INTELLIGENT
VEHICLE
INITIATIVE

BUSINESS PLAN

July 2000

Intelligent Transportation Systems
Joint Program Office

U.S. Department of Transportation

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INTELLIGENT VEHICLE INITIATIVE: BUSINESS PLAN

1. INTRODUCTION

This document is a revision of the Intelligent Vehicle Initiative Business Plan published in November 1997. It incorporates revisions in the scope of the program which resulted from stakeholder feedback.

2. BACKGROUND

The personal, social, and economic costs of vehicle crashes are substantial. They include the pain and suffering from personal injury and death, as well as the direct costs sustained by injured people and their insurers and, for many crash victims, a lower standard of living or quality of life. The taxpayer and society may be further burdened by health care costs not paid by individuals or insurers, by lost productivity and associated loss of tax revenues, and by providing public assistance for injured people.

In each of the last four years reported in the National Highway Traffic Safety Administration's (NHTSA's) *Traffic Safety Facts,* more than 41,000 Americans lost their lives in highway crashes. Driver error is cited as the primary cause in about 90 percent of all police-reported crashes involving passenger vehicles, trucks, and buses. Since the 1960s, government and industry have researched crashes to improve the crash worthiness of motor vehicles in order to reduce injuries and deaths caused by crashes. However, more than 6 million motor vehicle crashes continue to occur on our highways every year, causing approximately 3.2 million injuries, and costing more than $150 billion per year.

During the Intermodal Surface Transportation Efficiency Act (ISTEA) era (1991-1997), the U.S. Department of Transportation (U.S. DOT) conducted research in crash avoidance, in-vehicle information systems, and automated highway systems (AHS) that pointed to new safety approaches and promising solutions with the ability to significantly reduce motor vehicle crashes. Extensive analysis of crash data was performed to define collision problem areas and causal factors. Based on these and other considerations, such as related human factors research activities, projects were initiated to develop performance specifications for countermeasure systems. This research established an extensive collision avoidance knowledge base. The development of new research tools was initiated, such as the Variable Dynamics Test Vehicle (VDTV) and the National Advanced Driving Simulator (NADS). Advances were made in understanding driver behavior and workload. This led to design guidelines for advanced traveler information systems. In addition, we have conducted operational tests to examine the capabilities and benefits of Intelligent Cruise Control (ICC) and Automated Collision Notification (ACN) systems. The AHS program integrated various control technology combinations in test vehicles, including passenger cars, trucks, buses, and highway maintenance vehicles. Integrated vehicle control and the potential acceptance of the systems were successfully demonstrated at the AHS Demonstration in 1997 on

I-15 near San Diego, CA.

Using this body of research, the NHTSA was able to develop initial estimates which show that rear-end, lane change, and roadway departure crash avoidance systems have the potential, collectively, to reduce motor vehicle crashes by one sixth, or about 1.1 million crashes annually. Such systems may take the form of warning drivers, recommending control actions, and introducing temporary or partial automated control of the vehicle in hazardous situations.

Since the passage of the Transportation Equity Act for the 21st Century (TEA-21) in 1998, the U.S. DOT has harnessed these efforts into one program, the Intelligent Vehicle Initiative (IVI). Research has been focused on eight safety related areas: rear-end collisions, roadway departure collisions, lane change and merge collisions, intersection collisions, driver impairment monitoring, vision enhancement, vehicle stability, and safety impacting systems. We have completed development of the research tools initiated during the ISTEA era. These tools are now being used to complete the development of performance specifications, objective test procedures, and evaluation methodologies for the problem areas. Our understanding of crash problems has increased sufficiently to allow us to initiate operational tests of near-term systems in several of the problem areas. These operational tests will allow us to understand the required technical performance, user acceptance, and benefits of the collision countermeasures. Detailed descriptions of the accomplishments to date are included in the roadmap discussion later in this document.

3. THE IVI VISION

The U.S. DOT's vision for IVI is a system of roads, vehicles, and drivers, where Americans:

- Operate in a significantly safer environment
- Enjoy greater mobility and efficiency as a result of the widespread use of vehicle-based autonomous and infrastructure-cooperative driving assistance features

This vision was inspired by our analysis which showed that the widespread deployment of advanced driver assistance systems has the potential to significantly reduce the annual number of motor vehicle crashes.

4. THE FEDERAL ROLE

In order to achieve this vision, the U.S. DOT has a two-part role. The first is to ensure that safety is not compromised by the introduction of in-vehicle systems. Of particular interest for the IVI is the safety impact of combining multiple systems, such as route guidance and navigation, adaptive cruise control, cellular telephones, and in-vehicle computers. We will investigate the impact that these systems may have on driver behavior by measuring any changes in the level of driver workload and distraction.

The second part of the Federal role in IVI addresses our responsibility for *reducing* deaths, injuries and economic losses resulting from motor vehicle crashes. This role, which is a cornerstone of U.S. DOT's mission, will be carried out by facilitating the development, deployment, and evaluation of driver-assistance safety products and systems. An analysis conducted by NHTSA showed that the widespread deployment of advanced driver assistance systems which address just three of the eight IVI problem areas has the potential to reduce motor vehicle crashes by 17 percent annually. Based on this analysis, the IVI program was formed to more definitively evaluate the effectiveness of these technologies and, depending on the results, encourage their availability in the marketplace.

There are two critical factors which influence the definition of an effective role for the U.S. DOT in this endeavor.

- IVI systems will be primarily developed by the private sector. U.S. DOT will work cooperatively with industry to define performance specifications for safety systems.
- IVI services will be deployed by the motor vehicle industry, fleet operators, and local transportation agencies. The U.S. DOT will support these stakeholders by providing information on the necessary technical performance, user acceptance, and benefits of systems which address the IVI problem areas.

With these factors in mind, we have defined a role for the U.S. DOT that will define the performance requirements for crash avoidance systems, evaluate their effectiveness and, depending on results, encourage their market availability. Some products which address the IVI problem areas with varying levels of effectiveness have been and will continue to be made available even without a federally-funded IVI program. But with the IVI program, we may expect *better systems available sooner*.

5. PROGRAM SCOPE

The IVI program underscores the significant and continuing role of the driver in achieving improved highway safety. The activities conducted under this program emphasize the following problem areas: rear-end collisions, roadway departure collisions, lane change and merge collisions, intersection collisions, driver impairment monitoring, vision enhancement, vehicle stability, and safety impacting systems. Potential countermeasures for these problem areas include vehicle-based and vehicle-infrastructure cooperative communication systems. Countermeasures may be applicable for passenger cars, light trucks, vans, sport and utility vehicles, commercial trucks, transit and intercity buses, and specialized vehicles, such as emergency and enforcement vehicles, highway maintenance vehicles and snow plows, on all types of roads. Research is being conducted to develop performance guidelines, specifications, objective test procedures, architectures, and standards, and will test and evaluate the safety impact of the most promising configurations. A major focus of the IVI program is to research and evaluate the benefits resulting from these systems. These activities will be accomplished through the combined efforts of the U.S. DOT’s modal administrations; the motor vehicle, trucking, and bus industries; state and local governments; and other stakeholders.

6. PROGRAM ORGANIZATION AND STRATEGY

6.1 Program Focus

The IVI program is focused on solving traffic safety problems through development and deployment of vehicle-based and vehicle-infrastructure cooperative systems. 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 provides specific input to improving the overall knowledge base and understanding of systems that address one or more problem areas.

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

We have analyzed data regarding primary causal factors and contributing circumstances in crashes, performing case studies, and other research to develop a statistical view of these factors; and identified promising approaches for crash prevention. Crash problem analysis includes the review of individual cases, identification of relevant pre-crash circumstances, and preliminary assessment of 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 1998 General Estimates System (GES) data) that present the maximum opportunity for safety improvement through the introduction of effective collision avoidance systems/products. The emphasis in the program has been on 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 70 percent of all crashes.

This insight is the basis for having focused programs for each of these three types of crashes. Other considerations in determining the initial focus of the IVI program are technical tractability and readiness of countermeasure systems.

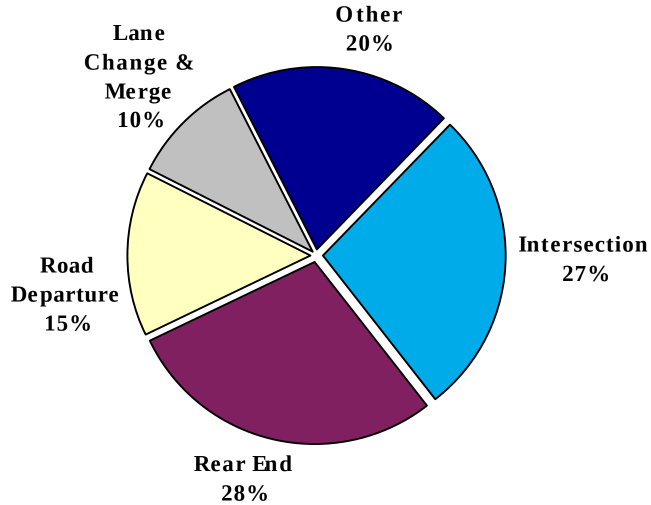


Figure 1.

Distribution of Crash Types

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 crash rates. Contributing factors in crashes 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. A summary of the major causal factors for all collision types is shown in Figure 2. This figure shows that the interaction of the driver and vehicle must be addressed by 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 for problem areas described earlier and their application in acquiring an understanding of the performance of the driver interface element of the collision avoidance systems.

