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STRATEGIC PLAN FOR

Intelligent Vehicle-Highway Systems

in the United States

Report No: IVHS-AMER-92-3
Prepared by IVHS AMERICA
May 20, 1992

Abstract

The purpose of this Strategic Plan is to guide development and deployment of Intelligent Vehicle-Highway Systems (IVHS) in the United States. The plan includes: goals and objectives for a national IVHS program; challenges to deployment and ways to resolve them; suggested roles for public, private, and academic participants; a course of action; and cost estimates.

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This Strategic Plan was developed through a consensus-building process that involved the entire IVHS community, including the public and private sectors and academia. Literally hundreds of people have participated, too many to acknowledge individually. The Board of Directors, Coordinating Council, and 14 technical committees of IVHS AMERICA all provided substantial guidance and input.

Two groups were responsible for supervising the development of the Strategic Plan. The Strategic Planning Subcommittee, a subcommittee of the Coordinating Council of IVHS AMERICA, assumed overall responsibility. It was chaired by Thomas Deen, Executive Director of the Transportation Research Board. In addition, an ad hoc group, the Jefferson Group, provided guidance on the plan structure and early content. Some members served on both groups; rosters appear on the following page.

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This was a major effort by the IVHS community, with a multiplicity of inputs reflecting the broad base of interest in IVHS in the U.S. Although many people contributed to this report, responsibility for errors of fact or emphasis lies with the Writing Group.

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APPENDICES

Technology alone cannot solve today's transportation problems, but in combination with sound management of capital and human resources, technological advances can offer significant assistance in meeting transportation needs.

Innovation and technological advances within the transportation field will be vital to ensure that the system can meet the Nation's transportation requirements for the 21st century. We need to focus on innovation and technology to fulfill national transportation goals of safety and efficiency and meet the transportation needs of the future. Many of the resources, as well as the imagination and creativity necessary to support transportation advances, will come from the private sector, along with the opportunities for applying new ideas and knowledge. Colleges and universities, non-profit research groups, and State and local governments will also contribute to transportation research and innovation. Institutions in a position to apply research and technological advances will have to be prepared for and receptive to change.

From the increased interest in advances in the transportation field and corresponding creative and technological resources drawn to transportation, the Nation will long reap the benefits of rising productivity and competitiveness and an enhanced quality of life.

from "Moving America — A Statement of
National Transportation Policy"
US. DOT
February 1990

I. EXECUTIVE SUMMARY

Introduction: The Needs

Surface transportation in the United States is at a crossroads. The mobility we prize so higbly is threatened. Many of the nation's roads are badly clogged. Congestion continues to increase, and the conventional approach of the past — building more roads — will not work in many areas of the country, for both financial and environmental reasons.

Safety continues to be a prime concern. In 1991, 41,000 people died in traffic accidents, and more than 5 million were injured. Public transportation systems, chronically short of funds, are seen by many as an unattractive alternative to driving.

"The mobility we prize so highly in the United States is threatened."

Congestion takes its toll, too, in lost productivity, costing the nation an estimated $100 billion each year. Traffic accidents — many caused by congestion itself — drain away another $70 billion per year. Numbers alone can't measure the loss of life or consequences of long-term injury. There are also other costs. For example, inefficient movement of vehicles reduces productivity, wastes energy, and increases emissions; trucks, buses, and automobiles idled in traffic waste billions of gallons of fuel and needlessly emit tons of pollutants each year.

Recognition of these problems led to the passage of the Inter-modal Surface Transportation Efficiency Act of 1991 (ISTEA), signed by President Bush on December 18, 1991. The purpose of ISTEA is clearly annunciated in its statement of policy: "...to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy efficient manner."

IVHS: An Answer

There is no single answer to the set of complex transportation problems that confront us. But a group of technologies known as Intelligent Vehicle-Highway Systems (IVHS) can help tremendously in meeting the goals of ISTEA. Indeed, Congress recognized this in the Act by authorizing a $660 million IVHS program over the next six years. IVHS is composed of a number of technologies, including information processing, communications, control, and electronics. Joining these technologies to our transportation system can save lives, save time, and save money.

Goals for IVHS in the U.S.

- Improved safety
- Reduced congestion
- Increased and higher quality mobility
- Reduced environmental impact
- Improved energy efficiency
- Improved economic productivity
- A viable U.S. IVHS industry

IVHS can improve safety, reduce congestion, enhance mobility, minimize environmental impact, save energy, and promote economic productivity in our transportation system. It will multiply the effectiveness of future spending on highway construction and maintenance and will increase the attractiveness of public transportation. IVHS will be as basic a transportation raw material as concrete, asphalt, or steel rail.

The challenge lies in the diversity of IVHS. The technology is highly interdisciplinary, ranging from physics to psychology. The public arena is equally diverse, demanding new working relationships among all levels of government. New public/private partnerships must be formed. Legal issues such as product liability and privacy must be addressed. Many participants in IVHS compete for resources and customers; many have objectives and constituencies at odds.

If IVHS is to succeed, however, this diversity must generate concerted action — a coherent national program of technical exploration and operational tests leading to deployment across the continent. Research must be planned, executed, and coordinated. Institutional and legal barriers must be addressed and their effects mitigated. Both public investment and private investment in IVHS are crucial. The effort to secure such funding must begin now.

IVHS is not a distant vision. Already, real systems, products, and services are being tested throughout the U.S. Some first-generation systems are, in fact, on the market or are being developed. These systems:

- Collect and transmit dynamic information on traffic conditions and transit schedules for travelers, whether they are at home, in the office, or en route. Alerted to hazards and delays, they are able to change their plans to minimize inconvenience.

- Expand the capacity of our highways by reducing the number of traffic incidents, clearing them more quickly when they occur, rerouting traffic flow around them, and automatically collecting tolls.

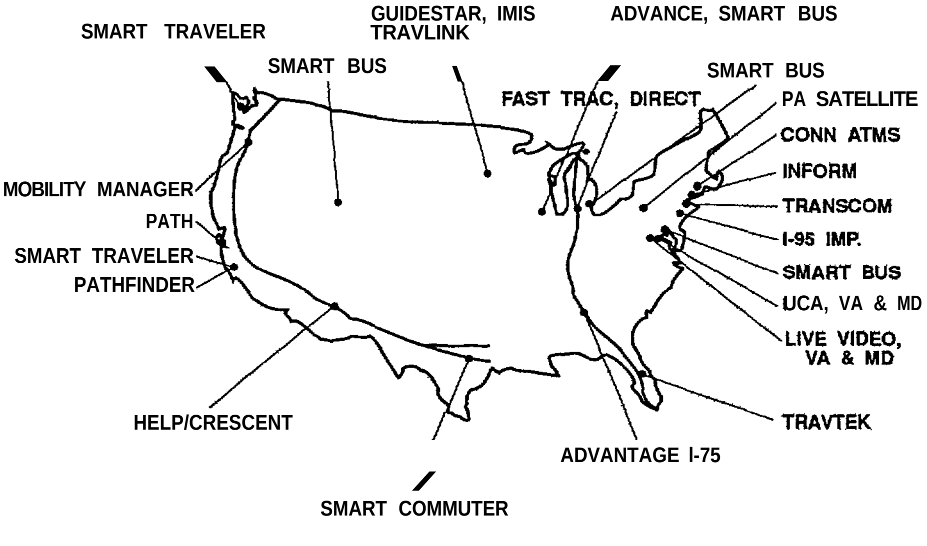
- Improve the productivity of commercial, transit, and public safety fleets by using automated tracking and dispatch systems that dynamically reroute vehicles to accommodate changes in customer needs.

- Assist drivers in reaching a desired destination with navigation systems enhanced with pathfinding, or route guidance. Stored directories that are part of such systems will provide information on nearby businesses or tourist attractions.

More than 20 real-world operational tests are now under way or are planned as federal/state/private ventures to evaluate more advanced IVHS concepts and components than those described above. The figure below highlights a number of those tests.

With significant R&D programs under way, the future holds the promise of even more-advanced products and services. These include collision avoidance systems that will prevent many accidents and in-vehicle signage that will display information about road conditions, including curves, speed limits, and construction projects. Research is being done on route guidance systems that will automatically incorporate traffic information, providing drivers with the fastest routes and allowing them to skirt delays; enhanced vision systems that will cut through the dark, fog, and dust to show the driver the road ahead; and systems that will automatically weigh trucks — and uniquely identify them — as they pass "transparent" state and international borders.

CURRENT AND PLANNED IVHS OPERATIONAL TESTS



Benefits

Over the next 20 years, a national IVHS program could have a greater societal impact than even the Interstate Highway System. As with the Interstate, effects are difficult to predict at the outset of the program. In view of this, the Strategic Plan envisions a series of R&D programs to evaluate the societal impact of IVHS. Still, it is clear that IVHS can yield substantial benefits widely distributed among our society. There are benefits, for instance, for rural drivers as well as those in congested metropolitan areas; for older as well as younger drivers; and for the current riders of public transportation systems as well as those who will be attracted to public transportation by the enhancements that IVHS helps make possible. The key benefits expected are enumerated below. Because of the anticipated scale of the economic, legal, and social effects of IVHS, it is important that there be penetrating, systematic evaluation of IVHS through the planned operational tests.

Safety

IVHS brings information and control to the operation of motor vehicles and therefore offers the potential for substantial improvements in traffic safety.

Historically, development of safety features in motor vehicles has alternated between primary systems that help prevent collisions and secondary safety systems that help reduce injuries sustained in a crash. Between 1930 and 1950, the emphasis was on such primary systems as brakes, headlights and signaling. Later, the focus switched to secondary systems such as occupant restraints. Today, the advent of IVHS technologies offers unprecedented opportunities for achieving breakthroughs in crash avoidance features.

Such primary safety systems could warn drivers that they are too close to a car in an adjoining lane or that they are in danger of running off the edge of the road. This may prove of greatest benefit to rural travelers. More than half the fatal accidents in the U.S. occur on rural roads because of poor road conditions and high speeds.

Important infrastructure improvements will also increase safety. For example, new traffic control systems will reduce the number of vehicle stops, minimize variations in vehicle speeds, and enhance traffic flow. All of these, in turn, reduce the number of accidents.

Experts have estimated that IVHS can reduce traffic fatalities by eight percent by 2011. That’s 3,300 lives saved and 400,000 injuries avoided each year at current traffic levels. These figures, however, could prove to be quite conservative. If there are breakthroughs in IVHS applications such as collision avoidance, it is possible that there would be a dramatic reduction in the number of crashes, deaths, and injuries.

Reduced Congestion and Improved Mobility

IVHS can help reduce street and highway congestion in a number of ways. Information provided to travelers will permit many to avoid congestion by allowing them to go around the congestion, choose alternative modes of transit, or delay their trips.

Rapid detection and clearing of accidents and incidents will reduce congestion and the secondary collisions that frequently result and cause additional delays. Enhanced public transportation systems can divert highway traffic. Real-time, dynamic traffic control systems will adapt to traffic conditions automatically.

Electronic Toll and Traffic Management (ETTM) can reduce congestion around toll plazas by collecting tolls automatically and can provide the basis for congestion pricing, a demand management tool for which ISTEA has authorized an R&D program.

Congestion is not simply an urban issue. In rural areas, traffic is disrupted by accidents, construction and maintenance operations and associated detours, congestion on tourist routes, and other causes. IVHS can help alleviate all these problems.

There will be new flexibility in organizing car- and van-pools. This will increase the number of vehicles with multiple riders, thus reducing the total number of vehicles in the traffic stream. Guiding drivers directly to available parking spaces is yet another way IVHS will reduce congestion.

Improved mobility as well as improved convenience and comfort for all surface transportation is a goal IVHS can help fulfill. Better information — for example, real-time transit schedules and intermodal connection information — can make public transportation more marketable to potential riders. Better information on volunteer services and transit schedules will enhance the mobility of older Americans and disabled travelers in urban and rural areas.

According to estimates, traffic congestion can be reduced as much as 20 percent by 2011 in cities that adopt IVHS technologies.

Enhanced Economic Productivity

The importance of efficient transportation to the nation's economic health cannot be overstated; nearly all economic activity uses transportation directly or indirectly. Improving the efficiency of our transportation system will boost economic productivity.

Operators of many commercial and public-sector fleets will realize a variety of economic benefits from IVHS, including safety improvements, minimized delays due to traffic congestion, efficient routing of vehicles, and quicker movement of freight by such innovations as electronic toll collection and in-motion electronic identification of vehicles crossing state lines.

Energy Efficiency and Environmental Quality

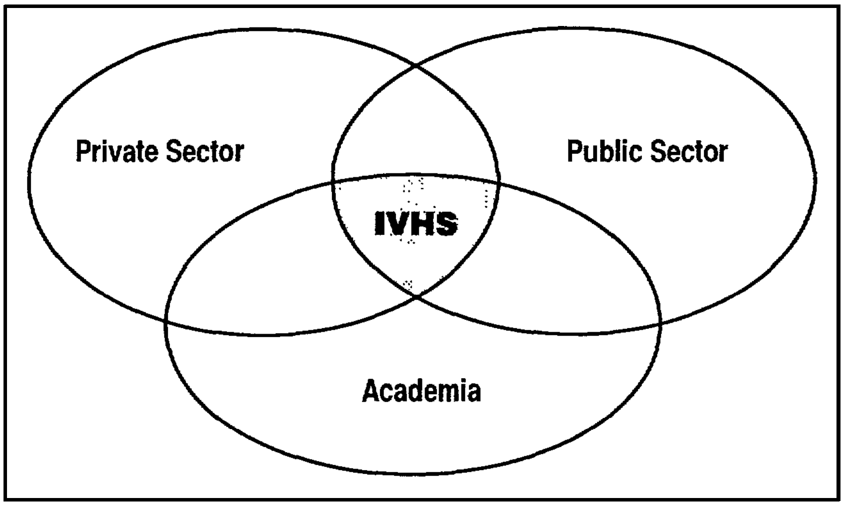
Minimizing congestion and diverting passengers from single-occupancy vehicles will increase the energy efficiency of the transportation system. Emissions will be reduced by smoother, more evenly distributed traffic flow, as well as by increases in the use of public transit and car- and van-pooling. There is some concern that any congestion relief may merely encourage more travel, thus negating most if not all gains in reduced energy consumption and pollution. This question must be researched. But it should be noted that IVHS provides the means to implement demand management systems based on road-pricing, if public policy determines this to be a desirable way to limit or shift demand.

IVHS Participants: Roles and Responsibilities

IVHS embodies a wide array of technologies, but the challenges are not solely technical. Organizational, institutional, and legal issues must be resolved before significant implementation can take place. In fact, implementing IVHS will require unprecedented cooperation among all levels of government, the private sector, and academia. IVHS can serve as a national model for the deployment of technology-based systems where public and private sector coordination is a central concern. Every sector is crucial — key needs include the following:

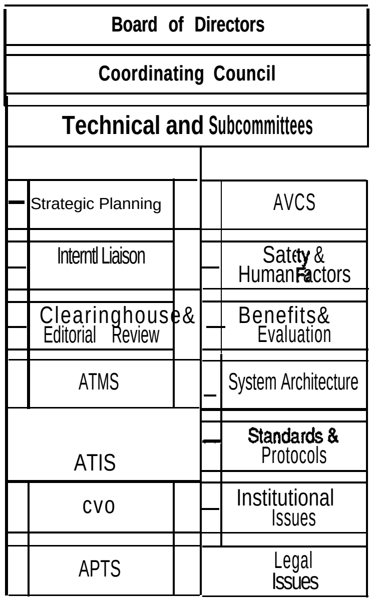
- Development of new public/private partnerships
- New forms of cooperation among local, state, and federal agencies
- Agreement on an overall system architecture
- Stable R&D funding and management
- Adoption of appropriate standards and protocols
- Education of a new generation of transportation professionals

"Implementing IVHS will require unprecedented cooperation among all levels of government, the private sector, and academia."



IVHS AMERICA

IVHS AMERICA Organization



A leading role in the design of a national program of IVHS research, development, and deployment will be played by the Intelligent Vehicle Highway Society of America (IVHS AMERICA). Its mission is to stimulate interest and activity in IVHS and to coordinate and foster public/private/academic partnerships that will make the U.S. transportation system significantly safer and more effective. IVHS AMERICA is a forum where the private and public members of the IVHS community come together to reach consensus and take action to accelerate implementation of the technology. A major function of the society is to coordinate development of this Strategic Plan, and, over time, to review progress of IVHS and make necessary modifications to the plan. As a utilized Federal Advisory Committee to the Department of Transportation, it will help guide the federal government's IVHS activities and will advise DOT on establishing program priorities. IVHS AMERICA will also inform the public about the progress of IVHS and its social implications.

IVHS AMERICA will work with established standards-setting bodies to ensure the adoption of workable IVHS standards. For the most part, the organization itself will not create standards. A similar philosophy will guide the approach to research. Research needs will be identified and appropriate agencies and organizations, public and private, will be urged to carry out the work.

Private Sector

Partnership Responsibilities

IVHS AMERICA
- Maintain Strategic Plan and clearinghous
- Provide forum for solving problems
- Evaluate and advise

Federal Government
- Fund and manage research and testing
- Remove institutional barriers

State and Local Government
- Deploy IVHS
- Operate and maintain IVHS

Professional Societies
- Develop standards
- Disseminate information

Private Sector
- Develop products
- Market products
- Act as research partner

Federal Labs
- Transfer technology
- Provide development expertise

Academia
- Educate IVHS professionals
- Act as research partner

The private sector's role in IVHS is fundamental. Industry will make by far the largest investment in IVHS, but only in expectation of profits. The marketing of IVHS products and services is best understood by the private sector, which will develop the technology and market the wide array of products and services that will make IVHS a reality.

IVHS can be a significant business opportunity for automakers and for companies in the electronics, computer, communications, and information industries. The market is not limited to vehicles — for example, hand-held devices will provide a variety of traveler information, including bus schedules, directories of business listings, and tourist attractions. Similar information services could also be provided on home or office computers.

While significant private investment is required for IVHS to move forward, there may also be a need for government funding to encourage development of consumer products and services that have potential for significant public benefit, but require high-risk R&D programs.

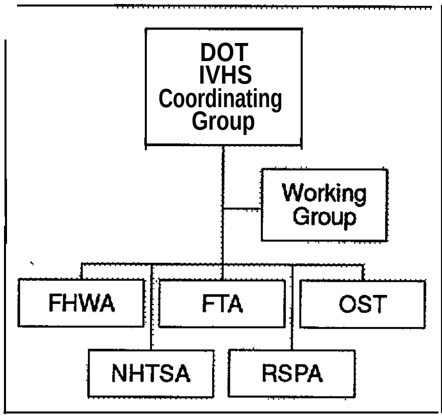
Fulfilling IVHS infrastructure needs will also create a large market. Needs in this area include sensors and actuators, beacons, and hardware and software for electronic toll collection and area-wide traffic management systems.

IVHS calls for development of entirely new public and private roles in transportation. For instance, the private sector could privately finance and operate a variety of infrastructure services, such as collection of traffic data, if it received a franchise from the appropriate public agencies.

The Federal Government

The federal government will provide a national perspective on IVHS. Federal spending, as exemplified by the ISTEA, will be required to catalyze private and local spending. The U.S. Department of Transportation (DOT) has the key responsibility for encouraging and coordinating the development of the technology in conjunction with state and local governments, private industry, and academia. DOT will commission research, fund demonstrations and operational tests, assure uniformity of evaluations, encourage implementation, and ensure nationwide compatibility of systems when required.

IVHS Coordination Within U.S. DOT



The Federal Highway Administration (FHWA) has been designated as the lead agency for DOT's program. The Office of the Secretary, as well as other DOT administrations, will also play key roles consistent with their primary responsibilities. Those other key DOT administrations are the National Highway Traffic Safety Administration (NHTSA), the Federal Transit Administration (FTA), and the Research and Special Programs Administration (RSPA).

Other federal agencies will also be involved in aspects of IVHS. These include the Federal Communications Commission, the Department of Energy, the Environmental Protection Agency, the Department of Justice, and the Interstate Commerce Commission.

State and Local Government

State and local governments are responsible for building, operating, and maintaining surface transportation systems, and for managing traffic. This makes their participation in IVHS fundamental to its success. If IVHS is ignored or rejected by local government, it will fail.

State governments own the Interstate highways, U.S. highways, and state roads. Local governments own arterial highways and local roads. Many transit systems are owned by either state or local government or multi-jurisdictional agencies. State and local governments will install, maintain, and operate the IVHS infrastructure, or they will possibly contract these functions out to the private sector.

Carrying out such programs will require extensive federal assistance. ISTEA emphasizes the importance of Metropolitan Planning Organizations (MPO's) in coordinating region-wide transportation systems.

State and local governments in neighboring jurisdictions must find new ways to cooperate in order to develop and deploy IVHS. Moreover, when systems that reach across jurisdictional boundaries are installed, cooperation will be required to operate them — coordinating transportation control operations is just one example of such a requirement. Local governments may also want to use IVHS to promote other transportation-related social, political, or economic objectives.

Academia

Universities must develop new academic programs that will educate a new type of transportation professional, one schooled in the disciplines and concepts fundamental to IVHS. These include, for example, communications, computer science, systems engineering, and institutional studies. Academia must develop new concepts and knowledge germane to IVHS and must integrate new academic disciplines with transportation. Academia will also help implement this Strategic Plan, assessing the current state of likely technological improvements and performing basic and applied R&D and operational tests.

A Strategic Plan for Implementing IVHS

To guide the implementation of IVHS, Congress requested DOT to prepare a strategic plan. DOT, in turn, asked IVHS AMERICA to prepare its own strategic plan to serve as a foundation for the Congressional report. In writing its plan, IVHS AMERICA received inputs from the broad IVHS community, including federal, state, and local government agencies: industry; academia: trade associations; and consumer and public-interest groups.

The purpose of the Strategic Plan is to guide development and implementation of IVHS technology in keeping with the goals of safety, enhanced mobility, and improved productivity of our transportation system. Foremost among the plan's aims are to:

- Establish the goals and objectives of a national IVHS program and predict its costs and benefits
- Identify key challenges to IVHS deployment and seek ways in which they can be resolved
- Suggest appropriate roles for the public, private, and academic participants and help build cooperation among them
- Outline a course of action to develop, test, and deploy IVHS technology
- Estimate the magnitude and sources of funding required

Technical Implementation

The Strategic Plan is a road map for IVHS implementation over the next 20 years. But IVHS consists of technologies that continue to advance rapidly. This, therefore, will be a "living plan" that will evolve with changes in technology and experience gained through operational tests and deployment of IVHS.

A series of key assumptions and principles underlie the program for development and deployment. The plan is the IVHS community's consensus — working through IVHS AMERICA — of what must be done. Among the most important of these assumptions and principles are the following:

- Government spending on infrastructure — particularly on advanced traffic management systems — is essential.
- The marketplace will be a major force in the development of IVHS. Consumer acceptance of the various products is also equally essential to success. Other driving forces include the need to provide such public benefits as safety improvements and congestion relief.
- Private sector (and consumer) spending will pay for the bulk of IVHS development, products, systems, and services, especially for in-vehicle products. In some cases, public funding will be needed in early development phases to pave the way for private investment.
- Existing standards should be utilized where appropriate and new standards developed where needed to ensure that different systems work together throughout the U.S. and North America. Systems, products, and services will be developed and deployed within our framework of federalism and the market economy, with decentralized power and decision making.
- Deployment of proven technologies will be emphasized initially .
- R&D will be conducted in areas where existing technologies do not meet requirements or where requirements need to be established (human factors, for example).
- Large-scale operational tests conducted as public/private ventures in real-world conditions are critical to the transition between R&D and commercial deployment of the technologies.
- Benefits of IVHS, while potentially enormous, are difficult to quantify without further study; continuing work should be undertaken. As experience is acquired, estimates of benefits can be refined.

The Five Functional Areas of IVHS

A wide array of technologies makes up IVHS, including electronics, computer hardware and software, control, and communications. Five functional areas have been identified in which these technologies are applied. These are:

- Advanced Traffic Management Systems (ATMS)
- Advanced Traveler Information Systems (ATIS)

- Advanced Vehicle Control Systems (AVCS)
- Commercial Vehicle Operations (CVO)
- Advanced Public Transportation Systems (APTS)

CVO and APTS are largely applications that use the technologies of the first three areas. All five functional areas apply to transportation in rural areas as well as in urban areas.

ADVANCED TRAFFIC MANAGEMENT SYSTEMS (ATMS)

ATMS will integrate management of various roadway functions, including freeway ramp metering and arterial signal control. In more sophisticated implementations, ATMS will predict traffic congestion and provide alternative routing instructions to vehicles over wide areas, in order to maximize the efficiency of the highway network and maintain priorities for high-occupancy vehicles (HOV's).

ATMS will collect, utilize, and disseminate real-time data on congestion on arterial streets and expressways, and will alert transit operators of alternative routes. Dynamic traffic control systems will respond to changing traffic conditions across different jurisdictions and types of roads by routing drivers around delays where possible. Rapid detection and response to traffic incidents will be especially effective in reducing congestion on expressways.

ATMS is the basic building block of IVHS. All other functional areas will utilize the information provided by ATMS.

ADVANCED TRAVELER INFORMATION SYSTEMS (ATIS)

ATIS provides a variety of information that assists travelers in reaching a desired destination via private vehicle, public transportation, or a combination of the two.

On-board navigation systems are an ATIS building block. In future systems, these will be augmented by information from the ATMS. The information will include locations of incidents, weather and road conditions, optimal routes, recommended speeds, and lane restrictions. While such information will be utilized in vehicles, it could also be used for pre-trip planning at home, in the office, at kiosks, or even by owners of portable or palm-top computers.

ADVANCED VEHICLE CONTROL SYSTEMS (AVCS)

AVCS enhances the driver's control of the vehicle to make travel safer and more efficient. Accidents could be avoided, as opposed to just having their consequences mitigated. AVCS includes a broad range of concepts that will become operational on different time scales.

