CAATS), Icelandic Air Defense System and General Motors Human Factors Graphic Interface Development System. The Lab houses two Apple Macintosh II color systems, including a 19-inch full-spectrum color monitor, a HP Vectra IBM-compatible system, several smaller PC systems, a terminal/modem link to Hughes' Computer Aided Design and Manufacturing System (CADAM) as well as an eight-color HP Ink-Jet Plotter. Several design and graphic prototyping software tools are used to create animated and static displays for preliminary design evaluation prior to full software development. These preliminary designs are converted into software specifications after evaluation by engineers and test subjects.

The RSG Lab contains the Hughes Driving Simulator, a wide field-of-view, driver-in-the-loop, fixed-base automobile simulator, developed as an outgrowth of military flight simulators used for designing cockpit displays and controls. The simulator was conceived as a key product development tool for automotive Heads-Up Displays (HUD), Virtual Image Displays, holographs displays, and related driver interface products. The driver is surrounded by a sensory environment that mimics key subsets of the anticipated cues experienced while driving an automobile (e.g., visual scene, engine and roadway sounds). Display information can also be presented with a reconfigurable HUD and, when required, on a head-down instrument panel display. A precision response time measurement system, developed by Hughes engineers, is available for tracking driver

TABLE D.5.2-I. PLAN TO DEAL WITH MAJOR FACTORS IN SELECTION OF CCLOR PALETTE

Design-Sensitive Factors	Related Plans for Color Use
Ambient Lighting (Facilitation or Interference)	Interaction of ambient lighting with display colors will be analyzed, simulated and factored into color specifications
Color Brightness	Display colors will be designed to appear approximately equally bright for data categories of equal importance
Color Naming	Color codes will employ hues with commonly understood names, such as red, green, blue and yellow (cyan, magenta, amber, etc. will be avoided during early applications)
Color Constancy	Each displayed color will be selected to appear to be the same hue under all levels of ambient illumination and drive intensity as well as in all planned combinations of adjacent colors and color presentation sequences
Color Contrast and Control of Background Hues	Color contrast will be used as one means of adjusting data conspicuity and for object emphasis. Background fields will be designed to achieve desired color contrast effects
Color Stereopsis	The use of highly saturated red and blue will be avoided where practicable
Optical Color Transformation	Effects of anti-glare coatings, special filters and other transmission media (between face plate and controller's retina) will be determined and accounted for in color specification
Code Standards	Established specifications and proven guidelines for color coding will be followed where practicable in assignment of colors within the MMI language

reaction times to any event in a simulation. The system measures driver reactions to visual and auditory events in tenths or hundredths of a millisecond. A schematic of the simulator configuration is shown in Figure D.5.2-1. The Driving Simulator will be used as a "mockup" to replicate the eventual configuration for in-vehicle testing. Soft mockups may be used to "size" the Driver-Alert Warning System hardware prior to installation.

Hughes intends to empirically test selected icon/symbols (tell-tales), for recognizability/appropriateness, comprehensibility and effectiveness, using monochrome and color applications. Colors will be selected based on probable hazard levels defined in Report No. FHWA/RD-81/124. The selected symbols will be tested individually as well as when paired with voice messages, tones, and with tones and voice. Primary measures of effectiveness will be accuracy/correctness of response and timeliness of response (response time).

The subjects used for laboratory testing will be drawn from Hughes population of hourly workers and engineers, university students and professors and available General Motors personnel. This will allow access to a broad range of education, age, and respondents with varying associations or familiarity with icons/symbols. The subjects will be apportioned into age groups representative of the groups to be used for final system testing. That is, young (approximately 16 to 35 years of age), middle aged (approximately 36 to 65 years of age), and old (over 65 years of age).

The results of the selection and testing of a driver-alert warning system will be summarized in a report that identifies the procedures followed, sample populations and measurements used, statistical analyses employed, equipment and software configurations, and summary conclusions.