A final foundational element of the program is the assessment of the most appropriate type of vehicle-based system for each problem area. The four general types of solutions consist of combinations of types of situations and types of countermeasures. There are two basic types of situations -- those for which attention to a potentially hazardous situation would be useful to the driver, and those where a crash is imminent and immediate action is needed to avoid the crash. The two types of intervention are advice to the driver, with the expectation that the driver will provide any necessary corrective action, and control systems in which the vehicle takes control from the driver for the purpose of managing the situation. Thus, the four general types of systems are: automatic control of potentially hazardous situations (Adaptive Cruise Control (ACC) is an example of this type system), warning of a potentially hazardous situation (this is the conceptional direction of the lane change/merge program), warning of an imminent crash (this is the direction of the rear-end crash avoidance program), and automatic control of imminent crash situation (not currently in any near-term plans. The choice of type of system has a major impact on the timing of advice, the acceptability by the driver, and the effectiveness in avoiding crashes.

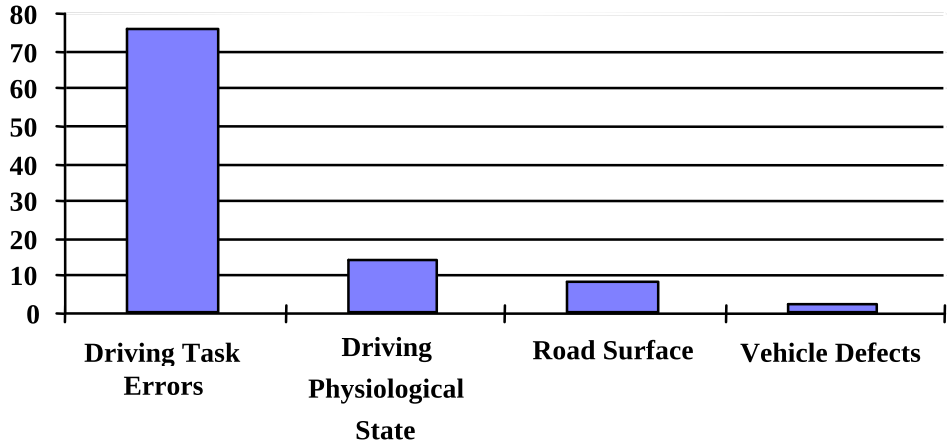


Figure 2. Casual Factors Breakdown

6.2 Problem Areas

In general, the IVI program focuses on the more significant safety problem categories as indicated by statistical analyses of crash data. However, other factors were considered in setting program priorities and schedules. For some problem areas, the complexity of the countermeasure required an extended research and testing program. In other cases, promising crash countermeasures were ready to be tested in the field. Thus, in some cases, countermeasures to address smaller problem areas were selected for development because they were considered closer to deployment and could produce early benefits in terms of reduced crashes, injuries, and deaths. Additionally, the IVI program includes countermeasures for platforms other than passenger cars. Platforms such as commercial vehicles in 1998, transit buses, and specialty vehicles have specific safety needs, offer unique opportunities to test and evaluate countermeasures, and are often early implementers of advanced technologies. There are eight problem areas currently under study by the IVI program:

- Rear-End Collision Avoidance: A rear-end crash occurs when the front of a vehicle strikes the rear of a leading vehicle, both in the same lane. There are approximately 1.8 million police-reported rear-end crashes annually. These crashes accounted for more than 855,000 injuries and 1,570 fatalities in 1998. It is estimated that a significant percentage of these crashes would be addressed by collision avoidance systems that could sense stopped or moving vehicles in the forward lane.
- Lane Change and Merge Collision Avoidance: Lane change and merge crashes accounted for approximately 600,000 crashes in 1998. They occur most often on metropolitan arterial streets. A collision avoidance system that reduces this type of collision will help decrease travel delays caused by this type of collision in addition to improving safety.

- Road Departure Collision Avoidance: Single vehicle road departure crashes represent the most serious crash problem based on the national crash data analysis. Analyses of 1998 crash data indicate that approximately 937,966 police-reported crashes of this type occur each year. This number represents approximately 15 percent of the total crash problems and leads to more than 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 has significant technical challenges.
- Intersection Collision Avoidance: Intersections are among the most dangerous locations on U.S. roads. Approximately 1.7 million crashes occurred at intersections in 1998 (27 percent of total crashes), causing more than 6,700 fatalities and significant numbers of serious injuries. It is more technically challenging to prevent this type of crash with detection and warning technology than other crash situations. Because of these technical challenges, this is viewed as a longer term program area, but one with potentially large safety benefits.
- Vision Enhancement: Approximately 39 percent of all crashes and 53 percent of fatal crashes occur at night or during other degraded visibility conditions, according to GES crash statistics in 1998. These 2.5 million annual police-reported crashes, including 15,000 fatal crashes, represent crashes for which reduced visibility may be a contributing factor. A number of interrelated factors contribute to the high crash rate at night, including alcohol, fatigue, and reduced visibility. Driver vision enhancement systems help drivers by providing an augmented view of the forward scene.
- Vehicle Stability: Commercial vehicle rollover crashes do not occur frequently, but the occurrence of rollover as a crash factor increases the likelihood of serious or fatal injury to the occupant. NHTSA data shows that while rollovers are involved in 6 percent of all crashes for combination trucks, in 1998 it was a factor in over half of all fatal crashes of combination trucks. Various countermeasures are being considered to help reduce the incidence of commercial vehicle rollovers.
- Driver Condition Warning: NHTSA estimates that approximately 100,000 crashes annually are caused primarily by driver drowsiness or fatigue. Of these crashes, data from the Fatality Analysis Reporting System indicate that drowsiness/fatigue was a factor in crashes in which more than 1400 fatalities occurred in 1998. Up to 40 percent of long-haul truck driver fatalities may be related 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 crashes among paid drivers, the high cost of commercial vehicle crashes, and the relative affordability of such systems for high-value heavy trucks. Ultimately, drowsy driver monitor systems should also be deployable at a lower cost in all passenger vehicles.
- Safety Impacting Services: Whereas the other seven problem areas were based on an analysis of crash data, this area is a result of a growing concern that the increasing number of safety and convenience systems which are being deployed in vehicles may have a safety impact whether positive of negative, on motor vehicle safety. A particular interest for the IVI program is the safety impact of combining systems, such as the

resultant changes in task allocation and loading experienced by the driver. These systems may also be combined with safety-specific technologies as they are tested and readied for deployment. Systems that may be combined include: route guidance and navigation, adaptive cruise control, automatic collision notification (discussion of this service is contained in Appendix C), cellular telephones, and in-vehicle computing. Research in this area will first determine if there is a safety problem from multiple in-vehicle systems. If such a problem can be defined, follow-up research will develop measurement tools and guidelines to allow system designers to minimize driver workload and distraction.

7. ELEMENTS OF THE IVI PROGRAM

In order to fulfill the program requirements, the IVI program must identify and conduct the necessary research to ensure that the driver warning, driver assistance, driver intervention, and travel information systems work effectively and reliably in both independent and integrated modes, that they operate in a consistent and efficient manner and are easily understood by drivers, and that drivers accept and use the systems. The results of previous research and stakeholder feedback identified significant issues that have been incorporated as critical elements of the IVI program.

7.1 Multiple Platforms Focused on Light Vehicle Benefits

Research in the problem areas is being conducted in the context of four classes, or platforms, of vehicles. These are light, commercial, transit, and specialty vehicles. Vehicles have been categorized into the four platforms to focus on the unique problems encountered in their respective environments. There is also a cross-cutting area to address issues common to all vehicle classes. The differences in environment are characterized by the use of the vehicle, training of the driver, operating environment, and financial cost. The unique environment of each vehicle platform impacts the services that can be placed on each platform. For example, if a driver has professional training, as in the case of transit or commercial vehicle operators, more complex systems can be used. Considerations such as these will be critical to ensuring successful integration of IVI technologies into the various vehicle platforms.

The inclusion of the four individual platforms will allow us to expedite the commercial availability of driver assistance systems across all platform types. Although the largest problem area is in light vehicles, we will be able to conduct field tests and quantify the benefits of some systems in the other platform areas before they are ready to be tested on light vehicles. This will give us a better understanding of the benefits and give guidance on where best to conduct future research. It is important to note that the program relies on synergism and planned cooperation between and among platforms. The passenger vehicle (light vehicle in IVI terminology) requires the development of systems that are adaptable to the widest variety of heterogeneous driver and vehicle characteristics. Human factor considerations and robust performance become dominant considerations in the design and deployment of these systems. Development of IVI systems for commercial vehicles will take advantage of the capabilities and interests of professional drivers and fleet operators, while considering problems that are of particular concern to the operations of these vehicles such as vehicle stability. Transit systems will also take advantage of the presence of professional drivers, while recognizing their usual operation in a congested urban environment with the high levels of distraction that come with serving and driving among the general public. Specialty vehicles, such as snow plows and Emergency Medical Services (EMS) vehicles, must operate under environmental and roadway conditions that include the worst weather and critical emergency conditions. But, because of their operation on known routes, and the fact that they are frequently operated by public agencies, transit and specialty vehicles will be most able to take advantage of cooperative systems. The unique environment of the platforms is expected to allow the initial deployment of services on a specific platform, which will eventually migrate to the other platforms. For example, driver monitoring systems are expected to be introduced on commercial vehicles, but will migrate to the light vehicle fleet.

