Report to Congress on the

National Highway Traffic Safety Administration

ITS Program

Program Progress During 1992-1996

and

Strategic Plan for 1997-2002

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Table of Contents

List of Figures

List of Tables

Executive Summary

Congress recently requested the Intelligent Transportation Systems (ITS) Joint Program Office and the National Highway Traffic Safety Administration to update the 1992 ITS plan “to deal with the fiscal year 1997 through fiscal year 2002 period, and also to assess progress made regarding the objectives specified in the first plan.”

This report provides an update to the previous (1992) NHTSA ITS Plan, which described “the scope and nature of NHTSA’s anticipated efforts in IVHS safety issues during the next 5 years”. The report has two major sections. The first details the progress made to date against the objectives of the previous ITS plan. The second section discusses the NHTSA ITS Strategic Plan for fiscal years 1997-2002, including an assessment of the state of ITS safety-related collision avoidance systems development, testing, and deployment potential.

Over the past five years a substantial effort has been accomplished to lay the foundation for continuing research and development of collision avoidance systems. Extensive analysis of accident data was performed to define collision problem areas and causal factors. Based upon these, and other considerations such as related human factors research activities, projects were initiated to develop performance specifications for countermeasure systems. Progress has been made in the development of new research tools, namely efforts to design and build the Variable Dynamics Test Vehicle (VDTV) and the National Advanced Driving Simulator (NADS), and the completion of the design for, and the initial application of, the Data Acquisition System for Crash Avoidance Research (DASCAR). The research program has established an extensive collision avoidance knowledge base which is a key element in NHTSA’s efforts to facilitate deployment. In addition, NHTSA has initiated operational tests to examine the capabilities and benefits of Intelligent Cruise Control (ICC) and Automated Collision Notification (ACN) systems.

The NHTSA ITS Strategic Plan for 1997-2002 remains similar in focus to the previous plan, while reflecting the progress made during the last four years and adjusting for changes in direction and priorities within the overall ITS program. In the next 5-year period NHTSA will continue and/or initiate a broad set of activities to achieve overall crash avoidance objectives. The crash avoidance research program, while relying on enhancements of conventional safety systems such as braking and lighting, places an increased emphasis on the use of advanced ITS technologies in preventing vehicle crashes. The program includes detailed assessment and analysis of pre-crash situations and collision types, development of performance standards for systems to assist drivers in avoiding collisions, application of research tools, such as the (VDTV), (DASCAR), the System for Assessing the Vehicle Motion Environment (SAVME), and (NADS) in the development, testing and evaluation of promising crash avoidance systems and products, and cooperation with industry partners to expedite commercialization of crash avoidance technologies.

NHTSA intends to continue efforts aimed at developing an improved understanding of the causes of crashes on today’s highways, the potential for reducing these crashes through the

application of advanced technologies, and to use this knowledge base to encourage and facilitate industry efforts in developing and introducing effective Collision Avoidance (CA) and other safety/security enhancing products.

To achieve overall program goals NHTSA will continue research to increase the understanding of system performance levels (capabilities) for CA products and systems; the degree to which these products can be successfully used by drivers, users' perception of usefulness in improving their driving safety; and the potential for market acceptance, considering factors such as performance, usability, and product cost. Finally the overall benefits to be derived from introduction of CA products/systems will be estimated and refined based upon the above factors.

Mission

The mission of the National Highway Traffic Safety Administration (NHTSA) is to reduce traffic accidents and resulting injuries and deaths. NHTSA employs various means to accomplish its mission, including the application of intelligent transportation systems (ITS) technology, sponsoring highway safety programs, and proposing regulatory actions when appropriate.

In regard to ITS, NHTSA will continue to fulfill its mission of saving lives, preventing injuries, and reducing traffic related health care and other economic costs, by facilitating the development, deployment, and evaluation of safety products and systems. Among other things, this involves research into the science of crash avoidance to enable the development of safety-enhancing products. The agency will continue to establish the safety goals for crash avoidance technology, develop performance guidelines and specifications for crash avoidance systems, evaluate the safety performance of such systems, and work with industry to demonstrate the most promising ones and to facilitate their deployment in the marketplace. These activities will be accomplished through the combined efforts of NHTSA, the automobile industry, and other technology companies, working together under cooperative programs and partnerships that are sponsored by NHTSA.

NHTSA will continue to play a key role in ensuring the system safety of ITS initiatives including automated highways and mobility-enhancing systems. Where appropriate, infrastructure and in-vehicle systems being introduced to mitigate other travel-related problems and to improve the efficiency or through-put of our nations highways, will be evaluated to ensure that safety is not compromised by the introduction of these systems and technologies. It is also consistent with the 1995-99 NHTSA Strategic Execution Plan. This plan identifies the specific agency objective of improving the crash avoidance capabilities of motor vehicles and outlines internal milestones for implementing the Crash Avoidance Research Plan.

The Office of Crash Avoidance Research is the principal office involved in implementing the NHTSA ITS plan.

The Vision

In NHTSA’ s vision of the future driver-vehicle-highway environment, a wide variety of innovations will appear within and outside of the motor vehicle to supplement the driverss efforts at vigilance and control. Among the systems envisioned, new products will monitor the driver’ s own state of fitness, enhance driver situational awareness on a continuous basis, provide advance warnings of potential danger, intervene and assist with emergency control if a crash is imminent, and perhaps eventually automate the driving process on specialized roadways of the future. The next generation cruise-control system, for example, will automatically maintain a safe distance from vehicles ahead. With a lane tracking system, imminent departure from the roadway will be predicted by on-board electronics, and the driver will be alerted in time to recover. A cooperative intersection will communicate data on the state of the traffic signal and warn of the presence of conflicting traffic to further reduce the risk of intersection collisions.

Vision at night and during inclement weather conditions will be enhanced by systems that sense images that the driver does not normally perceive and converts them into visible forms for detection by the driver. Overall, these products will sense objects in the near-field around the vehicle, process information with the aid of artificial intelligence, communicate with other vehicles and roadside devices, and deliver assistance to the driver through visual, audio, and tactile presentations, and through supplementary control. When a crash does occur, emergency help can be summoned to the site of the crash through a (manual or automated) collision notification transmission. Systems which incorporate collision detectors, Global Positioning System (GPS) position location receivers, and communications systems that provide increased safety and personal security are currently available in selected automobiles while others are undergoing testing.

The many forms of ITS products, especially those that assist in crash avoidance and those that reduce hazards by smoothing the flow of traffic, are expected to make positive contributions to safety as they are introduced, while minimizing possible negative influences. In this sense, ITS technology and initiatives supplement the more traditional program activities that have served to prevent and/or reduce the severity of injuries in crashes that do occur.

The process of developing and deploying safety-enhancing products will be facilitated by increased cooperation between NHTSA, the automobile industry, and other innovators of safety-related products. This cooperation will include the identification of countermeasures whose development can be jointly pursued/expedited, and the development of objective guidelines for the safety performance of individual system types. Furthermore, the time to field crash avoidance products can be shortened by a comprehensive, standardized program for testing/evaluating products. Through the above approach, the performance, effectiveness, benefits, and market acceptability of safety-enhancing products can be assessed, in support of the overall goal of facilitating their deployment.

Close coordination between the NHTSA CA efforts, which are focused on the near and mid-term introduction of safety-enhancing products, and the FHWA Automated Highway Systems (AHS) efforts will ensure that synergies between program areas are fully exploited. The CA knowledge base, as well as relevant sensor, display, and vehicle control technologies developed within the NHTSA program will be available, as required, to the AHS program. Furthermore, coordination efforts may also lead to adjustment of program priorities and research activities to better support the goals and objectives of both program areas.

This Program Plan presents a balanced program that builds a foundation for advancing the state-of-practice of injury prevention in key areas as quickly as possible. In large part it is a benefits driven program, where priorities are established based upon: (1) the severity of the problem area addressed; (2) the availability of technology to support mitigation approaches; and (3) the estimated effectiveness of the approach in producing the intended level of benefit. The benefits from CA systems are a reduction in the number (and severity) of collisions, the number of injuries (and/or their severity) and fatalities (with their related economic costs), as well as elimination of associated congestion with related travel time, fuel, and emissions benefits.

Progress Highlights (1992-1996)

Overview

In 1991, NHTSA launched a major new initiative to improve the collision avoidance capabilities of the motoring public. Aware that wide spread deployment of effective collision warning technologies was a decade or more away, NHTSA laid out a strategic plan to facilitate the development and early deployment of safety-related electronics systems. NHTSA’ s first ITS Strategic Plan had a five year perspective and focused on establishing the knowledge base, research tools, and prototype development activities essential for operational tests and evaluations that would become possible in the late 1990s.

The NHTSA Crash Avoidance Program made significant progress during this first phase. Accident data have been extensively analyzed and the crash avoidance (CA) opportunities that were identified are guiding CA concept development. Key human factor and system design issues have and will continue to be studied, and preliminary performance specifications for systems that can assist drivers in avoiding collisions have been formulated in five areas. A number of joint efforts with motor vehicle industry partners to collect data and assess technologies were completed or are well underway. A set of new research tools are being developed. During the next phase of the NHTSA Program, these tools will provide significantly enhanced capabilities for analyzing and evaluating technical performance of CA countermeasures and estimating their real-world operational benefits.

The ITS program was structured to extend the existing understanding of the causes of collisions, identify and evaluate potential solutions, and to work in partnership with industry to facilitate the development and deployment of effective collision avoidance products. The research program focuses on updating and extending the knowledge base regarding the benefits to be derived from collision mitigation systems, the performance capabilities of prototype systems, and the various factors that influence user acceptance and willingness to buy/use these safety-related products. Statistical and causal accident analysis was performed to characterize the nature of collisions and their causal factors and to identify collision avoidance opportunities. Based on the analysis of collision problems and causes, mitigation concepts were identified. Finally a series of programs were initiated to move the collision mitigation concepts to system prototypes and to begin proof-of-concept demonstrations in conjunction with the automotive industry. Proof-of-concept demonstration activities are supported by a variety of research tools (i.e., simulators, test vehicles, and in-vehicle data collection suites), as well as operational test activities through cooperative efforts of both the public and private sectors. At each stage of this process the additional program knowledge and insight is captured to update and expand the Collision Avoidance knowledge base.

The program recognizes also that different problems and problem countermeasures exist for heavy vehicles. System capabilities, user acceptance issues as well as benefits from countermeasures, in many cases, must be evaluated against different metrics than for automobiles. The fact that trucks are much more expensive vehicles, carry expensive payloads, and travel more miles may make some countermeasures more cost-effective for trucks than for automobiles.

This section summarizes program accomplishments and status since its inception in 1992. It is organized according to five major areas of research activity:

- Build Research Tools and Compile Knowledge Base,
- Identify Promising Crash Avoidance Opportunities,
- Demonstrate Proof of Concepts for Crash Avoidance and Mitigation,
- Facilitate the Development of Crash Avoidance Products Toward Commercialization, and
- Assess the Impact on Safety of Other ITS Concepts.