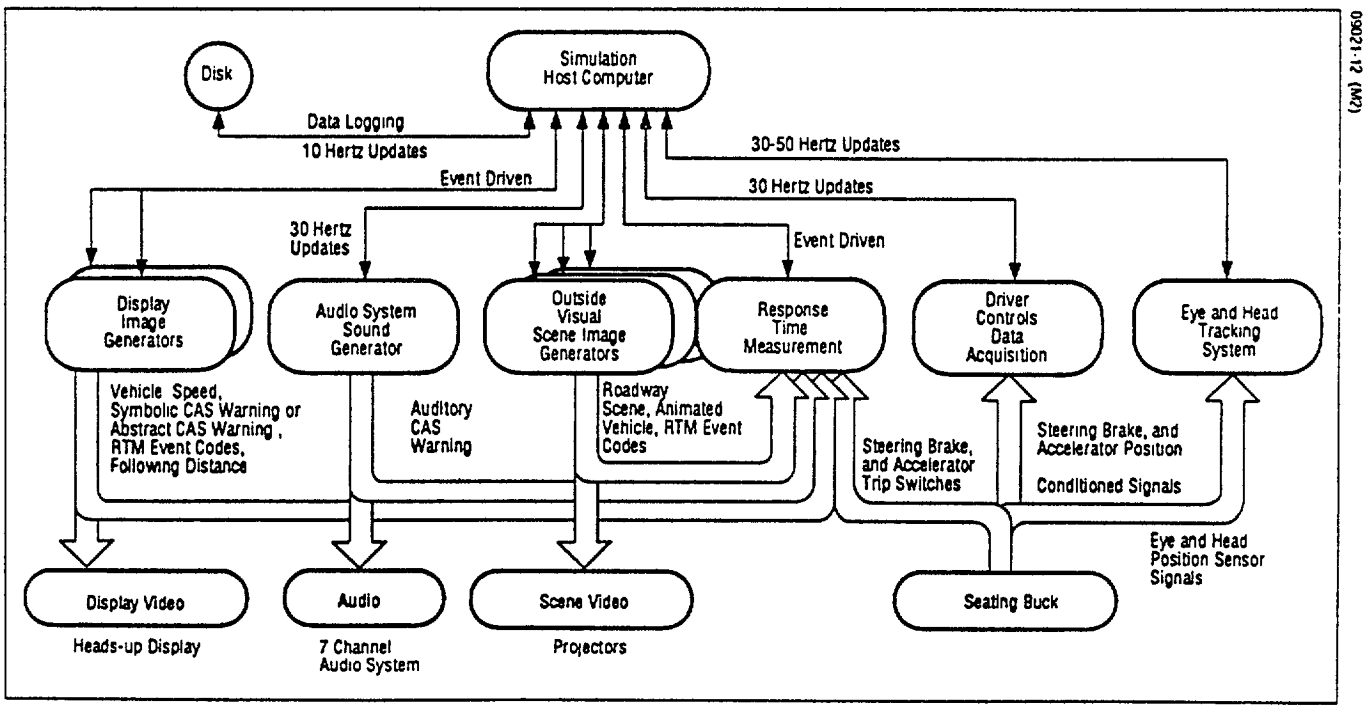

Figure D.5.2-1. Hughes Driving Simulator. The Driving Simulator provides the full range of visual and auditory input capability and can expertly test all of the Driver-Alert Warning System scenarios needed for the study evaluations.

1. Fabricating the IVSAWS

RFP Ref: Task F; Section L.I.D.

Previously tested commercial off-the-shelf components will be used to evaluate the Driver Alert Warning System.

The demonstration Driver-Alert Warning System (DAWS) hardware design will consist of selecting as much commercial off-the-shelf (COTS) hardware as possible. In addition, the use of as much existing vehicle hardware will be used. Hughes plans on using one of many test vehicles supplied by their parent company (General Motors Corporation) for evaluating the IVSAWS concepts developed during this study. Demonstration testing will be implemented using **a** commercially available portable personal computer (PC) for driving the demonstration hardware/software, COTS low noise amplifiers (LNAs), receiver, transmitter, spread spectrum modem, voice synthesizer and color display system. Since the demonstration will be viewed as a concept validation only, no attempt will be made to reduce demonstration hardware cost.

Hughes currently envisions using a Telesystems Inc. Advanced Radio Local Area Network (ARLAN) spread spectrum transceiver for the NSAWS demonstration system. This system was previously purchased by Hughes to support an ongoing vehicle communications project for GM. The ARLAN spread spectrum system is a low-cost 20-MHz spread spectrum data link that uses a combination of time and code division multiple access techniques for communicating asynchronous data rates ranging from 300 bps to 19.2 Kbps. The transceiver is physically small (2.5” x 4.75” x 10” envelope, 2.2 pounds) with an RS-232C serial user interface. The system includes up and down converters to a 915 MHz center frequency. Based on experience with applying ARLAN to the Chevrolet Racing Team telemetry project, where the ARLAN had limited range, Hughes will add a power amplifier if needed, to obtain the required range.