Light Vehicles. Light vehicles are passenger vehicles, light trucks, vans, and sports utility vehicles. The most research has been conducted in this platform, growing out of the NHTSA Intelligent Transportation Systems (ITS) Crash Avoidance Program. The problem areas are well defined and documented. Preliminary performance specifications are near completion for rear-end, lane change/merge, roadway departure, and intersection collision avoidance. Operational tests and evaluations of individual systems have been completed for intelligent cruise control and automatic collision notification systems. Original equipment manufacturers and aftermarket suppliers are deploying systems with limited capabilities for adaptive cruise control, backing assistance, Mayday and automatic collision notification, and vision enhancement.

Commercial Vehicles. Commercial vehicles are heavy trucks and interstate busses. This platform area has also benefitted from significant research under NHTSA's ITS Crash Avoidance Program as well as the ITS Commercial Vehicle Operations (CVO) Program. The problem areas are also well defined and documented. Commercial vehicles will leverage the performance specifications being developed under the light vehicle program for rear-end, lane change/merge, roadway departure, and intersection collision avoidance. The commercial vehicle platform will lead the research in drowsy driver, rollover and stability-related crashes, intelligent diagnostics, and electronic braking. Systems with limited capabilities have been deployed in commercial vehicles for adaptive cruise control, rear-end collision warning, and lane change warning. Electronic braking systems are available in Europe.

Transit Vehicles. Transit vehicles include all non-rail vehicles operated by transit agencies. The preliminary work on transit vehicles was conducted under the AHS program. A transit bus operating under automated control was included in the 1997 AHS Demonstration in San Diego, CA. An assessment of the safety problems for transit vehicles that may benefit from advanced technologies has been completed. During 1998 and 1999, development of performance specifications has been initiated for rear-end (forward impact), lane change/merge, and rear-impact collision avoidance for transit vehicles.

Specialty Vehicles. Specialty vehicles include emergency response, enforcement, and highway maintenance vehicles. An assessment of the safety problems for specialty vehicles that may benefit from advanced technologies is underway. A jointly funded partnership with several state Departments of Transportation has been created to leverage the research that is being conducted at the state level for highway maintenance vehicles.

Cross-cutting Issues. In addition to the four platforms, there are cross-cutting issues that are being addressed as well. General guidelines for the driver-vehicle interface for some collision avoidance/warning systems have been completed. Guidelines for the design of in-vehicle advanced traffic information systems have been completed. We have initiated studies to determine the need for integration of the driver-vehicle interfaces of multiple systems; determine the feasibility and benefits of sensor friendly highway systems; and determine product liability, insurance, and other societal and institutional issues.

7.2 Public/Private Partnership

In December 1997, U.S. DOT published an Intelligent Vehicle Business Plan that described the vision, mission, goals, and implementation strategy of the program. In 1998, we conducted a lengthy dialogue with stakeholders on the contents of the business plan. This resulted in a letter of advice from ITS America, which we received in August 1998. In the letter of advice, the stakeholders validated the vision, mission, and goals of the program, but asked for a greater role in the governance of the research program. In April 1999, in a letter to Secretary Slater, ITS America, provided their recommendation on mutual governance of the program.

To achieve the goal of commercial availability of safety technology, it is critical that the U.S. DOT work cooperatively with organizations that can achieve the deployment of these systems. For the IVI program, product deployment refers to the actions by motor vehicle manufacturers and their suppliers to make and offer IVI systems to highway users in motor vehicles coming into production. Operational tests will demonstrate the benefits of IVI services. Once these benefits have been determined, IVI systems will be ready for deployment by manufacturers as part of their standard product line. This requires partnering with vehicle original equipment manufacturers, their suppliers and fleet operators, and with state and localities where the vehicles will operate. The IVI program will be conducted through cooperative agreements with individuals and groups of these stakeholders, as well as some contracted research. Public/private partnerships will be a key element of making IVI technologies rapidly available to the user community. The U.S. DOT is implementing this advice through a series of activities. An enabling research consortium composed of automobile manufacturers is being formed to focus on precompetitive issues, a consortium of state Departments of Transportation is being organized to focus on infrastructures issues, and a series of individual cooperative agreements and contracts will be implemented to address additional research and operational testing activities.

7.3 Infrastructure

The IVI addresses vehicle-related safety problem areas. Results from the crash avoidance program and the AHS program indicate that in some problem areas a high level of system performance can only be achieved with cooperative vehicle infrastructure and cooperative vehicle-to-vehicle systems. For example, the intersection collision problem may not be completely addressed without a cooperative infrastructure component. For this reason, the role of infrastructure will be addressed in the individual problem areas as well as from a cross-cutting perspective.

7.4 Multiple System Integration

Driver error is a factor in 90 percent of vehicle crashes. The introduction of cellular telephones and traveler information systems into the vehicle threatens to further increase the driver’s workload and may increase distraction. The IVI program will address this issue as well as the impact of any driver assistance systems that the intelligent vehicle program may introduce into the vehicle. The IVI program will address the potential impact, both positive and negative, of integrating multiple systems which provide IVI services. The impact on driver workload from multiple systems competing for the driver attention will be studied in the context of human factors. The potential benefits from combining multiple services will also be studied. For example, a digital map database used in vehicle navigation could assist a roadway departure system as well as an intersection collision avoidance system.

7.5 Generations

Developing solutions to the eight problem areas is a highly complex undertaking. It involves determining causality, developing performance specifications for potential countermeasures, measuring the technical performance and user acceptance of applicable systems, and estimating and validating benefits. In order to provide near-term benefits, the IVI program will evaluate and encourage the deployment of effective systems that may only partially address the problem areas. In order to implement this incremental approach, the IVI will focus on developing generations of vehicles with increasing capabilities which address the eight problem areas. During the period covered by TEA-21, the U.S. DOT intends to support work on Generations 0, 1, and 2. Each succeeding generation is expected to address systems with more advanced capabilities, higher levels of integration, and increased infrastructure cooperation.

Each generation will culminate in multi-platform *operational tests*, which will objectively evaluate improvements in safety and driver performance resulting from the integrated intelligent vehicle systems. These operational tests will be competitively awarded. They will involve multiple platform types of integrated systems. Most systems evaluated are expected to be within five years of commercial deployment. The applicants for these operational tests must be capable of deploying these systems. These operational tests will serve as a performance indicator for the IVI program by allowing us to measure the progress resulting from each generation's research investment.

In preparation for each generation's operational tests, the U.S. DOT will conduct *problem area research* and *field tests* in the eight problem areas. The activities undertaken in the problem area research will result in an improved understanding of technical performance required to achieve suitable levels of driver acceptance and benefits. The field tests of individual systems differ from the Generation Operational Tests in that they evaluate individual problem areas. The subject of each field test is identified by U.S. DOT based on the problem area research. The systems evaluated are longer term and not necessarily expected to be deployed within five years. As with the Generation Operational Tests, cooperative agreements will be entered into with public/private partnerships. The partners will provide significant cost share. These field tests of individual systems will be the first time these countermeasures are evaluated on real roads using real drivers.

Generation 0. Generation 0 systems are those that are expected to enter production preparation by 2003. This initial generation is intended to leverage the service development which occurred under the IVI's predecessor programs. We will assess the technical performance, determine user acceptance, and measure the benefits of driver assistance systems from incorporating early IVI services into vehicle platforms. The U.S. DOT will focus on developing the ability to meaningfully evaluate integrated services, while industry and stakeholder partners will develop the vehicles with these IVI services.

Generation 1. Generation 1 systems are expected to be ready for production planning by 2008. The majority of the U.S. DOT-initiated work has focused on problem areas for which Generation

1 systems appear to be the most realistic. Generation 1 is expected to address systems with more advanced capabilities which may incorporate higher levels of integration and increased infrastructure cooperation. The Generation 1 activities will advance the capabilities of selected IVI problem areas. Generation 1 is expected to include advanced collision *warning* systems and possibly some early collision *avoidance* systems. Research will be conducted to improve our understanding of the technical performance and user acceptance required to achieve improved benefits. This will involve the development of advanced performance specifications and field testing of individual services. We will also assess the impact of service integration on technical performance and human factors issues. This will lead to the development and field testing of Generation 1 vehicles for the purpose of validating the safety benefit estimates.

Generation 2. This generation is expected to build on the accomplishments of Generation 1. Generation 2 systems are expected to be ready for production planning by 2012. Generation 2 systems may be the most realistic expectation for effective countermeasures for the most complicated problem areas such as intersection collision avoidance. These systems may include an increased role of infrastructure and vehicle-to-vehicle cooperation. During FY2001, we will conduct research in the most complex problem areas to improve our understanding of the technical performance and user acceptance required to achieve improved benefits. Improved benefits are expected from systems which achieve higher performance from advanced technology and infrastructure vehicle cooperation. Initially, we will focus on developing advanced performance specifications. In later years we will include field testing of individual services.

We will also assess the impact of service integration on technical performance and human factors issues. This will lead to the development and field testing of Generation 2 vehicles for the purpose of validating the safety benefit estimates.