Build Research Tools and Compile Knowledge Base

In the 1992 plan, it was recognized that new research tools were needed to support the collision avoidance research, prototype development, testing, and evaluation, ultimately leading to the development and fielding of commercial safety-enhancing products. These research tools will provide new sources of insight, that is fundamental to the entire crash avoidance research program. The tools encompass a wide variety of simulator, test vehicle, and data acquisition resources.

National Advanced Driving Simulator (NADS)

Simulators are considered essential to the efforts for understanding driver behavior and for testing of various situational, display, and control conditions rapidly without endangering the experimental subject. NHTSA is focusing on the development of a high-fidelity, moving base simulator, to replicate the highway driving scenario. This will be a national research facility for human-in-the-loop, real-time vehicle driving simulation. With this facility, researchers will be able to present the antecedent events of a likely crash situation and then study the responses of research subjects (drivers) as well as the vehicle. Within the simulator these events can be presented in a precise and repeatable manner, efficiently, while providing complete safety to the human subjects.

The NADS project has completed a design competition phase, and a contract was recently awarded to TRW for the development of the simulator facility. The NADS will be housed at a specially designed facility at the University of Iowa. Current plans call for the completion of NADS by early 1999.

Data Acquisition System for Crash Avoidance Research (DASCAR)

NHTSA has developed a portable instrumentation suite to support the collection of data on how drivers react to avoid collisions. The systems can monitor and record driver/vehicle and environmental parameters such as vehicle speed, lateral placement, eye glance, longitudinal and lateral acceleration, etc. This instrumentation package is designed to be easily installed, and to operate in an unobtrusive manner to permit the collection of driver performance/behavior data on the road, in support of "naturalistic" field studies. The DASCAR systems will be used to assess the effectiveness of candidate ITS accident avoidance countermeasures and other driver information systems, address issues of design and safety consequences, develop a baseline/ normative driving database, characterize incidents/near misses and support implementation of other tools such as the NADS and the Variable Dynamics Test Vehicle (VDTV).

The first project using DASCAR was recently initiated. It will gather data on driver behavior prior to making lane changes.

System for Assessing the Vehicle Motion Environment (SAVME)

This project is developing and validating a measurement system that can quantify the specific motions that vehicles exhibit as they move in traffic. In addition, the system will sense and record the location and motions of all other vehicles within the field of view relative to roadway boundaries and other features of the driving environment. In operation, the SAVME will gather information on successful collision avoidance maneuvers, including the reaction to other vehicles cutting in front, headway maintenance, typical lane changing trajectories, and response to inclement weather and other conditions which degrade visibility and performance.

Investigation of sensor concepts for the SAVME led to the dropping of a ranging laser concept and the selection of a charge-coupled camera which directly converts the image to a digital format. Sensor selection has delayed this activity, with current schedule calling for a fully functioning prototype to be available by late-1997.

Variable-Dynamics Test Vehicle (VDTV)

The VDTV is a test tool that will be used to establish safe performance envelopes for safety systems that will directly control vehicle motion. This vehicle will support the determination of the vehicles performance limits that would determine the performance envelopes of certain collision avoidance systems. It will also permit determination of how drivers react to various proposed ITS crash avoidance concepts and the effects of vehicle characteristics on control device effectiveness. The VDTV will also be used to validate NADS control algorithms and as a crash avoidance research vehicle to support safety evaluation of automated highway system (AHS) concepts.

An agreement has been signed with the Jet Propulsion Laboratory of the California Institute of Technology for design and construction of this tool. The VDTV is scheduled to be available for research projects by mid-1998.

Collision Avoidance Knowledge Base

The NHTSA research program has developed a safety-related database which continues to be updated and enhanced. This database comprises the collective knowledge developed by the NHTSA CA research program.

A substantial effort has been accomplished in the research (statistical analysis and case studies) of the major causes of crashes and in the understanding of pre-crash factors which contribute to the crash. This knowledge base provides the (causal analysis) background to identify crash mitigation approaches as well as the statistical basis for focusing NHTSA' s program activities. The knowledge base also includes initial performance specifications, benefit estimates, and development and test guidelines for crash avoidance concepts and/or products. Finally as program activities continue, the results of test and evaluation activities will produce data on system effectiveness, producibility, and market potential for the various CA systems/products being investigated.

The NHTSA research program has also developed a base of knowledge of the human factors that affect traffic safety. This database comprises the collective knowledge obtained by agency research to date, and continues to be updated and enhanced.

The purpose of these efforts is to ensure that systems utilizing new technologies function as intended and are safe when used by the wide array of drivers in the driving population, and under the wide range of driving conditions that will be encountered when the systems are in regular use. To do this, research has focused on three areas: developing an understanding of driver behavior in collision avoidance situations, optimizing the driver-vehicle interface for specific collision avoidance countermeasures, and determining the effects of new technologies on driver capabilities and workload. All three of these factors need to be considered in the development of countermeasures. Individual drivers vary greatly in their responses to emergency situations, and in their ability to assimilate additional information, so developing a complete understanding of these human factors is a difficult task. In most areas, the research performed to date has provided only a rudimentary level of understanding. More complete understanding of these factors will be achieved through the use of DASCAR, advanced simulation capabilities, and from on-going/planned CA projects.

NHTSA has also worked closely with the human factors research community as a whole, to establish uniform standards for what human response variables will be measured and how the data will be recorded and accessed. A uniform protocol called Test PAES has been established. This is an important step that will allow future research results, whether from agency research or outside, to be more easily added to the body of knowledge already at hand.

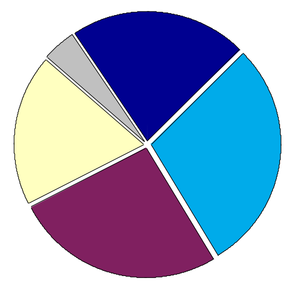
The CA knowledge bases are used throughout the research and development process, from statistical problem and causal analysis, crash mitigation concept development, generation of performance specifications and test guidelines, to understand driver-vehicle interactions and driver capabilities, and finally in the evaluation of system effectiveness and estimation of system benefits. They will be continually updated and extended with results from on-going projects, updated CA system performance specifications, new test and evaluation guidelines, and through continuing performance assessment activities.

The knowledge base, which is also available to those developing new CA products, is a key resource in achieving the overall NHTSA goal of encouraging and facilitating development of viable (cost effective) products for collision avoidance. This resource includes an extensive set of technical reports and papers which have been generated by the research program.

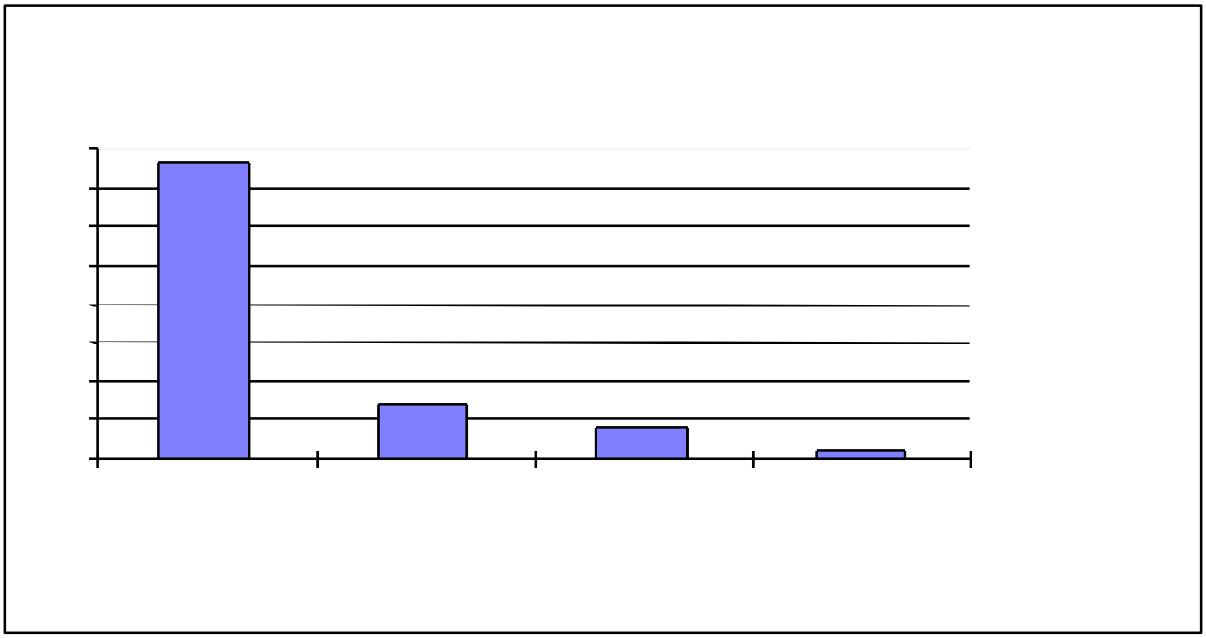
Identify Promising Crash Avoidance (Mitigation) O

Efforts in this area have been focused on analyzing data regarding primary and associated causal factors in crashes, performing case studies and other research to (1) develop a statistical view of these factors and (2) identify promising approaches for crash mitigation. Crash problem analysis includes the review of individual cases, identification of relevant pre-crash circumstances, and preliminary assessment of some intervention mechanisms. This activity has contributed to an increased understanding of the dynamics of the events that precede specific types of crashes. This understanding is key to the development of performance specifications for collision avoidance systems and for subsequently determining the anticipated benefits of collision avoidance countermeasures when deployed.

Figure 1 shows the distribution of crash types, for all highway vehicles, (based on 1994 GES data) that present the maximum opportunity for safety improvement through the introduction of effective collision avoidance systems/products. One category of collision avoidance projects is focused on developing countermeasures for specific crash types. As can be seen from this figure, the three largest subsets of crash types are rear-end, intersection, and road-departure, which together account for almost 75 percent of all crashes. This insight is the basis for having focused programs for each of these three types of crash. Other considerations in determining the initial focus of the NHTSA program are technical tractability and readiness of countermeasure systems.



Causal analysis identifies a second category of collision avoidance systems, namely those dealing with driver performance enhancement. Systems that enhance driver performance essentially cut across the various crash types, and provide alternative approaches for reducing accident rates. Contributing factors in accidents such as reduced visibility, e.g., at night or in degraded weather conditions, and driver drowsiness, occur across the spectrum of crash types shown in this figure. The Volpe National Transportation Systems Center (VNTSC) supported NHTSA in performing a thorough review of collision data to determine collision causal factors for each crash type. A summary of the major causal factors for all collision types is shown in Figure 2. This figure dramatically shows that the interaction of the driver and vehicle must be addressed by advanced collision avoidance systems if a countermeasure is to have a significant impact on reducing the number of collisions. This realization underlies the development of the research tools described earlier and their application in acquiring an understanding of the performance of the driver interface element of the collision avoidance systems. This also gives rise to several countermeasure programs which are aimed at enhancing driver performance under a variety of driving conditions.