The ARLAN transceiver is a packet-based system which allows for full-duplex RS-232 user interfaces with half-duplex carrier operation. The spectrum spreading processing gain derived from this transceiver provides additional link margin as well as interference rejection. The antenna system used with ARLAN will be 5/8 x1/4 wavelength omni-directional vertical whip with 3-4 dB gain over isotropic. The antenna includes a magnetic mount with a 5/8 wavelength top element, l/4 wavelength bottom element and center impedance matching/resonator coil. The ARLAN transceiver includes built-in self-test logic, which checks for proper operation on power turn-on. The transmit function of the ARLAN system will not be utilized in the test car unless the results of Task C show that the operation of the IVSAWS baseline can be enhanced by two-way operation.

Other than a small amount of mechanical design for mounting the subject hardware in the vehicle per human factors directives, the main design task for the IVSAWS demonstration consists of generating the necessary software for use in the PC. The PC software will include several modules including those for down-loading and storing serial data from the spread spectrum modem, selection and activation of canned messages to be used by the voice synthesizer card for audible responses, and control of the video display.

The PC used for the IVSAWS demonstration will be an MS DOS based ruggedized lap-top PC with a 20 Mbyte hard disk. The PC will require an expansion slot for incorporation of a voice synthesizer card. The lap-top PC will include a conventional monochrome back-lighted LCD display. This display will not be used for monitoring and control of the test environment only. A separate small (4” to 7”) commercially available color monitor will be used to simulate the final IVSAWS color display system. The color monitor will be installed on the test vehicle dash panel using double backed tape (i.e., no extensive mounting provisions will be used).

1. Generate Test Plans and Procedures

RFP Ref: SOW Task G; Section L.I.D

Testability is designed into the IVSAWS Program. In programs similar to IVSAWS, it has been proven that a very comprehensive Master Test Plan must be generated that places emphasis on performance and allows the system to be tested at the module level as effectively as the full system demonstration.

The test environment must be planned to provide the correct conclusions of pass or failure and proper scenarios must be derived to conserve time and resources during the test period.

Breadboard testing is performed on all new electrical designs. After the performance requirements have been met, the prototype is assembled and unit level testing is performed. The complete transmitter-receiver paired system will then be fabricated and the propagation tests performed. After final system installation and integration the System Development Test is completed.

As depicted in Figure D.7.1-1, the concurrent test planning and feedback plays an important role in program development. Test engineers, working as copartners with the design engineers, establish procedures to verify the operation of the equipment and systematically exercise the applicable item under all the identified conditions. Procedures are established for identifying test objectives, translating these objectives into designs for tests and exercises.

The approach to system development will be empirical: to basically build a "strawman" (an initial configuration) and then use it to see what works and what doesn't. Then build a better "strawman" (a revised configuration), and ay again.

At each stage of the development, the system must undergo test and evaluation. While differing in degrees of formality, the test and evaluation cycle flows in a logical sequence. Identification of the issues to be addressed leads to establishment of the overall test design and the detailed test plan. The test is run, and after the data are recorded the analysis is performed to see what worked and what didn't, and the test report is prepared. This test cycle approach helps to develop the necessary methodology so that subsequent iterations can be compared on both relative and absolute scales.

To run effectively the Test Program must be properly managed by a Master Test Plan (MTP), prepared and monitored jointly by the design team and the test team, which provides for the selection and scheduling of test objectives.

The Master Test Plan will provide a formal means of directing test activities to ensure a significant return for the effon expended in key areas. This time/cost saving approach ensures that only meaningful tests and exercises are conducted.

Each test/exercise procedure will be designed to ensure that only the proper data is collected, recorded and analyzed. This design concept will include a method of correlation across individual test objectives.

Proper use of these design concepts eliminates the all-too-common problem of collecting larger amounts of information that is never used or is useless. The MTP will allow priorities to be assigned to the investigation of test objectives and the development of the scenarios and exercises, thereby permitting improved use of time and resources. The MTP will define the scope of each test objective and exercise, and will serve as a control on the amount of effort expended in test preparation.