7.6 Human Factors in the IVI

A major part of the program is the study of human factors and how they relate to driver performance. These studies are integrated with other types of study, such as sensor performance, to create the systems approach to vehicle-based safety improvements. The systems approach is the hallmark of the IVI program. The importance of the human factors studies is due in large measure to the fact that the IVI program is charged with helping find human-centered solutions to the human-centered problem of highway crashes, and resulting deaths and injuries.

This section discusses the IVI program human factors studies and describes how they fit with other elements of the program. As noted elsewhere, the primary emphasis of the IVI program is prevention of crashes. As the IVI program has evolved from the predecessor NHTSA Crash Avoidance program and the Federal Highway Administration (FHWA) AHS program, three distinct, but related, emphases have developed. The first emphasis is on systems that can enhance safety, i.e., help drivers avoid crashes. In this part of the program there is a focused emphasis on finding advanced technology systems that effectively help drivers avoid crashes that would otherwise occur. The second emphasis is on systems that are related to safety, but do not directly contribute to changes in safety. The emphasis in this part of the program is on understanding the safety impact, i.e., the likelihood of decreasing or increasing the number of crashes and severity of crash consequences. The third area of emphasis overlaps both of the other emphases. This is the study of how combinations of more than one system affect drivers and their safety-related performance. Thus, in a simplistic way, the charter of the IVI is to find solutions to the human-centered problem of crashes on the nation's highways.

For safety-enhancing systems, the underlying concept is that a crash will occur if the system does not intervene with timely and effective advice or control of the vehicle. A major factor in the human factors work in this area is the broad variety of types of study. Some of the studies are traditional human factors experiments, i.e., those that are for the purpose of testing hypotheses about human performance by means of experiments with volunteer subjects, and other studies that are not traditional, e.g., analysis of crash data files. This variety is best seen by looking at a typical sequence of studies that evolve during the course of seeking an understanding of the problem and a solution for the specific problem area.

- Crash data analyses that lead to basic understanding of dynamic conditions that existed prior to a crash and causal factors for crashes. These analyses were facilitated when, in 1994, five new pre-crash data elements were added to the NHTSA crash data files. These analyses of crash data files, when combined with dynamic modeling, also provide key inputs to the understanding of the potential for use of different types of systems. For example, in rear-end crashes it was found that following too closely, stopped or stopping vehicles, and diversion of attention away from the forward field of view were major contributing factors.
- Driving simulator or test track studies which provide basic driver performance in relevant situations using artificially activated warning times.
- Basic estimation of benefits that might accrue to use of a countermeasure system.
- Additional driving simulator or test track experiments for the purpose of refining timing and usability of warning or advisory messages.
- Additional driving simulator or test track experiments for the purpose of developing necessary and sufficient features of driver/vehicle interface.
- Naturalistic driving with no intervention for the purpose of estimating level of annoyance that countermeasures might produce and to establish a baseline distribution of relevant situations that can be used for refinement of estimates of benefits.
- Refinement of benefits estimates.
- Operational test of the most promising system(s) for the purpose of measuring effectiveness and user acceptance, as well as providing a basis for further refinement of benefits estimates.

By contrast, the underlying concept for understanding safety impacting-systems is different than the concept for safety-enhancing systems. (The concept for safety-impacting systems is that crashes will not occur unless the system causes dangerous behavior in pre-crash situations.) Thus, the human factors studies associated with safety-related systems consist of two parts. The first is a determination of changes in driver causal behavior that would produce a crash if the surrounding driving environment is inconsistent with that type of behavior. The second part is to determine if the driver chooses to use the system in situations that, when combined with the causal behavior, can produce crashes.

The mental model behind this concept for safety-related systems is that drivers interact with in-vehicle systems for one of two reasons: either there is a need to interact (for example, answering an in-vehicle phone and applying the brakes at a stop sign) or a desire on the part of the driver to interact which is independent of the external circumstances (for example, checking the speedometer, changing a CD, or dialing a cellular phone.) These interactions with in-vehicle systems involve the driver activating what can be called causal behaviors (for example, applying pressure to the brake pedal, directing the driver's eyes to the system in question, or even changing mental focus from driving to another emphasis.) When done in a protected environment, each causal behavior may have no effect on the safety of driving; however, when these causal behaviors occur in inappropriate driving environments, crashes can occur.

Another area of emphasis is a combination of more than one system. These studies typically follow development of understanding of individual systems and follow a similar sequence of human factors studies. A major challenge in this part of the work is to do it in a way that the results are generalizable. The ideal goal would be to establish relationships for functional descriptions of systems and their performance; however, experiments and measures of performance are for specific implementations and are not easily generalizable. For example, rules for integration are not defined and combinations of systems will occur as individual manufacturers choose to proceed with product plans. Work in this area is presently based on experiments with basic measures such as eye activity relative to baseline activities such as tuning a radio (specific implementation.) The challenge is how to relate these measures to safety.

7.7 Anticipated 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.

In 1996, NHTSA estimated the number of crashes that could be avoided in the United States with full deployment of rear end, road departure, and lane change and merge collision avoidance systems. These estimates were based on detailed analyses of crash scenarios and causal factors and the best empirical and analytical research available regarding operation of the collision avoidance systems. The study defined the subset of crashes that could be addressed by countermeasure systems and also computed estimates of countermeasure effectiveness for the relevant subset of crash types. The results of this preliminary study are summarized in the Table 1. This study indicates that with full deployment of just three IVI systems, one in six crashes would be eliminated annually. The results must be considered preliminary in nature pending further research, refinement of potential countermeasure effectiveness estimates, and field experience. During FY2000, this study will be expanded to include all of the IVI problem areas as well as to incorporate the latest research results.

Crash Condition	Total Number of Crashes	Relevant Crashes Addressed by Countermeasures	Effectiveness Estimates for Relevant Crashes	Number of Crashes Reduced
Rear-End	1.66	1.55	51%	0.79
Lane Change/Merge	0.24	0.19	47%	0.09
Road Departure	1.24	0.46	65%	0.30
Total	**3.14**	**2.20**		**1.18**

Table 1. Crash Countermeasures – Estimated Deployment Benefits

(Numbers in Millions)

Safety benefits are highly dependent on 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 crash avoidance 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 are a continuous process during the concept development, prototyping, and testing cycle for systems. As additional data to estimate effectiveness becomes available (through program activities), the benefits estimates will be refined. The process will include several elements:

- Benefits estimation methodologies that are based on before and after data (i.e., compare numbers of collisions that occur when no crash avoidance system is present to the number that would occur when a crash avoidance systems is present).
- Procedures to obtain estimates of effectiveness for crash avoidance 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.

8. ROADMAP FOR GETTING THERE

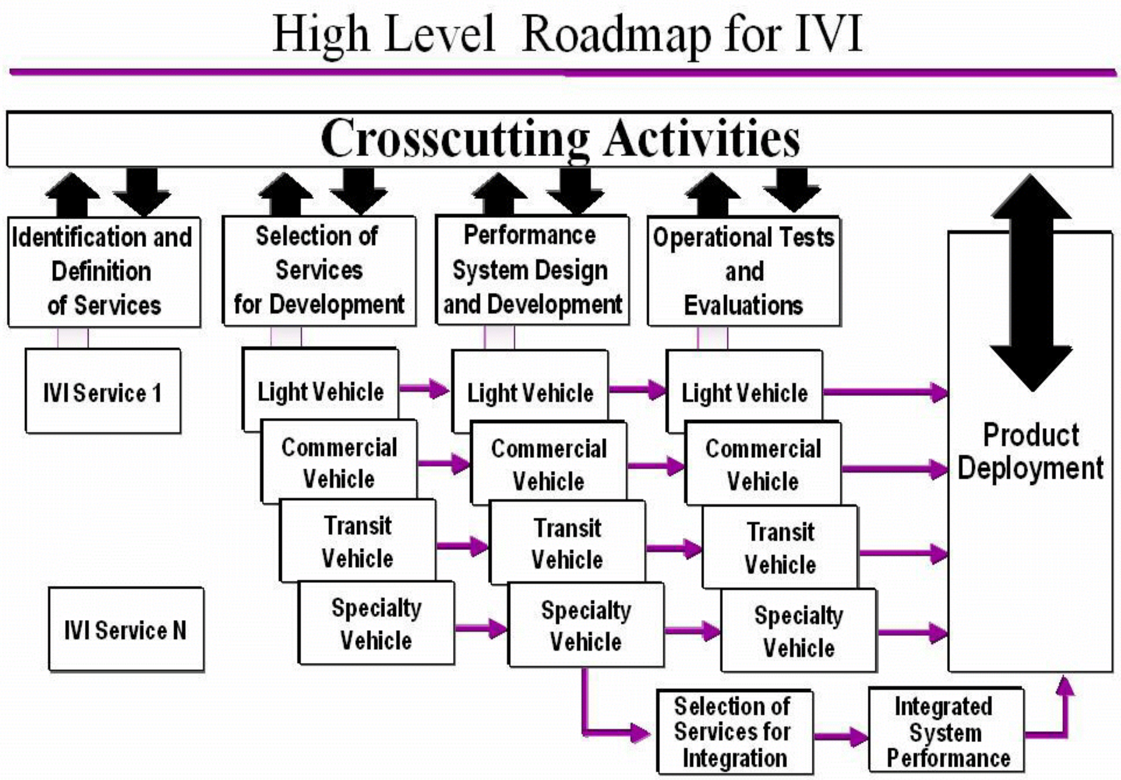
8.1 Overall Plan

The IVI program will be advanced primarily through research and testing, but will also include program assessment and development of standards. In order to achieve the program objectives, the roadmap focuses activities in four areas: identification and definition of problem areas (services), selection of services for development, system design and development, and operational test and evaluation. This process will be carried out in each problem area. The work in each problem area is focused on solving the traffic safety problems primarily for light and commercial vehicles. Work in transit and specialty vehicles is based on the ability to benefit light vehicle safety problems. This strategy was developed to address the largest problem areas, while taking advantage of the unique characteristics of the individual platforms. In order to have a cohesive process, each research area is tied to the cross-cutting activities. The end result is envisioned to be market driven, deployable products which enhance roadway safety, overall mobility, and system efficiency.