Demonstrate Proof of Concepts for Crash Avoidance and Mitigation

A key NHTSA role is to demonstrate that advanced technology can practicably enhance the crash avoidance performance of motor vehicles. NHTSA' s program includes the development of performance guidelines for crash avoidance technologies and the testing of prototype hardware systems. Activities in this area support the development and testing of prototype CA products and systems. They build on the previously described statistical and causal analysis activities, as well as the human factors knowledge base. Starting with an understanding of the mechanisms and factors that contribute to each collision category, the driving behaviors, and the performance capabilities of drivers during situations that result in those collisions, mitigation concepts and conceptual solutions are identified. Preliminary performance specifications are developed for each CA approach, including specifications for the driver/vehicle interface. System effectiveness and potential benefits are estimated for each countermeasure. Concept demonstration/validation occurs at various stages within each program area, beginning with the examination of potential system performance using simulators, test vehicles, and finally with more mature prototype systems in operational tests involving a representative set of drivers.

NHTSA has participated in various public outreach activities to increase awareness of program initiatives and potential program benefits. For example, NHTSA jointly conducted a series of highway safety-related workshops with ITS America. Other outreach activities included participation in conferences and seminars, and publication of papers in technical journals. Operational test programs that were initiated in 1995 also support public outreach goals by exposing individual drivers to safety-related system prototypes.

Performance Specifications for Collision Avoidance Systems

The ITS collision avoidance program is developing performance specifications for systems that could assist drivers in avoiding collisions. NHTSA has or is beginning research projects in eight safety-related problem areas. They are rear-end collisions, road-departure collisions, intersection collisions, lane change and merge collisions, collisions involving drowsy drivers, collisions associated with reduced visibility, heavy vehicle stability, and automatic collision notification.

These performance specifications are technology-independent functional guidelines that define the relationship between specific safety problem areas, countermeasure performance requirements, and safety benefits. They provide the basis for conducting countermeasure design, prototyping, and test and evaluation program activities.

Preliminary performance specifications, covering the sensing, processing, and driver interface functional elements have been developed for many of these collision systems. These specifications which are developed initially through analysis of data from NHTSA accident files, causal analyses activities, and data generated from driving simulators, will continue to be refined and updated based on results from technology studies, ongoing/planned simulator studies, test vehicle projects, and operational test activities. Brief summaries of selected projects follow:

Rear-end Collision Avoidance System

This project has developed performance requirements (both hardware and human factors) for advanced technologies to prevent or decrease the severity of rear-end crashes. This involves the identification of requirements for major system components (or subsystems) such as candidate sensor, processor, driver warning/interface, and control elements. This project is oriented toward countermeasure systems that would be self-contained within the vehicle, although it does not exclude from consideration those countermeasures that may require, or be improved by auxiliary equipment installed on the roadside or in other vehicles. Limited capability systems involving intelligent cruise control capabilities are currently being tested in operational tests, and are expected to lead to validation/update of system performance specifications. Additional field and operational tests will be planned to test and evaluate full-capability rear-end CA systems.

Road-departure Collision Avoidance System

This project has developed performance specifications for road departure countermeasure systems. In addition the project will develop two prototype systems and a testbed vehicle for system test and evaluation. Sensor technology to support detection of roadway or lane boundaries are being examined while investigating potential approaches for prediction of imminent road departure.

Lane Change/Merge Collision Avoidance System

This project is investigating the feasibility of equipping motor vehicles with countermeasure systems to assist drivers in safely carrying out lane change, merging, and backing maneuvers. The study considers the effectiveness, reliability, costs, and implementation practicability of such systems. Preliminary performance specifications as well as methodologies for estimating benefits of potential countermeasure systems have been developed.

Intersection Collision Avoidance Systems

This project has completed a thorough analysis of intersection collision problem size and causal factor analysis. Based upon the results of the causal analysis activity, simulation routines were utilized to evaluate the effectiveness of conceptual collision avoidance systems. Both in-vehicle systems, infrastructure-based systems, and hybrid vehicle/infrastructure systems are being studied. Performance requirements for system components have been examined and a preliminary set of performance specifications have been produced. Further efforts will involve the development of a intersection CA system test bed and the refinement of system specification, prior to development of prototype systems for test and evaluation.

Heavy Vehicle Collision Avoidance Systems

A number of research projects have been initiated in this area. These include efforts to develop and test a drowsy driver monitor for heavy vehicles, heavy vehicle stability projects, and projects aimed at collision warning and improved braking performance. Many of these projects have resulted in performance specifications and prototype systems, which are currently being tested. Additional details are found in later sections describing efforts to facilitate the commercial development of crash avoidance products.

Enhanced Emergency Medical Service (EMS) Response

This project is examining the feasibility of equipping motor vehicles with high-technology sensing and communications systems, that as collisions occur, will automatically inform the EMS provider of the occurrence and location of the collision. These systems are expected to reduce the time between an accident and the arrival of life-saving support, both by shortening the notification time and by providing an exact location of the accident site to the responding agency. Additionally, other potential features of the system would allow determination of the severity of a crash and other parameters to enable the EMS dispatchers to decide on the appropriate type of medical attention that may be necessary. As an example, special sensors and algorithms could be utilized to provide estimates of crash victim medical conditions, while smart card technology could provide driver medical history to the dispatcher.

An ACN operational test was initiated during 1995 in the Buffalo, New York area and will be completed in 1998. In addition, this test is being coordinated with other ITS operational tests involving driver-initiated systems for requesting roadside assistance. Related tests are currently underway in Colorado, Washington (Seattle area), and Minnesota (Minneapolis-Rochester). These tests involve driver-initiated calls to a service provider, whereby the nature of the problem can be verified, prior to the dispatch of help.

Vision Enhancement Systems for Night-time and Inclement Weather

The project is investigating the feasibility of motor vehicle-based vision enhancement systems that could help drivers avoid collisions with other vehicles, pedestrians, and other objects on the road due to reduced visibility conditions (e.g., at night and during inclement weather). The project addresses sensor capabilities and the visual information requirements for successful crash avoidance, as well as driver usability requirements, to ensure that supplementary vision enhancement systems do not distract drivers or otherwise degrade their overall driving performance. A state-of-the-art review of research and technologies that are relevant to driver vision enhancement systems has been completed. A follow-on effort to perform a preliminary assessment and field evaluation of currently available vision enhancement technologies is anticipated.

Driver Status and Performance Monitoring

This research is addressing the concept of a vehicle-based device to unobtrusively monitor driver performance and psychophysical status. The device would monitor driver status/performance, detect degraded performance and provide appropriate warning signals or otherwise alert the driver of his/her degraded performance capability to operate the vehicle. This project is currently developing a prototype system for testing in a fleet of heavy trucks.

Driver Behavior and Performance Considerations

For each of the collision mitigation concepts described above, support is provided through additional research projects to address human-vehicle interaction and related problems. Most of these projects address issues that are germane to more than one collision avoidance problem area.

Initial guidelines have been established for the presentation of safety warnings to the driver. This research, which is continuing, looks at the relative effectiveness of various visual, aural, and haptic warnings, and makes recommendations on which type of warnings are likely to be the best for a particular application. The results of this research are used to develop initial performance specifications for the driver/vehicle interface for the various countermeasures.

Research has been conducted and is continuing to determine what cues (visual, audible, displacement, speed, feel, pedal feedback, etc.) drivers use to make decisions regarding vehicle control inputs (such as braking, steering, or acceleration) in crash-imminent situations. This research is used to better define the optimum driver/vehicle interface for ITS collision avoidance (countermeasure) systems.

Lighting and visibility research projects attempt to define drivers' requirements for direct and indirect visibility, determine optimum location of displays for lane change/merge systems, and the viability of head-up displays (HUD) as a means of communicating information to drivers, especially with older drivers in mind.

Recognizing that new technologies have the potential to increase driver workload and distraction, NHTSA has developed a workload evaluation protocol that can be used to assess the potential of any in-vehicle system to create excessive workload thereby degrading safety. The unique feature of the protocol is the strong association of the measures to safety. It is not possible to directly assess the workload effects of most ITS systems because they currently do not exist in sufficient numbers in the vehicle fleet. Cellular telephones offer a convenient surrogate, having similar features such as display and potential for distraction or mental overload, as other relevant devices. An ongoing research project is looking at the safety implications of cellular phones as well as other in-vehicle devices to gain insight into ways to minimize driver workload for ITS systems.

Facilitate the Development of Crash Avoidance Pro
Commercialization

NHTSA has actively solicited and supported industry initiatives to research and develop safety-enhancing products. This approach is considered key to the development and introduction of safe and effective products that address specific safety problem areas (collision scenarios). As discussed earlier, NHTSA is actively preparing and updating functional performance specifications for specific collision avoidance focus areas, and working with industry to assess performance, reliability, maintainability, failure modes/consequences, driver acceptance potential, costs and market readiness of promising systems. Collision avoidance system performance and testing guidelines, as well as an array of research tools, including simulators, data collection suites, test vehicles, and test beds are being developed to support the cooperative efforts in developing safety-enhancing products, and in evaluating their feasibility for introduction.

Many cooperative research and testing activities have been undertaken in this area, and are continuing at this time, including:

C Looking Automotive Radar Sensor studies, by the Environmental Research Institute of Michigan (ERIM) and TRW. These activities will include evaluation of a Forward-Looking Automotive Radar sensor by ERIM, and the development of a database of radar return data by TRW based upon laboratory measurements and measurements from freeway settings using a prototype automotive radar system.

C Factors Aspects of Autonomous Intelligent Cruise Control, with the Ford Motor Company and Systems Technology, Inc. To date, the research has completed on-road experiments to identify the dynamic behavior of drivers in a vehicle where the headway is automatically controlled. This information will be This project is investigating driver acceptance and performance issues related to the introduction of an intelligent cruise control system. Currently the project is using an instrumented vehicle with variable driver interface features to collect driver acceptance and performance data. useful in setting desirable automatic headway control (ICC) system characteristics. The next phase of the program will focus on experiments to determine desirable braking and acceleration limits and ICC display interface characteristics,

C Forward Crash Avoidance Systems, by University of Michigan Transportation Research Institute, using Leica’ s infrared-based ICC system. This project is evaluating concepts and approaches for vehicle deceleration, such as braking and transmission down-shifting, to determine effectiveness and safety critical performance issues. This research is expected to provide the foundation for exploring how ICC systems could be useful as more fully functioning collision avoidance systems,

- Analysis for Collision Avoidance: Heavy Commercial Vehicles. This project is investigating the feasibility of automatic braking for heavy vehicles, as an additional capability for ICC systems. This project has two separate focus areas, one involved in the identification of design requirements to accomplish assisted braking through modification of existing ABS/traction control system components and the costs/benefits for potential accident reductions, while the second investigates methodologies for determining driver reaction to assisted braking under controlled conditions,

- Intelligent Cruise Control (ICC) Field Operational Test. During 1995 NHTSA initiated an ICC operational test to evaluate the safety improvements offered by ICC systems. This is a two year test program, that is expected to provide valuable information on system performance, usability, user perceptions/acceptance, and potential safety benefits. The test is expected to serve as a bridge between ongoing research activities and deployment of ICC products, and

- Lane Detection Sensors, with Rockwell International. The objective of this project is to collect and analyze dynamic vehicle lane position data to support a feasibility study of using continuous monitoring of vehicle lateral lane position as a means to determine the safety status of the driver and vehicle. The project objective is to be achieved by developing, testing, refining and calibrating a lane position measurement system in the laboratory and subsequently in full-scale on-the-road vehicle tests. The project is scheduled to be completed by October 1996. Currently, activities are concentrated on the analysis of field test data to determine sources of vehicle lane position estimation variability to refine the driver warning thresholds. Future efforts will involve the testing and analysis of a two camera system for comparison of performance with the present single camera system.