Collision warning systems would alert the driver to an imminent collision. In more advanced systems, the vehicle would automatically brake or steer away from a collision. Those systems are autonomous to the vehicle and are likely to be developed by the automotive industry and its suppliers. They should offer substantial benefits by improving safety and reducing accident-induced congestion, justifying public sector funding during the initial development stage.

Longer-term AVCS concepts rely more heavily on infrastructure information and control that could produce major increases in roadway throughput — by as much as two or three times, perhaps more. One example is limited-access, automated lanes, in which the movements of all vehicles are automatically controlled while they are in the special lane. Such a system will likely require close communication between the roadway and the vehicles, and between the vehicles themselves. ISTEA calls for development of a completely automated highway and vehicle system that will serve as the prototype for fully automated IVHS systems. The goal is to have the first fully automated roadway or test track in operation by 1997.

COMMERCIAL VEHICLE OPERATIONS(CVO)

Operators of fleets of trucks, buses, vans, taxis, and emergency vehicles have already begun adopting IVHS technologies. Their leadership role is expected to continue because fleet operators can clearly see the economic benefits of implementing IVHS.

Thousands of heavy-duty trucks are already equipped with automated location systems and two-way radios that link drivers with their dispatch centers. Automated Vehicle Identification (AVI) systems are already automating toll collection and thus improving traffic flow in New York, Texas, and Oklahoma. The benefits of electronic toll collection are not limited to commercial vehicles. Indeed, passenger car drivers are the principal beneficiaries — the increased number of vehicles that can move through electronic toll lanes reduces congestion. A number of commercial and public fleet operators use Automated Vehicle Location (AVL) systems — on-board navigation, Loran-C, a terrestrial-based location system, or the Global Positioning System (GPS). With these systems, dispatchers can instantly determine the location of any vehicle.

ADVANCED PUBLIC TRANSPORTATION SYSTEMS (APTS)

APTS will use constituent technologies of ATMS, ATIS, and AVCS to improve operation of high-occupancy vehicles, including transit buses and car- and van-pools. ATIS will inform the traveler of the alternative schedules and costs available for a trip, while ATMS will provide instantly updated information. Real-time ride matching is another application that gives car- and van-poolers new flexibility in planning trips.

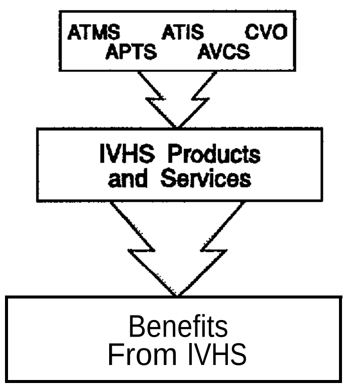
Smart Cards will enable consumers to board transit vehicles, as well as to pay tolls and parking fees, all without cash. In addition, preferential measures (such as selective traffic-signal timing) for HOV's are included in APTS.

Integration of IVHS Technologies

Successful integration of the separate technologies of IVHS requires that a number of cross-cutting issues and technologies be addressed early in the program. These include system architecture, standards and protocols, system safety and human factors, communications, and operational tests.

IVHS will progress as advanced technology and information are integrated with conventional infrastructure to provide an expanding set of consumer services over ever-increasing geographic areas. As development proceeds, there will be ever-greater interaction among ATMS, ATIS, and AVCS. IVHS can be more than the sum of its parts, but this inherent synergy can be tapped only if it is regarded, from the start, as an integrated set of capabilities.

IVHS Products and Services



An undertaking as far-reaching as IVHS cannot spring into being overnight. It requires a long-term commitment to a carefully planned and executed program. IVHS is expected to be implemented incrementally — that is, systems will be created separately in various areas of the country. These "islands" will be linked eventually to include the entire nation, much the same way that the Interstate Highway System grew. Phased implementation will hasten delivery of benefits to travelers and will help create public demand for further deployment.

For the consumer, IVHS will provide products and services that will save time and make travel more convenient, safer, or quicker. Much of this Strategic Plan deals with the underpinnings that make these products and services possible — for instance, the hard work involved in integrating a wide range of technologies, or developing standards.

It would be a mistake to forget that the consumer is principally concerned with the personal benefits of a technology, not with issues of integration or standards or possible societal benefits. In the end, consumers will determine the fate of IVHS by voting with their dollars. This suggests the need for very careful attention to human factors in the design of IVHS hardware and software and public education programs to ease the transition to IVHS. Public agencies, which will buy a substantial amount of IVHS hardware, software, and systems, are crucial customers as well.

Figure I-l shows the IVHS products and services of interest to consumers and the time frames in which they may become available.

KEY IVHS PRODUCTS AND SERVICES (Approximate First Availability)		
Near-Term 1992 – 1996	Mid-Term 1997 – 2001	Long-Term 2002 – 2011
TRANSPORTATION MANAGEMENT		
▪ Local area traffic monitoring and control for 15 metro area corridors and 3 inter-city corridors	▪ Area-wide, real-time, adaptive traffic and transit fleet control for corridors in 50 metro areas and 25 inter-city corridors	▪ Area-wide, full-featured systems to manage intermodal surface transportation nationwide in large urban areas and major rural corridors
TRAVELER INFORMATION SYSTEMS		
▪ Transportation data available at home, at the workplace, at public kiosks, at stations and transfer points, and through hand-held devices ▪ Static route guidance with business/tourist data in new vehicles and as a vehicle after-market product	▪ Real-time transportation system condition information for regional and rural travel and multiple modes of transportation ▪ Real-time car-pooling connection information ▪ Route guidance reflecting dynamic traffic conditions ▪ In-vehicle display of road signs	▪ Multi-modal demand-responsive information systems ▪ Area-wide transportation control integrated with optimal routing
PRODUCTIVITY ENHANCEMENTS		
▪ Productivity management systems for commercial and transit fleets ▪ Electronic toll collection ▪ Electronic transit fare collection ▪ Electronic credential checking	▪ Electronic record-keeping for vehicle fleet operations ▪ Integrated electronic transit fare, parking, and toll collection ▪ Automated HOV lane use verification	▪ Transparent borders for commercial vehicles ▪ Fully integrated transportation user-fee collection systems
SAFETY AND DRIVER ASSISTANCE		
▪ Roadway and environment safety systems ▪ Near-obstacle warning ▪ Simple vehicle performance monitoring ▪ Adaptive cruise control	▪ Automated highway demonstration ▪ Semi-automated Mayday capability ▪ Passenger security systems ▪ Perceptual enhancement systems ▪ Vehicle monitoring systems ▪ CVO safety inspection systems ▪ Collision warning ▪ Automated collision avoidance	▪ Automated vehicle operation on specially equipped roadways ▪ Fully automated Mayday systems with coordinated dispatching ▪ Intersection hazard warnings

Figure I-l.

Key Institutional and Legal Issues

Technical feasibility is not the sole determinant of whether a technology realizes its promise. Success depends on a broader environment, including institutional, legal, economic, and social issues. These issues are discussed throughout this document, and this section identifies the most important of them.

Institutional Issues

A principal challenge to IVHS is the need for new relationships among institutions involved in the national program Agreement on the roles and responsibilities of the participants is the first step in overcoming this challenge.

Many institutions will have to adapt to meet the challenges presented by IVHS. Highway agencies, for instance, will have to build strong expertise in a variety of other disciplines, in addition to the traditional emphasis on civil engineering. Government and industry, frequently adversaries, will have to find means of cooperating. Government procurement practices, which often make joint efforts difficult, may have to be re-examined in light of IVHS.

Legal Issues

A number of legal issues could greatly affect IVHS R&D and deployment. Resolving these issues will require studies of the problems and forums where the interested parties may seek agreement on the issues confronting them. They then will need to seek legislation to resolve those issues. Key legal issues include tort and product liability, antitrust, privacy, and intellectual property.

International Cooperation and Competition

Substantial IVHS programs are under way in Western Europe and Japan. The U.S. should not isolate itself from the rest of the world in developing its IVHS program. Doing so might deny U.S. manufacturers the opportunity to penetrate overseas markets or to benefit from overseas technological advances A much larger, truly international market would be more attractive to manufacturers, and the increased volume would result in economic growth and lower prices at home. Agreement upon international standards and protocols, wherever possible, would help build an international market.

Efforts already under way to create a North American IVHS program are consistent with recent developments toward increased economic cooperation between the U.S., Canada, and Mexico.

Costs

IVHS will be paid for principally by the users of its products and services: Consumers, commercial users (such as the trucking industry), toll authorities, transit operators, and the like. As in the case of the highways themselves, government infrastructure spending will be the foundation for growth.

The development costs for IVHS will be largely paid for by the private sector in its quest to develop products for what promises to be a very large market. In addition to infrastructure spending, federal government support will be needed to back long range R&D, academic research, and essential activities that cannot be self-sufficient, such as the legal and institutional implications of IVHS. The public sector will also purchase advanced electronic equipment to improve the performance of transit vehicles, with support provided by the Federal Transit Administration.

IVHS Development (R&D and Testing) Costs-Next 20 Years

- Development requires public lead
- 85% private sector
- 15% public sector

Market uncertainties, rapidly changing costs for evolving technologies, and other demands for development capital make it difficult to predict the program costs, especially over a 20-year period. Therefore, estimates can only be provisional. As results from operational tests become available, it will be possible to predict consumer interest and total program costs more accurately.

IVHS Deployment Costs-Next 20 Years

- Deployment must be consumer led
- 80% private sector
- 20% public sector

Achieving the aims set out in this Strategic Plan is expected to require a public infrastructure investment on the order of $40 billion over the next 20 years. End-user spending for products and services over that same period could reach $170 billion or more, depending on market response. The public expenditure for IVHS may seem large, but it is small relative to expected total public transportation expenditures — less than 3 percent of the $1.6 trillion expected to be spent on ground transportation in the same period. Cost estimates for the development and deployment of IVHS are given in the following tables; detailed cost analyses are given in Chapter III and Appendix D.

DEVELOPMENT COST ESTIMATES ($ Millions)

	Near Term (5 Year)	Mid Term (5 Year	Long Term (10 year)	TOTAL
Research and Development	600	900	600	2,100
Operational Testing	1,200	1,200	1,500	3,900
TOTAL	1,800	2,100	2,100	6,000

* Proprietary development costs not included.

DEPLOYMENT COST ESTIMATES ($ Millions)

Sector	Near Term (5 year)	Mid Term (5 year)	Long Term (10 year)	**TOTAL**
Public	2,000	8,000	29,000	39,000
Private	5,000	26,000	139,000	**170,000**
TOTAL	7,000	34,000	168,000	209,000

Near-Term Actions

Chapter III of this plan, the "Course of Action" details a wide-ranging set of tasks that constitute the IVHS Strategic Plan. Distilled from Chapter III and listed below are key actions to be accomplished in the near-term that will provide a vital impetus to the program and ensure its success.

From R&D Through Deployment

- Provide consistent, dedicated public funding

  A dependable source of funds is essential for effective planning within DOT, as well as for administration and support of activities initiated by federal and state departments of transportation. Furthermore, consistent, predictable public funding can stimulate larger private sector investments. Funding should come from federal, state, and local governments.

- Provide resources for research and development

  Although no major scientific breakthroughs are required to accomplish stated goals, substantial R&D and operational testing are needed to develop practical systems and demonstrate their safety, effectiveness, and marketability. Resources will be needed from all IVHS participants.

- Deploy advanced transportation management centers

  Transportation management centers will contribute to the integration of traveler information services for public, private, and commercial use. A variety of public and private arrangements can be used to create and operate these centers.

- Test and deploy key services and applications, including:

  - Traveler information provided in the home, at the workplace, and at convenient public locations
  - In-vehicle safety systems
  - In-vehicle route guidance systems.

  IVHS will be accepted through the development and availability of products and services useful to the consumer. The private sector should take the initiative in devising, testing, and bringing products to market. Public and private cooperation will be needed to make systems a reality.

- Conduct operational tests for vehicle fleet operations

  Priority should be given to products and systems that promote increased productivity and safer and more effective vehicle fleet operations. All IVHS developers and users will benefit from early testing and implementation of technologies. These operational tests will be achieved through partnerships of state authorities, DOT, and fleet operators.

Integration

- Create well-defined procedures for operational tests and establish test sites

  Guidelines must be established for selecting technologies to be tested, for experimental designs and for evaluation of test results and quantification of benefits. DOT should play a primary role in establishing these guidelines, with major contributions from IVHS AMERICA's technical committees.

  Specially selected sites should be identified for operational testing of alternative technologies in multi-modal applications. This can be done using medium- and long-term test projects, instrumenting test beds, and establishing a small number of shared operational test facilities.

- Develop a system architecture

  Effective integration of the various components of IVHS requires a system architecture — its design will take time and must draw from multiple disciplines. It must be an open architecture, able to accommodate different system implementations in diverse settings. The architecture should be developed largely by the private sector and academia, with requirements from the public sector, and with primary funding from DOT.

- Promote standards and protocols

  Standards and protocols play an important part in product development and in ensuring compatibility among systems. Existing organizations should be relied upon in this standards-setting effort. Existing standards should be adopted or adapted wherever possible. IVHS AMERICA should take a proactive role in defining needs and fostering the overall process.

- Define RF spectrum needs and get appropriate allocation

  Many current and proposed tests and several major applications and architectures employ radio frequency (RF) communications. RF spectrum matters often involve extensive analysis as well as political negotiation. IVHS AMERICA should coordinate efforts to define requirements and work with DOT and private industry to seek appropriate RF spectrum allocation from the FCC. Coordination with Canada and Mexico is needed for continent-wide spectrum allocation for IVHS.

Organizational Program

- Address key institutional issues.

Challenges to the success of IVHS involve important institutional issues. Development of effective public/private partnerships is essential. Establishing IVHS AMERICA was a key step. Institutional arrangements should be developed for combining public and private resources in joint programs.

Cooperation among state and local jurisdictions in the implementation and deployment of IVHS facilities is also of prime importance.

- Seek resolution of key legal issues and procurement procedures

Several legal issues present important challenges to the success of IVHS. Special effort should be initiated now to address two of these, tort liability and privacy issues. DOT should commission studies in these areas and the IVHS AMERICA Legal Issues Committee should continue to address them.

Government agencies should recognize the significant costs and complications for the private sector in doing business with the federal government. Changes to procurement procedures are needed to avoid undue restraint on development.

- Pursue international cooperation

Representatives from all sectors should engage in discussions and exchange of information with international IVHS groups concerning standards, research and development, and testing. The private sector should give consideration to participating in international consortia for the development of IVHS technologies. IVHS AMERICA should continue to foster a global perspective — sharing information and seeking members from around the world.

Education and Training

- Establish university-based IVHS research and education centers

Centers for IVHS research and education should be established in the academic community. Substantial funding should come from the federal government, with monetary and in-kind contributions from state and local governments and industry.

- Develop the human resources needed to support IVHS

New skills are required for the deployment, operation, and maintenance of IVHS facilities. State departments of transportation and local bureaus of public works will need to provide appropriate training of existing personnel and seek different kinds of professionals.

- Inform the public about progress

  It is important that the public and those responsible for and concerned with IVHS be kept fully informed about its development. IVHS AMERICA, through its publications, clearinghouse, and media relations, should report on the progress of the IVHS program.

Planning

- Update the Strategic Plan and provide advice to DOT

  Significant effort in the development of IVHS is taking place and progress is rapid. IVHS AMERICA should institute a mechanism to update the Strategic Plan annually to incorporate the results of IVHS activity as well as the knowledge gained from continuing R&D, operational tests, and deployment.

- Make tactical plan recommendations to DOT

  Annual program planning advice should be provided to the DOT to meet federal budgeting requirements for the next two federal fiscal years.

II. STRATEGIC ASSESSMENT

Introduction

A program of Intelligent Vehicle-Highway Systems (IVHS) — the application of advanced technology to improve the operation of our highway and public transportation systems — is building momentum in the U.S. and abroad. Working through an informal organization known as Mobility 2000, transportation professionals from the public and private sectors and academia in the U.S. worked together for four years to develop a national vision for IVHS, completing the work in March 1990. Building on these efforts, a more formal organization, the Intelligent Vehicle Highway Society of America (IVHS AMERICA) was incorporated in August 1990. IVHS AMERICA is a utilized Federal Advisory Committee to the U.S. Department of Transportation (DOT) and is the organizational framework for cooperation and consensus-building for a national IVHS program. It spans the entire IVHS community, including a broad spectrum of about 400 members in the private sector, the public sector, and academia.

DOT asked IVHS AMERICA to draw on its membership to develop a Strategic Plan for IVHS in the United States and set it in an international context. This document is that Strategic Plan. Written by the Strategic Planning Subcommittee of IVHS AMERICA, it can fairly be called a consensus of the IVHS community in the U.S.

"The Strategic Plan is a guide for future action."

The Strategic Plan is intended to be a guide for the eventual widespread deployment of IVHS around the nation, leading to safety improvements, amelioration of congestion, reduced environmental impact, more efficient energy use, and enhanced national productivity. The plan is composed of three major chapters: the preceding chapter, an executive summary; this chapter, a strategic assessment; and a concluding chapter, a course of action.

This chapter, a high-level strategic assessment of IVHS in the United States, contains:

- A vision for IVHS, including the benefits of IVHS deployment
- The ***mission*** that must be undertaken by the IVHS community to form the necessary public/private/academic partnerships to develop IVHS
- A description of the social and technological ***setting*** in the U.S. and abroad, in which needs are identified and ongoing IVHS activities are described
- An analysis of the ***opportunities*** and ***challenges*** which face the U.S. in deploying IVHS, including technical and institutional strengths to exploit and weaknesses to overcome
- A discussion of the ***goals*** and ***objectives*** for a national IVHS program

Chapter III of this Strategic Plan outlines a course of action for implementing the IVHS program. It addresses the technical, organizational, institutional, and cost questions and provides a basis for moving forward promptly and with direction.

IVHS is a dynamically evolving combination of disciplines and technologies. The intention of the Strategic Plan is to be dynamic as well, with regular revisions to reflect the evolving state of the field.

IVHS is not a distant vision. All of the technologies needed are available now or are achievable through research and development. No major scientific breakthroughs are required. The question lies in deciding how IVHS should be delivered through products and services from government and industry — that is what this Strategic Plan is about.

Vision

Transportation is a fundamental element of our society "

In the U.S., the transportation system has shaped our society. How we live — the way we raise our families, the way we work and play — all are conditioned on mobility. We build our cities, choose our jobs, and buy our houses based on the premise that the transportation system provides accessibility. We go where we want to, when we want to; our lives and destinations are in our own hands.

But that does not tell the whole story. The image of individual choice overlooks the collective infrastructure that has grown up around the transportation user to facilitate mobility and minimize its fiscal and human costs. And especially in recent years, our ability to travel freely in some areas has become constrained by congestion, the cost of highway travel, and by financial problems that hamper the services offered by public transportation.

Surface transportation has evolved over the past century — the rudimentary road network gave way to networks of city streets and improved crosstown and inter-city roads. Through and between the cities, the Interstate Highway System grew to provide fast, safe long-haul mobility both for goods and people. Public transportation systems have evolved from horse-drawn operations to accessible, multi-faceted systems built around advanced technology.

But now transportation is at a crossroads. Despite soundly engineered roadways carrying vehicles that have never been better built, mobility is declining and safety is at risk. Many roads are clogged and, particularly in urban areas, building additional roads is difficult and costly. The suburbs have spread about as far as they can for tolerable commuting and, as the roads continue to congest, the commute is becoming less tolerable. Although highway safety is improving, loss of life and limb on the road remains a drain on the national spirit and purse. Air quality is a serious national issue, in significant measure because of automobiles and trucks. Public transit, which should be a relief and a welcome alternative, is too often viewed as an unattractive alternative to driving. Commercial vehicles, on which the movement of so much of our goods depends, spend significant time not rolling, but standing in line to be weighed, pay tolls, and handle administrative paperwork; many spend a good deal of their time out of touch with their home bases. In addition, mobility and safety still depend on vehicles that are manually controlled and on decisions by individual drivers, working mainly through experience, with little guidance from advanced technology.

Thus, we stand at a decision point. While construction of highways and public transportation systems is needed and will continue, this will not be enough to meet our nation's future requirements — we need to do more. The federal/state/local partnerships developed during the construction of the Interstate System and during capital improvements for urban transit, along with the complementary relationship between public and private investment in our current transportation system, can be the basis for additional programs to address the transportation issues of the 21st century.

"Our society is information- and communications-intensive."

The introduction of innovative construction and manufacturing technologies in the early part of this century made the current transportation system possible. We now need a new round of technological innovation appropriate to the transportation issues of today. And the time is ripe, for in parallel with its development as a mobility-intensive society, the U.S. has also evolved as an information- and communications-intensive society.

The current generation has seen an explosion in the pervasiveness, speed, and power of computers. No one imagined the arrival of computers on every desk, in every pocket — or under every hood. Modest personal computing power used to be available to only a few and cost as much as a medium-priced car. Now enormous personal computing power is available for the cost of a medium-priced sound system.

At the same time, a parallel explosion has occurred in personal and business communications. Cellular telephones, nationwide satellite networks, low cost sensors, and fiber optic links to home and office have profoundly changed the way we work and live.

These technologies have provided the basis for our evolution into an information and communications-based society. They enable the U.S. mobility revolution by combining with conventional transportation infrastructure to form Intelligent Vehicle-Highway Systems — IVHS. This is the transportation/information infrastructure — a new addition to surface transportation.'

IVHS is a paradigm shift — the transportation/ information infrastructure. "

IVHS is, in fact, a paradigm shift. The transportation/information infrastructure is a new way of looking at, thinking about, and improving mobility — a sociological as well as a technological revolution. The shift is ongoing in air and rail transportation. That paradigm shift is needed in highway and public transportation as well.

The transportation/information infrastructure creates a new range of important improvements by providing information and control assistance to the traveler through in-vehicle and hand-held devices, by providing the ability to coordinate transportation operations in metropolitan areas, and by providing travel choices and aid in selecting the best trip for a particular traveler. It transforms individual mobility into an integrated, cooperating system.[2]

IVHS is already demonstrating its potential, helping keep commercial and transit fleets operating smoothly and efficiently. Traffic control systems have begun to reduce vehicle delay and effectively manage incidents. IVHS has begun to interconnect formerly independent traffic management jurisdictions and transit dispatch centers. New systems are already collecting tolls electronically. Figure 11-l shows some of the components of IVHS.

This is just a beginning. In the upcoming decade, we can expect to see the following:

- Traffic information and communication systems that advise drivers about current and expected traffic conditions, road hazards, weather expectations, today's recreational attractions, and where to find parking

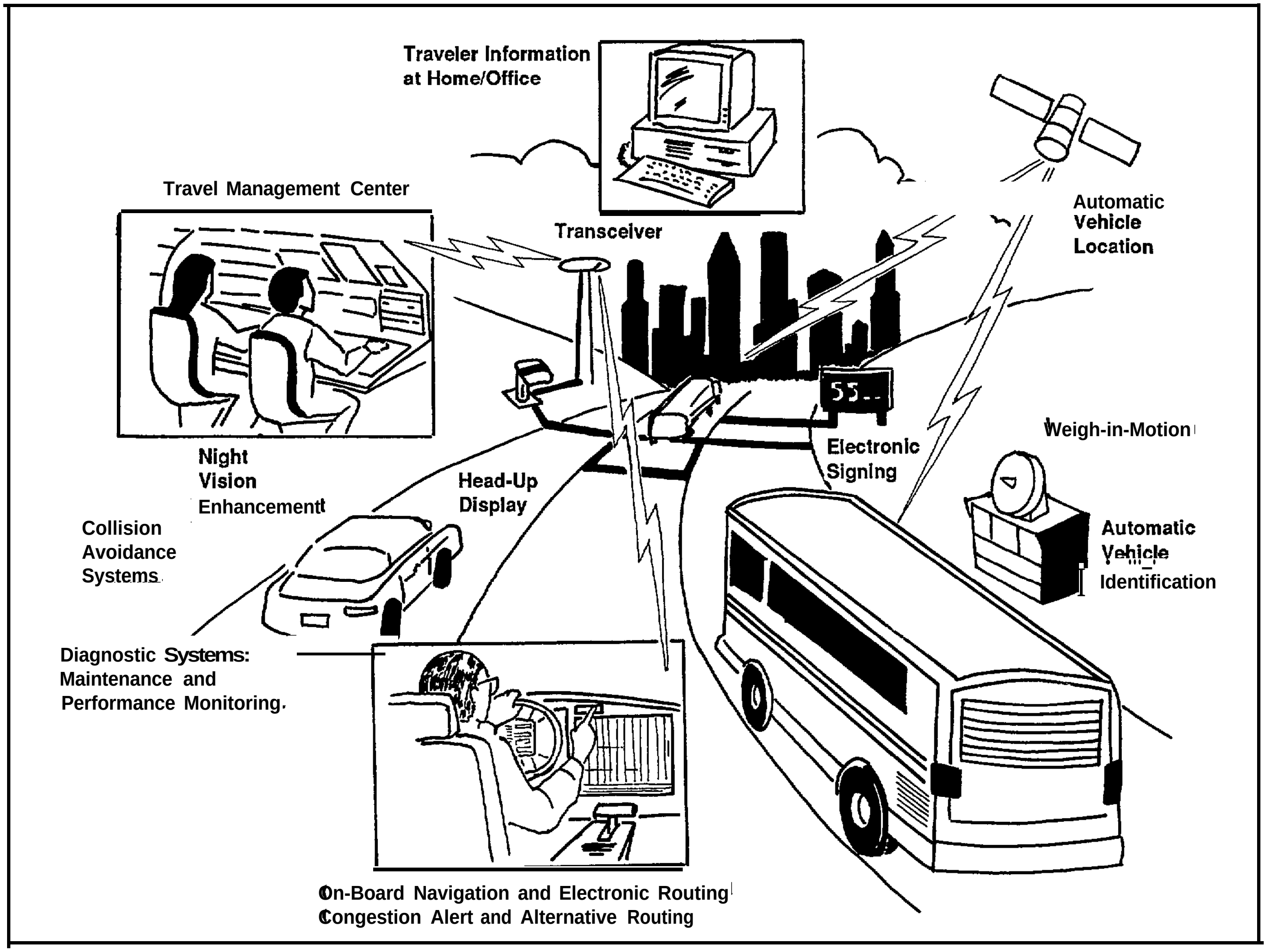


Figure 11-l. Some components of an Intelligent Vehicle-Highway System (Adapted from U.S. Department of Transportation National Transportation Strategic Planning Study, March 1990).