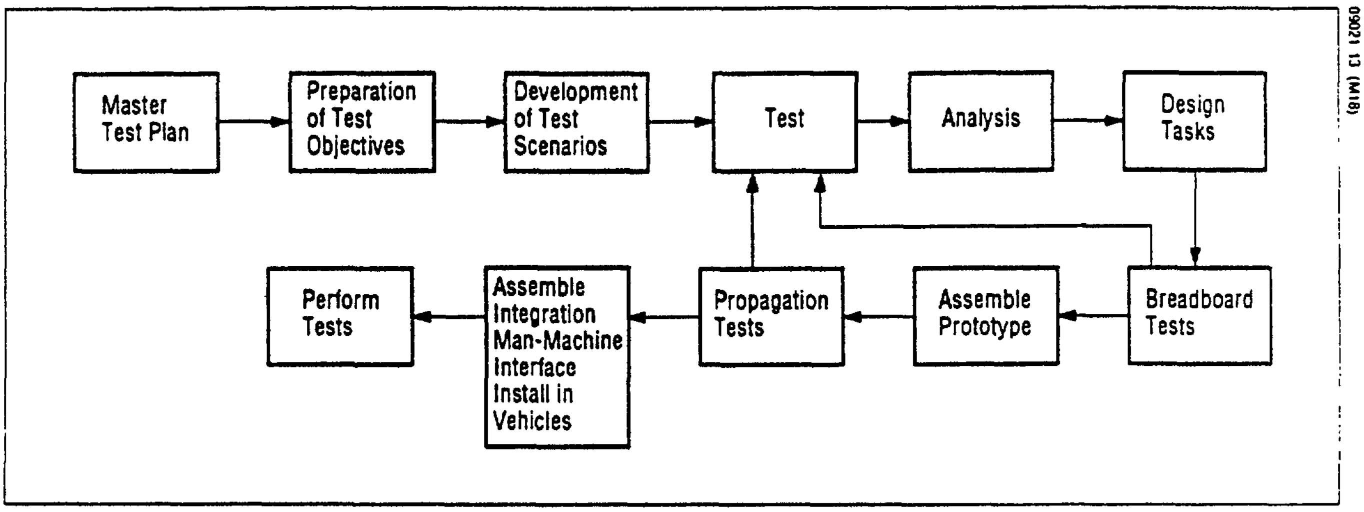

Figure D.7.1-1. Test Planning and Feedback Methodology. Testing and Design are copartners and will be used as such to ensure system effectiveness.

2. Radio Propagation Test

RFP Ref: SOW Task G; Section L.I.D

Extensive experience in modeling enables performance trends to be modeled and verified in field tests.

Hughes has developed a set of simulation tools for the evaluation of communications propagation parameters as delineated in Topic D.3.1. Because of the great number of variables that affect the performance of the IVSAWS, a unique set of accurate and yet flexible parameters will be selected and fine-tuned.

After modeling the candidate operating frequencies will be selected. Radio propagation tests will then be performed on the candidate transmitter and receiver to determine the communication performance of the design approach to IVSAWS.

Hughes has recently worked extensively with two major developments requiring extensive propagation tests. The first testing program involved an array of antennas mounted in the roof of the test vehicle (1987 Cadillac). The frequency spectrum covered by this array of antennas was 500 KHz (AM Broadcast) to 2.5 GHz (RDSS Down-Link, a proposed Mobile Subscriber Communications System).

Extensive link margin tests were performed while the vehicle was turned slowly on a turntable as the source transmitter outputs were varied and receiver sensitivity was measured. After extensive testing in this configuration the vehicle was driven on adjacent freeways in actual traffic to verify the results of the turntable tests.

The second program involved the Chevrolet Racing Team. These tests were performed to verify candidate transceiver performance and applicability to the proposed Chevrolet Race Vehicle Telemetry System. The testing was performed on a vehicle-mounted ARLAN 130/150 transceiver. These transceivers are direct sequence spread spectrum radios with a center frequency of 915 MHz. The test objectives included transmitter power output, receiver sensitivity, optimum packet transmission size, and ignition noise interference.

Numerous tests were made by driving the test vehicle to different locations within line of sight of the test base station and collecting measurements.

For the IVSAWS propagation testing Hughes will use captive tests using a fixed transmitter site. Receivers will be maneuvered around it in distinctive patterns to collect receiver sensitivity measurements, with and without interference, to demonstrate the reliability of the hazard warning concept.

Then the receiver will be mounted in a test vehicle and the transmitter in a test van and the two vehicles operated on an adjacent mountain highway (Ortega Highway) with many switchbacks, dense foliage at intervals, and many steep canyons. This test area will be ideal for demonstrating the hazard warning system in a myriad of situations. The van will be positioned at different locations to act as a fixed transmitter site, though it can also act as a slow-moving vehicle (school bus or maintenance vehicle). The test vehicle with the receiver will then approach the van from various directions and with various antenna locations , and propagation data will be collected. The various scenarios should reveal path-fading receiver discrimination, false alarms and effects of the real environment on propagation.

These parameters, path-fading in particular, will be compared to the simulation results and those tests data obtained from the turntable testbed. Attention will be paid to those situations where the signal is sufficiently weak or corrupted to cause interruption of the communications path and thus possibly cause a false alarm. Due to the robustness of the strawman system relative to interference and noise injection, and the system's high level of discrimination against corrupted transmissions, false alarm conditions due to corrupted information should be virtually non-existent.