The roadmap in Figure 3 illustrates the IVI Process. The progression of activities generally moves from left to right on the diagram. Also, the level of cooperative involvement with the motor vehicle industry increases from left to right. At the current time, the majority of the work within the IVI program is in, and to the right of, the middle column. This represents a significant U.S. DOT effort to develop an understanding of the details of system performance that describe effective safety enhancing systems. As noted in the roadmap, much of this work is being done in the context of the individual platforms. A more precise description of status for each problem area is provided in the next section. The status of various problem areas is also a function of the state of production-readiness of commercially available systems.

The state of production-readiness is generally described by the generation of the system in question. The definitions of Generation 0, Generation 1, and Generation 2 were provided earlier in Section 7.5. However, in summary, Generation 0 systems are expected to be ready for production planning by 2003, Generation 1 systems are expected to be ready for production planning by 2008, and Generation 2 systems are expected to be ready for production planning by 2012. The majority of the U.S. DOT-initiated work has focused on problem areas for which Generation 1 systems appear to be the most realistic solution. However, in some cases, for example crashes at intersections, Generation 2 systems may be the most realistic expectation for effective countermeasures. The planning of the program in each problem area began with a thorough analysis of crash data files. This work took place in the early 1990s and is reflected in the left column in the roadmap. Subsequently, decisions were made on which problem areas should be emphasized in the U.S. DOT work. This corresponds to the second column from the left in the roadmap. The *Generation concept* illustrates the iterative nature of the roadmap process. If we use the rear-end problem area as an example, testing of a commercially available system for commercial vehicles is being conducted under Generation 0. Under Generation 1, performance specifications are being developed and testing will be conducted of a more advanced system for light vehicles.

Figure 3



The problem areas that were selected are discussed in more detail later in this report, as are the considerations that went into the decisions. The work in some of these problem areas has progressed to the point that it is feasible to design and fabricate prototype systems that would be available for use in operational tests; most notably rear-end crashes. As work progresses in other problem areas, additional operational tests of Generation 1 systems will be initiated. Deployment of effective intelligent vehicle systems is the domain of the motor vehicle industry, so the right column on the roadmap reflects design and production by vehicle manufacturers and suppliers. The concept of Generation 0 systems is a relatively new concept in the IVI program. The idea behind this concept is that there are safety-related systems which are nearing production that could benefit from an evaluation based on results of an operational test. A Request for Application, published in December 1998, has resulted in operational tests of such systems. These projects enter the roadmap at the operational test level. Two other aspects of the roadmap are significant. The cross-cutting block represents those activities that cut across platforms, e.g., the development of general-purpose research tools and the assessment of institutional issues. Another perspective of consolidating activities is reflected in the integration box at the bottom of the roadmap. These activities are associated with combinations of two or more proven systems, usually within a single platform. A key question which comes up is whether the combination system, and especially the driver/vehicle interface for the combination, is more or less effective than the individual systems. Within this same box are studies of the impact on safety of combinations of systems that, by themselves, have little or no impact on safety.

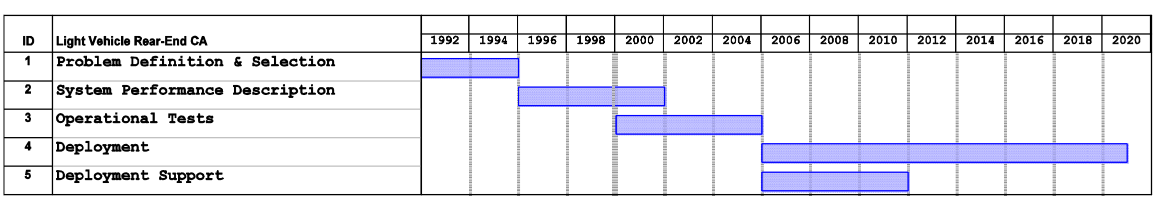
8.2 Problem Areas

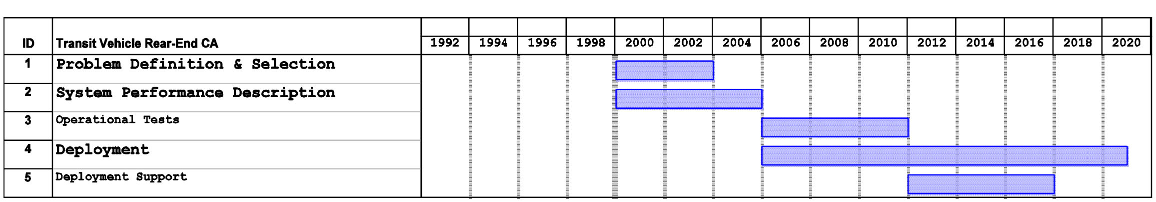
The following sections provide a more detailed description of each of the eight problem areas. They also provide a timeline for each problem area and their development stage in terms of problem definition/selection, system performance description, operational tests, deployment, and support.

8.2.1 Rear-End Collision Avoidance

This problem area requires the ability to sense the presence and speed of vehicles and objects in the vehicle's lane of travel. Initially this service will provide warnings and limited control of the vehicle speed (coasting or downshifting) to minimize risk of collisions with vehicles and objects in front of the equipped vehicle. Early versions will extend current ACC capabilities to areas such as detection and classification of stationary objects and improved determination of lane geometry and occupancy in front of the vehicle (discrimination of threat). Later versions may include increased longitudinal control through vehicle braking, and, ultimately, the capability to perform coordinated lateral control and braking actions. This is a significant category of crashes, accounting for one in four of all crashes (over 1.7 million in 1998.)

Rear-end crashes are generally reported as either “lead vehicle stationary” or “lead vehicle moving.” This can over-simplify the interpretation because there are many situations that are inconsistently reported; for example, such as when a rapidly-decelerating vehicle stops and then is quickly struck by a following vehicle. The incidence of lead vehicle being stationary occurs twice as often as a moving lead vehicle.





Since 1993, rear-end collision avoidance has been actively studied by the U.S. DOT. Several research projects have been completed since that time:

- Completed causal factor analysis for the crash problems.
- Completed operational tests of ICC systems. This activity provided an understanding of ICC system capabilities, user acceptance, and potential safety benefits. As stated earlier, ICC systems are considered an important technological stepping stone toward the development of full capability rear-end collision avoidance system.
- Completed preliminary system performance specifications. U.S. DOT has developed a basic understanding of system capability and potential benefits that could be achieved.
- Developed objective countermeasure test procedures. This effort updated and refined performance specifications and test metrics in preparation for the development and operational testing of prototype countermeasure capabilities over the next several years.
- Built an extensive human factors data base for rear-end collision avoidance systems. This includes data on driver performance and driver-vehicle interface (DVI) issues (i.e., how and when to issue warnings.)
- Initiated a joint research project on vehicle crash warning systems with General Motors (GM) and Delphi Delco. This is a follow-on to the recently completed Automotive Collision Avoidance Systems (ACAS) program. The project will develop and integrate key technologies to create a prototype forward collision warning system. The prototype system will be tested and evaluated under an extensive field operational test that will be conducted during the latter half of the 5-year project.

Previous studies have indicated that the use of multiple sensors can improve the ability of the countermeasure system to detect and to discriminate target objects in the host vehicle path from fixed objects alongside the road or in adjacent lanes. Combining the outputs of multiple sensor systems (or sensor fusion) is expected to aid in removing sensor clutter caused by roadside objects such as signs and other highway structures. This issue will be addressed in more depth in follow-on projects within the IVI program.

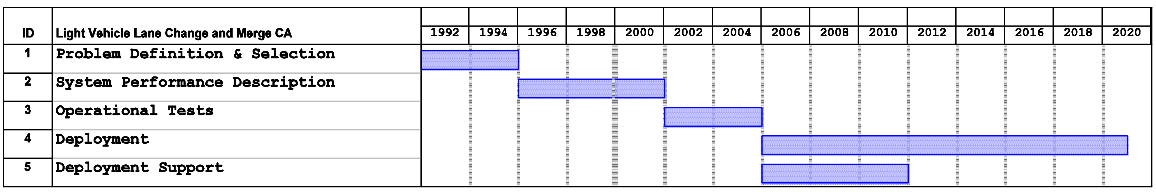
The centerpiece of continuing activities is a 5-year joint research program between the U.S. DOT and General Motors Corporation. This program will build on previous research to create prototype crash warning systems and conduct operational testing and evaluation, using licensed drivers under real world driving conditions. The prototype countermeasure system is expected to be equipped with multiple sensors (radar and optical), warning displays, map data bases, and Global Positioning System receivers.