- Transportation management systems that flexibly adjust lane usage, speed limits, traffic signals, and roadway access based on actual traffic conditions
- On-board electronics in vehicles to help drivers plan and follow safe, efficient driving routes
- Improved access to information on the availability, schedules, and proximity of public transportation
- Additional capabilities allowing commercial fleet and transit operators to track their vehicles and communicate with their drivers in order to offer new flexible demand-responsive services

- First demonstration of automated vehicle/highway control systems
- New interactions between roadway jurisdictions and vehicles that will allow all tolls to be collected, trucks to be weighed, truck permits to be issued, and cargos to be checked, largely without requiring vehicles to stop
- Improved instrumentation that will increase safety by informing drivers that they are getting too close to another vehicle or that objects are in their path, by enhancing their ability to operate their vehicles at night or in bad weather and receive information from the roadside, and by automatically signaling for help in an emergency

Initially, many of these systems and approaches will be experimental and exploratory. Many of the implementations will be local or regional. There is still much to learn about how traffic works and how people react. As our base of knowledge and technology grows, as we find out what works best, what the market will support, and what prudent management demands, the systems will expand and mature, taking on a national character.

"We envision, during the next 20 years, the implementation of a national IVHS program."

We envision, during the next 20 years, the implementation of a national IVHS program, comparable in scope to the Interstate Highway System, with major participation of the private and public sectors. The primary focus of such a program is a balanced transportation system which includes the following:

- A national system of travel-support technology, operating consistently from vehicle to vehicle and from state to state to promote safe, expeditious, and economic movement of goods and people
- A new level of cooperation between the public and private sectors to deliver the systems and create the infrastructure that will implement a mobility revolution
- A vigorous U.S. IVHS industry supplying both domestic and international needs
- An attractive, efficient public transportation system that complements and interacts smoothly with improved highway operations

IVHS deployment will improve highway safety, relieve congestion, and curtail environmental impact. Benefits will be broadly distributed. Urban and rural travelers will benefit. People traveling to work and for leisure will benefit. The auto-traveling public and users of public transportation will benefit. Transit and commercial operators will benefit. Elderly and disabled travelers will benefit. Regional and national productivity gains will be achieved and economic growth will be stimulated. The nation as a whole will benefit from development of an IVHS industry. In Figure 11-2, some of the benefits are shown along with those who will be affected.

Illustrative Beneficiaries of IVHS

Society as a whole	Commuters Shoppers Public transportation users Tourists
sector Operators	Trucking companies Bus companies Taxis Small package delivery Emergency services
Industry	Automotive manufacturers Electronics manufacturers Traffic system suppliers Researchers
Public Sector Operators	State DOT's Traffic departments Transit agencies

Illustrative Benefits of IVHS

Travel	Decreased travel time Increased safety Increased comfort and convenience Increased security Decreased cost
Economic	Increased productivity and reliability Improved international competitiveness Product innovation On-time delivery
Environmental	Decreased air pollution Decreased noise pollution Increased fuel savings
Infcrmetion	Increased trip efficiency More uniform and effective traffic enforcement Improved trip planning Improved emergency response

Figure 11-2[3]

With such changes in the transportation system, a comprehensive enumeration of benefits and societal impacts is impossible — simply put, we cannot predict all that will occur. Just as the benefits and societal impacts of the Interstate System were underestimated both in magnitude and in kind, we cannot foresee all that a newly structured transportation system will lead to. Clearly, however, the transportation/ information infrastructure will enable a superior transportation system for the 21st century.

Mission

The mission of the IVHS community in the U.S. — composed of all levels of government; the automotive, electronic, communications, and information industries; and academia — is first, to improve surface transportation by deploying IVHS technology broadly throughout the nation and, in cooperation with Mexico and Canada, throughout North America, and second, to develop a U.S.-based IVHS industry to provide technology in the U.S. and abroad. We must start immediately to deploy available technology and to work toward increasingly advanced IVHS systems over the next several decades.

Deployment of IVHS calls for substantial investment in infrastructure and in research and development to bring products to the marketplace. It also requires new forms of public/private/academic partnerships for the development and deployment of new technology. Neither the public nor the private sector can do the job itself; individual companies and individual government jurisdictions cannot do it alone. IVHS requires new and constructive ways for organizations to work together to advance their mutual interests. The U.S. traditions of pluralism, autonomy of the private sector, and decentralized decision-making will govern these new relationships.

The challenge lies in the diversity of IVHS. The technology is interdisciplinary, involving mechanics, electronics, data processing, physics, telecommunications, and psychology. The public arena is similarly diverse, touching all levels of government in thousands of separate but interlocking jurisdictions, not only across the U.S. but across North America. The legal obstacles, including the risk of liability in deploying significant new technology, and privacy implications must be addressed. Many participants in IVHS are in competition for resources and customers; many have objectives and constituencies that are in conflict.

"The Strategic Plan provides the framework for concerted action."

If IVHS is to succeed, concerted action must proceed from this diversity — a coherent national program of technical exploration and operational tests leading to deployment on a continental scale. Research must be planned, executed, and coordinated. Institutional and legal barriers must be addressed and mitigated. Substantial funding from both public and private sources must be found in order to move ahead.

This Strategic Plan provides the framework for such concerted action.

Setting

This section considers the environment in which IVHS will be developed and deployed. First, the needs addressed by IVHS are described, after which ongoing IVHS activities, in the U.S. and abroad, are discussed.

Needs

The U.S. faces a number of critical issues that IVHS deployment can address. IVHS is an idea which has the potential to improve our quality of life. Consider the dimensions of the issues the nation faces, and how IVHS can address these needs:[4]

SAFETY

"In 1991, 41,000 people died on U.S. Highways."

Safety on our nation's highways is an important public health problem. In 1991, the U.S. paid the extraordinary costs of 41,000 deaths and 5,000,000 injuries on our highways. Traffic accidents cost the country an estimated $70 billion in lost wages and other direct costs annually.[5] The economic loss from traffic crashes is 2% of the U.S. gross national product. It amounts to $.05 per vehicle-mile traveled or $600 per year per motor vehicle.

The public's concern has been manifested politically in many geographic areas by seat belt, helmet, and tough drunk driving laws, and in the marketplace by the increased market penetration of such equipment as air bags and anti-lock brakes. Design standards for highways also reflect this emphasis, and indeed, "over the past decade, highway fatality rates continued to decline in both rural and urban areas."[6]

However, safety is a continuing problem on the nation's highways. The number of deaths related to highway accidents still far exceeds that of any other mode of transportation. Efforts to reduce crashes and their consequences routinely focus on establishing the causes or contributing factors of these crashes, or both. The relative contributions of human, vehicle, and highway/environmental factors have been compared in a number of studies that have consistently shown human error to be the leading causal or contributory agent. In one study, 93% of the time human errors were determined to be a definite or probable cause or a severity-increasing factor.[7]

By the year 2020, the number of drivers over age 65 will have increased substantially. This population's special requirements, resulting from reduced visual acuity, particularly at night, as well as hearing loss and increased reaction time, must be met to provide for their mobility needs.

Rural accidents are of special concern, since 57% of fatal accidents occur in rural areas where collision speeds are likely to be higher; night driving is a particular concern.

"IVHS technology can help improve highway safety."

IVHS technology can help improve highway safety by assisting the driver and by performing some functions better than he or she can, thus reducing accidents due to human error. Devices such as proximity sensors can warn drivers of impending collisions or that they are coming too close to the edge of the highway. In-vehicle displays, on which roadway signs are shown, can help drivers with reduced vision, as can infrared sensing equipment, particularly for night driving and fog conditions. IVHS can redirect drivers away from existing accidents, reducing secondary accidents at those sites. A variety of in-vehicle devices to make trucks safer are also under development.

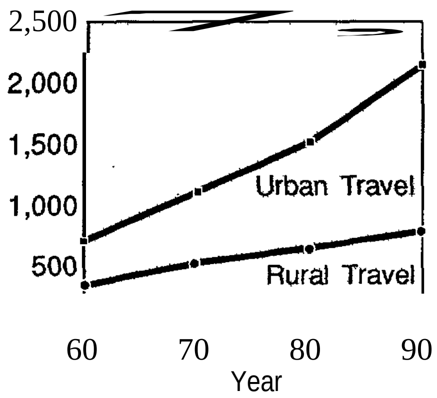
CONGESTION

The nation's highways are faced with very high levels of congestion. Congestion has become a national issue, with cover stories in national magazines highlighting "gridlock" as a major public policy issue for the 1990s. Projected traffic growth, coupled with the difficulty of providing adequate additional lanes for new capacity, suggests that congestion will continue to be a major issue in many metropolitan areas.

"Congestion has become a national issue."

More and more, we are recognizing the economic impact of this congestion: decreased productivity, lost wages, and direct costs. The loss of national productivity due to congestion is estimated at $100 billion annually.*

Annual Vehicle Miles



Data Source: FHWA

In 1989, travel reached 2.11 trillion vehicle miles — an annual increase of 4.17% since 1983. Of this travel, 60% occurred in urban areas which had a 4.82% annual growth rate. Between 1985 and 1989, combination truck travel grew at an annual rate of 4.68%. Travel grew at a faster rate than capacity. While the overall number of vehicle miles traveled between 1960 and 1987 increased 3.7% per year, or about 168%, the number of new highway miles increased by only 9%. Forecasts project that travel demand on the highway system will continue to increase. By the year 2020, vehicle miles of travel are expected to almost double to 3.8 trillion. The number of new highway miles constructed will continue to be outpaced by demand increases.

From the highway passenger's viewpoint, traffic delays are substantial and growing. Rush hour conditions in many metropolitan areas often extend throughout the day. The percent of peak hour travel on urban interstates that occurred under congested conditions reached 70% in 1989, up from 41% in 1975 (see Figure 11-3). Urban freeway delay is now 2 billion vehicle hours per year, about 65% of this due to non-recurring incidents. Significant increases in congestion can be expected — one study predicts increases in urban freeway travel of approximately 50 percent by 2005, and increases in delays of 400 percent or more if improvements are not made to the current transportation system.

"Speed and reliability of freight movement is increasingly important."

As the trend to globalization of the economy accelerates, our domestic industry will compete increasingly with international companies. Inefficiencies in our domestic transportation system hurt U.S. industry in this competition. The importance of congestion will likewise increase as trends toward Just-In-Time (JIT) inventory systems increase. Speed and reliability of freight movement will become increasingly important as the production of high value commodities grows.

Congestion is not simply an urban issue. In rural areas, traffic is disrupted by incidents, accidents, construction and maintenance operations and associated detours, congestion on tourist routes, and other causes.

"IVHS can reduce congestion."

IVHS can reduce congestion. Through area-wide traffic management, IVHS can make efficient use of existing facilities by routing traffic selectively and efficiently. Rapid detection and clearing of accidents and incidents will reduce congestion — so will accident prevention itself. Enhanced public transportation systems can divert highway

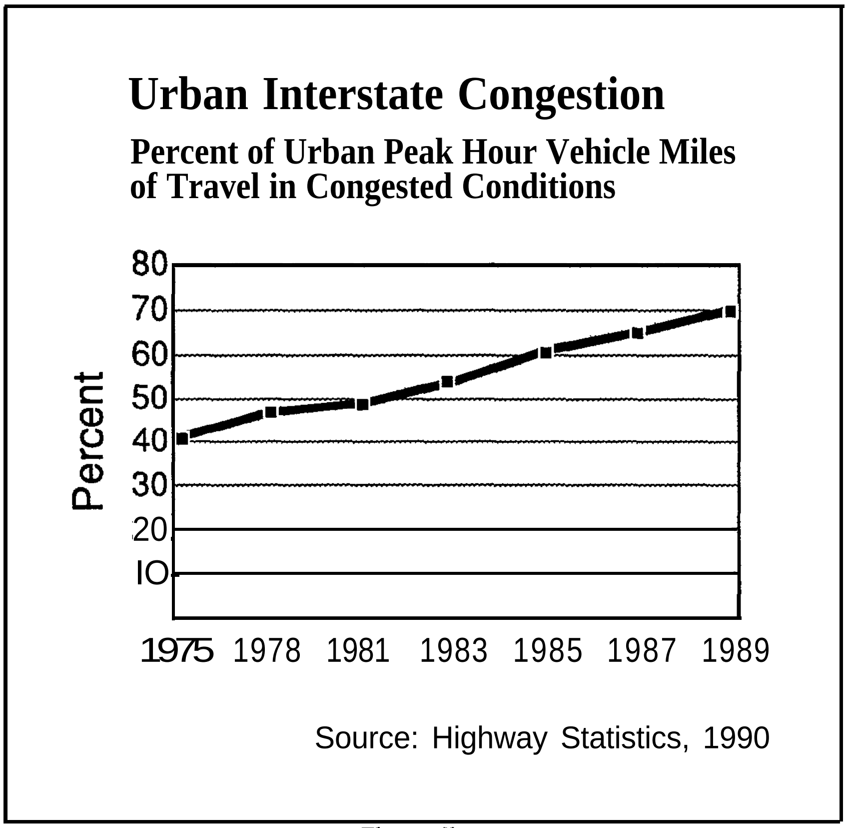


Figure II-3.

traffic. Accurate information on traffic conditions will result in travelers planning intermodal trips and choosing modes of transportation or departure times to avoid congestion. Substantial capacity increases can be realized with the eventual availability of automated highways.

As demand for highway transportation grows over time, IVHS can help to accommodate more traffic without corresponding increases in congestion, an economic benefit in itself. By making transportation more efficient, IVHS can promote new travel and land use patterns (with enhanced land use values) in urban, suburban, and rural areas.

Furthermore, IVHS enables rapid implementation of congestion pricing as a demand management mechanism, if public policy deems this to be an appropriate strategy. For example, automated toll collection, in addition to reducing congestion around tollbooths, can facilitate the use of congestion pricing measures.

Congestion pricing has long been discussed by economists and transportation specialists as a policy tool, but implementation of this concept is non-existent in the U.S. and rare abroad. A "Congestion Pricing Pilot Program" is included in the Intermodal Surface Transportation Efficiency Act of 1991, so the concept may well become more implementable in circumstances where it is needed. IVHS provides the capability to do this. However, IVHS, in and of itself, does not imply the implementation of congestion pricing.

ENVIRONMENT

Air quality, particularly in designated urban areas, is an important concern. A U.S. Environmental Protection Agency report! states that emissions from transportation sources accounted for 43% of total U.S. emissions of nitrogen oxides, 31% of hydrocarbons, and 66% of carbon monoxide. Urban area contributions are much worse. In Los Angeles, mobile sources account for 59% of the nitrogen oxides, 46% of the hydrocarbons, and 87% of the carbon monoxide. Currently, approximately one-half of the nation lives in areas exceeding the smog standard and one-third lives in areas exceeding the carbon monoxide standard.

"One ha/f of the nation lives in areas exceeding the among standard."

Environmental quality is of increasing concern as evidenced by the recent Clean Air Act Amendments (CAAA) and by actions taken by many states in setting high air quality standards. The CAAA list specific transportation related requirements.[6] Transportation systems for the future will continue to take environmental issues into account.

IVHS can be part of the solution to these environmental problems. Smoother traffic flow resulting from improvements in congestion, improved route selection resulting from information to drivers, and diversions to public transportation can reduce environmental impacts.

ENERGY

"Transportation is a major consumer of energy, accounting for 27% of U.S. energy consumption and 63% of petroleum consumption in 1989. Both of these relationships are projected to remain relatively stable through 2010."[10] The highway mode dominates the energy picture — in 1988, 73% of the transportation sector's consumption of petroleum was highway-based."

The use of oil for transportation purposes has major national and international implications. Nationally, mere are environmental concerns with the development of new sources of oil. There is also concern about the United States' continued dependence on foreign oil, and its attendant foreign policy and national security implications.

It is estimated that two billion gallons of fuel are wasted annually due to congestion. IVHS can help reduce wasted fuel by reducing congestion. As noted above under "Environment," optimal routing and diversion to enhanced public transportation systems can help as well.

MOBILITY AND ACCESSIBILITY

In recent years, the concept of universal mobility and accessibility to highway and public transportation has gained acceptance. Accessible, innovative, and comprehensive transportation are critical factors in determining the quality of life for the elderly, the disabled, and the economically disadvantaged. As noted earlier, the elderly segment of U.S. society is growing. Moreover, some eight million disabled persons are mobility impaired.

The Americans with Disabilities Act, passed in 1990, establishes mobility as a significant right for a broad set of our population and touches virtually every federally sponsored or supported program. There is renewed emphasis on making our transportation system accessible and safe for all segments of society.

'IVHS can help to make transportation more accessible and safe for all segments of society."

Here, too, IVHS can help. The elderly driver will benefit from vision enhancement at night and in bad weather. Better public transportation service will benefit a broad spectrum of the population. Car- and van-pools and other special transportation services, for example, services for disabled people, can operate more effectively.

PUBLIC TRANSPORTATION

Nine billion trips annually are taken on public transportation systems, ranging from large metropolitan systems to small fleets serving rural areas. While public transportation is an important factor in many urban areas, nationally it looms less large. Only 5% of work trips are carried by public transportation? The development of the U.S. highway system and changes in population distribution have diminished the role of mass transportation, which has been steadily losing market share since World War II. Financial problems have been a fact of life for public transportation for some time.

Public transportation can play an important role in addressing the problems discussed earlier, provided user acceptance can be increased and operating costs can be lowered. Studies have shown that public transportation use would increase if it was perceived as more reliable and more predictable.

IVHS can improve public transportation. '

IVHS can improve public transportation operations and make it a more viable option. Fleet management for buses can greatly improve service and reduce costs. Providing accurate information to travelers, in the home and en route, can enhance ridership and revenues. IVHS can expedite the operation of high occupancy vehicle lanes and, as noted above, can improve car- and van-pool services. New service concepts will develop around IVHS technologies, improving mobility and attracting single occupant auto users. IVHS will help in intermodal trip planning through improved scheduling and interchange information, allowing efficient interchange with commuter rail, light rail, people-movers, AMTRAK, and other modes.

NEEDS SUMMARY

All of the above needs are important for the U.S., and IVHS can address each of them. All are related to the fundamental issue of economic productivity and the requirement that the U.S. improve on this critical dimension. This Strategic Plan describes how, through a program of research and development, operational tests, and deployment, IVHS will lead to improvements in all of these areas.

Ongoing IVHS Activities

This section summarizes IVHS activities taking place in the U.S. and abroad. The descriptions are brief, as the footnotes provide references for further information, and Chapter III fully describes the roles and responsibilities of many of the organizations introduced here.

U.S.ACTIVITIES

Recent History

While start-up IVHS activities in the U.S. have been ongoing in some form for years, IVHS has only coalesced into a broad-based national initiative over the past four to five years. Beginning in 1987, a group of transportation professionals from the public and private sectors and the academic community met to develop the outline of a national program of IVHS. Called Mobility 2000, this group's work was effective in developing a program and culminated in two major workshops hosted by the Texas Department of Transportation and the Texas Transportation Institute, in San Antonio in 1989 and in Dallas in 1990. Those workshops produced proceedings"[11 12] that outlined an initial national vision for IVHS. The Dallas workshop proceedings included a program plan describing program milestones, research and development needs, operational tests, program investment requirements, and organization, as well as a description of technical issues. This Strategic Plan draws heavily on that seminal document.

"IVHS has coalesced into a national initia five during the past four to five years."

IVHS AMERICA

Building on Mobility 2000's efforts, IVHS AMERICA was conceived by the IVHS community at the IVHS National Leadership Conference in Orlando in May, 1990 and was incorporated in August, 1990 as a non-profit 501(c)(3) organization. It is a framework within which all interested organizations can participate. IVHS AMERICA was created to accelerate deployment of IVHS and to make it more orderly and unified. It is a utilized Federal Advisory Committee for the U.S. DOT and, as part of this responsibility, has been charged by U.S. DOT with coordinating development of this Strategic Plan. To develop this plan, IVHS AMERICA drew on the IVHS community through its 14 committees and subcommittees.

"The IVHS community is an important concept."

The concept of an "IVHS community" is an important one. While many organizations in the public and private sector are working to develop their own IVHS programs, it is also fair to say that a consensual IVHS community is developing, which aims toward an integrated national program for IVHS. This community has recognized the IVHS activities abroad, has seen the need for a program, and has worked in close cooperation to establish a national framework for IVHS, using IVHS AMERICA as the mechanism.

The Private Sector

The U.S. private sector is active in IVHS, with a number of products already on the market. These include various mapping systems for in-vehicle routing and guidance, Electronic Toll and Traffic Management hardware and software, and other devices. While the current market is in its early stages, companies in the automotive, electronics, communications, computer, and navigation industries anticipate robust growth in the market for hardware, software, and services in support of IVHS and are performing research and development to develop these markets. The range of anticipated products includes in-vehicle equipment, support of various traveler information systems, infrastructure-related hardware for traffic measurement, routing aids for drivers, safety warning and perceptual enhancement systems, and software for transportation network management.

"IVHS is a market opportunity for the private sector, and U.S. industry is pursuing that market."

Clearly, the private sector is more than just an equipment supplier. Operation and maintenance of IVHS services and systems present another market. The private sector is moving forward in this area. Their active participation can help assure the availability of cost-effective IVHS services.

Over 200 industry firms are currently members of IVHS AMERICA. They range from very large automobile manufacturers and communication companies to rather small, specialized hardware and software organizations. Roles clearly exist for firms of all sizes as the IVHS enterprise goes forward. The program will require both the capital resources of the large firms and the flexibility inherent in smaller organizations. Doubtless, many joint ventures will arise.

Actions of the private sector are central to the success of IVHS. Estimates suggest that approximately 80% of IVHS investments will come from the private sector. A consumer market must develop for IVHS equipment if private sector participation is to be viable. How will the consumer react to spending upward of $1000 for in-vehicle equipment? Will the consumer see the safety and travel benefits as justifying these costs? Will the consumer prefer IVHS to other options on the automobile? Will the deployment of infrastructure, greatly enhancing the effectiveness of in-vehicle equipment, take place in a timely fashion? As technology becomes more cost-effective and benefits become more dramatic, the consumer should respond favorably to IVHS.

The private sector must control the resources it expends. However, such expenditures are most likely to be made if there is an IVHS marketplace where products can be marketed nationally — and internationally — based on consistent standards. The challenge of IVHS is to construct an environment which provides freedom of action for all stakeholders but has a coherent structure, leading to the need for such standards.

The Public Sector

At the national level, DOT provides focus for IVHS activities and is actively expanding its program. The lead agency for IVHS within DOT is the FHWA, which has developed a management structure for the effective coordination of IVHS. Other participants within DOT are the National Highway Traffic Safety Administration, the Federal Transit Administration, the Office of the Secretary of Transportation, and the Research and Special Programs Administration, with potential future involvement of the Federal Aviation Administration and the Federal Railroad Administration. An overall group to coordinate IVHS activities within DOT is in place (see Figure H-4).

National Transportation Policy

Themes
- Maintain and expand the nation's transportation system
- Foster a sound financial base for transportation
- Keep the transportation industry strong and competitive
- Ensure that the transportation system supports public salety and national security
- Protect the environment and quality of life
- Advance U.S. transportation technology and expertise for the 21st century

DOT sees IVHS as an essential part of its mission. In February 1990, DOT published its national transportation policy.[13] Many of the goals of this policy are congruent with those of IVHS, particularly those dealing with new technology development in support of transportation improvements. Indeed, IVHS was highlighted in the policy statement.[14] DOT has worked closely with IVHS AMERICA and is represented on all of IVHS AMERICA's committees.

At the state and local levels of government, IVHS activity is ongoing and building. Twenty-one state departments of transportation have already joined IVHS AMERICA. The state and local levels are where the action will be in the deployment of IVHS infrastructure. Coordination among local jurisdictions, particularly in metropolitan areas, will be important in implementing area-wide IVHS programs. Around the nation, such cooperative ventures have already begun.

"Without the active participation and resources of state and local government, IVHS cannot be deployed."

To highlight the importance of state and local government, Table 11-l notes a number of IVHS projects and operational tests. Every one of these includes strong participation by states, cities, and other local government organizations. Without their active participation and their resources, IVHS cannot be deployed. State and local government will have responsibility for operating IVHS infrastructure. They will have a number of roles in IVHS research, development, operational testing, and deployment. They will recruit and train professionals who will participate in IVHS, deal with new operating procedures and data collection systems, as well as participate in system evaluation Their role is central.

Partnership between the private and public sectors is critical to the success of IVHS. A stable IVHS program is needed with government and the private sector serving as reliable partners to each other.

Academic Community

The academic community in the U.S. has been involved in IVHS from its inception. The original Mobility 2000 steering group contained several faculty members from major research universities. Currently, 17 universities are members of IVHS AMERICA.