These tests will exercise the transmitter-receiver pairings at various distances, in different types of climate, time of day, with or without outside interference in different types of terrain and foliage. Some of the specific parameters and conditions that will direct the selections of the test environment are:

Transmitter directivity
Transmitter location
Receiver-transmitter sensitivity
Structures and terrain
Interference such as machinery, power lines, vehicle ignitions systems

Test results will be analyzed for anomalies and deviations from the modeling, then the test conditions will be modified to enable the testing of those areas that were uncertain or contaminated during the previous tests.

On completion of these propagation tests, final analysis will be performed and a summary documented.

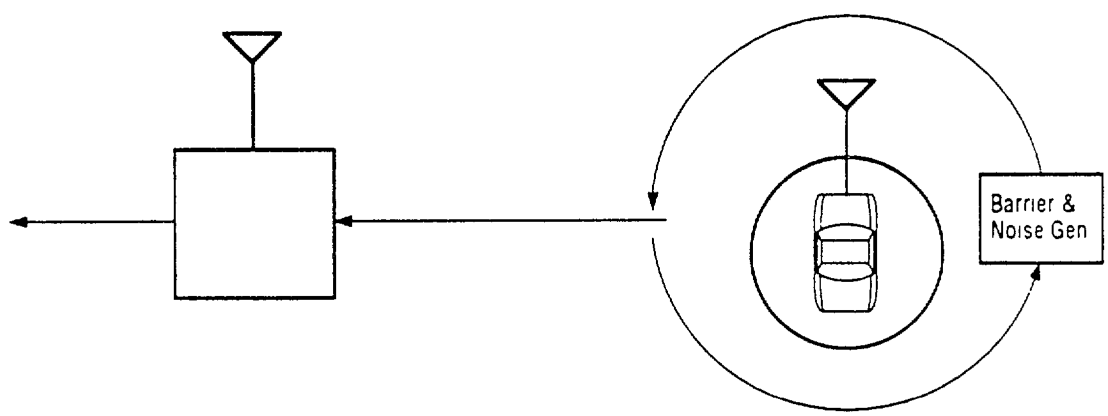

Figure D.7.2-1. Propagation Test Facility. The receiver is mounted in a vehicle, which is then placed on a turntable. The transmitter is moved to various distances from the turntable, with a barrier and noise generator revolving around the receiver-mounted vehicle. Sensitivity measurements will be taken at various geometric configurations.

3. Conduct System Demonstration

RFP Ref: SOW Task G; Section L.I.D

The challenges facing Hughes in the System Demonstration Test are (1) directing the test fxlow to achieve the objectives of the system test, (2) obtain consistency in **the test parameters, (3) incorporate the results of the previous propagation and human factors testing. Scenarios will be generated to direct the testing** to **achieve these objectives with minimum time and resources.**

Upon complete design, fabrication, assembly and integration of the transmitter and receiver systems, the receiver and driver alert equipment will be installed in a test vehicle and the transmitter will be deployed in a test van. The vehicles again will be dispatched to the Ortega Highway locale. See Figure D.7.3-1. The hazard warning uansmitter will be placed at various locations and will be programmed to report specific incidents or types of fixed hazards. Various drivers of the test vehicle will then execute different driving maneuvers over designated routes and respond to different scenarios as the equipment is operated under actual environmental conditions.

The driving tests will include tests of the following general performance requirements:

- Ability of the system to operate with natural background interference.
- Ability of the system to selectively alert drivers only on specific routes and in a specific traffic direction.
- Ability of the system to operate under various weather conditions.
- Ability to operate with no false alarms.
- Capability of the driver to respond to the alert and warning of the IVSAWS transmitter in a timely fashion.

The exact requirements for the System Demonsuation Test will be defined in the Master Test Plan to be developed during the design and fabrication of the equipment. It is expected, however, that the test effort will take place during a two-month period at the end of the program.

The total test effort will include the conduct of approximately twelve specific scenarios, which will include various types of hazards, road conditions, environmental. and geometric situations. The test will demonstrate the reliability of the system to be selective in reporting and devoid of false alarms. The duration and amount of testing is based on the criteria of two successful tests of each type plus the possibility of rescheduling 25% of the tests because of unexpected difficulties in their conduct, i.e.. equipment failure, human error.

Hughes has a broad background in field testing of communications systems. The testing department has just completed an extensive field test on the Enhanced Position Location Reporting System (EPLRS), where 100 radios were deployed in the local area and the network was exercised against various operational scenarios in an actual operational environment. Other recent testing programs have involved our Joint Tactical Information Distribution System Radios (JTIDS) and the Short Term Anti-Jamming (STAJ) applique to the AN/PRC- 104 HF Radio.