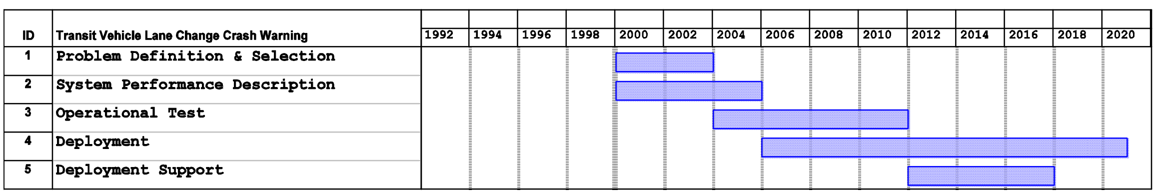
In addition to this joint research program, a number of related activities is planned to address outstanding capability and driver acceptance issues. These research plans include continuing human factors studies, detection/warning algorithm development, and benefits estimation efforts. Results of these supporting activities will be provided to the joint research program, and factored into the prototype development and evaluation efforts in that program.

8.2.2 Lane Change and Merge Collision Avoidance

This problem area requires a service to provide various levels of support for detecting and warning the driver of other vehicles in adjacent lanes. These systems will monitor the lane position and relative speed and position of vehicles, including motorcycles, beside and to the rear of the vehicle, and will advise the driver during the decision phase of a lane change maneuver through an appropriate driver/vehicle interface of the potential for collision. It is expected that the first implementation of this service will be through in-vehicle technology. Lane change and merge crashes accounted for 1 in 10 of all crashes in 1998. Nine out of 10 of the crashes in this category are due to lane changing and 1 out of 10 to merging. They are primarily angle/sideswipe impacts with less than 5 percent due to rear-end collisions following a lane change maneuver.

Research has focused on lane change and merge crash avoidance since 1992. This is also a major problem for transit buses accounting for 28 percent of all transit bus crashes (based on 1998 GES statistics). A project to address this has just begun.





In 1993, a performance specification project was initiated for evaluating enabling technologies, performing causal factors analysis, and test bed development and testing. Both sonic and radar sensor technologies were evaluated. The study determined that radar systems are necessary to detect the presence and closing velocities of more distant vehicles (e.g., up to 100 feet behind equipped vehicle), especially over a range of lane geometries and weather situations.

Test bed fabrication and checkout has been completed. Prototype testing is underway, with emphasis on measuring system performance parameters, driver acceptance and usage patterns. The test bed uses a scanning laser as the Lane Change/Merge (LCM) sensor to measure driver behavior and evaluate countermeasure effectiveness. LCM countermeasure system performance specifications are being refined and will be published in 2000.

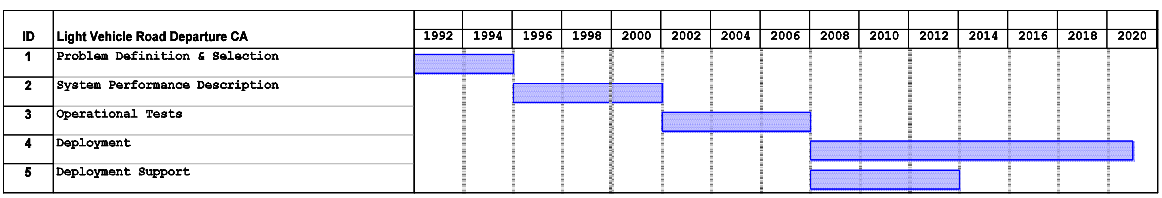
This program area is entering a second stage in problem definition where additional naturalistic driving data are being collected. This involves instrumenting vehicles to measure data on pre-crash events (as opposed to reconstructing such data from post-crash information). These data are necessary due to the lack of information on the timing of critical pre-crash events and opportunities for (countermeasure) intervention.

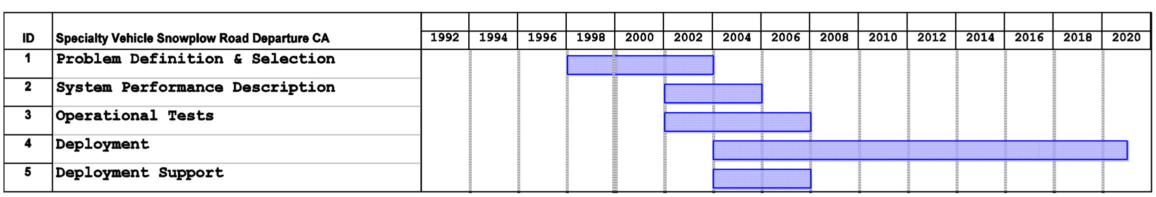
The potential for unintended safety problems is an issue. LCM countermeasure systems that address only the adjacent vehicle problem may create additional safety problems since these systems cannot detect fast-approaching vehicles and could potentially give the driver a false expectation of a safe lane-change maneuver. Driver behavior studies will be required to determine actual benefits and disbenefits of this type of LCM system.

8.2.3 Road Departure Collision Avoidance

This problem area requires services that provide warning and control assistance to the driver through lane or road edge tracking and advice on the safe speed considering the road geometry in front of the vehicle. The system will warn the driver when the vehicle is (potentially) deviating from the intended lane of travel and may provide advice on the appropriate driver steering or braking response to correct the problem. More advanced capabilities would include an integrated ACC function where vehicle speed could be adjusted on the basis of road geometry (based on inputs from an enhanced map database and navigation system). Furthermore, information from the infrastructure (or in-vehicle sensors) regarding road surface conditions (wet, icy, etc.) could also serve to adjust vehicle speed. Driver inattention may also be incorporated into their systems and ultimately supported the driver condition warning service.

This category is dominated by the single-vehicle incident -- the vehicle leaving the road prior to the first harmful event, not as the result of a collision on the roadway. Nearly one in five of all crashes was reported as a Single Vehicle Road Departure (SVRD) crash in 1998. SVRD crashes are the most likely crash type to occur at night, on high-speed roads, and to involve alcohol. Second only to opposite direction crashes, SVRD crashes are most likely to be fatal.





A project to develop and validate performance specifications for road departure countermeasure systems has been conducted by Carnegie-Mellon University over the past six years. Project activities included a thorough analysis of the road-departure crash problem, development of countermeasure concepts, testing and evaluation of enabling technologies (including driver/vehicle interface options), and the development and refinement of system performance specifications. The final report for this project will be published in 2000.

Several prototype systems have been developed and tested under real-world driving conditions. The current version of a vision-based road-departure countermeasure system has undergone on-the-road testing. Updated performance specifications for this system will be published before the end of 1999.

Algorithm development has focused on the ability to track lane geometry using vision-based sensors. Other concepts have been explored involving the use of map data base and navigation systems to enhance or augment the lane-tracking capability. Map database information is considered crucial to providing speed-related warnings for longitudinal road-departure scenarios. Requirements for a more detailed definition of road geometry in map databases have been developed and limited testing has been performed to validate the approach.

Additional data on lane-tracking sensor performance will be gained from the planned inclusion of optical lane-tracking equipment in the sensor suite for the GM/Delphi Delco prototype rear-end collision countermeasure system scheduled in planning for field operational tests. The sensor will augment forward looking radar sensors to support the identification of threats in the vehicle forward path.

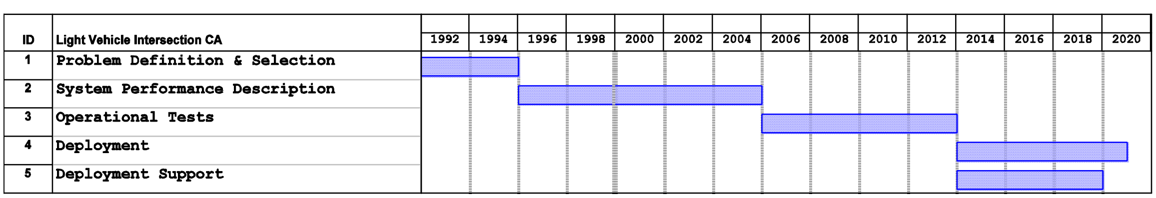
A project aimed at the developing objective test criteria for road departure crash avoidance system will begin in FY2000. Two other projects are also planned: 1) a research project to establish a human factors data base for lateral road departure algorithm development, and 2) a simulation study of commercial off-the-shelf (COTS) speed/curve warning systems.

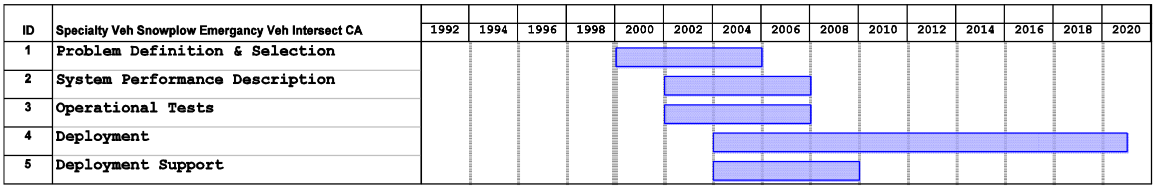
8.2.4 Intersection Collision Avoidance

This problem area requires a service to provide a warning to the driver when the potential for collision exists at an intersection. Due to the complexity of the intersection collision problem, it is anticipated that a cooperative vehicle-infrastructure solution will be needed to fully address all of the subsets of this problem. Complexities include sensing vehicles on intersecting roadways and determining the intent of these vehicles in terms of slowing, turning, or potential for violation of traffic control devices.