Assess the Safety of Other ITS Concepts

A continuing part of the NHTSA ITS activities are the oversight and involvement with other key ITS operational tests that deal with in-vehicle displays and the provision of traffic related information to the driver while driving. NHTSA has been an active participant in TravTek, Advance, and TravelAid operational tests.

TravTek

TravTek was an operational test of an advanced motorist information and route guidance system that was conducted in Orlando, Florida, during 1992-1993. This test involved a total of 100 specially equipped vehicles for a period of 12 months. The test vehicles were equipped with a traveler information system as well as a route guidance and navigation system, and were made available to visitors to the Orlando area and to a number of high mileage local users. As part of the test, a thorough study of the impact on safety was performed. Results of this operational test have been published and are available from the FHWA. The study indicated that the provision of navigation and route guidance information had safety benefits, and that driver interfaces that are properly designed to avoid information overload and confusion on the part of the driver are safety-neutral. Study results indicated that the provision of voice to augment the visual display improved driver safety performance.

Advanced Driver and Vehicle Advisory Navigation Concept (ADVANCE)

The ADVANCE project was similar in nature to the TravTek project, but was planned to include a substantially larger number of test vehicles, and to test a routing and navigation system that was installed in vehicles as an aftermarket product. Again, the safety advantages and disadvantages of the in-vehicle display and the content of these displays are the primary area of interest for NHTSA. Similar to TravTek, a camera car, which records significant actions of the driver and vehicle motion is being utilized to support detailed driver performance and safety analyses. This project will be completed during 1996.

TravelAid

The TravelAid project will test the utility of in-vehicle devices and variable message signs to improve the safety of travelers along a 40-mile stretch of heavily traveled I-90 across the Snoqualmie Pass in Washington State. Electronic equipment is installed to monitor traffic, speeds, and road/weather conditions. The project will evaluate the utility/effectiveness of providing warning and speed information to the travelers and will determine the effects of this information on traveler safety. This project is expected to be completed during 1997.

NHTSA ITS Plan (1997-2002)

Introduction

During the period between 1991, when the program was begun, and 1996 a significant amount of work has been completed to lay a solid foundation. This includes the development of preliminary performance specifications for first-generation systems that address several types of collisions as well as the development of critical new research tools. During this period, a foundation of cooperative partnerships with industrial and academic partners has also been established. However, at this time, collision avoidance systems are not readily available to the buying public as standard or optional equipment in their vehicles. The emphasis of the future program will be on the steps necessary to make effective systems available to car buyers. This will include developing an enhanced understanding of the trade-off between desirable and achievable system capability, developing a much greater understanding of user acceptance and expectations, and extension of efforts to estimate benefits that will accrue to users of collision avoidance systems.

Much of this work will be done as part of NHTSA' s leadership role in safety research. However, as systems and an understanding of the expected safety benefits are developed, questions will arise about how NHTSA can assist in getting effective systems into the hands of the driving public. Traditionally, NHTSA has initiated rulemaking actions as one means of expediting deployment of safety features on motor vehicles. In the case of crash avoidance countermeasures using ITS technologies, NHTSA wishes to ensure the safe introduction of these new technologies. Where the technology may need to be mandated, in consultation with the industry, the agency would set forth appropriate safety performance requirements. In most cases, procedures such as negotiated rulemaking might be used to reach consensus on the most appropriate form for setting performance requirements. However, regulations are not the only means of assisting deployment and may not be necessary or feasible during the period of the plan.

During this period there will be a concerted effort to share research results and understanding of system performance with the automotive industry and with consumers. The approach during this period is to use whatever means that are appropriate to encourage introduction of one or more commercially available collision avoidance systems to the buying public. Through a proactive outreach process NHTSA will seek to work with product designers, research staff in the automotive industry, and the buying public. It will also be necessary for NHTSA to be sensitive to industry' s concerns regarding competitive advantage and the protection of proprietary information as we jointly search for methods to overcome deployment impediments.

The automotive industry traditionally introduces and develops new products in an evolutionary, rather than revolutionary, manner. Thus it might be expected that new ITS products will be initially introduced in one or two models of a manufacturers product line. Further refinement and introduction in additional models would follow after initial experience. It appears that the introduction of route navigation and guidance systems fits this pattern, and crash avoidance products are not expected to be any different from these other products.

The strategic goal of the program for the next 5-10 years is to demonstrate improved capability of collision avoidance systems, ensure that systems are both effective and usable to consumers, and provide a basis for understanding the benefits, (i.e., collisions, injuries and fatalities that will be avoided). Within each problem area, there are projects which evolve from a rudimentary understanding in each of these areas to refinements which provide a more rigorous and defensible understanding.

Starting in 1997-1998 there will be a major shift in the character of the projects; shifting from narrowly focused projects to projects which address the larger issues of system capability, usability, and benefits. This shift in focus recognizes that effective collision avoidance systems will be made available to consumers if the motor vehicle industry is convinced that these products will be successful in the marketplace. Consequently, NHTSA will intensify on-going outreach activities to increase public awareness of the capabilities and benefits of CA products. Operational tests and demonstrations of CA systems will be tailored to provide broad exposure of these systems to the driving public.

Also, in this time period, the program will begin looking at the advantages of systems that address multiple CA problem areas. These integrated systems will also incorporate and build upon other in-vehicle capabilities, such as route guidance, which is not directly related to solving a safety problem, but may enhance CA system performance. The development of an in-vehicle data bus that can support the transfer of data from sensor, computational, driver interface, and control elements within the vehicle will potentially reduce costs of collision warning devices. In addition, the data bus will facilitate the installation of these devices in the vehicle.

The central focus of the program has been, and continues to be, the development of a broad understanding of how advanced technology systems can be used to help avoid collisions on the nation s highways. The approach to implementing this focus is to arrange projects by problem area. Each of the projects in the program provide specific input to improving the overall knowledge base and understanding, of systems that address one or more problem areas. The problem areas that are being addressed in the program are:

Specific Crash Type
C Rear-end Collision Avoidance
C Intersection
C Road Departure
C Lane Change/Merge
C Heavy Vehicle Stability

Driver Performance Enhancement
C Drowsy Driver
C Vision Enhancement

Crash Consequence Mitigation
C Automatic Collision Notification

One new element during this period will be efforts to demonstrate that effective collision avoidance systems are not just a long-term vision, but in fact can be near-term reality. This will be accomplished through the development of a low-cost demonstration vehicle that can be used to illustrate the usefulness and practicability of advanced-technology collision avoidance systems.

Approach

In each problem area, NHTSA will assess system capability, user acceptance, and benefits of potential countermeasure systems. The objective of each program area in this plan is to help advance the capabilities, user acceptance, and benefits of collision avoidance systems.
refers to the technical performance of the systems and its components -- sensors, processors, and driver interface or controls.   addresses the interaction with the driver, including
ease of use, desirability of the system, effects on driver performance, and affordability. The primary
 are reductions in the number of collisions and their associated injuries and costs.

A full understanding of potential benefits is the ultimate research goal of each program area. In some cases, the goal of the program area during this time period may be something less than this ultimate goal. For example, in the area of school bus pedestrian protection, we may never be able to have an experimental basis for estimating benefits, so an ultimate goal for the program may be an improved understanding of user acceptance. The program plan aims to achieve the goals in the shortest possible timeframe.

Progress in achieving these objectives is measured by the levels of understanding reached o rudimentary, improved, and full. The definitions of these levels differ for each of the objective characteristics above, and are presented in Table 1:

Table 1. Levels of Understanding to be Achieved in NHTSA CA Program Areas

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System capability refers to the operational performance of the system components or subsystems (sensors, processors, controls, and driver interface) to reduce the potential for collisions and associated injuries, damage, and costs. From a functional performance perspective three categories of CA systems are possible within a project area each implying additional sophistication within the system. Category 1 systems will provide drivers with cautionary warnings when the potential for a collision exists. Category 2 systems will provide warnings to the driver when the system predicts that a collision is imminent and immediate action is required by the driver. Category 3 systems will provide support when the vehicle is on a collision course and automatic vehicle control will be required to avert the collision or to minimize the severity of a crash. Each CA project will follow an iterative process to develop and refine performance specifications for systems that address the targeted CA problem areas; and to test and evaluate concepts and prototypes.

For each problem area, projects which address system capability will progress through three levels. The first level will assess performance in terms of subsystem performance. The second level will describe performance in terms of test procedures for sensors, the computational subsystem, and the driver interface for all pertinent driving situations where a warning is needed. Consideration will also be given to some measures of user acceptance such as effect of correct, false and/or misleading warnings. The third level will express performance in terms of objective test procedures and criteria on system performance for all pertinent driving situations, those requiring a warning and those for which a warning should not be issued. These objective procedures and criteria will be based on test-track tests, use of the variable dynamics test vehicle, and use of advanced driving simulators such as the National Advanced Driving Simulator (NADS).

Each project identifies and builds upon common technology solutions, extending from the simpler functions of problem detection and warning to the more complex functions of limited or fully automated vehicle control. For example, forward looking detector systems that are being designed and evaluated to support intelligent cruise control will form the basis for rear-end collision warning systems. One cross-cutting outcome of the full program will be an evaluation of the degree to which common technologies can effectively support the requirements of multiple project areas, and to identify where different technological approaches will be needed.

User Acceptance

A number of issues must be considered (as trade-offs) in determining the viability of candidate CA systems. These include: system performance, consumer cost of production systems, and perceived value and acceptability to vehicle drivers, especially in combination with other in-vehicle systems. In combination, these factors will directly influence the ability to deploy new CA products in motor vehicles. System performance estimates consider the number and types of collisions that will be avoided as well as negative performance factors, such as erroneous warnings, that would potentially degrade performance and reduce expected benefits.

The acceptability of a system to a driver depends upon whether the driver perceives the benefits obtained from the system to be greater than its cost. "Cost" can include not only the actual initial dollar cost of the system, but the costs of maintenance as well as intangibles such as the annoyance caused by systems that prove to be unreliable, difficult to understand or in need of frequent attention, or ones that give false readings. While increased system performance and reliability will generally increase the benefits of the system, they usually will also increase the final product cost, thus reducing the chances of user acceptance.