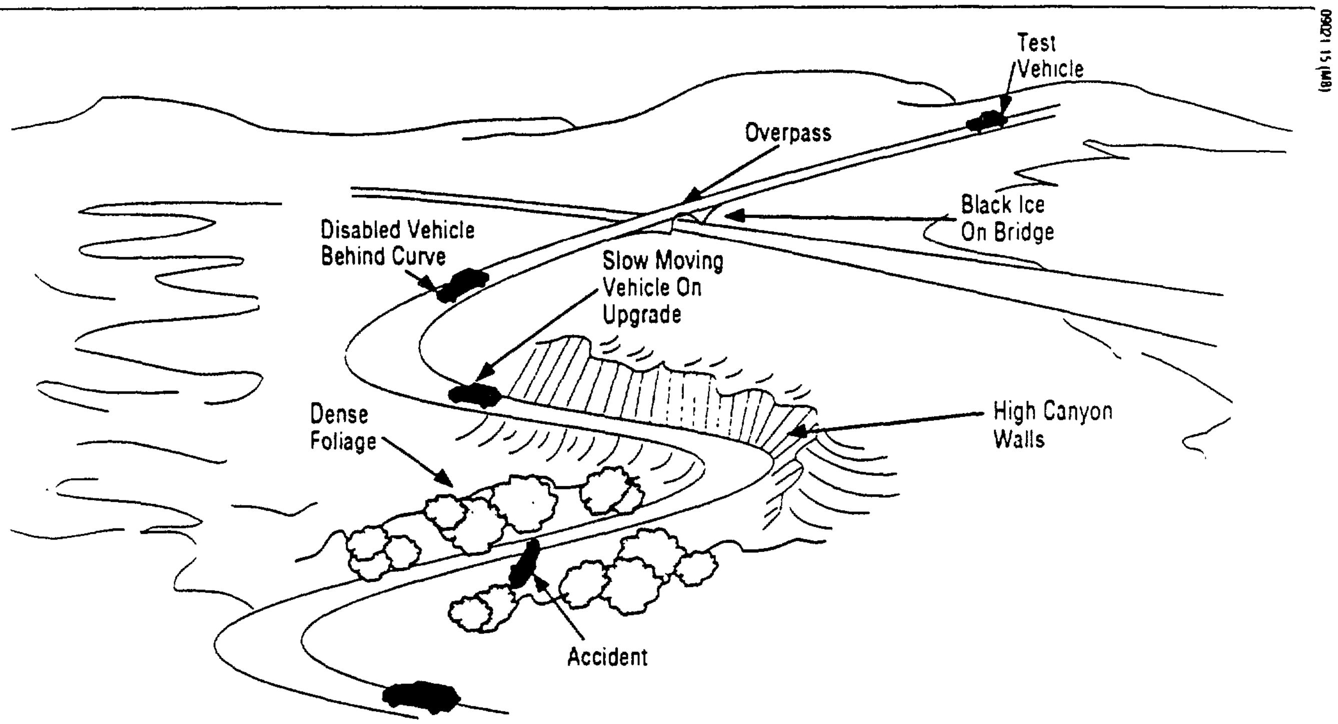

Figure D.7.3-1. Typical Environment for System Demo. The local highway system provides diverse spots to exercise the many uses of the IVSAWS system.

[FHWA H-56]

4, Human Factors Participation in Test and Demonstration

RFP Ref: SOW Task G; Section L.I.D

Human Factors tests will be structured to accurately measure each sample driver's correctness and speed of response to visual and/or auditory hazard cues. The procedures and measurement requirements will be detailed in the Master Test Plan prior to conducting each test.

Human Factors test and evaluation of the final driver-alert warning system will be conducted after installation hardware and software checkout has been completed. Human Factors personnel will participate in the installation procedures to assure that display location is within appropriate viewing distances for the young, middle aged; and old drivers, that controls are within appropriate reach distances for activation/deactivation, and are of appropriate size for the type of activation required (single or multiple fingers. etc.), and that auditory warning signals exceed the ambient noise level by at least 20 dB.

During design and installation Human Factors will also inspect the driver-alert warning system hardware for maintainability and reliability effectiveness. This includes such factors as ease of access, commonality of tools, voltage cautions, proper grounding. parts selection, weight, sharp comers, and skill requirements.