Analysis of 1993 GES data concludes that 27.2 percent of all crashes were Intersection/Crossing Path (ICP) in nature; that is, 1,720,000. ICP crashes are categorized as signalized intersection straight crossing path (3.2 percent), unsignalized (4.9 percent), and left turn across path (7.5 percent). Another 441,000 (7.0 percent) of all crashes involved left turns across path/initial perpendicular direction with 18 percent occurring at signalized intersections and 82 percent at unsignalized intersections.

This problem area clearly affects each of the IVI vehicle platforms. Light vehicle projects concerning ICP collision avoidance have been underway since 1992. Specialty vehicle platform projects to address this problem are under consideration.





Based on the data analyses summarized above, Veridian Engineering developed an intersection crash avoidance system (ICAS) test bed design. In keeping with the focus of developing systems that have a high likelihood of being implementable in the near term, the test bed design represents a first incremental step in solving the intersection collision problem. Along these lines, initial plans to include a signal-to-vehicle communication system were eliminated. Also, the original radar system design was complex, and a decision was made to use commercially available radar. While this represented a compromise solution, it allowed the development of a countermeasure at a reasonable cost.

The in-vehicle ICAS test bed included a threat detection system, the Geographical Information System/Global Positioning System (GIS/GPS), the driver vehicle interface, and the vehicle support system. The threat detection system utilized three Eaton VORAD millimeter wave radars to acquire data on vehicles approaching the intersection.

U.S. DOT also conducted a field test on an infrastructure-based ICAS concept. The focus of this project was safety at unsignalized intersections. The system provided active warning signs, based upon loop detectors embedded in the roadway, for drivers at an unsignalized (two-way stop sign controlled) intersection with limited sight distance at a pilot location. Sensors embedded in the pavement detected the presence of vehicles waiting to enter the intersection (on the minor roadway), and measured the speed of approaching vehicles on the major roadway. The information was collected by a computer controller at the intersection that estimated the various vehicles arrival times and activated roadside warning signs accordingly.

Key accomplishments of these projects include:

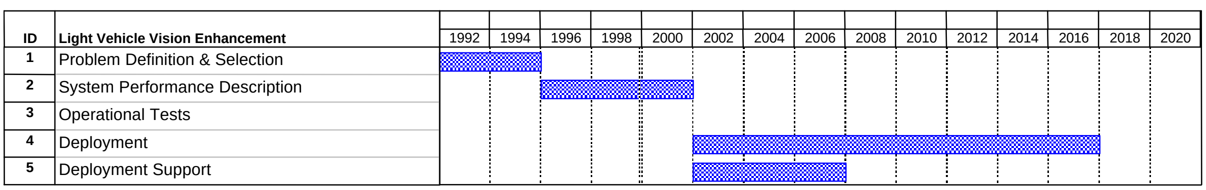
- Developed performance metrics for an in-vehicle, autonomous system to warn drivers of potential intersection violation and targets on perpendicular paths
- The in-vehicle ICAS equipment was successfully integrated into a Ford Crown Victoria for testing and evaluation.
- Visual, auditory, and haptic warnings were tested for the in-vehicle system.
- Linked map information and radars to reduce false alarms in the in-vehicle system
- For infrastructure-based ICAS, demonstrated positive driver safety behaviors at the test intersection where that system was deployed.

Future work on intersection collision avoidance will continue to seek vehicle-based solutions to this complex and difficult problem. However, there is a wide difference between the common pre-crash scenarios in the intersection crash population and their causal factors – this calls for different functionalities of the sub-parts of an intersection collision avoidance system. U.S. DOT will conduct a more detailed systems study to explore next-step options to improve intersection safety. U.S. DOT will coordinate near-term ICAS deployment options with state and local infrastructure deployment (e.g. photo enforcement as a synergistic countermeasure for red-light running and the associated collisions avoided).

Additionally, U.S. DOT plans to investigate infrastructure-based sensing to identify hazardous vehicle movements and possible pedestrian conflicts and interfaces with traffic control systems to recognize current phase and times to next phases. In general, new approaches to communicating with motorists will be considered, such as special communication systems to convey ICAS information to on-board intelligent vehicle ICAS.

8.2.5 Vision Enhancement

This problem area requires systems to augment the driver's vision under conditions of reduced visibility. Reduced visibility is a crash circumstance that affects all classes of crashes and problem areas. Reduced visibility conditions have to do with levels of lighting such as glare, dawn, dusk, dark, and artificial lighting; and with weather conditions such as rain, sleet, snow, and fog.



Impaired visibility clearly contributes to the danger inherent in all maneuvers requiring accurate visual interpretation and subsequent rapid response. Analyses have suggested that for incidents that were probably (as distinct from, possibly) the direct result of reduced visibility, a third involved SVRD crashes, and a fifth were rear-end collisions. In addition to these factors, one-third of all pedestrian/cyclist impacts occur at night or in other reduced visibility conditions. Hence, vision enhancement can offer safety improvements on several fronts. The effectiveness of recently released commercial night vision enhancement products and of more capable experimental systems has yet to be measured.

Early efforts on vision enhancement included a Technology Reinvestment Program (TRP) project to investigate the feasibility of developing commercial products (system size, form factor, cost reduction, etc.) from military vision enhancement systems. This study began in the early 1990s.

A project was initiated in 1994 to investigate the feasibility of vehicle-based vision enhancement systems that would help drivers avoid collisions with vehicles, pedestrians, and other objects on the road, under conditions of reduced visibility. This project conducted a state-of-the-art review of relevant vision enhancement technologies. Subsequent efforts have addressed sensor capabilities, driver visual information needs for crash avoidance, and other driver performance issues. The study team conducted a preliminary assessments and field evaluations of an available night vision system and infrared vision enhancement prototypes from the U.S Army’s Driver

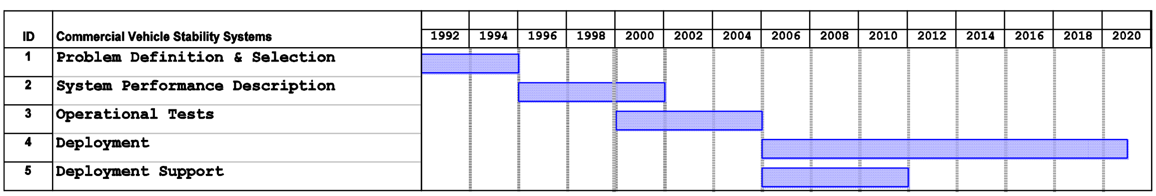
Vision Enhancement Program.

Other accomplishments include the completion of a pilot study that produced a human factors evaluation plan for infrared night vision enhancement systems.

The light vehicle manufacturers are beginning to offer vision enhancement systems as optional equipment on high-end vehicles. Equipment suppliers are also developing systems that could be installed in Sport Utility Vehicles and light trucks on an aftermarket basis. Given current commercialization activities, future IVI program efforts for this area will be limited to the development of objective test procedures and evaluation criteria to measure the safety benefits of vision enhancement systems.

8.2.6 Vehicle Stability

This problem area requires that vehicles be equipped with systems that will enhance their stability on the road. The efforts are concentrated on commercial motor vehicles. These vehicles are prone to stability problems due to their inherently high centers of gravity and (sometimes multiple) articulation points. Instability of a commercial vehicle may manifest itself as the inability of the driver to maintain directional control, jackknife, rollover, or a combination of those results. Most incidents of heavy vehicle instability are triggered either by braking or rapid steering movements, but other causes may be wind gusts, road roughness, tire failure, or simply cornering too fast for road conditions. Because they often result in rollover, heavy vehicle instability incidents are particularly serious in terms of potential for loss of life, injuries, property damage, and traffic tie-ups.



Efforts to date have focused on two countermeasures. One, called a Roll Stability Advisor (RSA), is an in-cab device that will indicate to a truck driver what the rollover threshold of the combination is, and how close to that threshold the driver is driving at any particular time. It is meant to provide feedback to the driver that will allow him or her to adjust his or her driving to a safer level. The other is a system for multiple-trailer combinations that will actually take action, without any driver input, to stabilize the combination by selectively applying braking at individual wheels. This system is intended to suppress the natural tendency toward a phenomenon called rearward amplification, where each successive trailer in the combination experiences a more severe reaction to an initial steering input by the driver. Rearward amplification can result in the rearmost trailer rolling over, and possibly taking the rest of the combination with it. In order for this system to be implemented, the entire combination must be equipped with an electronically controlled braking system (ECBS). ECBS is now a production option from one tractor manufacturer, but is not yet offered on production trailers in the U.S. Ongoing IVI research also includes projects to accelerate the deployment of this ECBS-enabling technology.

University of Michigan Transportation Research Institute was recently awarded a contract to develop and demonstrate a trailer-based system to detect and suppress rearward amplification that can lead to rollover crashes. A previous system developed under a U.S. DOT-sponsored cooperative agreement required complementary sensors and processors on both the tractor and trailer. However, some industry sources have stated that deployment would be better served if there were a stand alone system for trailers.