For each problem area, research will be conducted to gain a better understanding of the user acceptance of the proposed collision avoidance system. These projects will include consideration of the effects of measures of performance such as false positives, false negatives, nuisance warnings, perceived non-warnings, driver workload, factors affecting performance such as driver demographics, and cost. Initial studies will take the form of focus group discussions and questionnaires.

It must be recognized that the design of CA systems is an iterative process. If during the development of a system, it is found that the driver/vehicle interface or some other property of the system as initially specified based upon early research (and a rudimentary level of understanding) results in unforeseen problems which affect user acceptance of the system, the system performance specifications may be modified to remedy that situation, leading in turn to changes in user acceptance.

The level of understanding regarding driver acceptance will increase as projects proceed from conceptual systems, studied with the aid of simulation and computer analysis, to prototypes and test vehicles, and finally to operational tests involving a large number of drivers, vehicles, and operational conditions. Until a substantial sampling of drivers can be exposed to and can evaluate the performance of prototype or pre-production systems under realistic roadway environments, the state of knowledge regarding user acceptance will remain only at the “rudimentary” or “improved” level.

A major challenge is the need to assess practicability and acceptability of CA systems (demonstration of the usability of fully developed technology and measurement of customer acceptance). This will be accomplished by:

- integrating state-of-the-art capability into vehicles that can be driven on the highway under normal driving conditions; and
- conducting operational tests of selected collision avoidance systems in an integrated environment.

Benefits

The reduction of collisions, fatalities, collision severity, and injuries will be the ultimate measure of success of this program. In addition to these primary safety benefits, several other benefits will accrue to these improvements in safety performance. For example, a reduction in injuries from motor vehicle collisions will have a direct impact on the cost of health care. The cost of these injuries and related lost productivity and property damage in this country alone is more than $150 billion per year. A reduction in injuries could result in a proportional reduction in direct economic costs. Developing new technologies will lead to additional economic benefits. These new applications will provide increased job opportunities with a resultant positive impact on the global economy. Thus, the deployment of ITS safety systems will help tie America together and will also provide critical linkages between the intelligent transportation infrastructure and in-vehicle systems.

Safety benefits are highly dependent upon the levels of system capability and user acceptance that are ultimately achieved by deployable products. Initial estimates of safety benefits are derived from computer models and experimental data, while improved levels of benefit estimation will result from use of the Data Acquisition System for Crash Avoidance Research (DASCAR), the System for Assessing the Vehicle Motion Environment (SAVME), driving simulators and other test vehicle projects. A more complete "full" level of understanding of the benefits to be derived from potential CA systems will be obtained after operational tests are conducted to thoroughly examine driver/system interactions and to assess the performance of each system under a variety of operational conditions.

Benefits estimation and assessment is a continuous process during the concept development, prototyping, and testing cycle for CA products. As additional data to estimate effectiveness becomes available (through program activities) the benefits estimates will be refined. The process will include several elements:

- benefit estimation methodologies that are based on "before" and "after" data (i.e., compare numbers of collisions that occur when no CA system is present to the number that would occur when a CA systems is present);
- procedures to obtain estimates of effectiveness for CA systems under a full range of driving situations or scenarios;
- test procedures to support an objective assessment of the performance of systems and subsystems under repeatable test conditions.

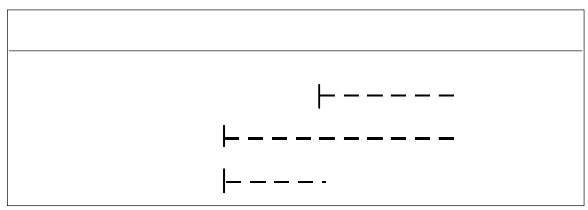
Human factors research projects will play an important role in determining the CA system effectiveness especially in combination with other in-vehicle systems. If drivers do not perceive that the safety potential of a countermeasure system outweigh the costs (regardless of whether the actual potential benefits outweigh the costs or not), they either will not buy the systems or will not use them, and the actual safety benefits obtained will be zero. On the other hand, if drivers perceive that the system offers greater safety potential and enhances driving, they may then resort to riskier driving behavior, such as driving faster in closer proximity to other vehicles, which could degrade safety. Research will be undertaken to gain a better understanding of how closely driver's perception of CA system capabilities match its actual capabilities, and of their tendency toward (and potential effects of) risk compensation. This research will incorporate insights from the extensive research on related topics, like pilot reactions to installation of safety systems in aircraft, already conducted or being conducted by the Federal Aviation Administration, The National Aeronautics and Space Administration, and the Department of Defense.

The benefits focus requires continued development of test and evaluation tools and techniques, and the application of these tools in a coordinated test and evaluation process. Research tools and critical knowledge bases will continue to be enhanced and updated as a result of these efforts.

The NHTSA program addresses the collision problems in three countermeasure areas, focusing on countermeasures for specific collision types, system approaches that enhance driver performance under certain situations, and approaches for mitigating the consequences of collisions (improving victims survival chances). The project areas are a continuation of activities started within the previous plan period. In the 1997-2002 timeframe several will receive increased emphasis, while others will either be integrated and/or merged with other CA projects.

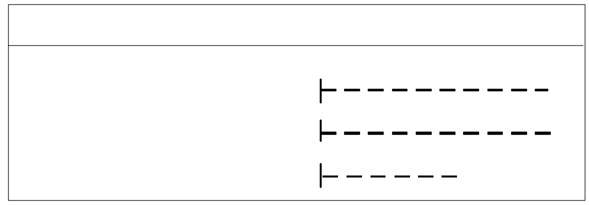
The programs for each of these areas are discussed in the following section. The steps to achieving increased levels of understanding in the NHTSA ITS Plan are presented for each program area in the following sections of this document (see table 1 earlier for detailed explanation of terms). A simplified chart is provided for each program area to illustrate expected progress during the plan’ s timeframe -- 1997 to 2002. An annotated example progress chart is presented in figure 3.

Figure 3. Example Progress Chart



In this example, progress in understanding for Program Area X is indicated horizontally for each of the three aspects of collision avoidance system research -- capability; user acceptance; and benefits. Vertical bars (|) indicate the level of understanding in 1997, and diamonds () represent the expected level of understanding by 2002. For any program area, the levels of understanding may differ across the three categories. In this example, the level of understanding for capability begins at the rudimentary level in 1997, but starts out at virtually no understanding of user acceptance and benefits. By 2002, the program area expects to achieve improved understanding of capability and user acceptance, and a rudimentary understanding of benefits.

Rear-End Collision Avoidance Program Area



A rear-end crash occurs when the front of a vehicle strikes the rear of a leading vehicle, both in the same lane. In 1994, there were approximately 1.66 million police-reported rear-end crashes. These crashes accounted for over 920,000 injuries and 1,160 fatalities. It is estimated that about 50 percent of these crashes could be avoided by collision avoidance systems that could sense stopped or moving vehicles in the forward lane.

The rear-end collision avoidance system (RECAS) concept is to monitor the forward path of the host vehicle, detect other vehicles and objects, and help the driver maintain a safe headway relative to a preceding vehicle (Category 1 system) or warn the driver if a collision is imminent (Category 2 system). At present, the technology to provide effective rear-end collision avoidance systems is generally believed to be more advanced than systems for some other collision types (e.g., run-off-the-road.).

Intelligent cruise control (ICC) systems, currently being introduced to consumers abroad, will provide the foundation and experience to develop deployable RECAS. ICC systems do not detect stationary vehicles and will be capable of being activated by the driver at speeds above a manufacturer determined threshold. However, NHTSA views this project as a high priority effort since ICC has the potential for introduction of effective products by the automotive industry within the next 5-8 years. The research program is structured to develop a better understanding of the overall system capabilities and to validate system performance and benefits estimates through development and testing of prototype systems.

<u>Program Area Objectives and Planned Activities</u>

Two key objectives of the RECAS program area are:

C achieve a high level understanding of benefits; and
C completion of research by DOT to ascertain feasibility and performance potential of countermeasure systems.

<u>To achieve these objectives, NHTSA will</u>:

This will provide a rudimentary level of understanding of system capability building upon the rudimentary understanding of benefits achieved in 1996. A first generation RECAS will have the capability to sense stopped vehicles, and will operate under a limited range of vehicle speeds for certain collision scenarios.

This will achieve an improved level of capability, user acceptance, and benefits understanding for ICC systems. Initial studies have shown that when ICC systems are used, they effectively smooth traffic flow and maintain safer separations among vehicles, under uncongested traffic conditions. This ICC test is important to RECAS development as ICC systems are seen as a technology "stepping-stone" to collision avoidance capability. The FOrward Collision Avoidance System (FOCAS) cooperative agreement and the Collision Avoidance Metrics Program (CAMP) project , which will be under a cooperative agreement between the auto manufacturers and NHTSA, will add to the understanding of system capability.

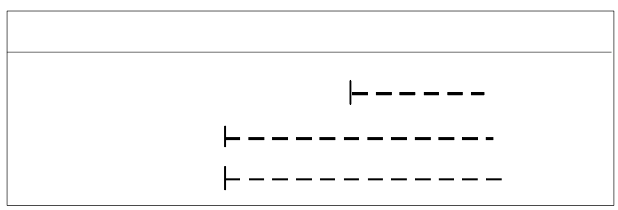
This will refine, update, and improve the preliminary performance specifications prepared for first generation RECAS.

This will develop procedures for improved estimation of benefits from RECAS based upon the results of planned operational tests.

Near-misses will be analyzed to predict system effectiveness. At the same time risk compensation behavior by drivers will also be examined. Completion of this operational test will provide an improved to full understanding of user acceptance for second generation systems by 2001.

Driver interface tests will build on work of CAMP, and the Delco/ARPA consortium. It may also include input from the In-Vehicle Information System (IVIS) work at FHWA. This will provide a full understanding of system capability. Full benefits understanding will come after the completion of large scale operational tests beyond 2002.

Intersection/Railroad Collision Avoidance Program Area



Intersections are among the most dangerous locations on U.S. roads. Approximately 1.95 million crashes occurred at intersections in 1994 (30 percent of total crashes), causing over 6,700 fatalities and significant numbers of serious injuries. There are more intersection collisions than any other crash type. However, it is also more technically challenging to prevent this type of crash with detection and warning technology than other crash situations. Because of these technical challenges, ICAS is viewed as a longer term program area, but one with potentially large safety benefits. Prototype vehicle-centered systems will be evaluated during the next 5 years, but are not expected to be operationally feasible in that period.

During the next five years, NHTSA will investigate three categories of intersection collision avoidance systems (ICAS) autonomous vehicle-based systems; vehicle-vehicle communication systems; and systems that require instrumented intersections. Vehicle-based systems will provide autonomous capabilities (not dependent upon instrumented roadways), and system costs will be paid for by the user (automobile purchaser), while instrumented intersections will require major public sector capital investment in the infrastructure. It is quite possible, however, that the latter approach is more technically feasible. For example, the wide variety of intersection geometries dictate a sensor that is virtually capable of seeing around corners. Also, since a great variety of possible maneuvers at an intersection can pose threats to another vehicle, the ICAS processor must be very fast and smart in recognizing/predicting these maneuvers and providing effective warnings. Also, because of the possibility of encountering relatively large numbers of vehicles at an intersection, the threat assessment processing could be very complex. The current study is expected to answer some of the key performance questions in this area.