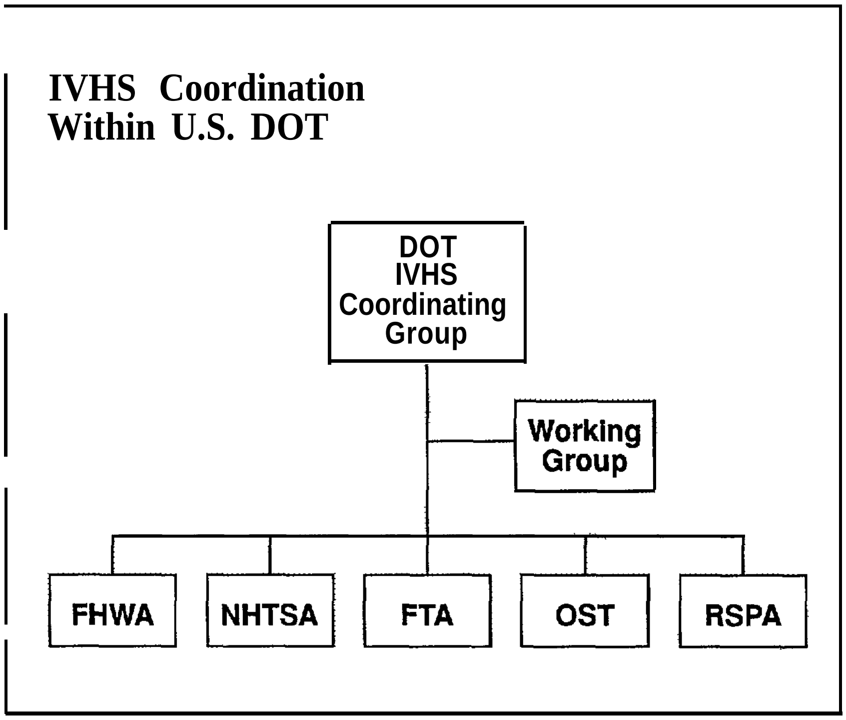


Figure 11-4.

"IVHS research and education programs are under way at U.S. universities."

The transportation academic community sees IVHS as a major opportunity to rejuvenate its mature transportation programs. Research programs in IVHS are ongoing at U.S. universities and a number of theses, papers, and research reports are in the open literature. Several universities are developing educational programs focused on IVHS at the graduate and professional levels, reflecting the needs of a new kind of transportation professional that is required for IVHS. Joint public and private sector programs with several universities are under way, as is university participation in operational tests.

Other Organizations

A number of other organizations have an interest in IVHS, in addition to those already noted. These reflect the wide diversity of benefits and beneficiaries, interests in standards, academic accreditation, and so forth. The following are included as a partial list:

- ASSOCIATIONS

  — American Association of Motor Vehicle Administrators
  — American Association of State Highway and Transportation Officials
  — American Bus Association
  — American Consulting Engineers Council
  — American Public Transit Association
  — American Public Works Association
  — American Taxicab Association
  — American Trucking Associations

- — Association of American Railroads
- — Association for Commuter Transportation
- — International Bridge, Tunnel and Turnpike Association
- — Motor Vehicle Manufacturers Association of the U.S.
- — National Association of Counties
- — National Association of County Officials
- — National Association of Regional Councils
- — National Center for Regional Mobility
- — National Conference of State Legislatures
- — National Governors' Association
- — National Grange
- — National League of Cities
- — National Private Truck Council
- — United States Conference of Mayors

■ LEARNED SOCIETIES

- — National Academies of Science and Engineering
- — National Research Council/Transportation Research Board

"Interest in IVHS in the U.S. is broad-based."

■ FEDERAL GOVERNMENT

- — Department of Transportation
- — Department of Commerce
- — Department of Justice
- — Environmental Protection Agency
- — Interstate Commerce Commission
- — National Labs
- — National Science Foundation

■ PROFESSIONAL SOCIETIES

- — American Petroleum Institute
- — American Society of Civil Engineers
- — American Society of Mechanical Engineers
- — Human Factors Society
- — Institute of Electrical and Electronics Engineers
- — Institute of Transportation Engineers
- — National Society of Professional Engineers
- — Operations Research Society of America
- — Society of Automotive Engineers

■ STANDARDS-SETTING GROUPS

- — American National Standards Institute
- — American Society for Testing and Materials
- — Institute of Electrical and Electronics Engineers
- — International Standards Organization

— Society of Automotive Engineers

- USER GROUPS

— American Association of Retired Persons
— American Automobile Association
— American Trucking Associations
— Highway Users' Federation for Safety and Mobility
— National Private Truck Council
— National Safety Council

Present Funding

There is already substantial funded activity in IVHS around the nation. The federal government has built its research and technology funding for IVHS from a modest $2 million in FY89 to $4 million in FY90 and $25 million in FY91. These funds are devoted to basic studies, operational tests, and experiments. At the state level, by way of example, California will provide $1 billion over 10 years for capital improvements for traffic management systems and $10 million per year for IVHS research and development. Numerous other state and local programs are very active as well, often in leadership roles that preceded federal involvement.

A survey in early 1990 revealed that, at that time, there were 750 people in North American industry, government agencies, and academia working full-time on IVHS-related subjects. A conservative estimate of $100,000 per person per year would suggest that the level of North American expenditures in IVHS was about $75 million, with the majority of those funds invested by private industry.

"ISTEA is a transportation watershed."

In December 1991, President Bush signed the Intermodal Surface Transportation Efficiency Act (ISTEA), a watershed in transportation in the U.S. ISTEA represents a major shift in transportation investment.

> ***An era has ended. A new era has begun.***
>
> ***For the 35-year period, 1956-1991, America's surface transportation policy was dominated by a focused national effort to complete the world's greatest public works project, the National System of Interstate and Defense Highways. With that system almost complete, it is now time to concentrate on new priorities.***[15]

One of these new priorities is IVHS.

"IVHS is an ISTEA priority."

Federal IVHS support under ISTEA will expand funding dramatically. For the six-year period beginning in 1992, $660 million has been allocated, with additional funds of $139.8 million available for FY92 from the IVHS Appropriations Bill. Funds will be allocated for the IVHS Congested Corridors program, for technical planning and operational testing assistance, and for research in both technical and non-technical areas. This funding is designed to support the goals of the long-term IVHS program.

Under ISTEA, DOT is required to submit an IVHS strategic plan to Congress by December 1992, and it is expected that this Strategic Plan, developed at DOT's request through IVHS AMERICA, will serve as the basis for the DOT submittal.

While ISTEA is a major step forward, we should not lose sight of the importance of private industry and state and local government funding for IVHS. Indeed, it is reasonable to expect that state and local governments and the private sector will respond to the federal spending by increasing funding for their programs.

A number of projects and operational tests of IVHS technologies are ongoing or imminent, funded from various public and private sources. Those are summarized in Table II-1.16 Although the list is accurate at this writing, new projects and tests are continually being announced and implemented.

Table 11-1 Current U.S. IVHS projects and operational tests.

Current U.S. IVHS Projects and Operational Tests		
Project	Participating Sponsors	Project Focus
PATH Berkerley, CA	CALTRANS University of California Ford Motor Company FHWA	Integrated traffic management and traveler information Automated freeways Roadway electrification Multimodal traveler information
GUIDESTAR Minneapolis, MN	Minnesota DOT University of Minnesota FHWA	Traffic data collection and distribution Autoscope video imaging
INFORM Long Island, NY	New York State DOT FHWA	Integrated systems Freeway management Variable message signs
TRANSCOM Northern NJ & Metropolitan NY	New York State DOT New Jersey DOT and other TRANSCOM member agencies FHWA	incident management Automated vehicle identification Vehicle probes
SMART Los Angeles, CA	Los Angeles County Transportation Commission CALTRANS California Highway Patrol City of Los Angeles FHWA	Highway advisory radio Changeable message signs Emergency response Coordinated inter-agency traffic management
FAME Seattle, WA	Washington State DOT Washington State Transportation Center FHWA	Incident management Integrated systems Ramp metering
Integrated System Project Anaheim, CA	CALTRANS City of Anaheim FHWA	Incident management Institutional coordination Traffic operation center
Incident Management & Integrated Systems Demonstration Minneapolis, St. Paul, MN	Minnesota DOT FHWA	Traffic information Incident response, Information systems Heavy truck incident management
Pathfinder Los Angeles, CA	CALTRANS General Motors FHWA	In-vehicle navigation Probe vehicles Information systems
TRAVTEK Orlando, FL	City of Orlando Florida DOT General Motors AAA FHWA	In-vehicle navigation Traveler information Motorist services Real-time traffic information Traffic probes Dynamic route guidance
ADVANCE Northwestern Suburbs of Chicago	Illinois DOT Motorola, Inc. Illinois Universities Transportation Research Consortium FHWA	Dynamic route guidance In-vehicle navigation Probe vehicles
FAST-TRAC Oakland County, Ml	Michigan DOT Siemens Automotive Ford Motor Company, Chrysler, General Motors Road Commission for Oakland County City of Troy FHWA	Dynamic route guidance and driver information system Beacon technology Advanced traffic management integrated traffic management and traveler information

Current U.S. IVHS Projects and Operational Tests		
Project	Participating Sponsors	Project Focus
I-95 Intermodal Mobility Project Philadelphia, PA	Pennsylvania DOT FHWA	Urban transportation corridor Satellite communication Freeway surveillance
Urban Congestion Alleviation Project I-95 in Northern Va	Virginia DOT Virginia Transportation Research Council FHWA	Video imaging detector system Incident detection
DIRECT Greater Detroit area, MI	Michigan DOT FHWA Several priiate firms	Motorist advisory systems Radio data system, Cellular phone Automated highway advisory radio
Urban Congestion Alleviation Demonstration Project I-95 in Baltimore, MD	Maryland State Highway Administration FHWA	Changeable message signs Highway advisory radio
HELP/Crescent	DOTS of Alabama, Arizona, California, Idaho, Iowa, Minnesota, Nevada, New Mexico, Oregon, Pennsylvania, Texas, Utah, Virginia, Washington British Columbia Port of New York and New Jersey Motor Carrier Industry FHWA	Integrated heavy vehicle monitoring system Automated vehicle identification Automated vehicle classification Weigh-in-motion Urban/rural operations On-board computers System integration
ADVANTAGE I-75	DOTs of Florida, Georgia, Kentucky, Tennessee, Ohio, Michigan Ontario, Quebec, Motor Carrier Industry FHWA	Motor carrier operations Urban/rural operations
Washington State Portable Traveler Information System (I-90, Snoqaimie Pass)	Washington State DOT FHWA	Rural test in-vehicle radio receivers Road condition information
Live Aerial Video Montgomery County, MD	Maryland State Highway Authority Montgomery County Departments of Traffic and Police FHWA	Live video from aircraft to traffic management center
Live Aerial Video Fairfax County, VA	Virginia DOT Fairfax County Police Virginia Transportation Research Council FHWA	Live video from aircraft to traffic management center
Connecticut Freeway Traffic Management Hartford, CT	Connecticut DOT FHWA	Freeway surveillance and control Roadside radar detectors Closed-circuit television
Traveler Information System — Dulles Corridor Herndon, VA	Virginia DOT Dulles Area Transportation Association Town of Herndon, Virginia Metro Traffic Control FHWA	Highway advisory radio Cable system Transit vehicle display
Advanced Traffic Management Systems Model Portland, OR	Oregon DOT City of Portland Metropolitan Services District Washington State DOT	Area-wide system Incident management Institutional issues
Advanced Traffic Management Systems Model Denver, CO	Colorado DOT	Advanced traffic management system

Current U.S. IVHS Projects and Operational Tests		
Project	Participating Sponsors	Project Focus
Bellevue Smart Traveler Bellevue, WA	Metro Transit Bellevue Transportation Management Association City of Bellevue, Washington Metro Transit Washington State DOT Jniversity of Washington FTA	dynamic ride-sharing Dial-up information (Traffic Reporter) Mobile communication
California Smart Traveler Various metropolitan areas	CALTRANS six local sites in California) FTA	Real-time traveler information Jideotex and audiotex traveler information Dynamic trip match, Smart cards -land-held devices (travel cards, mobile telephones)
Houston Smart Commuter Houston, TX	Texas Transportation Institute Metropolitan Transit Authority City of Houston State Department of Highway and Public Transportation FTA	Real-time traveler information Dynamic trip match Audiotex & videotex traveler information Variable message signs Smart kiosk
4nn Arbor Integrated Smart Bus & Smart Traveler Ann Arbor, MI	Ann Arbor Transportation Authority City of Ann Arbor University of Michigan FTA	Automated customer information Multiple use smart card Traveler security, Vehicle location Computer-assisted dispatch Advanced displays Personal travel cards
Twin City Mobility Manager St. Paul-Minneapolis, MN	Regional Transit Board Minnesota DOT Jniversity of Minnesota Metropolitan Transit Commission FTA	Mobility manager Automated vehicle location technology Smart card Specialized transit services
Portland Smart Bus Portland, OR	Tri-County Metro Transportation District FTA	Audiotex and videotex traveler information Multi-modal transportation operations control Fixed-route and dial-a-ride integration Route deviation Smart kiosk, Personal travel card Automated customer information Geographic information systems
Chicago Smart Bus Chicago, IL	Chicago Transit Authority City of Chicago PTA	Service reliability Automated vehicle location Signal preemption Real-time service adjustments
Anaheim IVHS Operational Integration Anaheim, CA	City of Anaheim Orange County Transit District CALTRANS PTA	Smart kiosks Real-time traveler information Variable message signs Transportation management center
Rogue Valley Mobility Manager Medford. OR	Rogue Valley Council of Government Rogue Valley Transportation District Group Ride Service Ashland Senior Program Upper Rogue Community Center Call-A-Ride PTA	Single point of contact Smart cards Real-time transit information Demand-responsive transportation Geographic information systems Automated third party billing Computer assisted dispatch Multi-modal trip reservations

Current U.S. IVHS Projects and Operational Tests		
Project	Participating Sponsors	Project Focus
Baltimore Smart Bus	Baltimore MTA Westinghouse FTA	GPS AVL Computer-aided dispatch Management information system
Denver Smart Bus	Denver RTD Westinghouse PTA	GPS AVL Computer-aided dispatch Management information system
PIKEPASS	Oklahoma Turnpike Authority	Electronic toll collection (implementation)
ExpressToll	E-470 Public Highway Authority	Electronic toll collection (implementation)
TOLLTAG	Louisiana Department of Transportation Greater New Orleans Bridge Commission	Electronic toll collection (implementation)
Grosse Ile, MI	Grosse Ile Bridge Company	Electronic toll collection (implementation)
TOLLTAG	Texas Turnpike Authority	Testing of electronic toll collection devices
Buffalo, NY	New York State Thruway Authority	Testing of electronic toll collection devices
Goethals Bridge, NY	The Port Authority of New York and New Jersey Triborough Bridge and Tunnel Authority	Testing of electronic toll collection devices
New Hampshire	New Hampshire Department of Transportation	Testing of electronic toll collection devices

INTERNATIONAL ACTIVITIES

The U.S. is not alone in the IVHS arena — very substantial IVHS activities are under way in Western Europe and Japan. These international programs are well funded and well coordinated. Overseas companies clearly have an interest in the U.S. IVHS marketplace. More than forty foreign organizations are members of IVHS AMERICA.

Europe[11]

"IVHS is a world-wide program."

The two largest European IVHS programs are PROMETHEUS (Program for European Traffic with Highest Efficiency and Unprecedented Safety) and DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe). Both include government and private sector funding.

PROMETHEUS is part of the Eureka collaborative European research and development initiative, which is aimed at boosting European competitiveness. A main objective of PROMETHEUS — in addition to efficiency and safety — is a stronger European position in the automotive electronics market. PROMETHEUS is an eight-year research effort expected to cost $800 million. Participants include most of the major European-owned motor vehicle manufacturers; more than 70 research institutes and universities from West Germany, France, the United Kingdom, Italy, and Sweden; and more than 100 electronics and supplier firms. Industry research focuses on electronic driver aids, vehicle-to-vehicle communications, and vehicle-to-road communications. The universities and research institutes are focusing on basic research in artificial intelligence, in-vehicle processing hardware, communication methods and standards, and evaluation methodologies.[18]

PROMETHEUS' active research phase began in 1988 and is scheduled to last until 1994. This pre-competitive phase includes projects designed by the participating companies and is intended to show technical feasibility of various IVHS technologies. Subsequently, some projects will lead to commercial products that are proprietary to individual companies.

DRIVE focuses on technologies for road infrastructure, rather than on in-vehicle technologies. In fact, many PROMETHEUS projects related to road infrastructure and traffic management have fallen under the management of DRIVE. DRIVE's goals are to improve road safety, improve transport efficiency, and reduce environmental pollution. To be eligible for DRIVE sponsorship, a project must include participation from at least two member states, and one participant must be a commercial entity.

Launched by the European Commission in 1988, the initial phase of DRIVE was funded at 120 million ECU's ($150 million), half from the European Commission and half from participating research institutions themselves.” DRIVE II was initiated in 1991 with total funding of 240 million ECU's ($300 million), also divided equally between the European Commission and the participating research institutions. DRIVE II emphasizes validation and pilot projects; strategies for the use of technologies, telematic services and systems, and contribution to the definition of common functional specifications; and technologies and experimental development of systems.”

Japan[21]

Japan has several major research projects under way, including RACS (Road/Automobile Communication System), AMTICS (Advanced Mobile Traffic Information and Communication System), and VICS (Vehicle Information and Communication System). These are discussed in detail below.

RACS is a joint program involving the Public Works Research Institute of the Ministry of Construction and 25 private companies. Its goal is to establish a roadside beacon-based driver navigation and communication system. The system has three major components — navigation, traffic information, and individual communication. Tests of the system started in March 1987, in a region covering parts of Tokyo and Yokohama City.[22]

AMTICS is sponsored by the National Police Agency and supported by the Ministry of Posts and Telecommunications. About 60 companies are participating through the Japan Traffic Management Technology Association. Designed for route guidance and information in urban areas, AMTICS employs in-vehicle navigation devices that use dead reckoning with map matching. Rather than roadside beacons, AMTICS uses tele-terminals (similar in operation to cellular radios) for communication between the navigation units and the traffic control center. The pilot tests of this system were first carried out in Tokyo in 1988,[23] and later in Osaka in 1990.[24]

VICS was recently started in an attempt to better integrate AMTICS and RACS. Plans call for the National Police Agency to expand Traffic Control Centers and analyze traffic and for the Ministry of Construction to operate a system of roadside communication beacons. The two government agencies may operate parallel systems for supplying data to vehicles, the Ministry of Construction by its roadside beacons and the National Police Agency by some wide-area broadcast system such as FM sideband. The Ministry of Posts and Telecommunications participates as well.

In keeping with the Japanese orientation toward early commercialization and exploitation of available technology, autonomous navigation systems are now offered as new-car options in Japan and have proven to be quite popular.[19] Estimates are that about 12,000 vehicles per month are being sold in Japan equipped with navigation systems, at approximately $3,000 per unit (including some top-of-the-line, non-IVHS extras in the package).

"Japanese consumers are buying navigation systems at a substantial rate."

The Japanese are moving ahead on IVHS with an ambitious schedule, particularly in advanced driver information systems. As Ervin notes,*' "An infrastructure for advanced driver information systems is undergoing a final stage of definition and appears to be near deployment in Japan. It is expected that by 1995, the larger cities in Japan will provide a continuous data radio broadcast of travel time and other traffic characterizations covering tens of thousands of road links." He further observes that Japan is ahead of the rest of the world in this facet of IVHS.

Clearly, the world is moving forward in IVHS. The U.S. IVHS community has been active in communicating with colleagues in Western Europe and Japan. In October 1991, an IVHS AMERICA group visited Europe to discuss IVHS programs. They met with more than 60 agencies, corporations, and other groups in Belgium, the Netherlands, Germany, France, Sweden, and the United Kingdom. A similar trip to Japan took place in April, 1992.

The relationship of these overseas programs to those in the U.S. needs to be more fully explored as the strategy for IVHS in the U.S. is developed. Further discussion appears in Chapter III.

Opportunities and Challenges

In the development of the U.S. IVHS program, we can take advantage of some important opportunities. At the same time, realism demands that we consider the challenges that the IVHS community must address and overcome in order for IVHS to succeed. In this section, we discuss key challenges and opportunities to help set the stage for the action plan discussed later in this Strategic Plan.

Opportunities

The IVHS initiative is timely for several reasons, listed below.

The nation has recently completed re-authorization of the Intermodal Surface Transportation Efficiency Act. That legislation, which substantially defines public investment in surface transportation in the U.S., is a watershed — for the first time in almost 40 years, the construction of the Interstate System was not the central focus. The country seeks a new vision for the transportation system of the future. IVHS, as authorized in the legislation, has the opportunity to be that vision.

The recently enacted Clean Air Act Amendments, a reflection of the national will in the environmental area, puts additional pressures on the transportation system to be environmentally benign. Also, the 1990 Americans With Disabilities Act requires our transportation system to be more accessible and available. IVHS can make important contributions in both regards.

‘Reductions in U.S. defense spending present an opportunity for I VHS. B

Furthermore, expected reductions in defense spending present two opportunities. First, federal funds for transportation may be less constrained. Second, the availability of unused capacity in the national laboratories and the defense industry could be turned into an IVHS asset.

Continued advances in relevant technologies and, in particular, the substantial lowering of costs for technological capabilities present cost-effective opportunities to the IVHS community, in an atmosphere in which cost issues are critical.

Several institutional trends present opportunities for IVHS, such as the following:

- Emerging recognition of public/private partnerships, by both the public and private sectors, as vital to the national interest
- Within metropolitan areas, the continued evolution and strengthening of inter-jurisdictional organizations such as Councils of Governments and others

"The transit industry sees IVHS as a major opportunity to expand its mission."

- Within the transit industry, an increasing recognition of a new mission beyond conventional transit, involving innovations for achieving public mobility and intermodal cooperation between the transit and highway modes
- Within state departments of transportation, the impending retirement of large numbers of technical people, providing the opportunity to strengthen the systems operations capabilities of these organizations in electrical, communication, and computer engineering — broadening their focus beyond construction and maintenance, which have traditionally called for conventional civil engineering disciplines

Momentum is building for the U.S. IVHS program. The entrepreneurial spirit in the public and private sectors, in national as well as local organizations, and in the research community, is an important strength on which to build. Examples of the growing momentum are listed below.

"IVHS is central to 'Moving America' — the national transportation policy."

- DOT is committed to this program — it is in close accord with "Moving America," its national transportation policy. DOT has already made important organizational moves to build a base for IVHS development.
- The Congress supports the IVHS concept, as evidenced by the ISTEA legislation.
- A number of state governments and local municipalities are building IVHS programs.
- IVHS AMERICA, a utilized Federal Advisory Committee to U.S. DOT. has been established.
- The U.S. private sector sees the potential for a profitable market in IVHS, both nationally and internationally, and is building programs accordingly.
- TRB Special Report 232 on IVHS, entitled "Advanced Vehicle and Highway Technologies," strongly urges a national program "for research, testing, and initial implementation of IVHS."
- U.S. research universities are actively building IVHS programs in research and education.

IVHS can be built on a strong political consensus. It is tied to critical national issues such as international competitiveness and economic health (for example, jobs). The diffuse political constituencies of IVHS can be consolidated.

Challenges

Although we currently have these favorable factors for IVHS, we still need to deal with several important barriers to success.

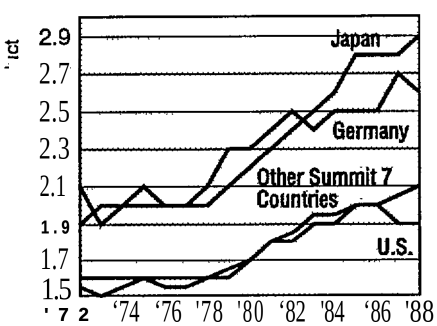
"Organizational and institutional issues must be effectively addressed."

Foremost among these challenges is the organizational question of the relative roles and responsibilities of the various levels of government, the private sector, and academia. Given that IVHS is both a consumer products and a public works program, how does the program successfully accommodate both? How do we determine which sector, public or private, pays for various aspects of the program? How, within this framework, do we establish a system architecture and standards and protocols to ensure a nationally consistent program? What should the role of the newly formed IVHS AMERICA be? What is the role of academia?

The eventual deployment of IVHS on a national scale will require the cooperation of many actors and stakeholders. Partnerships between the public and private sectors will be required, but the U.S. has not generally been effective at establishing public/private ventures. Both public and private investment will be required for success, with public investment in infrastructure increasing the benefits of consumer-purchased in-vehicle equipment. The public and private sectors may each wait for the other to take the first major initiative, delaying the program.

One aspect of this public/private interaction that could impede cooperation is government procurement practices. Laborious contracting negotiations and procedures and, often, the over-emphasis on low bid in contract awards are current difficulties in building effective relationships between the public and private sectors, particularly when innovative roles for the private sector are considered.

R&D Investment
(Non-Defense)



Sources: Council on Competitiieness and National Science Foundation

Another set of major challenges deals with the international setting for IVHS. In Japan and Western Europe, a different version of capitalism is practiced with much closer ties between industry and government than is the case in the U.S.[27] IVHS abroad has been developed in that environment, with close cooperation between strong public and private sector programs. In several ways, those IVHS programs have a clear head-start on U.S. activities. There is the danger that IVHS technologies from abroad may dominate the U.S. market.

Full deployment of IVHS will take many years, even decades, To get a substantial number of vehicles equipped and cities on-line will be a long-term process. Organizations, both public and private, will have to take a long-term perspective on systems development and deployment. A weakness of both the politically-based public sector and the short-term profit-oriented private sector in the U.S. is that both often have difficulty taking this long-term view. That may lead to uncertainty in program funding, rather than the long-term stable funding important to the success of IVHS. In Western Europe and Japan, longer-term views in both the public and private sector are the norm. A U.S.-based program will need to overcome that disadvantage.

IVHS must pass the test of the marketplace."

A major challenge is the ability of IVHS in-vehicle hardware and software to pass the test of the marketplace. IVHS will not succeed unless consumers buy equipment and they will not do so unless they see direct benefits in travel convenience and safety. It is doubtful that many people will buy because of abstract notions such as "IVHS will help the environment." No (non-proprietary) market studies are available on IVHS equipment, although history tells us that consumers respond to upgrades in vehicle technology and equipment (for example, automatic transmission, air conditioning, CD players, cruise control, and so on). Only time will tell whether U.S. consumers will respond the way Japanese consumers have to IVHS.

"Consideration of human factors and public education is critical for IVHS."

A related challenge is the human factors aspect of IVHS. People will have to learn to (safely) use an entirely new set of equipment. Will they be willing to acclimate to a new way of driving, albeit a superior one? Public education is required to ease the transition of the driving public. Clearly, the success of these programs in dealing with the human elements of IVHS will relate closely to the market penetration issues discussed above.