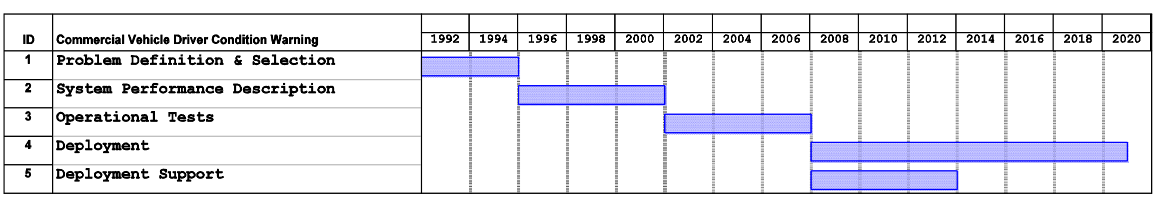
Two projects have recently been awarded under the Generation 0 of the IVI that will address vehicle stability from the points of view of the vehicle and its interaction with the roadway.

8.2.7 Driver Condition Warning

This problem area requires the capacity to provide a driver monitoring and warning capability to alert the driver to problems such as drowsiness. A real time, on-board device is being developed to inform drivers of their level of drowsiness. Additionally, provisions are being made to provide overall drowsiness status through feedback mechanisms in order to allow the driver to incorporate better sleep habits. It is expected that the first implementation of this service will be on commercial vehicles.

Available statistics on driver error indicate that truck driver fatigue is a factor in 3 to 6 percent of fatal crashes involving large trucks. Fatigue and inattention are factors in 18 percent of single-vehicle, large truck fatal crashes, which tend to occur more frequently in the late-night, pre-dawn hours. Also, the 1995 FHWA sponsored Truck and Bus Safety Summit, attended by over 200 national leaders in commercial motor vehicle and highway safety, including a large contingent of drivers, identified driver fatigue as the top priority commercial motor vehicle safety issue and driver inattention was identified as a significant risk factor. In addition, the number one reason commercial motor vehicle drivers are placed out of service at the roadside is for hours-of-service violations, i.e.. excess hours or no duty status record.

Ongoing efforts within the IVI program have concentrated on the development of a monitor that can detect driver drowsiness by a direct, unobtrusive measure of eyelid closure. Research has shown the percent of eyelid closure over time to be best known predictor of the onset of sleep.



Driver alertness and fatigue is a major area in Federal Motor Carrier Safety Administration (FMCSA) overall human factors research program, which includes Commercial Driver Training and Performance Management, Physical Qualifications, and Car and Truck Proximity Research. Recently completed projects include:

C Effects of Operating Practices on Commercial Driver Alertness: This study examined the effects of physical activity on driver performance during extended work hours.

- Commercial Driver Fatigue, Alertness, and Countermeasures Survey: This study was an adjunct to the Driver Fatigue and Alertness Study to extend prior research and to collect additional data about Commercial Motor Vehicle (CMV) drivers and their job characteristics.
- Ocular Dynamics as Predictors of Driver Fatigue: This driving simulator-based study addressed the question of whether directed eye movements and other eye activities could be monitored as "leading indicators" of fatigue. The results support the concept of early ocular indicators of fatigue.
- PERCLOS Technical Conference: A technical conference to discuss recent scientific validation findings regarding PERCLOS and other eye activity measures of alertness, and the status of efforts to develop in-vehicle sensors to continuously measure PERCLOS as an "alertometer."

FMCSA Driver Alertness and Fatigue projects that are currently underway include:

- Modeling of Driver Performance under Various Work/Rest Cycles: This project will gather data that will be used to improve and validate Sleep/Performance Prediction Models.
- Pilot Test of Technological Aids to Improved Fatigue Management: These pilot tests will include the actigraph, in-vehicle alertness monitoring, in vehicle "black box" performance monitoring, and a device which reduces backsteer and thereby reduces driver workload.
- Sleeper Berths and Driver fatigue: This 4-year study will determine the effects of sleeper berth use on driver alertness and driving performance.
- CMV crash Rates by Time of Day: This analytical study is assessing available crash data on CMV mileage exposure to determine the CMV crash involvement rate (per mile traveled) by time of day.
- Driver-Vehicle Interface for In-Vehicle Alertness Monitoring: This study will make recommendations regarding the optimal driver-vehicle design.

8.2.8 Safety Impacting Services

There are many ITS concepts which entail functions other than IVI, but which nevertheless influence the driving task. In this problem area, we will address such systems from the viewpoint of their safety impact. A fundamental goal of this work is to ensure that mobility and productivity enhancing systems do not degrade motor vehicle safety.

Activities in this area are not described in the IVI roadmap. As new mobility and productivity enhancing systems approach market readiness, U.S. DOT will consider the merits of its involvement in safety evaluation on the basis of additional knowledge to be gained, given system configuration and the nature of the driver interactions required by the system. In the NHTSA ITS Crash Avoidance Program, which preceded the IVI, safety evaluations were conducted of traveler information systems in the TravTek, Advanced Driver and Vehicle

Advisory Navigation Concept and TravelAid Operational Tests. In November 1997, NHTSA published the results of *An Investigation of the Safety Implications of Wireless Communications in Vehicles*. Based on the information collected it can be concluded that in some cases, the inattention and distraction created by use of a cellular telephone while driving are similar other distractions in increasing crash risk. The report presents a variety of operations for enhancing the safe use of cellular telephones by drivers, and addressing the many issues raised; to include educational, research, enforcement, and legislative considerations.

Of particular interest to the IVI program is the safety impact of combining systems - such as the resultant changes in task allocation and loading experienced by the driver. These systems may also be combined with safety-specific technologies as they are tested and made ready for deployment. Systems that may be combined include: route guidance and navigation, adaptive cruise control, automatic collision notification, cellular telephones, and in-vehicle computing.

9. CONCLUSION

The U.S. DOT's strategic safety goal is to "Promote the public health and safety by working toward the elimination of transportation-related deaths, injuries, and property damage." Success in achieving the safety strategic goal will be measured by realizing an improvement in the outcome goals. This program will contribute to the following outcome goals:

- Reduce the number of transportation-related deaths
- Reduce the number and severity of transportation-related injuries

At the conclusion of the period of performance covered by this plan, great strides will have been made toward delivering the safety benefits of IVI. 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 drivers' 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.

At the end of the period of performance, Generation 0 research and operational testing will have been completed. This is expected to validate the benefits of early IVI driver assistance systems for rear-end collision warning, vehicle stability, vision enhancement and lane tracking (precursor to roadway departure collision warning.) Generation 1 research will have been largely completed and operational testing will still be underway. This will increase our understanding of the required performance, user acceptance and benefits of more advanced systems which address rear-end, roadway departure, lane change/merge and driver monitoring collision warning systems. Generation 2 research will have been initiated to address intersection collisions and to assess the increased benefits of infrastructure cooperation for other services. Driver workload tools and methodologies will have been completed which will assist in evaluating safety-impacting services.

In summary, this business plan presents a research action plan for achieving an increased understanding of the capabilities, user acceptance, and potential benefits of driver assistance systems. This increased knowledge base will encourage the development and deployment of effective and affordable driver assistance systems which will reduce the number of motor vehicle crashes.

Appendix A - References

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Appendix B - Glossary

ACAS	Automotive Collision Avoidance Systems
ACC	Adaptive Cruise Control
ACN	Automated Collision Notification
AHS	Automated Highway Systems
CA	Collision Avoidance
CMV	Commercial Motor Vehicle
COTS	Commercial Off-The-Shelf
CVO	Commercial Vehicle Operations
DASCAR	Data Acquisition System for Crash Avoidance Research
DVI	Driver-Vehicle Interface
ECBS	Electronically Controlled Breaking System
EMS	Emergency Medical Services
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
GES	General Estimates System
GIS/FPS	Deographical Information System/Global Positioning System
GM	General Motors
ICAS	Intersection Condition Avoidance System
ICC	Intelligent Cruise Control
ICP	Intersection/Crossing Path
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	Intelligent Transportation Systems
IVI	Intelligent Vehicles Initiative
LCM	Lane Change/Merge

NADS	National Advanced Driving Simulator
NHTSA	National Highway Traffic Safety Administration
RSA	Roll Stability Advisory
SAVME	System for Assessing the Vehicle Motion Environment
SVRD	Single Vehicle Road Departure
TEA-21	Transportation Equity Act for the 21st Century
TRP	Technology Reinvestment Program
U.S. DOT	Department of Transportation
VDTV	Variable Dynamics Test Vehicle

Appendix C - Automated Collision Notification

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 Emergency Medical Services (EMS.) Based on 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 crashes 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 system automatically and immediately reports the occurrence and location of an automobile crash to an EMS provider. The system which is currently in an operational test also has 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 emergency medical services 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 2000 to determine the effectiveness of the prototype system, and to measure the user acceptance and feasibility of the product for deployment. The automobile industry has begun offering related systems as an option on certain car models. Subsequent activities will emphasize deployment through equipping EMS dispatch centers and will include monitoring proposed products and the continuing efforts to support the integration of safety-related capabilities and standards development. Within the scope of the Intelligent Transportation System, future activities in Automated Collision Notification will be carried out under the Advanced Rural Transportation Systems portion of the program.

The key objectives of the Automated Collision Notification project are to:

- Determine feasibility of large-scale deployment of Automated Collision Notification systems
- Assess the effectiveness of the systems in reducing injuries and fatalities
- Reach a decision point regarding further U.S. DOT research actions in support of Automated Collision Notification deployment