Human Factors personnel will participate in the development of approximately twelve scenarios used for both equipment and driver testing. To ensure sufficient complexity the scenarios will cover at a minimum:

- In Lane hazard (disabled vehicle, sharp turn)
- All Lane hazard (congested traffic, railroad crossing)
- Emergency vehicle (police, fire/rescue)
- Bad surface condition (debris, pot-hole)
- Intersection (crossroad, blind entrance)
- Slow vehicle (school bus, postal delivery)

The primary goal of Human Factors testing is to determine that the selected driver-alert warning system permits each subject driver to rapidly and correctly respond to each identified hazard. The Master Test Plan will detail the sample populations to be used. test schedule, the test measurement apparatus, number of trials, procedures, data retrieval methods and statistical analyses to be applied. The dynamic simulation will permit use of either direct observation and/or closed-circuit TV recording, electronic measurement of response time and accuracy. Time-of-day will also be a test factor to ensure variable ambient conditions, including daylight, dusk and night conditions, to evaluate anticipated and unexpected performance responses, such as the problems elderly drivers experiences visual discrimination loss during dawn/dusk conditions. For this reason, sample drivers will be visually tested for 20/20 vision (corrected or uncorrected) and color-blindness. Drivers will also be checked to ensure that they hold valid operating licenses.

Post test questionnaires will be used to obtain test drivers subjective opinions. Additional questions will be asked after each trial to determine each drivers' hazard alert comprehension or degree of confusion. Correct and incorrect driver responses, or correction of errors, will be tabulated in relation to the scenario depicted driver-alert, These data will be reviewed, analyzed and compared to response time data. The results and conclusions of the Human Factors test and evaluation will be reported in the draft Final Report. The Human Factors test results will also contribute to the development of the functional system specification for the in-vehicle safety and advisory warning system.

1. System Specifications

RFP Ref: SOW Task H; Section L.I.D.

Hughes has extensive experience in generating system level specifications for our military customers. Hughes will use MIL-STD-490 as a guide for the preparation of the system specification. Because of our experience with this format, it is anticipated that the preparation of a complete system specification will involve a minimal amount of effort.

The principal features to be covered in the specification are summarized in Table D.8.1-I The specification will delineate the architectural design of the IVSAWS systems including the three subsystems (e.g., the roadside transmitter, the in-vehicle receiver, and the driver alert warning system). It will address the list of significant hazards, the messages, waveforms and RF parameters. For each of the subsystems, it will address the functional requirements, the interfaces, the physical requirements including size, weight and power consumption, environmental requirements, and any software/firmware requirements. It will address the method of testing the system and the method for verifying that the system meets the specified requirements.

TABLE D.8.1-I. ITEMS TO BE SPECIFIED IN THE SYSTEM SPECIFICATIONS

- Operational Concept
  - Significant Hazards to be Reported
  - Operation of the IVSAWS System
- Architectural Design
  - Roadside Transmitter
  - In-Vehicle Receiver
  - Waveforms and Message Suucture
  - Driver Alert Warning System
- Interfaces
  - For Each Architectural Element
    - Electrical
    - Mechanical
    - I/O and Controls
- Performance
  - For Each Architectural Element
    - Processing
    - Software/Firmware
    - I/O Signal Definition
- Physical Characteristics
  - For Each Architectural Element
    - Size
    - Weight
    - Power
    - Environment
    - Reliability
- cost
- Fabrication

2. Tie-In of IVSAWS to Intelligent Vehicle Highway System

RFP Ref: SOW Task H: Section L.1.D

In IVHS the motorist needs two types of information, vehicle-specific and general, to provide a complete "traffic picture." The IVSAWS would provide the communication link from a Traffic Management Center to the vehicle.

The architecture suggested in Figure D.8.2-1 illustrates the relationship of IVSAWS to the Intelligent Vehicle Highway System (IVHS). The IVSAWS provides information pertinent to the motorist's immediate route. The Hughes team recognizes that given this architecture the IVHS infrastructure must support IVSAWS so that this information is timely. Furthermore, it is expected that the IVSAWS would be expanded to include other types of motorist information.

The IVSAWS is envisioned to provide dynamic hazard information, such as weather, incident, and road repair activity information in addition to fixed hazard information. The IVSAWS would be capable of being updated in the field, by the Traffic Management Center, or by emergency vehicles. Other uses of this communications link would include services, vehicle location, detour, route guidance, and special events. Although this latter information would not have the same priority as the hazard information the communications would have the capability to grow to include this latter type of information.

Other types of vehicle control information (e.g., road geometry, capacity, etc.) may be needed to be transmitted across the IVSAWS communications link to assist the vehicle for future enhancements such as lane control and automatic chauffeuring.

The IVSAWS link could eventually be capable of two-way communications. Information the vehicle would send across this link includes mayday, traffic link times. and special requests (e.g., yellow pages). This information would be used by the Traffic Management System to enhance its knowledge about the real-time traffic situation.