The current financial situation in the U.S. provides another challenge for IVHS. Federal and local government and private industry are constrained by financial limitations from exploring new initiatives. The federal deficit is a major issue, as is the deficit situation at the local level in some areas. Government jurisdictions having trouble funding conventional services may see new IVHS initiatives as beyond their means. Private industry may have problems finding the resources to follow through on IVHS initiatives.

There are also a number of legal issues which, if not addressed, could greatly constrain IVHS research, development, and deployment. Among those are the following:

legal Issues:
- Tort Liability
- Privacy
- Anti-trust
- Intellectual property

- ***Tort liability.*** Legal responsibility and liability for accidents may be shifted from the vehicle owners to the owners of the infrastructure, vehicle manufacturers and their suppliers, and the providers of traffic management and traveler information services.

- ***Privacy.*** There is public concern that the data collected for use by IVHS could be used inappropriately to intrude upon the privacy of individuals. Appropriate safeguards and guidelines to protect privacy must be built into IVHS to secure public acceptance and support.

- ***Anti-trust.*** Joint ventures and cooperation may still be inhibited by uncertainty as to where the line is drawn between pro-competitive and anti-competitive associations and between pre-competitive and competitive market development stages.

- ***Intellectual property.*** Legal arrangements must be established at the beginning of public/private ventures to strike an appropriate balance between proprietary and shared property.

An additional challenge deals with obtaining appropriate allocations from the electro-magnetic spectrum for IVHS communication needs. This is a critical requirement, because if adequate frequencies are not available to IVHS, deployment will be greatly constrained.

"Operational tests of IVHS play a central role in the program."

There is a final challenge: Success in IVHS requires the development of a national, mutually-supporting series of operational tests that will demonstrate technologies and perform experiments to advance the state of the art. The tests need to be integrated and coordinated to ensure efficient use of funds and timely deployment, but given that they will be carried out by many diverse organizations at many different sites, that coordination may be difficult to achieve. Selection of operational tests should be made on the basis of which ones will best advance the IVHS program.

Goals and Objectives[28]

Many people and organizations, both in the public and private sectors, participate in IVHS. Given this plurality, there is a broad array of goals and objectives. Those are discussed below.

Operational Goals and Objectives

IVHS addresses fundamental issues in safety, congestion, mobility, environment, and energy. This section describes goals and objectives in these areas.

Some objectives are stated in quantitative terms. The numbers are conservative; they depend on specific cited studies and data. The sense is that they will increase as further research and operational tests provide more IVHS experience and as market penetration estimates are refined. Those objectives will be updated periodically as uncertainties are resolved and better benefit prediction models are developed.

IMPROVED SAFETY

GOAL: To improve the safety of surface transportation

OBJECTIVES:

1. To reduce the number of annual fatalities and the number of annual injuries by 8% by 2011 (equivalent to 3300 annual deaths and 400,000 injuries at current traffic levels)[29, 30]
2. To improve personal security

"IVHS promises improvements in traffic safety."

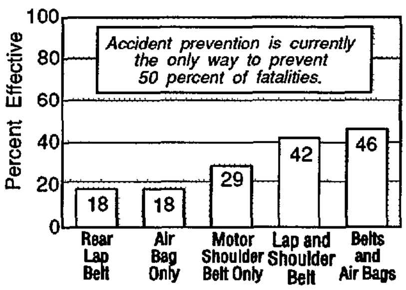
3. To improve the safety of transit fleets, general commercial vehicles, and hazardous material movement

Since IVHS brings new levels of information and control to the operation of motor vehicles, the concept promises improvements in traffic safety. The basic premise is that the driver will be assisted by technology to reduce the probability of collisions or single vehicle crashes. With technology for vehicle spacing and automatic braking, the potential exists for dramatic reductions in rear-end collisions, even approaching the elimination of such incidents on specialized facilities limited to appropriately equipped vehicles. Estimates are that IVHS can reduce commercial vehicle empty miles by 10 to 20 percent, with the accident reduction inherent in this. With eventual development of automated highways, even more safety improvements are expected. The numerical objectives in safety improvements noted above are reasonable to achieve by following the plan described in Chapter III.

"The next twenty years should see the focus shift toward crash avoidance, through IVHS technology."

In the development of a "safety technology" for highway transportation, IVHS represents a watershed. The issue is one of focus. In the past several decades, the primary focus of the world-wide effort to improve traffic safety has been based on the assumption that crashes happen, but steps can be taken to lessen the consequences. Thus, we have adopted many useful measures that improve the crashworthiness or "secondary safety" of the vehicle and roadside. The advent of the current generation of powerful advanced technologies offers an unprecedented opportunity for achieving breakthroughs in the crash avoidance features of motor vehicles. Thus, the next twenty years should see the focus shift toward crash avoidance. That is critical, because accident prevention is an effective way to prevent 50 percent of current fatalities.

Effectiveness in Preventing Fatal Injury



Data Source General Motors

In this country, technologies for improving primary safety will be an essential part of the IVHS program. Such systems will be of value to all road users over all geographical regions in both urban and rural areas. Safety for automobile drivers and truck operators will be enhanced. The benefits in question are important. As noted in the "Needs" section, the nation pays a high price in deaths, injury, and property damage on our highways. IVHS can help reduce this toll.

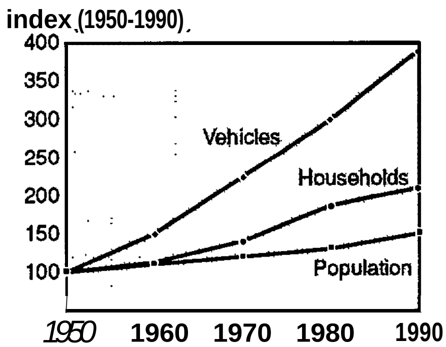
REDUCED CONGESTION

GOAL: To increase the capacity and operational efficiency of the surface transportation system

OBJECTIVES:

1. To reduce congestion costs by 10%, through IVHS, in a significant number of metropolitan areas by 2001[30]
2. To reduce congestion costs by 15-20%, through IVHS, in a substantially increased number of metropolitan areas by 2011[30]

Relative Growth in Population, Households, and Vehicles



Source: National Transportation Strategic Planning Study

"IVHS can shift traffic to routes with excess capacity."

3. To increase people-carrying capacity of the highways by increasing average vehicle occupancy
4. To increase the volume of people and goods that can be moved on existing facilities and in corridors
5. To reduce excess travel caused by navigational problems

The numerical objectives noted above in congestion improvement over the next several decades are reasonable to achieve by following the plan described in Chapter III. Indeed, they may well be quite conservative.[12] Some existing traffic management systems have achieved gains of this order and substantially more on local networks. For example, the Chicago Area Expressway program achieved a 30 percent reduction in peak period congestion.[31] The challenge is achieving these benefits on an area-wide basis. Achieving the benefits depends on many factors, including the extent of deployment.

A primary function of IVHS is to provide for a smoother traffic flow, allowing vehicles to reach their destinations with fewer stops and delays. These systems better utilize the capacity of the network by shifting traffic from routes of inadequate capacity to routes with excess capacity. Thus, the economic benefit of increases in potential overall traffic volume without a corresponding increase in congestion can be achieved. Information provided to drivers on congested routes will improve travel times, as will routing information. Technologies for Electronic Toll and Traffic Management (ETTM) can greatly improve traffic flow around toll facilities. Commercial and transit vehicles, as well as private automobiles, will benefit from reduced congestion. Also, changes in travel and land use patterns, with enhanced real estate values, can result from IVHS implementation.

A significant amount of current congestion is caused by non-recurring events, particularly crashes. Accidents are the cause of about 61 percent of urban congestion. Thus, a collision avoidance system that reduces collisions will also reduce congestion caused by lane blockage, as well as by the traffic that slows in order to "rubber neck." In fact, improved safety and reduced congestion are interrelated. Reducing congestion reduces stops and other speed changes. That will reduce crashes, further reducing congestion. Routing drivers away from crashes minimizes "secondary" accidents as well.

IVHS will provide pre-trip information to travelers on road conditions, transit schedules, and paratransit opportunities. Information on costs, trip times, dependable departure and arrival times, and dynamic ride matching are expected to be very effective in making shared-ride, HOV, and transit travel more attractive, thus increasing average vehicle occupancy and reducing congestion. IVHS can also contribute to increased vehicle occupancy by providing the means to implement preferential pricing and, where warranted, can control priority access for high occupancy vehicles. Transit efficiency can be improved through fleet management, making it a better option.

With the eventual development of automated highways, more substantial congestion reduction is feasible. Capacity increases of 100 to 200 percent have been projected in some studies.

The potential attraction of more automobile traffic when IVHS reduces congestion must be recognized and should be studied. IVHS does provide the capability for congestion pricing and demand management, if public policy determines that this is required.

INCREASED AND HIGHER-QUALITY MOBILITY

GOAL: To enhance mobility and the convenience and comfort of the surface transportation system

OBJECTIVES:

1. To improve accessibility to the surface transportation system by those at all income and age levels, in all geographic regions, and by the disabled
2. To improve travel time predictability
3. To reduce the level of stress associated with travel
4. To enable travelers to make alternative use of their traveling time for work or leisure activities

"IVHS will enhance mobility."

The introduction and use of IVHS technologies will enhance people's ability to use the nation's alternative transportation systems, mass transportation systems, rural and specialized services for handicapped people, urban public transportation, taxis, limousines and shuttle buses, car-pool, van-pool and other paratransit services. Ultimately, IVHS will serve the traveler whose trip includes an intercity rail or air segment by providing total integrated information on all travel-making opportunities.

IVHS technologies have the potential to make improvements in trip planning and to provide driving aids en route. For "routine" trips, there may be the ability to determine traffic conditions and current status of transit operations. Information can assist with planning a more reliable trip and can reduce the chances of being late. Advanced technologies like infrared sensing devices can help the vision-impaired driver and the elderly. Having an in-vehicle routing system so "you never get lost" can be a more comfortable, less stressful traveling experience.

Each feature, including those listed above and others, may seem modest, but in the aggregate they can add up to a much more comfortable and convenient trip and substantial mobility improvements.

IMPROVED ENVIRONMENTAL QUALITY AND ENERGY EFFICIENCY

GOAL: To reduce the environmental and energy impacts of surface transportation

OBJECTIVES:

1. To reduce harmful vehicle emissions
2. To reduce fuel wasted by congestion and travel inefficiencies
3. To reduce surface transportation energy consumption per vehicle-mile and per passenger-mile traveled

Fuel savings are an important target of the IVHS program. There is potential for fuel consumption savings in equipped vehicles on systems with supporting infrastructure.

IVHS permits vehicles to operate at *near/y* constant *speeds, saving fuel. "*

IVHS will provide balanced vehicle densities and maximum utilization of the infrastructure. When IVHS is implemented, vehicles should travel with minimal starts and stops and at nearly constant speeds. Using current EPA Fuel Economy Label values as a starting point, it is clear that the closer IVHS allows vehicles to perform in the "highway" mode, the higher the benefits.[12]

Fuel savings will also result from improved route selection. In a FHWA study,[32] it was shown that major improvements in distance traveled and time spent traveling could be achieved with navigational aids.

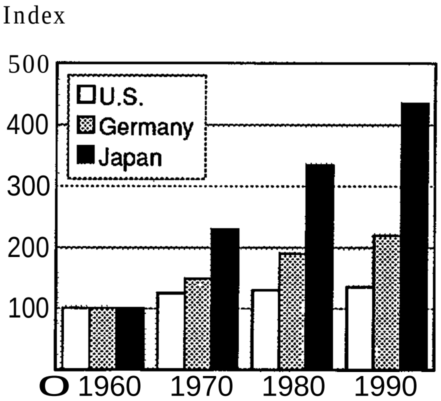
IVHS strategies offer hope for future improvement of air quality, particularly in designated urban areas because impacts will begin upon deployment. Such strategies are complementary to other air quality initiatives, such as alternative fuels.

The key to reduced energy consumption and improved air quality is smoother traffic flow and fewer vehicle miles traveled by automobiles. IVHS has the potential to accomplish this by enhancing capacity through traffic management, navigational aids, support to transit and paratransit and encouragement of their use, and HOV lanes. Also, IVHS offers the capability for controlling additional demand that might reduce environmental and energy efficiency gains.

IMPROVED ECONOMIC PRODUCTIVITY

GOAL: To improve effectiveness and efficiency of the surface transportation system, now and in the future, thereby improving productivity of individuals, organizations and the economy as a whole

Growth in Productivity



OBJECTIVES:

1. To reduce the costs and improve the effectiveness of all users of the surface transportation system — fleets, individual drivers, and mass transportation
2. To make better use of existing facilities and reduce the need for construction of new conventional facilities
3. To reduce the costs associated with and improve the quality of collection of data for transportation planning, operations management, roadway construction and maintenance services, and user fee purposes

The relationship between transportation and the economy is fundamental. Economic activity generates transportation demand and transportation helps the economy grow. Freight transportation and business-related passenger transportation are integral parts of the productive process. Nearly all economic activities use transportation directly or indirectly; cost-reducing improvements in transportation, such as more direct routing, increased speeds, reduced wear and tear on vehicles, or improved safety, increase economic productivity.[6]

"The link between transportation efficiency and productivity has, perhaps, never been so important."

The U.S. currently faces a serious challenge in the international marketplace. Our industrial organizations are in a critical struggle for market share, both domestically and abroad. The link between transportation efficiency, broadly defined, and productivity has, perhaps, never been so important. Therefore, a fundamental goal of IVHS is to improve the operation of the U.S. transportation system and the effectiveness of past and future investment in that system.

IVHS can do this through safety improvements, congestion reduction, energy and environmental enhancement, and through the more efficient administration of the surface transportation system. Productivity gains in the trucking and package delivery industry will occur through fleet management, electronic permitting for commercial vehicles, and many other technologies. IVHS has the potential for more effectively operating the infrastructure now in place, reducing the need for construction of new conventional infrastructure.

"Investment in IVHS will he/p national productivity."

Investment in transportation through IVHS infrastructure and in-vehicle devices has a direct impact on productivity. "Capital investment, including the development and maintenance of transportation infrastructure offers one of the most effective known catalysts of productivity growth. Transportation investment, and network improvements in particular, can trigger technological innovation in private firms, with important economic gains that extend beyond those previously associated with infrastructure development."[33]

IVHS provides a new range of capabilities in such areas as gathering and providing data, controlling the transportation system, and pricing transportation services. For example, the data available from IVHS on levels of demand, periods of peak use, and identification of locations of recurring congestion will be helpful in overall land use planning, facilities modernization and construction decisions, and operation management.[34]

Improvements in data acquisition and availability will allow the proper and appropriate assignment of user fees and charges to implement federal and local policies in transportation. Equity in financing and pricing of transportation services is achievable.

Institutional Goals and Objectives

In addition to the goals and objectives tied directly to IVHS operations and deployment, there are several goals and objectives related to important institutional factors connected with IVHS. This section discusses them.

IVHS INDUSTRY IN THE UNITED STATES

GOAL: To develop a viable and profitable U.S.-based IVHS industry

OBJECTIVES:

1. To establish a U.S.-based supply industry for in-vehicle IVHS hardware and software
2. To establish a U.S.-based supply industry for IVHS infrastructure hardware and software
3. To establish a U.S.-based IVHS transportation services industry
4. To achieve a substantial market penetration in the U.S. by U.S.-based industry of IVHS hardware, software, and services
5. To establish an international market presence by U.S.-based industry of IVHS hardware, software and services

IVHS is a significant business opportunity for U.S. industry. "

IVHS represents a significant business opportunity for automakers and for the electronics, computer, navigation, and communications industries. IVHS will add functionality to automobiles, and this increased functionality will increase the value of the automakers' products. That increase in product value translates into expansion in the overall automobile market and would bring with it new business opportunities for companies serving that market. IVHS gives producers an opportunity to sell a wide range of new and enhanced products, building new markets as well as preserving current business.

Software represents an important in-vehicle market as well, including items such as "electronic yellow pages" and in-vehicle route guidance services.

In addition to the vehicle-based market, there is also substantial opportunity to develop a market for IVHS-related infrastructure. Various sensors, beacons, ETTM hardware, and the like will be needed to operate traffic management systems, as will software to support transportation network operations.

Transportation services offered by the private sector have substantial potential as well. We envision private sector firms contracting to provide various IVHS services such as area-wide traffic management, operations, and maintenance.

In recent years, the U.S. IVHS industry has been moving aggressively in research and development and participation in operational tests. There is recognition of a market opportunity and the will to move forward.

The benefits of the development of such a U.S.-based industry are substantial. Clearly, the industry itself will benefit if a profitable venture can be established. However, broad-based economic benefits in such areas as job creation, capital formation, and balance of payments can be achieved if a U.S. presence in the national and international IVHS market can be developed.

THE TRANSPORTATION PROFESSION

GOAL: To redirect the transportation profession, expand the capabilities of existing transportation organizations, and bring new organizations into the transportation field

OBJECTIVES:

1. To develop new transportation educational programs in support of IVHS
2. To educate a new generation of transportation professionals
3. To integrate those professionals into public and private sector transportation organizations
4. To utilize the technical skills and technologies of the national labs and the defense industry to advance IVHS research, development, and deployment

"IVHS requires a new kind of transportation professional, versed in new technologies and institutional issues."

IVHS requires the education of a new kind of transportation professional, versed in new technologies and institutional issues germane to IVHS. The university community will take this responsibility and will develop substantial new educational programs. Disciplines such as information and communication systems, organization development, and others need to become integral to the transportation field. To accomplish this, it is important that the academic community be a full-fledged participant in IVHS research, for it is through that research that the educational program will evolve to this new model.

The impact of this will be:

- A revitalization of the transportation academic community as it draws intellectual strength from integrating new disciplines and concepts into its programs

- A revitalization of the transportation profession as those newly educated people are integrated into existing public and private transportation organizations

Some national labs and some defense contractors see the need to develop an additional mission as defense needs and budgets decrease. These organizations are a national resource with a large reserve of technical skills and technologies. The IVHS program can be the mechanism through which a partial transition to civil activities, including transfer of technology, is accomplished by those organizations. They can be a useful adjunct to the transportation community, to be used as appropriate to further the IVHS research, development, operational testing, and deployment efforts.

TECHNOLOGY DEVELOPMENT AND DEPLOYMENT

GOAL: To develop and demonstrate a new institutional structure for technology development and deployment in the U.S

OBJECTIVES:

1. To develop new modes of operation among organizations at all levels of government involved in IVHS
2. To develop new modes of cooperation among private sector organizations participating in IVHS
3. To develop effective public/private/academic partnerships in support of IVHS research, development, and deployment

IVHS can demonstrate a new institutional structure for technology development and deployment in the U.S.”

Earlier, the need was outlined for new kinds of relationships among public sector organizations (federal, state, local, and regional), among private organizations, and between the public and private sectors, including academia. The U.S. does not have a strong history of public/private cooperation: IVHS can provide an opportunity to develop experience in such relationships. IVHS can demonstrate a new model for institutional relationships in developing, deploying, and marketing new technology in the U.S.

The value of this goes beyond IVHS. This model can be used in comparable activities dealing with other technologies, allowing the U.S. to compete more effectively with the joint government/industry approaches used in Japan and in many nations in Western Europe.

Conclusion

IVHS will lead to benefits, for society at large and for specific groups and organizafions."

The previous section outlined goals for IVHS. Achieving them will lead to benefits, for society at large and for specific groups and organizations. Some observers have characterized IVHS as an urban congestion program, designed to aid the automobile driver on the journey to and from work. While there are certainly important benefits of this type, the overall benefits are much broader. Examples include the following:

- Economic productivity gains help the nation as a whole, even non-users of the system.
- Safety enhancements are as relevant in rural areas as in urban; indeed, the most lethal roads in the country are in rural America.
- Saving energy helps the balance of payments for the entire nation.
- Jobs resulting from an active U.S. IVHS industry will be geographically distributed.
- Public transit in large urban areas, small cities, and rural areas will have expanded capabilities and will run more efficiently, benefiting many passengers and contributing to reduced vehicle-miles traveled.
- Technology will assist the elderly driver and the disabled.
- Recreational areas will benefit from improved routing information and congestion control.
- Commercial fleet operations will achieve substantial improvements in productivity.

IVHS will enhance public transit in large urban areas, small cities, and rural areas."

More detailed quantification of IVHS benefits is a critical next step. The funding of future research and operational tests on IVHS described in the next chapter and in the appendices will allow quantification of the benefits of various IVHS technologies. With that information, deployment decisions can be made more effectively. Further, detailed economic analyses of IVHS should be a first priority, particularly with regard to the potential for penetration of the consumer marketplace by IVHS.

There are several high priority questions that need to be addressed in the Strategic Plan; they have been introduced in this chapter and are listed below. Chapter III describes the approach to answering those questions.

- Definition of the scope and magnitude of the worldwide IVHS program and determination of what should be included in the U.S. program

- Questions related to international competition and the relationship of the U.S. program to those overseas

- The question of how the public and private sectors can effectively work together to deploy IVHS

- Funding issues, including deciding who pays for what aspect of the program

- Standards and protocols, system architecture, and the achievement of a national system

"IVHS is an essential national program. Indeed, if is already happening."

There is substantial empirical evidence that IVHS is an essential national program. Indeed, it is already happening. Major public and private sector investment has been made. A number of traffic management systems and operational tests are well under way, and in-vehicle products are available. Cooperative efforts are occurring, for example, between the motor carrier industry and various toll authorities, among various governmental organizations, and between the public and private sector.

"A Strategic Plan for IVHS in the U.S. is essential,"

There will be an IVHS program in the U.S., even without this plan. However, an integrated national IVHS program is the best future strategy to achieve accelerated, orderly, and organized IVHS deployment. It is essential to have a Strategic Plan if we are to spend resources wisely, speed the achievement of IVHS benefits, and assure acceptable standards and national uniformity. The remainder of this document focuses on "Course of Action" — what we need to do to develop such a program technologically, institutionally, and politically.

Endnotes

1 This text was informed by discussions with many people in the professional community and by correspondence from D. Brand, Charles River Associates.

2 R. Weiland, SEI, correspondence.

3 Figure adapted from ***Proceedings of a National Workshop on IVHS sponsored by Mobility 2000,*** Dallas, TX, March 1990.

4 This section borrows extensively from FHWA, ***Intelligent Vehicle Highway Systems — A Public/Private Partnership,*** October 1991.

5 FHWA, ***Intelligent Vehicle Highway Systems -A Public/Private Partnership,*** October 1991.

6 U.S. DOT, ***National Transportation Strategic Planning Study,*** March 1990.

7 J.R. Treat et ***al., Tri-Level Study of the Causes of Traffic Accidents: Final Report — Volume I: Causal Factor Tabulations and Assessments,*** DOT HS-805085, Institute for Research and Public Safety, Indiana University, Bloomington, IN, May 1979.

8 Robert L. French, "Safety Implications of Automobile Navigation Systems," presented at the 46th annual meeting of the Institute of Navigation, Atlantic City, NJ, June 26-28, 1990.

9 EPA, ***National Air Quality and Emissions Trends Report,*** 1987.

10 ***IVHS AMERICA: Strategic Planning Workshop,*** Section 4, "FHWA 2000 at TFHRC," Westfields Conference Center, Chantilly, Virginia, July 22-24, 1991.

11 ***Proceedings of a Workshop on Intelligent Vehicle/Highway Systems by Mobility*** 2000, San Antonio, TX, 1989.

12 ***Proceedings of a National Workshop onIVHS Sponsored by Mobility*** 2000, Dallas, TX, 1990.

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15 Highway Users Federation and Automobile Safety Foundation, ***The Intermodal Surface Transportation Efficiency Act — A Summary,*** December 199 1.

16 Drawn partially from GAO Report, ***Smart Highways -An Assessment of Their Potential to improve Travel, May*** 1991. See also FHWA, ***Intelligent Vehicle-Highway Systems Projects in the United States,*** June 1991.

[17] This section borrows extensively from Office of Technology Assessment, ***Advanced Vehicle/Highway Systems and Urban Traffic,*** September 1989.

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[20] Lyle Saxton, Internal Memorandum, FHWA, November 1991.

[21] The reader is also directed to R. Ervin, ***An American Observation of IVHS in Japan,*** University of Michigan, September 1991,

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[25] R. Ervin, ***An American Observation of IVHS in Japan,*** University of Michigan, September 1991.

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[27] L. Thurow, "A Bear in the Woods," in ***MIT: Shaping the Future,*** edited by K. Manning, MIT Press, 1991.

[28] As background for this section, suggested reading is the "Benefits" section of ***Proceedings of the National Workshop on NHS Sponsored by Mobility*** 2000, Dallas, TX, March 1990.

[29] These estimates were obtained by multiplying the percent reductions in fatalities and injuries computed in the "Benefits" section (pg. 12) of the ***Proceedings of the National Workshop on NHS Sponsored by Mobility*** 2000 by a factor of 0.4. This factor reflects the lower penetration estimates for IVHS technologies in the Strategic Plan.

[30] This is relative to what would occur without IVHS at comparable traffic volumes.

[31] GAO Report, ***Smart Highways— An Assessment of Their Potential to Improve Travel,*** May 1991.

[32] FHWA, ***Economic Assessment of Potential Solutionsfor Improving Motorist's Routes,*** FHWA/RD-86/029, 1986.

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III. COURSE OF ACTION

Chapter II, the "Strategic Assessment," delineated a set of goals and objectives for IVHS: enhancing safety, mobility, economic productivity, air quality, and energy efficiency. This chapter, the "Course of Action," details how these goals and objectives can be achieved, what the costs will be, who will pay for them, and what are the challenges to successful implementation.

"A clear course of action is vital to realize the promise of IVHS."

A clear course of action is vital in order to realize the promise of IVHS. Technological advances — both those already achieved and those available in the future — are at the heart of IVHS. Continued progress in IVHS requires integration of these technologies. Still, the issues involve much more than technology. It is possible that many of the most difficult hurdles will not be technological, but organizational and institutional.