Another issue to be dealt with is the potential for compensatory driving behavior, in which either/both the driver of an equipped or unequipped vehicle may depend on the CA system to provide safety warnings and be inclined to take greater risks at an intersection. The difference between this and other collision avoidance services is that it may encourage drivers of vehicles other than the "host" vehicle (the one containing the CA system) to drive in a more risky manner. If certain drivers are inclined to violate traffic controls at intersections, they may be further encouraged to disregard those controls if they believe that other vehicles are equipped with systems to warn drivers of safety problems and cause them to yield to the driver who violates the right-of-way. This possible effect on driving behavior also has a bearing on whether the preferred intersection collision avoidance system should be one that advises the driver of the host vehicle to "stop the violation" or one that advises the driver to "stop the violator". Both of these approaches would correspond to Category 2 systems.

In parallel with vehicle-centered approaches to preventing intersection collisions, NHTSA will also coordinate with other DOT agencies working on infrastructure-based ITS solutions that address this crash problem. FHWA has begun work on intelligent signing, where either 1), a beacon at a signpost alerts the driver that he/she is approaching a traffic sign or 2), an in-vehicle navigation unit advises a driver of traffic signs. Federal Rail Administration (FRA) is currently spearheading efforts to develop warning systems for currently unsignalized railroad grade crossings. NHTSA will be supported in these coordination activities by VNTSC and the Vehicle Research Test Center (VRTC) in East Liberty, OH.

Program Area Objectives and Planned Activities

Two key objectives of the ICAS program area are:

- C determine if vehicle-based ICAS are viable; and
- C assess opportunities and requirements for integrating infrastructure-supported ICAS with FHWA programs to develop advanced intersection traffic management systems, FRA grade crossing safety program, other NHTSA collision avoidance programs such as Road Departure (common use of in-vehicle map data base), and the Automated Highway System program (common use of infrastructure sensing and computational capability).

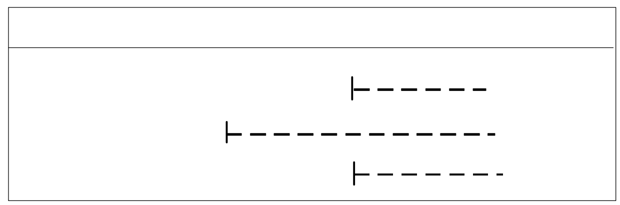
To achieve these objectives, NHTSA will:

This will include a full catalog of necessary actions to avoid most collisions that result from the key causal factors.

It will focus on performance of systems that reside solely within a vehicle, but many aspects of this performance can be transferred to systems which include infrastructure support. It will also address both systems that advise the driver to "stop the violation" and systems that advise the driver to "stop the violator". This work began in 1993 and the continuing efforts will provide [rudimentary] understanding of system capabilities and develop preliminary estimates regarding the benefits of these systems.

Railroad crossing collision avoidance systems and route guidance/navigation systems will include features that are related to elements of ICAS. The state of development of these systems may have a bearing on direction of the ICAS program area. Possible synergisms between programs may encourage further development that otherwise would not occur. Details of system development and capability for related ITS services will be analyzed.

Road Departure Collision Avoidance Program Area



Single Vehicle Road Departure (SVRD) accidents represent the most serious crash problem based upon the national highway accident data analysis. Analysis of crash data indicate that approximately 1.24 million police-reported crashes of this type occurred in 1994. This number represents approximately 19 percent of the total crash problem and lead to over 500,000 injuries and 13,000 fatalities. There are many different causes of these types of crashes, including weather/vision problems, driver impairment, and other improper driving behaviors. Due in part to these diverse causal factors, the development of countermeasure systems will present significant technical challenges.

This project focuses on the development of systems to provide the driver with road-departure warnings and will be complemented by other projects involving drowsy driver warning and vision enhancement systems. There are two key aspects of road departure countermeasure systems: lateral and longitudinal. The lateral road departure countermeasure system is a Category 2 system and is designed to prevent SVRD crashes caused primarily by driver inattention and driver relinquishing steering control due to drowsiness. This system detects when the vehicle begins to depart the road. A simpler version would notify the driver when the vehicle has crossed the lane edge onto the shoulder of the road. A more complex system would predict, based on road geometry ahead and vehicle dynamics, that the vehiclewill run on to the shoulder.

The longitudinal road departure countermeasure system is a category 1 system and addresses SVRD crashes caused predominately by excessive speed on curved roadways and loss of directional control. This system detects when the vehicle is traveling too fast for the upcoming roadway conditions. It utilizes vehicle performance data in combination with information about pavement conditions and upcoming roadway geometry to determine the maximum safe speed for the vehicle.

Program Area Objectives and Planned Activities

Two key objectives of the RD CAS program area are:

C determine the operational performance of deployable RDCAS

C assess the opportunities and requirements for integrating RDCAS with other collision avoidance systems

To achieve the first objective, NHTSA will:

Initiate integration of longitudinal countermeasure and route guidance/navigation system capability. This will be mainly accomplished through the use of an on-board map data base with improved information regarding roadway geometry (radius-of-curvature).

Develop and demonstrate an improved capability to sense roadway conditions, e.g., coefficient of friction, ahead of the vehicle as part of the longitudinal and lateral countermeasures. This may require some degree of infrastructure support.

Achieve an improved level of understanding of the relationship between CAS capability and user acceptance based on driver-specific adaptability of control/warning algorithms for both longitudinal and lateral countermeasures. This will include consideration of driver drowsiness and may be accomplished through a combination of studies with driving simulators, the VDTV, and field tests. Both driver warning and CAS crash predictive capability will be examined.

Achieve an improved level of understanding of benefits for alternative levels of CAS capability for both longitudinal and lateral road departure countermeasures using VDTV, simulations, and field tests.

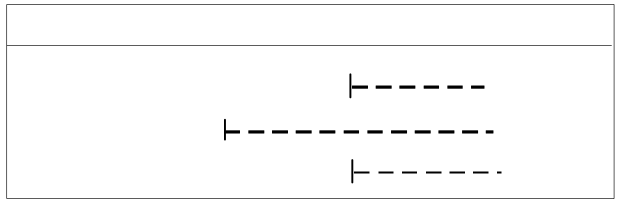
Define level of capability for CA systems to be used in a operational test. Initiate a comprehensive operational test program that is designed to provide necessary information regarding system capability, acceptability, and benefits.

To achieve the second objective (assess integration), NHTSA will:

Opportunities for sharing components, such as sensors, will be assessed. Also, expanded functions for integrated systems will be assessed. This will provide a rudimentary understanding of the potential benefits of integrated systems. Two candidates for integration with the road departure project are Automatic Collision Notification (common use of an on-board map data base) and Lane

Change/Merge countermeasures (common use of lane position sensing). Tests of integrated systems will be conducted after 2002.

Lane Change/Merge (LCM) Collision Avoidance Program Area



Lane change and merge crashes accounted for approximately 244,000 crashes in the United States in 1994 (4 percent of all crashes) and resulted in 225 fatalities and many serious injuries. They occur most often on metropolitan arterials and streets. A collision avoidance system that reduces this type of collision will also help decrease travel delays caused by this type of collision in addition to improving safety.

First-generation systems are expected to have Category 1 type of performance, i.e., they help the driver become more aware of proximate vehicles. Such systems warn the driver that it may be unsafe to change lanes. This occurs during the decision phase of the lane change or before the driver has initiated a lane change maneuver. Category 2 LCM systems require more sophisticated sensing and processing capabilities to determine the relative lateral position and velocity of vehicles in adjacent lanes during lane change and merging situations. Such a system would warn the driver of an impending collision under a wide variety of LCM situations. Based on results of current projects it appears that Category 2 type performance will not be practicable in the 1997-2002 timeframe.

This project area also addresses a special problem concerning the safety of school bus riders (and other pedestrians) after they disembark from a bus. In recent years approximately 25 school children per year have been killed and 400 to 500 have been injured by this type of accident. Two commercial products have been developed to address this problem, and some product evaluation has already been accomplished. These systems use Doppler radar sensors mounted on the front and right side (optional left side and rear sensors are also available) of the bus to detect and warn the driver of the presence of pedestrians around the bus during pupil pick-up and drop-off (Category 1 system).

Pedestrian detection systems could potentially be an "early winner" in the collision avoidance arena, but will require a stronger understanding of user acceptance and benefits. Concerns exist that drivers may come to overly depend on the warning system rather than continue using normal safety procedures. An independent evaluation of the operational effectiveness of these systems by NHTSA will serve a public need and contribute to the "outreach" of the ITS program at large.

<u>Program Area Objectives and Planned Activities</u>

Three key objectives of the LCM CAS program area are:

C identify minimum level of system capability that will provide a satisfactory level of user acceptance; and

- C assess opportunities and requirements for integrating LCM systems with other collision avoidance systems.
- C achieve a full level of understanding of benefits and user acceptance for available commercial products for pedestrian detection and (driver) warning.

To achieve the first objective, NHTSA will:

The specifications will address all three functional elements of the LCM system: sensors; information processing; and driver interface. This work began in 1994 and will provide an improved level of understanding of system capabilities and rudimentary level of understanding of potential benefits.

Driving simulators will be primary tools for conducting this work. However, currently available simulators may need to be modified to accommodate lane change/merge experiments. Rates of nuisance alarms will be measured and the effect on the driver will be determined. As part of this work, a range of performance capabilities will be investigated, from only sensing the presence of a vehicle a few meters away to determining the location and closing speed of threatening vehicles at greater distances. The simulator-based studies will be augmented by test track experiments and will provide an improved understanding of user acceptance. Ease-of-use will be determined through a variety of means including surveys of test participants and measures of driver behavior with and without the LCM systems. Category 1 LCM systems have the potential to be relatively inexpensive and deployable in the next five years, and could possibly eliminate a large fraction of lane change crashes. The minimum performance to ensure driver acceptance of these systems will be the key factor in cost and market introduction.

This will be accomplished by using baseline driver performance without a LCM obtained from experiments using the DASCAR and combined with results from studies using driving simulators.

Based on the results of user acceptance/system capability analyses, the specifications for a LCM system for use in an operational test will be developed.

This level of understanding will be acquired primarily through the analysis of operational test results. This activity will provide a full understanding of system capability, user acceptance, and potential benefits of a commercially viable LCM system.

To achieve the second objective (assess integration), NHTSA will:

Opportunities for sharing components, such as sensors, will be assessed. Also, expanded functions for integrated systems will be assessed. For example, a driver trying to avoid colliding with a stopped or decelerating lead vehicle may have to change lanes. This will provide a rudimentary understanding of the potential benefits of integrated systems. Tests of integrated systems will be conducted after 2002.