Dissemination of general information such as traffic alerts and wide area information will be an important part of the IVHS system. The IVSAWS system would provide the communication link from a Traffic Management Center to the vehicle. This type of information will be enhanced because of more complete information from the individual vehicles. This information is useful for pre-trip planning, and to enable vehicles to be dynamically re-routed around congestion.

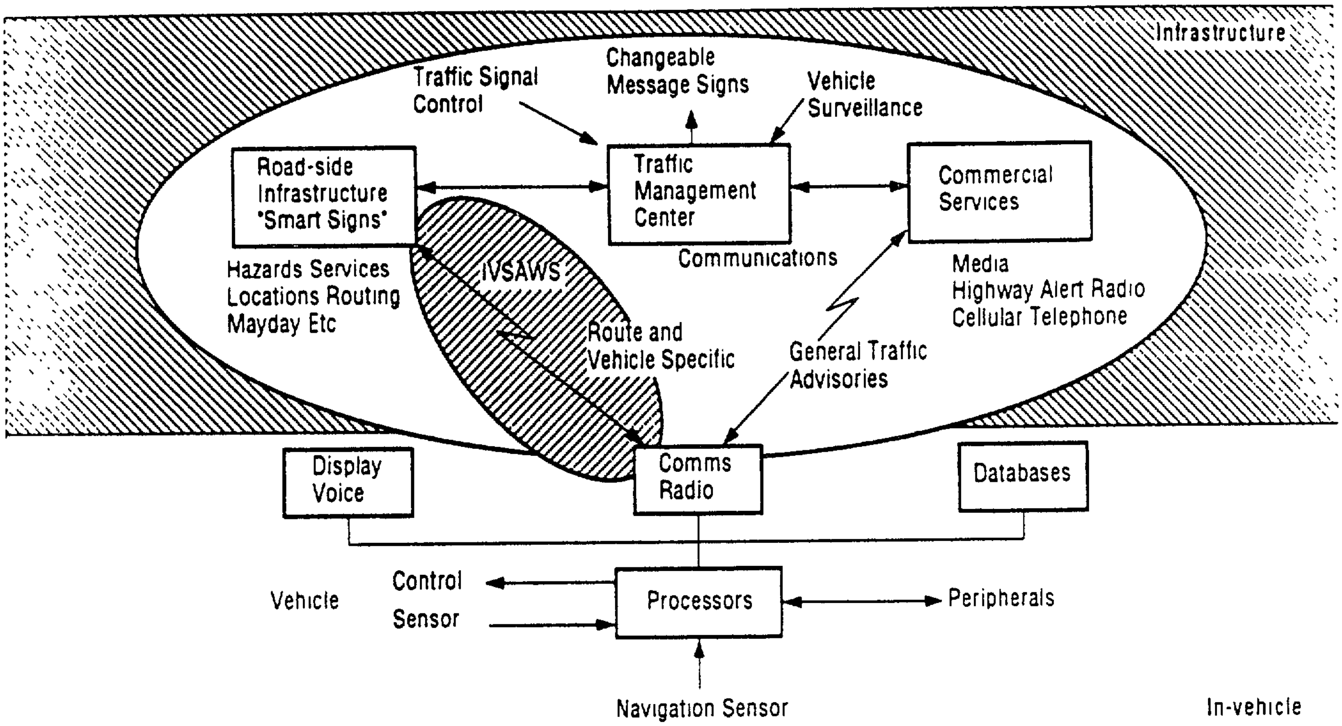

Figure D.8.2-1. Intelligent Vehicle Highway System (IVHS) IVSAWS is an Integrated Part of the IVHS System and is Used to Provide the Communication Link to the Vehicle

3. Technical Summary and Final Report

RFP Ref: SOW Tasks I and J; Section L.1.D

Hughes will prepare the four-page technical summary in accordance with the two-column format shown in Attachment 8 of the RFP. Recognizing that this document will he used to sell succeeding phases within the Federal Highway Administration, the Department of Transportation, and possibly to Congressional committees, Hughes will use its technical publications activities to ensure that the technical summary is a professional, concise summary of the effort.

During the course of the study, Hughes will use an Engineering Notebook system to document the results of significant analyses and tradeoffs. These documents will provide the substance of the input to the final report, and the task of preparing the final report will be limited to polishing and editing the material in the Engineering Notebook entries. Hughes will prepare a thoroughly documented set of reports as required at the end of Tasks A, C, and E. These reports will be included in the final report. The final report will contain the results of the testing phase (Le., Task G) as well as the reports from Tasks A, C, and E. Because the System Specification will be a large stand-alone document, it will not be included in the final report.

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