This chapter presents a framework for understanding the hurdles and overcoming them. It is organized as follows:

The ***Approach*** presents the overall assumptions and principles underlying the course of action and its key program elements. Next, a broad discussion of ***IVHS Development*** begins with descriptions and technical program plans for each of ***Five Functional Areas*** that, taken together, constitute IVHS. Those areas are: Advanced Traffic Management Systems (ATMS), Advanced Traveler Information Systems (ATIS), Advanced Vehicle Control Systems (AVCS), Commercial Vehicle Operations (CVO), and Advanced Public Transportation Systems (API'S).

The functional areas of IVHS do not exist in isolation. Although it is helpful to address them individually, they must be considered as a whole. The Integration section does this by discussing cross-cutting issues, including system architecture, standards and protocols, safety and human factors, communications, rural applications, and integrative research and development projects and operational tests.

The payoff will be in Deployment — large-scale commercial availability and usage of products and services. For each of the five functional areas, the availability of products and services is projected for 5, 10-, and 20-year timeframes.

"The payoff will be in deployment."

Deployment cannot take place without effective cooperation among the various public and private sector interests. IVHS provides a set of unique challenges that must be resolved for such cooperation to take place. That requires ***an Organizational Program*** that complements the technical program. The organizational program covers the ***Roles and*** *Responsibilities* of IVHS participants, *Legal Issues*, and *Institutional* ***Issues.***

The organizational program is followed by a section that estimates the ***Costs*** required for IVHS development and deployment. A list of suggested *Near-Term* ***Actions*** concludes the chapter.

Approach

The Course of Action is not a program plan in the traditional sense of a "top-down" prescription of precisely what tasks should be done, when each task should be undertaken, and who should perform each of them. Rather, it is the consensus of the IVHS community — working through IVHS AMERICA — on the activities that need to be undertaken if the vision for IVHS is to be realized. The reasons for this are explained later in this section.

The Course of Action is based on the following premises:

ORGANIZATIONAL SCOPE

- A national system of intelligent vehicle and highway technologies will be deployed across the American market during the next twenty years.

- Nationwide deployment of IVHS systems will occur within our national framework of federalism and a market economy. This inherently includes decentralized powers and decision-making.

- The marketplace will be a major force in driving the development and deployment of IVHS technologies. Other forces will include the need to provide public benefits such as safety improvements and congestion relief. Existing and new standards should be adopted to ensure compatibility among systems and across jurisdictional lines.

- Public/private/academic partnership arrangements should chart our national IVHS strategy, create overall system architectures, develop and evaluate technologies, and establish standards.

DEVELOPMENT AND DEPLOYMENT

- IVHS will be implemented in phases. Incremental implementation will hasten the delivery of benefits to travelers and the nation.
- Initially, deployment of proven technologies and associated operational practices will be emphasized. Much of the basic technology needed to develop and implement intelligent vehicle highway systems currently exists.

"Initially, deploymenf of proven technologies will be emphasized. "

- Research and development will be conducted for areas where existing technologies or institutional practices do not meet requirements or where initial requirements need to be established.
- Operational tests — conducted as public, private or joint ventures in real-world operational highway environments under live transportation conditions — are key to the transition between R&D and full-scale deployment of the technologies. The selection of sites and technical content of these tests should be governed by the need to enhance knowledge of IVHS performance, safety, benefits, economics, and user receptiveness.

FUNDING

- Public sector funding should include investment in programs and technologies where the public or societal benefits justify the costs and where the program would not be carried out or the technologies developed by the private sector without public participation.
- Private sector funding will be oriented toward products and services that respond to marketplace directions. The consumer will pay the largest portion of the cost for IVHS, primarily through the purchase of vehicles, equipment, and services. Consumer acceptance and the resulting private markets will be highly influenced, however, by public investments and policies regarding infrastructure facilities and related services.
- U.S. DOT research efforts will be devoted to areas where a federal interest and role exists. These include both technical research areas and non-technical research areas, such as human factors and policy-related research. They also include assessment of public benefits, establishment of functional performance specifications, and support for evaluations of research, development, and operational testing. Uniform evaluation will encourage consistent and fair comparisons of alternative technical and institutional strategies.

Management and Control

ALTERNATIVES

The Strategic Plan gives careful consideration to the type of management and control appropriate for the program. Some participants suggested that a centralized agency like NASA be established. This was based on the belief that only a powerful new agency with sufficient resources and control could meet the technical challenge of developing IVHS. At the other end of the spectrum, some suggested that the U.S. tradition of allowing the private sector to develop products and services in an unfettered market is most appropriate.

"It is impossible to work successful/y if divorced from institutional realities."

Unlike the space program, IVHS is much more than a scientific and engineering program. It is impossible for any single agency to work successfully if it is divorced from institutional realities. Working relationships between DOT and state and local transportation agencies are already established. State and local agencies have the primary responsibility for the deployment of traffic management systems. The need to coordinate vehicle equipment development with public highway and transit infrastructures across diverse agencies makes it impossible to rely completely on actions solely performed within the automotive and communications industries.

PUBLIC/PRIVATE COLLABORATION

Still, it is clear that the private sector will be able to develop and implement some technologies without regard to public sector activities. In some instances, there also can be centralized decision-making on particular technologies. For the most part, however, development and use of IVHS technologies will require collaboration and cooperation among independent participants. Public and private parties have agreed that a national institution is required to foster discussion, communication, cooperation, and consensus among the many autonomous yet interdependent IVHS participants. This institution would promote an integrated system, accelerate deployment, and achieve appropriate uniformity of markets. IVHS AMERICA was founded to fulfill this role.

Each company or government agency participating in the IVHS program is responsible for the management and operation of its own activities. No single authority will direct any agency or company to undertake any particular project. Instead, the public and private sectors and each agency or company within those sectors will assume responsibility for those projects and activities that fall within their own individual interests.

When responsibility is shared, it is expected that partnerships and collaborations will emerge. There is no single formula for the types of partnerships and collaborations that will materialize during the IVHS program. Various elements of IVHS can have vastly different implications for diverse organizations and can involve different customers and beneficiaries; those elements can require a variety of skills in order to be developed, implemented, and operated. That implies differences in program goals and needs between groups, and therefore differences in the partnership arrangements best suited for each program area. Partnership arrangements will develop for specific purposes, often for only limited durations.

Program Elements

The IVHS program will be composed of the following elements.

- ***A forum for IVHS community interests.*** Many diverse players and interests must come together to focus on objectives, issues, consensus-building, and program coordination. IVHS AMERICA was created to meet that need.

- ***A strategic and program plan.*** A broad programmatic strategy and plan is necessary to guide the sequence of actions and form a basis for public sector budgeting and private sector internal planning and budgeting. This Strategic Plan is the first step in that process.

- ***A system architecture.*** Working toward an overall system architecture or master framework will identify system elements and facilitate successful integration among them.

- ***Standards andprotocols.*** Standards must be developed and adopted to ensure compatibility among systems and across jurisdictional lines. As applicable, existing standards will be adopted to minimize the time and effort of the standardizing process. This will allow companies to sell competitive, interchangeable products over large national (or international) markets, and it will allow consumers to benefit from their personal investment in IVHS equipment as they travel through multiple jurisdictions.

- ***Research and development.*** R&D for near-term technology deployment will focus on adapting solutions — known, proven, or both — to vehicle and highway applications and moving quickly to operational testing to select the best technologies. Over time, more substantial R&D efforts will be required to bring the most promising benefits of the more advanced stages of IVHS (for example, automated highway segments and intersection collision management systems) to fruition.

- ***Operational testing.*** Operational tests are, in general, joint public/private ventures that serve as the transition between R&D and full-scale deployment of system technologies. A test is designed to provide progress toward operational deployment of one or more technologies or institutional or financial arrangements. Operational tests are needed to determine whether a promising technology or system is ready for deployment, whether the expected benefits can be achieved at the expected cost levels, whether a cost or benefit is more or less favorable than that achievable using an alternative approach, and to assist in the transition to the marketplace. In order to maximize the cumulative benefits of many such tests, a set of national test selection criteria, evaluation criteria, and evaluation methodologies needs to be administered with federal leadership. Longer-term operational evaluation will be needed to ensure that systems that are developed perform as intended and are cost effective, safe, reliable, durable, and maintainable.

- ***Deployment of both infrastructure and vehicles.*** It is likely that much of the deployment of the IVHS infrastructure will be funded by regular federal aid funds and other public sources, with construction and operations being managed by state and local agencies. Private development of facilities through contract or franchise is also likely. Deployment of equipment or systems on vehicles primarily will depend on decisions made by the private sector, based on expectations of market acceptance.

- ***Institutional and Legal challenges.*** Interagency cooperation in the effective management and operation of the vehicle-highway system across multiple jurisdictions is as critical as the deployment of the technologies. Anti-trust laws, product and tort liability, privacy concerns, and general public acceptance may affect progress in developing and deploying IVHS. Mechanisms must be developed to assess these constraints and bring about appropriate change.

- ***Education and training.*** IVHS will require expertise in a number of technical disciplines that are new to the transportation field. Broader education of transportation professionals will be necessary, including expertise in such areas as software systems, communications, informational systems, and institutional issues.

IVHS Development

Five Functional Areas

"The five functional areas are invaluable in understanding IVHS technologies."

Historically, IVHS has been divided into five functional areas. That approach has proven invaluable in understanding a complex and imposing array of technologies. This initial section follows that taxonomy, The areas are:

- Advanced Traffic Management Systems (ATMS)
- Advanced Traveler Information Systems (ATIS)
- Advanced Vehicle Control Systems (AVCS)
- Commercial Vehicle Operations (CVO)
- Advanced Public Transportation Systems (APTS)

The description of each functional area begins with a brief Definition. That is followed by Characteristics ***and Requirements,*** a review of ***Current Status,*** and a description of the program ***Plan Elements*** that are needed for advancement. Finally, ***Deployment*** issues and timing are discussed.

"The five areas are interdependent in many ways."

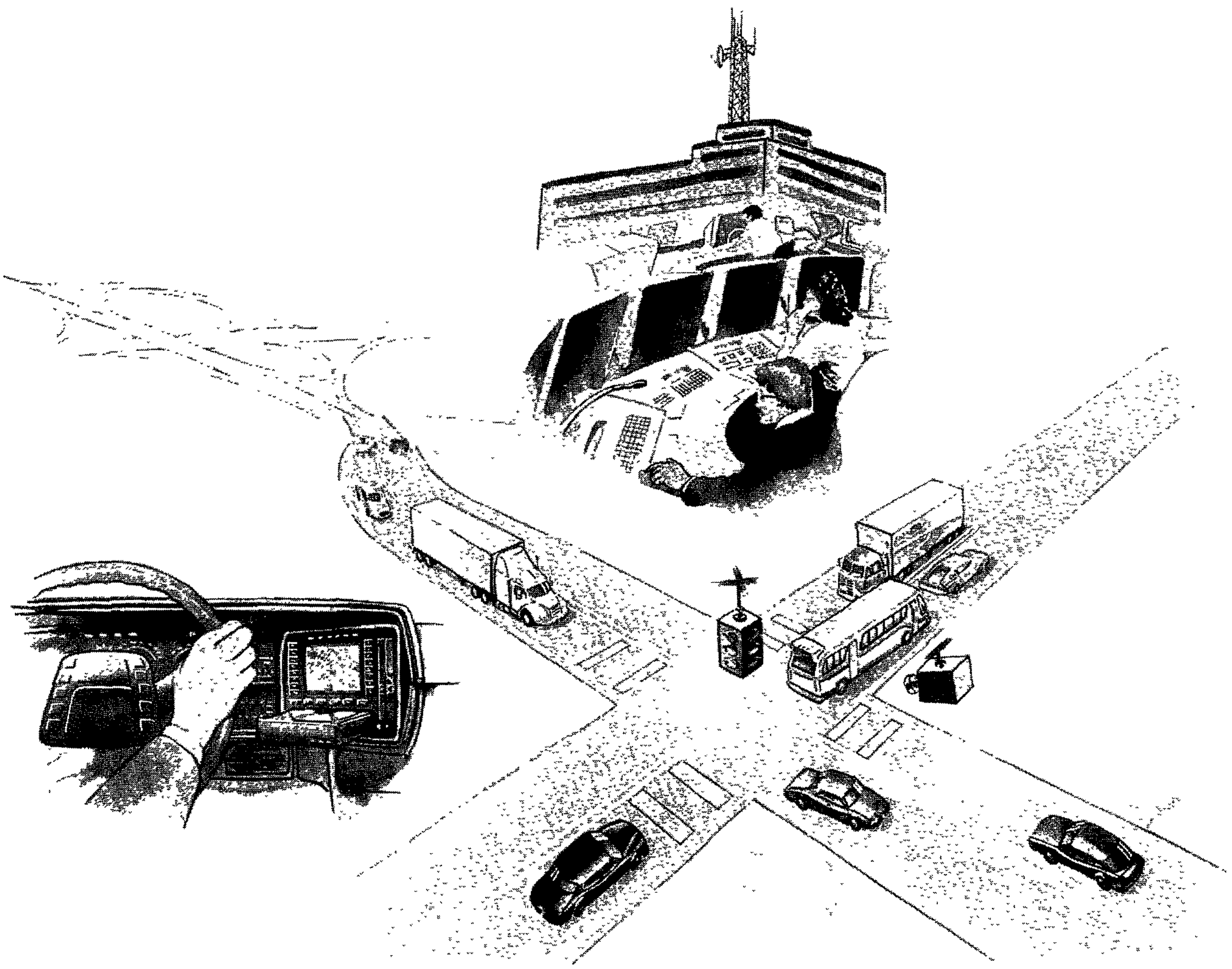
The five functional areas are interdependent in many ways and, therefore, integration issues are considered in a section that immediately follows the five functional areas.

ADVANCED TRAFFIC MANAGEMENT SYSTEMS (ATMS)

ATMS involves detection, communication, and control. The foundation is a surveillance system that detects traffic conditions over a wide geographic area and transmits the information to a traff ic management center. The traffic management center processes the information and combines it with information obtained from other sources, including vehicles acting as probes in the traffic stream. The processed information is used to:

- Manage the system by selecting ramp metering rates, adjusting signal timing, and managing incidents.

- Advise people about traffic conditions, how to avoid blockages, and where to find parking or other services



Advanced Traffic Management Systems (ATMS)

Definition

Advanced Traffic Management Systems (ATMS) employ innovative technologies and integrate new and existing traffic management and control systems in order to be responsive to dynamic traffic conditions while servicing all modes of transportation. Key features of ATMS are subsystem integration and real-time control adjustments that account for traffic fluctuations.

"ATMS is the foundation upon which all other IVHS technologies rely."

Traffic management systems apply traffic engineering technologies to bring order and efficiency to the movement of highway vehicles. One system that uses current technology is the use of vehicle detectors, communications, computers, and ramp signals to meter the flow of vehicles entering a freeway. The concept of ***advanced traffic management systems*** **(ATMS)** refers to the merger of current and evolving traffic operations technologies and the application of those to both the highway and the vehicle. This will bring about even greater operational efficiencies.

ATMS represents the "smart highway" with which the "smart vehicle" will communicate. It is the foundation upon which all other IVHS technologies rely.

Characteristics and Requirements

The following are the primary characteristics of ATMS:

- Collection of real-time traffic data
- Reaction to changes in traffic flow with timely traffic management strategies — predicting when and where congestion will occur based on real-time information, providing routing information to motorists, and making appropriate adjustments to control devices
- Area-wide surveillance and detection systems
- Integration of the management of various functions, including transportation information, demand management, freeway ramp metering, automated (electronic) toll collection, and arterial signal control
- Collaborative action on the part of transportation management agencies and jurisdictions in order to optimize the strategies available to improve traffic flow
- Rapid response incident management strategies

"ATMS involves detection, communication and control."

In order to implement ATMS, real-time traffic monitoring and data management capabilities must be developed, including advanced detection technologies such as image processing systems, automated vehicle location and identification techniques, and the use of vehicles themselves as traffic probes. New traffic models must be created, including real-time dynamic traffic assignment models, real-time traffic simulation models, and corridor optimization techniques. The applicability of artificial intelligence and expert systems techniques must be assessed, and applications such as rapid incident detection, congestion anticipation, and control strategy selection must be developed and tested. Responsive demand management concepts must be evaluated during periods when heavy congestion is predicted. That includes strategies such as providing HOV or transit information, controlling and defining parking restrictions, and collecting roadway user fees through the use of automated collection systems.

Current Status

Given the congestion problems faced by North America, remarkably little deployment of traffic management technology has taken place. In 1991, only fifty-five American and seven Canadian urban areas had any element of a traffic management system in place for freeway operations. Altogether, they barely covered 1,000 miles, half of which was in Southern California. Only one area, Long Island, New York, had a traffic management system (INFORM) that combined control of both freeway and arterial roadways to optimize traffic routing and efficiency.

Most arterial systems in place today cannot provide control on a network-wide basis and cannot respond to non-recurring congestion. Most can only enable smooth traffic flow in one direction. Existing systems do not optimize traffic flow on a corridor or area-wide basis.

In the U.S., several programs are under way to develop ATMS targets. The Smart Corridor project, located along the Santa Monica Freeway in Los Angeles, will integrate freeway surveillance, control, and computerized signal systems with various traveler information technologies, including highway advisory radio (HAR), changeable message signs, kiosks, and teletext. The project has advanced to the implementation stage, with construction continuing through 1993. California has also embarked on substantial research within its PATH program. That program involves development of IVHS technologies that facilitate both traffic management and driver information.

The Minnesota Department of Transportation is currently upgrading a Transportation Management Center to support its Guidestar program. The objective of Guidestar is to integrate ongoing ATMS and ATIS efforts with a wide range of new IVHS technologies. The purpose is to gather traffic information and distribute it to traffic managers and motorists. Image processing surveillance devices are currently being installed and broadcast-quality traffic flow information is being provided through cable television.

TRANSCOM, a consortium in New York and New Jersey, includes fourteen transportation and public safety agencies. The consortium's primary goal is to improve inter-agency response to traffic incidents. However, the project will also evaluate the use of automated (electronic) toll collection systems and systems for improving traffic monitoring and incident detection. Approximately 1,000 commercial vehicles will be equipped with small electronic transponders. Readers will be placed at selected toll booths to provide electronic toll collection for vehicles equipped with a transceiver. Readers at other locations will allow these vehicles to serve as traffic probes.

In spite of these promising developments, there has been a very low level of ATMS deployment. The oft-stated reason is lack of funding. The IVHS Corridors Program contained within ISTEA has authorized the expenditure of a substantial amount of funds — $501 million over the next six years — toward assisting the development and implementation of intelligent vehicle-highway systems along various transportation corridors throughout the U.S. That program — along with emerging state programs — will greatly enhance the rate of deployment for those systems. Funds earmarked by states for near and middle term ATMS development and deployment include $1 billion in California, $100 million in Minnesota, and $400 million in Texas.

"The ISTEA Corridors Program authorizes $501 million for ATMS deployment."

However, deployment involves far more than just funding. It also requires building area-wide coalitions. It requires sharing responsibilities. ATMS requires a commitment to continue the cooperative and efficient operation of many different highway and transportation systems. None of those requirements is easily met. Therefore, the ATMS elements of the Strategic Plan address not only the research and testing needs, but also the planning and engineering needs that must precede full-scale deployment of ATMS technologies. Other sections of this Strategic Plan address marketing, coalition building, funding, and other institutional issues as they relate to ATMS.

Plan Elements

The progressive deployment of ATMS in various urban areas throughout the country will be characterized by a range of types and sophistication. Many research, development, operational testing, and deployment activities will be undertaken simultaneously.

"Early implementation focuses on expanded use of available technology."

Early implementation of new or expanded freeway surveillance, incident management, and arterial roadway traffic signal control systems is critical to successful advancement of ATMS. In order to achieve the deployment levels projected in this Strategic Plan, federal funds are needed to help finance planning and preliminary design studies in at least ten metropolitan areas and five urban/rural corridors for each of me first five years.

The long-term vision for ATMS is a fully integrated, interactive, and adaptive system, characterized by the following:

- Integration of all modes of transportation, jurisdictions, and traffic management functions
- Support of proactive traffic control
- Fully automated data collection, congestion prediction, traffic control implementation, toll collection, and communication of traffic conditions
- A unified database structure is employed in support of integration, operating efficiency, and planning at all levels of decision-making
- Automated incident management

In order to realize this long-term vision, a comprehensive program must be initiated that consists of ATMS planning and engineering, research and development, and operational testing. The program must be carefully integrated with other IVHS technologies.

AREA-WIDE PLANNING AND ENGINEERING

The widespread deployment of advanced traffic management systems is predicated on immediate deployment of currently available traffic operations technology. Yet it is essential that planning and engineering be quickly initiated for installation of traffic management systems in those areas — urban and urban/rural corridors — that can potentially benefit the most.

Near Term

Throughout the Strategic Plan:
- *Near term means a 5-year timeframe*
- *Middle term means a 10-year timeframe*
- *Longer term means a 20-year timeframe*

Beginning this year (1992), at least ten major metropolitan areas are expected to complete area-wide ATMS planning and preliminary engineering studies each year. In addition, at least five major urban/rural corridors connecting metropolitan areas are expected to complete studies each year. Those studies should lead to the creation of state/local coalitions dedicated to the implementation of area-wide and corridor traffic management systems. At the conclusion of this period, 50 of the largest metropolitan areas and 25 of the busiest urban/rural freeway corridors will have preliminary engineering studies completed — coalitions will have been formed, and deployment will be well under way,

Middle Term

At the conclusion of this period, at least 100 additional metropolitan areas and 50 urban/rural inter-city freeway corridors should have completed planning and engineering studies.

Longer Term

Within the first half of this period, ATMS planning and engineering for the 245 largest metropolitan areas is expected to be completed, thus allowing full deployment to occur in those cities. When the implementation is complete, 19,000 miles of freeway and 40,000 miles of urban arterial roadways will be covered. In addition, inter-city freeway corridor planning will continue to link metropolitan areas so that most of the rural interstate mileage will be under ATMS control.

RESEARCH AND DEVELOPMENT

This Strategic Plan describes and supports a comprehensive R&D program: its goal is to make necessary ATMS technologies available so that full-scale operational tests can begin by 1997.

Near Term

The overall strategy during this period is to initiate a multitude of parallel studies, of equal priority, in five primary areas. Close coordination among those studies must be maintained to ensure required system integration prior to operational testing. Modularity, portability, and ease of upgrading are key elements. The five areas and the recommended research projects within each are listed below.

- Traffic Surveillance and Monitoring. Develop advanced approaches for the following:

  — Area-wide detection
  — Integration/fusion of traffic data from all sources (such as police reports, drivers, and automated surveillance)
  — Incident detection techniques for both freeways and surface streets
  — Vehicle classification
  — Trip/travel monitoring (origin and destination)
  — "Non-hardware" surveillance — relying on inputs provided by people (such as traffic reporters or cellular phone users)

- ***Traffic Control.*** Developments in this area will take into account multi-modal travel (such as HOV or mass transit) requirements, and will include the development of the following:

  — Real-time, traffic-adaptive logic for signal control
  — Real-time, traffic-adaptive logic for freeway control, including ramp and possibly mainline metering
  — Real-time integration of freeway and surface street control
  — Transit and emergency vehicle priorities

- ***Traffic Models.*** Develop models and algorithms that use real-time data to determine optimal control strategies. They must enable the real-time management of traffic while accommodating both pre-trip planning and en route travel plan modification. They must also provide the means for evaluating the benefits of various aspects of IVHS. Technologies that are likely to be useful include artificial intelligence, expert systems, and parallel computing. The traffic modeling projects include the following:

- Travel forecasting models
- Optimal routing methods
- Support systems for traffic management centers
- Dynamic traffic assignment models
- Traffic simulation models
- Network-wide optimization programs
- Driver/traveler behavior models (human factors)

■ ***Human Factors.*** From an ATMS viewpoint, define the following:

- Travelers' selection methods and information needs for:
  - Transportation mode selection
  - Determination of route alternatives and selection of route
  - Departure time selection
- The content and format of information that promotes traveler use of and compliance with system guidance
- Traffic management system operator information needs with respect to both content and format
- System operator-machine interface requirements
- Control center equipment and layout requirements
- Automated versus manual operation requirements

■ ***Integrated Systems.*** Define and develop functional requirements, specifications, and conceptual plans for the integration of advanced technologies. This must take into account the degree of automation, communication and data requirements, malfunction management (fail-safe operations), inter-agency coordination (such as state and local transportation authorities, police, fire, and rescue), and deployment strategies. It must also encompass the integration of ATMS with ATIS, CVO, APTS, and eventually with AVCS.

Middle Term

During this time, ATMS will emphasize deployment. The strategy will be to test the technologies listed above and to refine their operation and efficiency based on technological advancements and field experiences. During this period, the objective will be to optimize the products already developed while defining and conducting the research to address technological gaps. The proposed approach, in priority order, includes the following:

■ ***Implementation of Technologies.*** This item focuses on the implementation of technologies developed in the first five years through a comprehensive operational test program. It will also define the gaps between the state of the art and current practices.

■ ***Evaluations.*** The area of evaluation will provide the tools and procedures necessary to quantify the benefits provided by ATMS, the cost of ATMS implementation, and ATMS market acceptance. Accurate evaluation is essential to the success of ATMS. Without

"Accurate evaluation is essential to the success of ATMS."

it, many resources could be wasted as a result of developing and deploying systems that offer little value or have poor market acceptance. With accurate evaluation, resources can be focused on products with high benefit/cost ratios and eager market acceptance. Accurate evaluation will also contribute significantly to the definition of technological gaps, the assessment of the effectiveness of various educational and technology transfer activities for users and operators, and refinement of future strategies for subsequent national deployment of IVHS.

- ***Bridging Technologies.*** This area will develop the technologies necessary to bridge the state of the art and current practices. Near-term research will establish requirements for areas such as equipment functionality, amount and availability of data, and surveillance configurations. During this period, technologies and approaches to resolve those implementation issues will be actively pursued.