To achieve the third objective (regarding school bus/pedestrian warning systems) NHTSA will:

To date, only limited field tests were done to assess performance and to establish a rudimentary understanding of user acceptance. Those tests indicated that after a brief exposure to the systems (one day) drivers liked the technology and followed normal procedures while using it. The expanded scale operational test will support detailed assessment of user acceptance and driver behavior and will permit a more accurate estimation of system benefits.

Heavy Vehicle Stability Enhancement Systems Program Area

Heavy truck rollover crashes are not frequent occurrences, but the occurrence of rollover as a crash factor increases the likelihood of serious or fatal injury to the truck occupant. NHTSA data show that while rollovers are involved in 3 percent of all crashes for combination trucks, it was a factor in 13 percent of all fatal crashes of combination trucks. Two countermeasures have been identified by NHTSA to help reduce the incidence of heavy vehicle rollovers.

The first is a Roll Stability Advisory System (RSA), which is a Category 2 system. It measures the rollover stability properties of a typical tractor-semitrailer as it is operated on the roadway and provides the driver with a graphical depiction of the vehicle’ s loading condition relative to its rollover propensity. The RSA is intended to assist drivers in maintaining safe speeds on curves. The second countermeasure is a Rearward Amplification Suppression System (RAMS), which is a Category 3 system. An active brake control system coupled with Electronic Brake System (EBS) technology will selectively apply brakes to wheels to stabilize the vehicle and thus reduce the incidence of rear trailer rollover in double- and triple-trailer combination vehicles during crash avoidance steering maneuvers.

Program Area Objectives and Planned Activities

The objectives of the heavy vehicle stability enhancement program area are:

C demonstrate feasibility and practicability of truck rollover prevention systems
C evaluate performance and potential benefits

To achieve these objectives, NHTSA will:

This will provide a rudimentary understanding of system capability. The RSA system incorporates sensors located in the tractor s fifth wheel and on the trailer suspension as inputs to a vehicle dynamics model that determines the vehicle center of gravity height based on load transfer during normal vehicle maneuvers. The RAMS system will use the same on-board vehicle dynamics model to identify maneuvers that result in amplified lateral acceleration of multiple trailers, and apply a differential braking strategy to counteract this effect.

This will provide an improved understanding of user acceptance and system capability.

Undertake comprehensive analysis of accident data on heavy vehicle rollover crashes incorporating the results of RSA field tests.This will determine the number of relevant crashes that might be preventable with these countermeasure systems and will achieve an improved level of understanding of benefits for RSA.

This test will involve a large number of vehicles to fully determine performance and benefits of a wide-scale deployment. This operational field test will be completed in 2003, outside the duration of this plan. The results will provide a full understanding of benefits, user acceptance, and system capability for RSA.

A NHTSA-supported double trailer combination vehicle will begin service in 1998, and one triple trailer vehicle will begin service in 1999. A rudimentary understanding of RAMS user acceptance and system capability will be achieved by 2001. Increasing the levels of understanding will occur after 2002 when larger numbers of EBS equipped demonstration vehicles are expected to be field tested.

Drowsy Driver Monitor Program Area

NHTSA General Estimates System (GES) statistics for 1992 indicate that over 50,000 crashes are caused annually by driver drowsiness or fatigue. Of these crashes, data from the 1992 Fatal Accident Reporting System (FARS) indicate that drowsiness/fatigue was a factor in crashes in which over 1400 fatalities occurred. In the trucking segment, at least 80 truck-related fatalities occur annually, due to driver fatigue. The initial focus of this program area is on the commercial trucking segment for four key reasons; the extensive night driving in commercial operations, the need to minimize fatigue-related accidents among paid drivers, the high cost of commercial vehicle accidents, and the relative affordability of such systems for high-value heavy trucks. Ultimately, drowsy driver monitor systems should be deployable at a lower cost in all passenger vehicles.

Systems currently under consideration are Category 1. They rely on sensing of two features of driver performance. One feature is lane tracking maintenance, i.e., how well the vehicle stays within lane demarcations. The other is eye and eyelid movements. Additional indicators of driver performance include steering wheel motions, head movement, and lateral acceleration. The drowsy driver program is oriented toward identifying effective combinations of detection devices, development of drowsiness detection algorithms, and selection of the best detection devices for implementation.

This program area cuts across many of the other crash problem areas. Much of the basic research has been accomplished on the relationship between drowsiness and indicators of driver performance noted above. On-going activities focus on further development of countermeasure system requirements. Also being addressed are problems associated with developing affordable and effective products. Current research and prototyping have been oriented toward commercial heavy vehicle applications. Additional efforts are required to develop capabilities suitable for privately owned vehicles.

Program Area Objectives and Planned Activities

The two key objectives for the Drowsy Driver Monitor program area are:

C achieve operationally effective and deployable drowsiness monitoring systems for heavy trucks and passenger vehicles

C reach a decision for further NHTSA efforts to include stand-alone or integrated systems (i.e., drowsiness monitor and/or lane tracker) for heavy trucks/passenger vehicles.

To achieve the first objective, NHTSA will:

. Assess and validate
personal alertness monitoring devices and drowsy driver detection algorithms to provide an improved understanding of system capability, system design requirements, requirements for large scale operational tests, and system benefits. Field test data will be collected from late-1996 pilot demonstrations of driver/vehicle performance (e.g., head movement, eye closure, steering wheel velocities, and lane departure). Field test data will be collected using DASCAR in 1997 on both baseline and countermeasure equipped trucks. Studies will be conducted from 1997 through 1999. Studies will compare driver/vehicle operations with/without drowsy driver systems in a truck fleet, observe drowsy episodes during road departure program operational tests, and relate roadway performance to drowsy driving in a simulator.

Implementation of driver
surveys and outreach efforts in combination with field test results will provide an improved understanding of user acceptance, as well as an improved understanding of system capability for commercial motor vehicle systems.

To achieve the second objective, NHTSA will:

- . A key decision to be made in this timeframe is whether to develop a stand-alone system or an integrated lane tracker/drowsiness detection system. This decision will be based on a comparison of the heavy truck field test results with the results from testing similarly configured passenger vehicles. This research will also include insights that have been gained in similar research which has addressed drowsiness and inattention of aircraft pilots and railroad engineers. Results of the heavy vehicle field tests will be used to further define the requirements for an effective personal drowsiness monitoring system, as well as the requirements for a national operational test of the system in heavy trucks and passenger vehicles.

Based upon the results of previous field test and outreach activities, a test and evaluation plan will be developed to test the selected drowsy driver system configurations under normal operating conditions.

Prior to the operational test, an improved understanding of drowsy driver system capability, user acceptance, and benefits in passenger vehicles will be achieved. Improved understanding will be based upon the results from heavy vehicle field testing and the development of various passenger vehicle system configurations.

Operational tests will 1) focus on achieving a full understanding of benefits and user acceptance, 2) test systems for deployment using a large national sample of drivers, and 3) accommodate appropriate levels of on-board data collection.

Driver Vision Enhancement Program Area

Approximately 42 percent of all crashes and 58 percent of fatal crashes occur at night or during other degraded visibility conditions, according to NHTSA accident statistics. These 2.8 million annual police-reported crashes, including 23,000 fatal crashes, represent crashes for which reduced visibility may be a contributing factor.

A number of inter-related factors contribute to the high crash rate at night, including alcohol, fatigue, and reduced visibility. A recent analysis of Fatal Accident Reporting System (FARS) accident cases suggests that reduced visibility is a major factor in night-time accidents involving pedestrians and pedacyclists.

Driver vision enhancement systems help drivers when visibility is low by providing an augmented view of the forward scene. These systems fall into two broad categories: those that depend upon natural or infrastructure-based illumination; and those that depend on additional illumination from the vehicle. Infrastructure-based systems use reflective materials on pavement marking, road signs, and other fixed roadside objects to provide an enhanced view of the driving environment. On the other hand, vehicle-based systems use a suite of sensors and equipment to improve the view of the driving scene through an in-vehicle display.

The focus of this program is vehicle-based Category 1 systems. Prototypes of driver vision enhancement systems exist and are currently being used to support a wide range of engineering tests and product development activities. Fundamental questions about the causal relationship between visibility and safety have not yet been answered. Moreover, key performance requirements and user acceptability of in-vehicle vision enhancement systems are not yet understood.

Implementation of cost effective vision-enhancement systems for passenger and commercial vehicles is considered to be a significant technical challenge.

Program Area Objectives and Planned Activities

The key objectives of the vision enhancement program area are:

C establish a rudimentary level of understanding of the feasibility, benefits, and effectiveness of vehicle-based driver vision enhancement systems.

C reach a decision point on direction of further research.

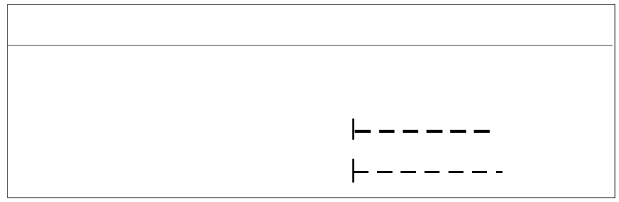
To achieve this objective, NHTSA will:

The end product of this work is to understand and describe the driving tasks, roadway scenarios, and driver characteristics under which vision enhancement systems may increase driver safety relative to standard, baseline headlight systems. An understanding and definition of required system functions and display characteristics as well as how they effect driver usability will also be achieved.

. This will provide a rudimentary understanding of benefits. There is presently no accepted methodology for estimating benefits for any vision enhancement systems. Thus, the first step to determining benefits will be the development of estimation methodologies that are applicable to the conceptual and prototype stage of system development. Some possibilities for collection of baseline data include comparative studies using driving simulators and controlled experiments on test tracks to measure driver performance with and without a vision enhancement system.

If initial studies demonstrate that in-vehicle vision enhancement systems are cost-effective and have the potential to provide driver benefits without significant adverse affects, NHTSA will continue its support of this program area to include the development of performance specifications for these systems and planning for the conduct of limited demonstration projects and operational tests.

Automated Collision Notification Program Area



This program area addresses the need to deliver rapid emergency treatment to crash victims, thereby saving lives and reducing the consequences of injuries to surviving crash victims. This problem is particularly acute for crashes that occur in rural areas. In many instances the accident is not immediately discovered and reported, lengthening the response time for rural EMS. Based upon NHTSA traffic accident and fatality statistics, in 30 percent of the traffic fatalities that occurred in rural areas, more than one hour elapsed from the time of the crash until the crash victims arrived at a hospital. In 23 percent of the fatal accidents in rural areas, more than 10 minutes elapsed between the time of the accident and EMS notification. In contrast, for urban areas, less than 8 percent of the fatal crashes required more than 10 minutes for EMS notification.