- ***Support and Maintenance.*** Early deployment of ATMS technologies, through operational tests, will yield valuable information regarding support and maintenance requirements. Staffing, level of expertise, funding, and overall resources required will be determined. During the middle term, malfunction management strategies will be refined and the overall performance of specific systems will be assessed with various components not functioning properly.

- ***Research and Systems Integration.*** Throughout this period, development will be emphasized, and research must continue to produce new and improved versions of ATMS. There will be technological advances in mass transit and deployment of AVCS technologies, along with the need to integrate ATMS with other systems.

Longer Term

During this period, ATMS will continue to be deployed while advancing the state of the art. The efforts include the following:

- Tailoring technologies for specific sites and applications
- Deploying mature ATMS systems
- Addressing long-term problems associated with the support and maintenance of ATMS
- Incorporating new technological advances
- Addressing additional mobility needs

OPERATIONAL TESTING

Operational tests of ATMS will be performed, incorporating various products from the research and development effort and demonstrating their effectiveness and reliability in an operating system. The operational testing program will be designed to gather data to promote and emphasize implementation of ATMS. Human factors testing will be included and emphasized in every operational test. Each test will include extensive evaluation.

Near Term

In the near term, ATMS operational tests will focus on integrating currently available technologies in order to create fully operational systems. The following tests are necessary:

- ***Advanced Detection Devices.*** Improvements in detection technology will be demonstrated on a system-wide basis. Demonstration of detection technologies will include video imaging, infrared arrays, microwave detectors, and other emerging technologies. The testing will be conducted within fully operational traffic management systems at multiple sites, including freeway and arterial roadway applications.

- ***Freeway/Expressway Variable Speed Limit Systems.*** Variable speed limit systems are used around the world for safety enhancement and traffic control. By slowing traffic before it encounters congestion, shock waves can be minimized, thus improving traffic flow and reducing the potential for rear-end accidents. Tests will demonstrate advanced systems for monitoring traffic flow, algorithms for setting speed limits, speed limit displays, and downstream congestion warning messages. Tests will be undertaken in both urban and rural settings.

"Human factors will be emphasized in every operational test "

- ***Advanced Control Hardware.*** More powerful computers, improved communication devices, and more powerful displays will allow further advances in ATMS. Those devices will need to be tested in operating systems to determine their effectiveness.

- ***Expert System/Artificial Intelligence-Based Management Strategies.*** Advanced software technologies will be tested, including expert system and artificial intelligence approaches to traffic control and traffic management. Incident detection, incident management, special event coordination, and network management are specific applications that may lend themselves to expert system and artificial intelligence approaches. Results from the research and development effort must be incorporated into operating systems to determine the viability of these approaches and to identify and resolve any interface problems that might occur.

- ***Automated (Electronic) Toll Collection.*** Many automated (electronic) toll collection methods are currently being tested and some are already in widespread use (over 250,000 vehicles are currently equipped). In certain areas, vehicles equipped with AVI transponders provide an excellent population of "probes" for advanced traffic flow studies. As technologies for automated vehicle identification continue to develop, applications for toll collection will need to be tested. The tests will demonstrate the effectiveness of electronic toll collection techniques and will compare competing technologies. Tests should be conducted in rural as well as urban settings.

- ***Lane Control Systems.*** Lane control systems have proven effective in Europe as incident management and construction traffic management tools. Tests will demonstrate display technologies and incident detection and verification systems that are necessary to make lane control effective: tests should be conducted in both urban and rural settings.

- ***Integrated Traffic Management Systems I.*** The viability and benefits of integrating the operation of multiple existing traffic management systems in a given region will be demonstrated — arterial and freeway systems and systems operated by several agencies (for example, state and local transportation authorities, police, fire, and rescue) will be included. Central to these tests will be the resolution of institutional issues surrounding corridor or area-wide integrated system operation. The primary focal points for the effort will be communication strategies to tie various systems together, institutional arrangements that are necessary among the various jurisdictions, databases able to integrate large amounts of information from a variety of sources, and management strategies that adapt to changing traffic conditions and treat multiple systems as a single network. The system will provide the platform for demonstration of the advanced control strategies being developed during this time frame.

"The benefits of area-wide integrated ATMS will be tested, and institutional issues will be resolved."

- ***Vehicles as Probes — ATMS Working With ATIS.*** The ability of vehicles equipped with AVI or AVL technology to enhance the data collected through existing detection techniques will be tested. Trade-offs between system detection and vehicle probe information need to be evaluated to determine their effectiveness both in detecting incidents and in providing the data necessary for management and control strategies. This empirical analysis must include determining the number of probes needed to provide adequate data for each strategy. Likely candidates for probes include buses and other fleet vehicles.

- ***Predictive Control Algorithms.*** Products that control traffic based on predicted information such as traffic flow, congestion, and traffic demands will be tested in operating traffic management systems. Candidate algorithms will be tested side by side to determine the applicability, strengths, and weaknesses of each.

- ***Advanced Communication Systems.*** Communication systems are the backbone of ATMS. As more data and information is exchanged among vehicles, roadside equipment, and control centers, more capable communication systems will be required. Operational tests will be used to quantify the cost-effectiveness, reliability, and maintainability of communication systems as they are developed.

Middle Term

During this period, ATMS operational tests will focus on technology and products that were developed during the first five years through the ATMS research and development effort. Tests to be undertaken include those listed below,

- ***Real-time Traffic Assignment,*** Real-time traffic assignment algorithms in operating systems will be tested. Those assignment models will also be used by route guidance systems. Incorporating the function of traffic assignment into traffic management and control algorithms will be the primary focal point of these tests, along with determining driver reaction to route guidance instructions.

- ***Integrated Traffic Management Systems*** II. These tests will build on the experience gained from the near-term testing (Integrated Traffic Management Systems I). They will focus on control functions, specifically demonstrating control algorithms that treat the entire network as a single system regardless of facility type (freeway or arterial) or jurisdictional borders. Institutional arrangements made for the first set of tests will allow a central computer to issue control commands to component subsystems. Predictive control algorithms, expert systems, artificial intelligence, and real-time traffic assignment will be incorporated.

"ATMS provides a fool-box' that will aid in implementing new public policies as appropriate."

- ***Integrated ATMS/ATIS System.*** This testing builds on the Integrated Traffic Management System II testing. It demonstrates optimized system performance by combining adaptive traffic control with route guidance and other ATIS strategies. The systems will be able to determine traveler reaction to various ATIS messages, displays, or instructions and will be able to account for those with changes in the system control strategies.

- ***Roadway User Fee Collection.*** IVHS technologies provide a "toolbox" that, when appropriate, can facilitate implementation of improved methods for collecting various types of roadway user fees (for example, to replace or supplement fuel taxes). In order to adequately evaluate fee collection technologies, operational tests will be performed on various types of roadway systems. Data will be collected and analyzed to quantify the benefits and drawbacks of various technologies and strategies. The tests will focus on the ability of the system to accurately track vehicles through the network at all times of the day and to keep track of the miles traveled by each vehicle.

Longer Term

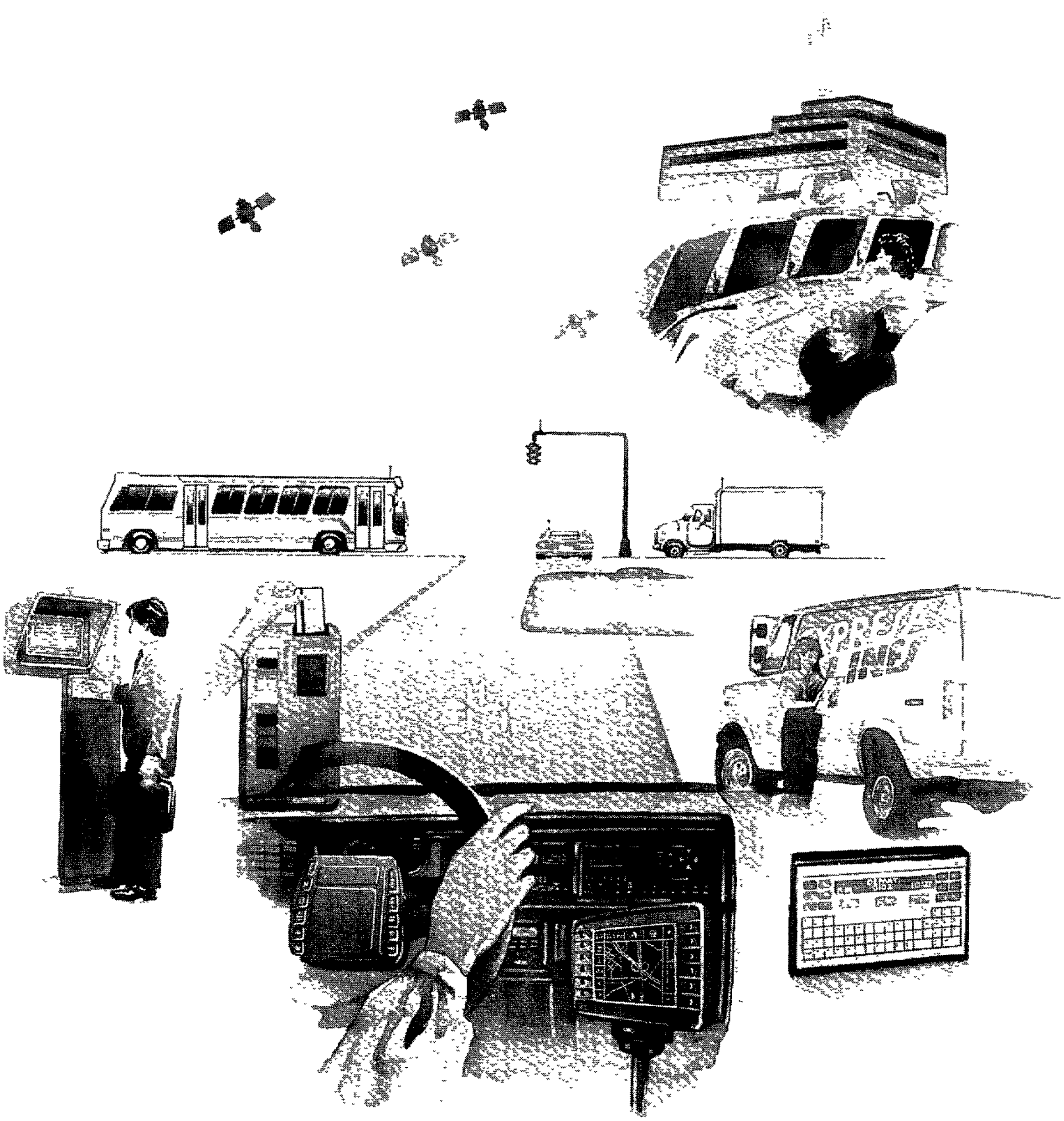
During this period, IVHS operational tests will be used to demonstrate full-scale implementation of IVHS technologies and to fully incorporate all aspects of IVHS. The primary focus of ATMS operational testing will be the integration of more advanced IVHS technologies into ATMS and the continued testing of developing ATMS technologies. ATMS testing during this period will be of similar scope to the tests conducted during the middle term. The large-scale tests necessary during that period will provide the integrated systems necessary to conduct technology-specific tests during this ten-year period. Specific developments will be tested in fully operational, area-wide integrated systems.

INTEGRATION WITH OTHER IVHS TECHNOLOGIES

ATMS is the primary channel through which information will flow between area-wide system operations and individual vehicle users. For that reason, ATMS must be carefully designed to work in harmony with all of the other IVHS functional areas. Early systems will closely interact with ATIS, CVO, and ARTS systems. Later systems will be required to closely support AVCS.

ADVANCED TRAVELER INFORMATION SYSTEMS (ATIS)

ATIS equipment in vehicles, at home, and away from home – in stores and offices and from sidewalk kiosks and portable receivers – will provide transportation users with information on traffic conditions, routes, and schedules.



Advanced Traveler Information Systems (ATIS)

Definition

Advanced Traveler Information Systems (ATIS) acquire, analyze, communicate, and present information to assist surface transportation travelers in moving from a starting location (origin) to their desired destination. The systems provide such assistance in a manner that best satisfies the traveler's needs for safety, efficiency, and comfort. The travel may involve a single mode of transportation, or it may link multiple modes together during various parts of the trip.

"ATIS systems acquire, analyze, communicate, and present information."

In this Strategic Plan, ATIS includes only those tasks that provide traveler information. Enhancements related to providing information that aids an operator in safely controlling a vehicle (such as obstacle warning) have been included as part of Advanced Vehicle Control Systems (AVCS) and are described later.

A major component of ATIS is providing information to the driver of a vehicle. Without utilizing any support from outside the vehicle (autonomously), ATIS can employ visual and auditory presentations to inform drivers of their current locations, aid them in planning their routes, help guide them to their desired destinations, and provide various informational services. ATIS may also provide communication between the vehicle and an Advanced Traffic Management System (ATMS) that provides continuous information to the driver regarding traffic conditions, roadway congestion, alternate routes, parking, and other up-to-date information. Real-time information could include locations of accidents, weather and road conditions, optimal routes, recommended speeds, and lane restrictions. ATIS equipment in a vehicle can also be used to provide safety warning information on potentially dangerous driver, vehicle, road, or environmental conditions.

Specific ATIS features and products include the following:

- Navigation systems with electronic vehicle or traveler position determination
- Data communication — transceivers (in-vehicle, home, kiosks, and hand-held) providing information to and receiving information from traffic management centers
- Route planning and guidance systems — multi-modal, single mode, or both — to aid in maximizing travel efficiency

- Automated vehicle identification (AVI) — for uses such as transit vehicle tracking, private vehicle toll debiting, or commercial vehicle credential processing and verification
- Flexible driver interface (variable format video displays and voice output) for providing maps, traffic information, route guidance, road sign information, and other travel information
- Warning systems for various operational and maintenance conditions on a transit, commercial, or private vehicle
- Emergency (Mayday) services with signaling (automated or manual) and response capabilities
- A wide variety of databases, including detailed maps, business directories, transit schedules, tourist information, and the location of various services
- Integrated ATIS/AVCS systems that channel AVCS vehicle control and driver condition information warnings through the ATIS
- Dynamic route guidance that can reroute vehicles around traffic congestion or incidents

Developing and deploying ATIS will be done in the context of a long-term vision so that early installations can evolve gracefully into permanent installations.

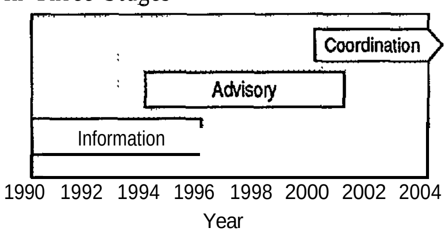
There is much overlap between the general functions provided by ATIS and the application of ATIS functions to both public transportation (such as transit schedule information provided at kiosks) and commercial vehicle operations (such as routing). This Strategic Plan has handled the overlap by addressing ATIS features that apply primarily to public transportation or to commercial vehicle operations in those respective sections.

Characteristics and Requirements

The evolution of ATIS is expected to occur in three stages: an information stage (near term), an advisory stage (middle term), and a coordination stage (longer term). Detailed descriptions of the operational features for each stage are provided in the following sections. It should be noted that not all ATIS products will necessarily evolve through all three stages. Some products may initially be deployed as coordination stage products, while other products may mature as information stage products. Since most of the required enabling technologies already exist, advancement through the evolutionary stages is not expected to require major technological breakthroughs. Thus, ATIS development will primarily be an engineering and applications task. However, research, development, and significant operational testing are required to apply the technologies, define standard interface requirements, quantify benefits, reduce costs, and assure that the systems operate in a safe and efficient manner.

In ATIS systems, it is important that the traveler not be confused by an overload of information. It is particularly important that a driver not be distracted, thus reducing attention to the driving task. The types and amounts of information and the methods of presenting information must be carefully studied in order to ensure that highway safety and traveler efficiency are enhanced and not degraded by information systems. Human factors studies, including cognitive and user demographic analyses, are required to establish the effectiveness and acceptance of any proposed communication or information system.

Development of ATIS in Three Stages



Advances in electronic technology have spurred development of an assortment of communication systems and media which make it easier to provide information. They allow information to be provided either to a driver in a vehicle or to a traveler in the home, for example, using a personal computer. Information such as electronic route maps, tourist guides, and service directories can be self-contained within the vehicle and can be accessed through media such as a compact disc (CD-ROM) or a computer disc. Vehicle status and warning indications can also be provided through self-contained in-vehicle sensors.

On-board display of roadside signs provides both safety and navigation benefits. Such devices replicate warning or navigational roadside signs that may be obscured or may be difficult to read during night driving or inclement weather. They can also display new information when signs need to have their messages changed, such as to lower speed limits during ice, snow, rain, or fog conditions. On-board displays allow messages to be tailored to the needs of specific vehicles, such as heavy trucks.

"Human factors studies are essential for ATIS effectiveness and acceptance."

Although all of these systems add convenience and security to the traveling experience, they lack the dynamic, or real-time, traffic and roadway condition information that is necessary to optimize route selection and other operational decisions. To obtain that information, communication links with ATMS must be established. A one-way link from ATMS to the traveler can provide up-to-date information on traffic congestion, safety advisories, parking lot status, and environmental conditions (such as ice, snow, and rain). A two-way communication link with a vehicle allows the vehicle to serve as a traffic sensor. As such, it can provide information to the traffic management system, allowing the system to anticipate congestion and provide relief measures. A two-way communication link also facilitates traveler interaction with ATMS, allowing specific information to be provided by both the traveler (for example, origin and destination or Mayday signals) and the ATMS (such as specific routing or Mayday acknowledgement).

Current Status

"ATIS development has been under way fur several decades."

Work on ATIS technology has been under way for several decades. Early work was supported by the Federal Highway Administration's (FHWA) Electronic Route Guidance System (ERGS) program. In the mid-1980's, the California Department of Transportation (CALTRANS) renewed its emphasis on utilizing advanced technology to deal with growing urban traffic congestion. Other government organizations, industries, and universities have since become active in this field. The United States led the world in developing ATIS technologies in the late 1960's and early 1970's, but now lags both Europe and Japan. Recent competitive efforts on ATIS in Japan and Europe are spurring U.S. companies to pursue ATIS technology more aggressively.

In 1968, FHWA recognized that many drivers cannot effectively use paper road maps, and that growing metropolitan areas contribute to navigation problems. As a result, they sponsored research to develop an ERGS system to provide in-vehicle directional guidance to the driver. If it had been implemented, ERGS would have improved driver navigation in urban areas by providing a series of directional arrows (displayed in the vehicle) to give route guidance between a preselected origin and destination. The proposed system included many of the characteristics that were later implemented in the Ah-Scout System of Berlin and the Autoguide System of London which are currently being planned and piloted. A planned operational experiment in Washington, D.C. was abandoned in 1971 when Congress questioned the timing of the need, the cost, and the technology.

In 1973, the Japanese Comprehensive Automobile Traffic Control System (CACS) project began. By 1979, it had established the feasibility of the ERGS technology. That work established the support for current field operational experiments that are under way in Japan (AMTICS, RACS, and VICS).

As traffic congestion increased in the United States in the 1970's and 1980's, radio transmissions were widely deployed to alert motorists of adverse traffic conditions (traffic advisories through commercial radio stations) and to provide local area guidance to special attractions (highway advisory radio [HAR]). Changeable message highway signs have been implemented on a limited basis to provide speed and warning messages to motorists. Since 1984, mobile communications have been available to the driver through cellular telephones, use of which is expected to climb to 20 to 50 million units by the year 2000.

In-vehicle navigation systems am becoming available that provide information to the driver using both video displays and voice outputs to provide electronic maps, route guidance, and vehicle location. More sophisticated systems will provide real-time information on traffic, road, and weather conditions and will provide route guidance to motorists based on real-time traffic conditions.

A number of technologies are currently available to provide electronic vehicle position determination. Most systems use "dead-reckoning" and "map-matching." Dead-reckoning is a technique that calculates the current location of a vehicle by measuring the distance and direction that the vehicle has traveled since leaving a known starting point. Map-matching minimizes the accumulated error of the dead-reckoned position by comparing the measured path to a map database and making appropriate corrections. Thedead-reckoning/map-matching approach can be supplemented by outside information, such as the land-based and satellite-based location and identification systems which are currently in use or are under development. Those systems rely on Global Positioning Satellites (GPS), LORAN-C transmitters, proprietary satellites, or land-based radio and use sophisticated triangulation techniques to determine vehicle locations. Other systems use "spot" beacons to provide the vehicle with a position "fix."

'Use of route planning sysfems, electronic maps, and in-vehicle signs can improve travel times. '

Route planning, improved maps, and more accurate and consistent signs can improve trip navigation and travel times. Pre-trip electronic route planning systems are being developed and are available at certain car rental counters. With those systems, the traveler's origin and destination are entered into a computer and a printout of directions is produced. For trip planning, the systems can estimate minimum time, distance, and travel-related expenditures. Route planning systems can also provide information on locations and schedules for public transportation.

Two broadcasting systems currently used to provide travel information are HAR in the United States and Autofahrer Rundfunk Information (ARI) in Europe. With some systems, drivers are alerted to tune the car radio to a specific frequency, and transmissions are received through the radio. With other systems, special receivers must be installed. Various traffic information broadcasting systems are being considered for use in the United States.

As mentioned earlier in this Strategic Plan, several ATIS operational tests are already planned or under way. Those include Pathfinder in the Smart Corridor of Los Angeles, Travtek in Orlando, and ADVANCE in Chicago.

The Information Stage of ATIS

Definition

During ***the information stage,*** the primary emphasis will be on providing each traveler with information to improve his or her individual travel planning and decision making. Most capabilities rely on resources contained within a vehicle or a traveler information unit (such as a personal computer or hand-held unit) and are not dependent on any infrastructure. Features falling into this category are transit schedule information units, dead-reckoning and map-matching navigation systems, on-board information databases, and static and dynamic route planning and guidance systems. With limited support from the infrastructure, real-time traffic incident information can be made available to assist travelers in personal route planning.

Characteristics and Requirements

The information stage is the start-up period for ATIS. Many types of systems with diverse features and capabilities will be explored during operational testing. The goal of those studies will be to evaluate the benefits that the various features can provide in real world situations. This stage establishes the technical and socio-political foundations critical to the future of ATIS, including launching the publicprivate sector alliances that are necessary to make ATIS a reality.

The information stage includes:
- *Navigation*
- *Planning*
- *Guidance*
- *Transit schedules*

An economically viable basic navigation/route guidance and receive-only traffic communications capability will be developed for use in both private and commercial vehicles. Those features form the core capabilities that will eventually reduce congestion and achieve safety benefits. Alternative approaches exist for determining the position of the vehicle. Each of the approaches will be investigated for cost, accuracy, and practicality in a North American system. Minimum requirements for database content will be established and standards developed. Those will encourage map makers and users to gain the mutual confidence necessary to establish a stable market that will become commercially attractive for private enterprise. Necessary human factors and behavioral studies relating to ATIS will begin. The studies will include performance issues, such as color, size, and location of displays, and will also explore the more basic issues of information intelligibility, cognitive performance in driving, and acceptability of various decision-making and routing strategies for both private vehicle and public transit travelers.

On-board route guidance instructions can be communicated to the driver in a variety of ways. In Japan's AMTICS project, the route is indicated as a highlighted overlay on a CRT map display. Auto-Guide (Great Britain) and Ah-Scout (West Germany) both use simplified displays showing schematics of intersections with directional arrows indicating the next action for the driver to take. All of those systems can be augmented with computer-generated voice, or voice can be used alone without a visual display. As flexible format head-up displays (HUD's) are developed, they will provide another alternative. Extensive human factors research is needed to determine driver reaction to the various approaches.

Alternative approaches also exist for communicating real-time traffic information to the vehicle. They can be as simple as an audio traffic message channel. Approaches that offer the potential for growth into later stages of ATIS include exclusive-channel digital traffic transmitters, digital messages on the sub-carrier of a commercial FM radio station (for example, Europe's Radio Data System's Traffic Message Channel, RDS-TMC), short-range RF or infrared transmitters (beacons) used as electronic signposts, and cellular telephones.

Plan Elements

RESEARCH AND DEVELOPMENT

Systems analysis is required to address overall system design issues, benefits, and trade-offs among the elements that constitute ATIS and its supporting infrastructure. That analysis must deal with the systems on at least three levels: (1) the complete IVHS system design, including technical, societal, and economic issues; (2) the complete ATIS system design, including users, vehicles, and infrastructure; and (3) individual subsystem designs for vehicles, stationary elements, and communication links. The results of those studies need to be corroborated by operational tests and experiments. The IVHS Integration section of this Strategic Plan further addresses R&D for all stages of ATIS, and specific projects are listed in Appendix A.

OPERATIONAL TESTING

Limited operational tests to gather real world experience with information stage ATIS systems are already planned or are under way. It will be necessary to build on that base by conducting additional experiments and operational tests using different approaches to ATIS in various roadway environments and in different sections of the country. The IVHS Integration section of this Strategic Plan further addresses those tests for all stages of ATIS, and specific tests are listed in Appendix B .

DEPLOYMENT

ATIS systems that will begin to be widely deployed during this time include the following:

- Autonomous navigation and route guidance systems that provide vehicle location, mapping, traveler route planning, and route guidance utilizing both visual and audible outputs

- Assisted navigation and route guidance systems that use outside information to provide general traffic condition information
- Automated (electronic) toll collection systems at tollbooths
- Vehicle condition warning systems
- In-vehicle display of road sign information using stored data
- Manual Mayday systems using cellular telephone or other communication means
- Various information systems to assist public transit travelers and features to assist in the efficient operation of commercial fleets (described in the APTS and CVO sections, respectively, for all stages of ATIS)

The Advisory Stage of ATIS

Definition

The ***advisory stage*** will supplement static information with up-to-date ("real-time") traffic information collected and transmitted by the infrastructure. That information will include the amount of time it will take to traverse various parts of the road network (link travel times), road sign information, traffic incident information, weather conditions, and other factors affecting traffic flow. It will also include travel and arrival times for transit systems. The information will be transmitted in a form that can be used by the various systems. The vehicle or traveler unit receives the information and uses it to compute optimum modes and routes. The information that is received will be sorted — only relevant items will be presented to travelers. Once a route is selected, a vehicle system will guide the driver, step-by-step, over the chosen route, providing critical information as needed and automatically modifying the route as road conditions change. Similarly, traveler information units will provide the transit user with real-time schedule information for planning a route, and will then provide guidance during the trip, for example, telling the traveler when and where to get on or off a particular bus in order to meet a connecting train.