An Automated Collision Notification (ACN) system automatically and immediately reports to an emergency medical services (EMS) provider, the occurrence and location of an automobile crash. The system proposed for operational testing will have the capability to sense (via on board accelerometers) that the vehicle has been in a collision, estimate the severity of the collision, including the primary direction of force and change in velocity, and instantaneously forward that information (via cellular telephone) to an appropriate authority to dispatch EMS. While not a part of the current test, special algorithms could be utilized to provide estimates of crash victim medical conditions, while smart card technology could provide driver medical history to the EMS dispatcher. Two-way communications will also be included to allow assistance providers to respond to the traveler, acknowledging the assistance request and informing the traveler that help is on the way.

This program area will continue through the end of the current operational test in 1998 to determine the effectiveness of the prototype system, and to measure the user acceptance and feasibility of the product for deployment. The auto industry has begun offering related systems as an option on certain car models. Subsequent activities by NHTSA will be limited to the monitoring of proposed products and the continuing efforts to support the integration of safety-related capabilities and standards development. At that point the ACN project activities will be merged into the road departure project area, which also addresses a predominantly rural problem.

<u>Program Area Objectives and Planned Activities</u>

The key objectives of the ACN project are to:

- determine feasibility of large-scale deployment of ACN systems,
- assess the effectiveness of the systems in reducing injuries and fatalities, and
- reach a decision point regarding further NHTSA R&D actions in support of ACN deployment.

To achieve this objective, NHTSA will:

The results from this test, especially when combined with results from other operational tests of systems for summoning assistance, will provide an improved level of understanding of capability and user acceptance. This program area, unique within the NHTSA Collision Avoidance program, must include the dispatcher in the user acceptance framework. It also must include the capability of infrastructure elements as part of the performance assessment. The operational test will also assess the willingness-to-pay and provide an improved understanding of potential benefits (through the relationship to market penetration). At present, there is an improved understanding of in-vehicle capability based on previous research undertaken by NHTSA. The readiness of industry to offer products in this area indicates that there is currently at least an improved level of user acceptance of ACN.

As discussed in the preceding sections, the ITS collision avoidance program is based on identification of safety problems and development of solutions to those problems. As the state of understanding of the solution to each problem matures there will be opportunities, and in some cases the necessity, to integrate the systems that provide these solutions. This integration will provide synergism of performance of system elements, including sensors, computational processors and driver/vehicle interfaces, and increased system capability.

Milestones for initiating specific integration activities are discussed in preceding sections. In addition to those milestones there are three other cross-cutting milestones in the program. One is the development of a demonstration vehicle and the other two are the integration of collision avoidance systems with other in-vehicle information systems, and with the automated highway system.

There are many observers of the ITS program who believe that it will be many years before collision avoidance systems are available to customers; and that, even then, they will only be available in expensive vehicles. The NHTSA demonstration vehicle will be used to explain and demonstrate that collision avoidance systems are within the realm of practicality. A low-cost vehicle will be used as a base and will integrate several collision avoidance systems (i.e., systems addressing more than one CA problem area). The vehicle will be finished with a production-quality interior. It will be used mainly for demonstrations and focus groups on driver acceptance. Results from use of the vehicle will provide a basis for understanding driver acceptance issues and the inter-operability of systems/technologies addressing more than one collision avoidance problem area. NHTSA will develop an integrated collision avoidance vehicle by year 2000.

In cooperation with the Federal Highway Administration, NHTSA has developed a comprehensive plan of research to address all aspects of the driver/vehicle interface for all types of in-vehicle information systems (IVIS). IVIS include not only the collision avoidance information discussed in this plan, but route guidance and navigation systems, advanced traveler information systems (ATIS), in-vehicle signing, and in-vehicle advisories of traffic and safety information related to such things as accidents, traffic tie-ups and road construction work areas. As these systems are integrated, human factors research is needed to address the prioritization of messages, message content, location and types of displays, and driver workload issues. This research will make extensive use of the DASCAR instrumentation, as well as FHWA's instrumented human factors field research vehicle (HFFRV). The culmination of this program will be the development of human factors guidelines and recommendations on how integrated driver information systems should be designed and function to maximize safety, mobility, efficiency, and driver acceptance.

One question which remains unanswered at the time of preparing this strategic plan is the relationship between collision avoidance systems and an automated highway system (AHS). The common link between the two programs is the organization of the systems that will provide both services. A system for providing assistance to drivers in avoiding collisions will have three subsystems, or functional elements. These are the sensor, the computational element, and the driver interface. Likewise, an automated highway system will consist of these same three functional elements, plus an automated control element, and additional elements to check the readiness of the vehicle to operate on the instrumented highways of the automated highway system and to check the readiness of the driver to resume normal driving tasks after leaving the instrumented highway. The driver interface of a collision avoidance system would be replaced with the automatic vehicle control element during automated highway driving. The National Automated Highway System Consortium (NAHSC) is in the process of evaluating various system concepts. However, it is generally accepted that the final AHS concept will rely heavily upon vehicle-based systems, including collision avoidance systems. After the final AHS concept selection is made, it will be possible to determine the areas where coordination and complementary work are most appropriate. Steps will then be taken to implement this coordination.

Other on-going ITS efforts within the FHWA, involving the application of Automated Vehicle Control Systems (AVCS) technology to automobiles and transit vehicles and the introduction of CVO productivity enhancements to heavy trucks, are expected to lead to the deployment of in-vehicle systems that may be exploited to reduce the overall cost of entry for CA systems. NHTSA will maintain an awareness of these activities to determine where complementary development efforts may be justified. On-going standards development activities and the establishment of requirements and standards for in-vehicle data bus capabilities are also considered complementary to the CA research program. NHTSA will also continue to monitor CA technology and product development efforts within other countries and where appropriate support the coordination of efforts leading to the development, test and evaluation, and subsequent fielding of effective CA products.

At the conclusion of the period of performance covered by this plan, great strides will have been made toward delivering the safety benefits of ITS. Many innovations will appear within and outside the motor vehicle to supplement the drivers' efforts at vigilance and control. Among the systems envisioned, new products will monitor the driver's own state of fitness, enhance driver situational awareness on a continual basis, provide advance warning of potential danger, and intervene and assist with emergency control if a crash is imminent.

The reduction in collisions, fatalities, collision severity, and injuries will be the ultimate measure of success of this program. This program will contribute to achieving goals that have been established within the Department of Transportation. For example, two of NHTSA's goals as part of the Government Performance and Results Act of 1993 are to "Reduce motor vehicle fatality and injury rates per 100 million vehicle miles traveled and per 100 thousand population" and to "Reduce the number of crashes per 100 million vehicle miles traveled and the involvement rate of drivers in crashes as a proportion of licensed drivers." In the larger context, this program will also be a major contributor to achieving the mission of the entire Department of Transportation. That mission is to "'Tie America Together' with a safe, technologically advanced, and efficient transportation system that promotes economic growth and international competitiveness now and in the future, and contributes to a healthy and secure environment for us and our children."

In addition, the expansion of ITS throughout all modes of transportation offers the possibility of substantial improvements in safety and service to travelers and shippers alike. Future multimodal systems will be safer and more reliable, and the interfaces between them should function more smoothly, as these technologies find more and more applications. The ITS activities described herein are already serving as a major catalyst to the achievement of this vision. Some government-industry cooperative agreements described in this document may be conducted in cooperation with the National Science and Technology Council.

To achieve these goals, the department must encourage industry to make such systems widely available, at a reasonable cost and with ever greater performance to maximize the number of cars equipped with collision avoidance systems. NHTSA will meet this challenge by teaming with Department of Transportation administrations and other Federal agencies to integrate collision avoidance services into other parts of the ITS program.

This plan describes a program that places emphasis on outreach and cooperative activities to reach the goal of achieving improved safety on the nation's highways. The plan also describes the process of moving from a focus on solving individual safety problems to a focus on integrating solutions to several problems while integrating in-vehicle collision avoidance capability with other advanced in-vehicle systems. There are many facets to this integration activity, some will be accomplished during the six years discussed in this plan and others will occur further in the future. Many of these activities will be initiated but not completed during the period covered by this plan. One is an extensive research program to address the integration of all driver interface features of motor vehicles. NHTSA will also continue to participate in the Automated Highway System (AHS) Program. It is envisioned that AHS will involve collision avoidance systems (CAS) in meeting its objectives. After the first generation of CAS which provide driver warning, are widely deployed, driver assist systems will become available. Specific applications of driver automation that are technically mature, may follow, because of their safety implications.

Certain collision avoidance systems may require the support of public infrastructure. Intersection collision avoidance countermeasures will benefit from vehicle to roadside communication/ cooperation while rear-end and lane change/merge may benefit from vehicle-to-vehicle communications. The deployment of the infrastructure portion of collision avoidance systems will be integrated into the transportation planning process. NHTSA will work with FHWA and FTA to leverage the success that these agencies have achieved on these issues. Though collision avoidance services will be developed to be compatible with the National ITS Architecture, the architecture may require revisions as this service area matures.

In summary, this report presents a research action plan for achieving an increased understanding of the capabilities, user acceptance, and potential benefits of collision countermeasure systems. In addition, the plan encourages the development and deployment of effective and affordable safety products for vehicles and highways. An extensive outreach effort is planned by NHTSA to publicize and demonstrate the safety benefits of collision avoidance products.

G l o s s a r y

ABS	Anti-Lock Braking System
ACN	Automated Collision Notification
ADVANCE	Advanced Driver and Vehicle Advisory Navigation Concept
AHS	Automated Highway Systems
ARPA	Advanced Research Projects Agency
ATIS	Advanced Traveler Information Systems
AVCS	Automated Vehicle Control Systems
CA	Collision Avoidance
CAMP	Collision Avoidance Metrics Program
CAS	Collision Avoidance System
CVO	Commercial Vehicle Operations
DASCAR	Data Acquisition System for Crash Avoidance Research
DOT	Department of Transportation
EBS	Electronic Braking System
EMS	Emergency Medical Services
ERIM	Environmental Research Institute of Michigan
FARS	Fatal Accident Reporting System
FHWA	Federal Highway Administration
FOCAS	FOrward Crash Avoidance System
FRA	Federal Rail Administration
GES	General Estimates System
GPS	Global Positioning System
HFFRV	Human Factors Field Research Vehicle
ICAS	Intersection Collision Avoidance System
ICC	Intelligent Cruise Control
ITS	Intelligent Transportation Systems
IVHS	Intelligent Vehicle Highway Systems
IVIS	In-Vehicle Information System
LCM	Lane Change/Merge
MOP	Measures of Performance

NADS	National Advanced Driving Simulator
NAHSC	National Automated Highway Systems Consortium
NHTSA	National Highway Traffic Safety Administration
R&D	Research and Development
RAMS	Rearward Amplification Suppression System
RDCAS	Road Departure Collision Avoidance System
RECAS	Rear-End Collision Avoidance System
RSA	Roll Stability Advisory System
SAVME	System for Assessing the Vehicle Motion Environment
SVRD	Single Vehicle Road Departure
VDTV	Variable Dynamics Test Vehicle
VNTSC	Volpe National Transportation Systems Center
VRTC	Vehicle Research Test Center