The advisory sfage adds "real-time" information about:
- *Traffic*
- *Transit schedules*
- *Road signs*
- *Weather*

Characteristics and Requirements

During the advisory stage of ATIS, the in-vehicle system will begin to do more than just inform the driver of conditions. Using knowledge from the infrastructure, it will also begin to advise the driver of the best course of action to take considering the current conditions. The advice must be credible and must be perceived as both accurate and advantageous, or it will be ignored. Thus, the accuracy of the navigation system, the route planning information, and the real-time traffic information become extremely critical during this stage.

A major goal of the advisory stage is to provide automated route selection and guidance using up-to-the-minute traffic information. The selection can be based on one or more of a variety of user-selectable criteria such as minimum time, minimum distance, or avoiding freeways. To accomplish this, it is required that traffic information centers acquire traffic data from a wide variety of sources and estimate current and near-future driving time information for all major links in the road network. The estimated link travel times must be periodically transmitted to the traveler information systems, which will use them to select the suggested routes. Additional approaches exist for real-time route selection and guidance. An alternative approach would be to have the route selection done on-board the vehicle using static information while incorporating real-time alternate route information that the traffic information center is transmitting regarding congested areas.

During this stage, ATIS will also provide on-board display of road signs. Those will include both permanent and temporary signs for freeway information, traffic control, and speed limits. The goal is to have the sign information available when the driver needs it, not just when the physical sign is visible. Traffic sign information could be carried in an on-board database, which would be updated by the traffic information transmitters, or the information could be communicated directly to the vehicle from the signs themselves. That could be done in a passive mode (optical reading of sign text by the vehicle) or in a cooperative mode (such as magnetic encoding in the roadway or short-range transmitters on the signs).

Plan Elements

RESEARCH AND DEVELOPMENT

Much of the systems analysis and human factors research described for the information stage of ATIS will continue during the advisory stage. The emphasis will gradually move toward decision-making and dealing with rapidly changing dynamic information. Systems analysis will address traffic data acquisition, data fusion, traffic network balancing issues, and vehicle-to-infrastructure communications.

OPERATIONAL TESTING

The operational tests during the advisory stage will build on those conducted during the information stage. The infrastructure already developed should evolve in concert with the development of new features, which systems will incorporate.

DEPLOYMENT

ATIS systems that are expected to begin to be widely deployed during this time include the following:

- Assisted navigation and route guidance systems that use outside communication to provide routing based on current traffic conditions and to facilitate improved vehicle position tracking
- Automated (electronic) toll collection at highway speeds
- Improved visual and audible user interfaces
- Real-time, changeable message road sign display systems
- Semi-automated Mayday systems
- Systems that provide the driver with AVCS warnings

The Coordination Stage of ATIS

Definition

In the ***coordination stage,*** the vehicles and the infrastructure will automatically exchange information to optimize the flow and safety of traffic over the entire network. Vehicles will report frequently on their intended destinations and on the traffic conditions encountered along the way. The infrastructure will combine that information with information obtained from all other sources and will be able to predict near-future traffic conditions. The information will be used to provide coordinated routing, traffic signal control, and transit dispatching. Individual vehicles requiring emergency assistance (such as from police or medical personnel or for vehicle mechanical trouble) can either manually or automatically summon the required services. Those services will then be automatically routed to the scene.

Characteristics and Requirements

"The coordination stage features vehicles reporting to the infrastructure."

During the coordination stage, the traffic information center of the previous stages will evolve into a more comprehensive Traffic Management Center (TMC), with responsibility for optimizing traffic flow throughout the network. Private, commercial, and transit vehicles will serve as traffic probes by automatically reporting to the TMC on the traffic conditions and link times they encounter as they travel through the network. Route selection by individual vehicles, using information supplied by the TMC, will account not only for current traffic conditions, but also for predicted traffic conditions based on the routes of other vehicles in the network. Traffic controls will be coordinated with vehicle routing to ensure the maximum effective capacity of the traffic network.

Coordinated route planning can now be accomplished because the TMC can perform route selection and can then transmit routes to individual vehicles or groups of vehicles. That can be done on a way-point basis — as a vehicle passes one way-point, an optimal route is provided from that way-point to the next way-point in the direction of the destination.

At this stage, the travelers' equipment and the infrastructure will be capable of supporting (without significant additional equipment) an automated emergency (Mayday) service feature. That feature will provide the capability to summon emergency assistance and provide vehicle location. It can be initiated either by the traveler or automatically, as in the case of an accident. The Mayday feature could automatically dial (for example, on a cellular telephone or over a satellite communication link) directly to a service provider that is equipped to deal with such digital messages.

Plan Elements

RESEARCH AND DEVELOPMENT

The coordination stage of ATIS requires additional systems analysis, including the following:

- Division of tasks between traffic management centers and vehicles
- Development of more capable software for traffic control, including multi-modal data fusion and routing
- Defining vehicle-to-vehicle communication system requirements

OPERATIONAL TESTING

Operational tests for this stage of ATIS will enable full-scale implementation of specific ATIS features which, in earlier stages, have proven to be beneficial and cost-effective.

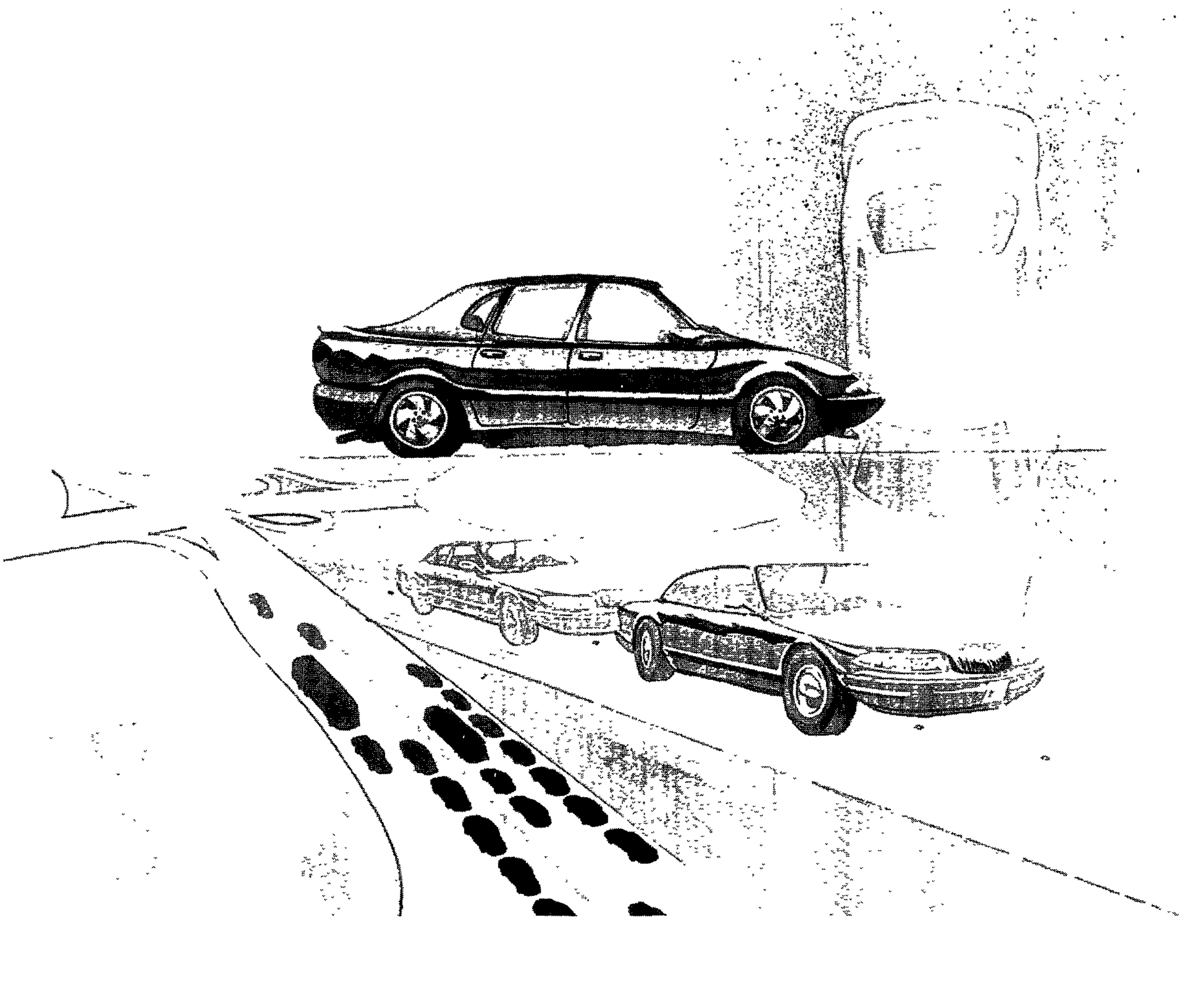
DEPLOYMENT

ATIS systems that may begin to be widely deployed during this time include the following:

- Route guidance systems that interact cooperatively with a traffic management center, providing the center with information, as well as receiving information
- Fully automated Mayday signaling and coordinated service dispatching

ADVANCED VEHICLE CONTROL SYSTEMS (AVCS)

AVCS enhances vehicle control by facilitating and augmenting driver performance. Vehicles are organized on the roadway for greater safety and capacity. Ultimately, AVCS could relieve the driver of most driving tasks in high-demand traffic corridors or on long-distance, high-speed trips.



Advanced Vehicle Control Systems (AVCS)

Definition

Advanced Vehicle Control Systems (AVCS) combine sensors, computers, and control systems in vehicles and in the infrastructure to warn and assist drivers or to intervene in the driving task. The purposes of AVCS include achieving much higher vehicle safety levels, ameliorating urban freeway congestion, achieving a new standard of inter-city highway productivity, and eventually creating entirely new concepts for surface transportation services. AVCS encompasses a broad range of products and systems that will become operational on different time scales. They have in common, however, the two new, unique features listed below:

Advanced vehicle control systems feature:
- Driver warning
- Driving assistance
- Full vehicle control

- ***Perceptual enhancement.*** AVCS will incorporate sensors to augment human eyes and ears. Those will give the driver a better sense of any impending danger and of the general situation in and around his or her vehicle.

- ***Automated controls*** that are faster, more precise, and more reliable than human reflexes. AVCS will aid in performing the driving task. Examples are automated steering, braking, and accelerating; automated compensation for lapses in driver judgement and skill; and, in time, provision of completely automated control of the vehicle when requested or when necessary.

There are many ways that these can be combined and exploited to produce new products. Some of the products will become operational within a few years, primarily as the result of private sector initiatives. Others will require a decade or more of development with significant public sector involvement, particularly in the early high-risk phases.

"AVCS promises safety improvements that are far beyond the reach of other IVHS elements."

There is abundant motivation for these developments, including the promise of improvements in safety that go far beyond what is possible with any other elements of IVHS. These include: major increases in road system capacity that are much less expensive and more environmentally acceptable than that achievable by adding additional concrete; easier and safer mobility for less skilled and elderly drivers; significant productivity increases for transit and commercial vehicle operators; and more pleasant travel for all.

Characteristics and Requirements

AVCS is not a single operational concept, but a broad range of capabilities that will be translated into products and systems in an evolutionary progression. The earliest AVCS developments will be autonomous vehicle-based systems (systems totally contained within the vehicle that do not require the existence of roadway or roadside equipment to perform a desired function) aimed at enhancing the primary safety function of avoiding crashes, rather than merely mitigating their consequences. Advanced technology can help drivers sense impending danger, alert them of lapses in their judgement or skills, aid them in performing the driving task and, ultimately, compensate for some of their errors. The principles are simple: combinations of specifically designed sensors detect imminently dangerous situations, such as closing too rapidly on the car ahead. The system then provides visual or auditory warning to the driver, and, in a later evolutionary stage, automatically takes control actions, such as applying the brakes to prevent collisions.

Impact of Automated Reaction Time

If two cars are traveling 50 feet apart at 50 mph and front car brakes:

With average human reaction time (1 second): Vehicles would collide at 27 mph

With automated vehicle reaction time: Vehicles would not collide

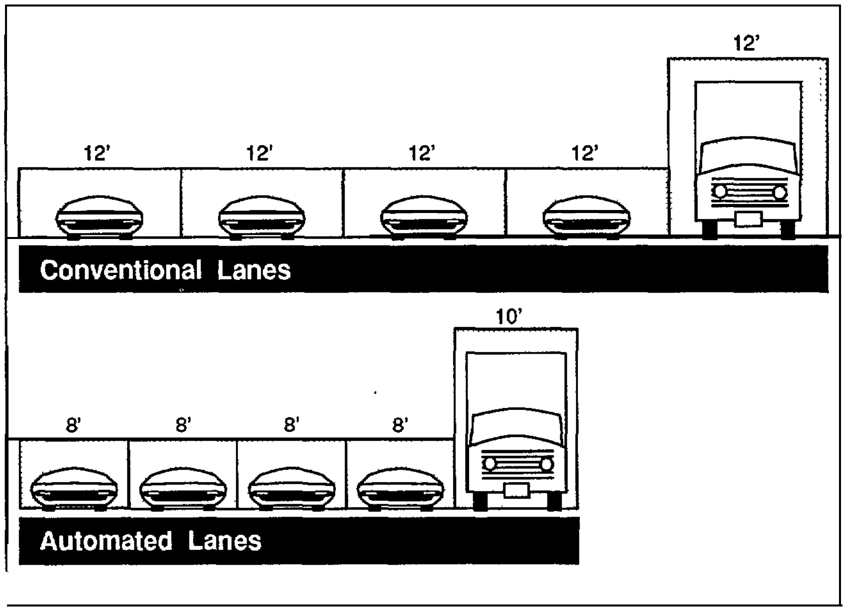
As development progresses, earlier individual products, such as automated braking and autonomous adaptive cruise control (maintaining a safe distance from the vehicle ahead), will evolve toward more comprehensively integrated systems. Systems are envisioned that sense both the behavior of the vehicle and the situation around it. If driver attention lapses occur or unsafe control actions are taken, the system will automatically compensate. Such automated “co-pilot” systems will make everyone a safer driver.

AVCS technologies can begin to confer safety benefits within the next five years without requiring infrastructure investments. Initial applications will serve as fundamental building blocks for future systems, thus offering potential for additional improvements. Some AVCS technologies will be available to the public in the near future, independent of any need for public investment in infrastructure.

Adding vehicle-to-vehicle or roadside-to-vehicle communication can enhance system performance, increase potential safety improvements, and yield some increases in roadway throughput, thus beginning the evolution toward higher levels of control. An early example of vehicle/roadway cooperation is intersection hazard management systems that warn drivers of cross traffic not visible to them. Eventually, those systems will prevent drivers from entering an intersection in the path of an oncoming vehicle. Serious crashes will be avoided not only in busy urban areas, but also at rural intersections. On urban arterial roads, AVCS will permit more precise control of vehicle movements so that intersection controls can be used more effectively than they are now. Queues at stoplights can be dissipated more quickly by enabling vehicles to accelerate to cruising speed promptly and uniformly.

More significant increases in both safety and capacity are achievable when fully cooperative vehicle roadway systems, with complete automation of vehicle control, are implemented. Faster and more precise automated control will permit vehicles to operate with closer longitudinal and lateral spacings and while traveling at higher speeds without sacrificing safety. Thus, the capacity of the existing road system will be significantly increased. The potential gains are dramatic — a four-lane freeway could reasonably be expected to safely carry the traffic that would require at least eight lanes under today's operating conditions. In time, even greater increases are expected.

Highway Capacity Improvements With Automated Control



It is most likely that these automated control technologies will initially be applied on a limited scale in a relatively controlled environment such as a special high occupancy vehicle (HOV) or truck lane on a freeway. That would minimize the scale of the required public infrastructure investment and would facilitate the verification of the expected safety and capacity improvements. The relatively "structured" environment of a single lane simplifies the technical requirements, compared to similar requirements for the general freeway or road system.

"Automated chauffeuring will increase safefy, driving convenience, and highway capacity."

After the benefits of automation have been demonstrated in limited scale applications, automated freeway operations could be extended to the whole freeway network of an entire metropolitan area, and then to inter-city and interstate highways as well. Offering "automated chauffeuring" from the origin on-ramp to the destination off-ramp will increase safety and convenience to the traveler while substantially increasing system capacity. Transit and commercial vehicle operators and urban commuters will all enjoy significant productivity improvements in urban areas. Both commercial and private drivers will benefit from relief of tedium on long trips.

These concepts illustrate the direct and natural collaboration between "smart vehicles" and "smart highways" that is the key innovation of IVHS. That collaboration makes it possible to control vehicle movements in ways that reduce the possibility of collisions and simultaneously enhance traffic flow.

Evolution will continue beyond that outlined here, leading someday to vehicles capable of origin-to-destination trips without driver control. Such technology can be employed to help solve transit system traveler collection and distribution problems. It would also permit remote automated parking, allowing prime real estate to be used for higher priority purposes. It is clear that in the distant future, a potential revolution in the mobility of people and goods is possible. Therefore, it is important to try to understand the long-term implications of that path.

The promises are real — lower-cost road capacity, improved safety, and more versatile and lower-cost transit. Many of the technological building blocks are available, in no small part from the nation's defense expenditures. The technical task is largely that of fitting the building blocks into workable and affordable systems and testing them under a wide array of conditions to guarantee robust and safe operation.

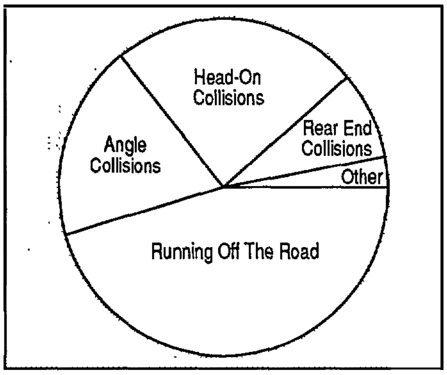
Current Status

Although AVCS is generally regarded as the most long-term of the IVHS functional areas, AVCS research and development work has been in progress in a variety of forms for over 30 years. Some of the enabling technologies for AVCS (anti-lock brakes, traction control, active suspension, four-wheel steering) are available as either standard or optional equipment on motor vehicles today and are increasing their market penetration. Other enabling technologies are under active development for non-automotive applications, such as factory automation, military and aerospace vehicle systems, and computers. These will be available for use in AVCS applications.

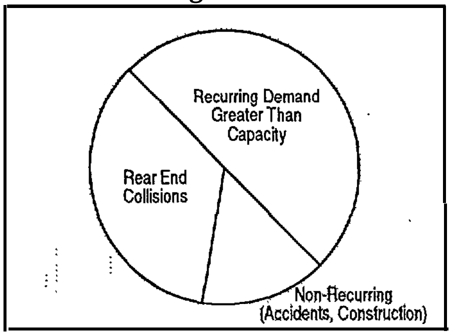
"Automated highways have already received significant aftenfion over several decades, but are still the longest- term IVHS area."

Driver warning, perception enhancement, and assistance/control systems are under very active research, development, and testing in the United States, Europe, and Japan by major motor vehicle manufacturers, as well as by large and small component supplier companies. The trade press regularly reports on these developments and on expected product introductions. The European PROMETHEUS program includes various "Common European Demonstrator" projects in areas including driver warning, perceptual enhancement, and assistance/control. Examples of those include autonomous adaptive cruise control, vision enhancement, proper vehicle operation, collision avoidance, cooperative driving, and emergency warning and calling. Although those projects are currently in the laboratory and develop-

Causes of Fatalities



Causes of Congestion



mental testing stages, extensive field tests (involving approximately 1,000 vehicles) are being planned for 1994 and beyond in Europe.

Vehicle-highway automation technologies for specialized lanes have received significant attention from both the public and private sectors. These technologies have longer development time frames than other AVCS applications and will require significant public sector investment both in R&D and in infrastructure deployment. Vehicle-highway automation is currently being pursued under the California PATH Program. Research, development, and small-scale testing have already been conducted. Larger-scale testing under realistic operating conditions is planned during the next several years. That work is a beginning toward demonstrating the feasibility of significantly increasing the density of vehicles in a lane of traffic, thereby enabling dramatic increases in effective freeway capacity. PATH is developing concepts and computer simulated models for electronic entraining of vehicles — a technique referred to as "platooning." There are a number of possible operational concepts that are based on this principle. It will require extensive evaluation of the alternatives before a preferred concept is chosen.

Japanese interest in AVCS technologies has recently increased, and plans are under development for a fully-automated freight (truck) lane on a motorway that will be built between Tokyo and Osaka. Volkswagen demonstrated a form of freeway automation using the concept of "convoy driving," with vehicles following each other at very close spacings, a form of platooning. Volkswagen has also demonstrated automated parking.

The application of fully autonomous vehicle concepts to road transportation has received more attention in Japan than elsewhere, with projects in the Personal Vehicle System (PVS) and Super-Smart Vehicle Systems (SSVS) programs conducted under the auspices of MITI. Work on those concepts has also been conducted in the U.S. industrial and academic sectors. Much work is based on military development of "Autonomous Land Vehicles," which are designed to operate in hazardous, unstructured off-road environments, and are not directly applicable to a road environment.

"The MEA-mandated automated highway demonstration in 1997 will accelerate development and merge public and private efforts."

AVCS is not as highly developed in the U.S. as the other functional areas of IVHS. That is in part because of the more challenging technical demands, but also because of non-technical — principally legal — considerations. The primary reason that the application of well-known control technologies to road vehicles has languished is that motor vehicle manufacturers have valid concerns about product liability. Automated control implies a potential to shift the blame for crashes from drivers to equipment manufacturers based on what lawyers call "driver control dilution." Given the propensity of juries to view commercial pockets as very deep, new liability-limiting legislation will be needed before the more advanced forms of AVCS will be enthusiastically developed by automotive manufacturers and their suppliers.

Until there is public sector commitment to spur development of automated vehicle and roadway components, motor vehicle manufacturers will remain understandably reluctant to seriously research the most promising aspects of AVCS. That includes those aspects that involve communication and interaction between smart vehicles and smart highways. With a strong, centrally funded, public sector research program, car makers will have a strong incentive to build smart cars. The passage of ISTEA with the inclusion of a congressionally mandated, federally funded, automated highway demonstration — required by 1997 — goes a long way toward both providing the incentive and pulling private and public efforts together.

Plan Elements

AVCS will advance via an evolutionary process, building upon available technologies while developing and refining needed new technologies. Much of the development activity is proceeding and will continue to proceed, primarily as product development work by the private sector in the motor vehicle and component supplier industries. The public sector will be involved in establishing design targets (goals in performance terms) for products that enhance safety, road capacity, and air quality. In situations where public benefit is high and private sector profit incentive is expected to be low, the public sector must actually foster development of products. The public sector will also be heavily involved in ensuring that the products developed are matched to the limitations and capabilities of the drivers who must use them: the public sector will also be involved in making the overall assessment of ultimate system safety.

RESEARCH AND DEVELOPMENT

The research and development work needed to advance AVCS in the early stages consists largely of the development of special purpose test facilities, data bases, software, and evaluation methodologies. Many of the enabling technologies for AVCS have been developed for purposes other than IVHS. Major R&D investments are necessary for the adaptation of those technologies to automotive use. Significant resources will be needed to select the most appropriate technologies, both for meeting specific AVCS needs and for integrating them into AVCS systems and subsystems.

During the initial phases of research, substantial investments will be needed to develop the tools to evaluate and compare alternative approaches and concepts, particularly with regard to their safety and human factors impacts. Those should include the following:

- System simulation tools and models

IVHS Enabling Technologies

Sensors
- Driver performance
- Vision detection
- Obstacle detection
- Lane sensing
- Road friction
- Distance (ranging devices)
- Absolute location
- Acceleration & velocity detection
- Angular rate
- Vehicle presence and speed
- Vehicle classification
- Weigh-in-motion
- Rollover detection
- Automated vehicle ID

Electromechanical Actuation Systems
- Antilock brakes
- Traction control
- Electronic throttle control
- Electronic steering
- Four-wheel steering
- Electronic braking actuation
- Electronic engine controls
- Electronic transmission controls
- Electric propulsion

Miscellaneous Electronics
- Vehicle/vehicle communications
- Vehicle/roadway communications
- High-speed computation
- Electronic voice synthesis
- Speech recognition
- Speaker verification
- Photonics
- Flexible format displays

Software and Systems Technology
- Artificial intelligence/neural networks
- Data fusion
- Automated. routing and scheduling
- Network flow optimization
- Diagnostics (fault detection)
- Fault tolerant system design
- "Threat" analysis
- Architecture for system integration
- Adaptive control design
- Human interface design
- Reliability engineering
- Local area networking

- Evaluation protocols to ensure consistent evaluations of safety and performance
- One or more driving simulators for conducting controlled experiments on the human interfaces of AVCS
- Two large-scale test tracks for testing AVCS in realistic operating conditions, one for cold and one for warm weather — needed so that alternative concepts and competing products can be subjected to controlled tests without exposing the public to unnecessary risks

The driving simulators and test tracks will not be used exclusively for AVCS. Therefore the investments can be shared with other IVHS, road-safety, and even non-IVHS programs.

Product development for stand-alone products will generally be conducted by private industry. Considerable research work will be required to adequately support that product development. The research includes subject areas such as sensing systems, software algorithms, and systems technologies. Public involvement and funding support are needed in the following areas:

- Establishment of functional specifications and standards for performance and inter-operability
- Safety evaluations
- Evaluation of fundamental human factors issues (including driver workload, responses to warnings and advisories, and acceptance of both control assistance and full control)
- Evaluating functional partitioning between the infrastructure and the vehicle

Research and development in support of the more advanced middle- and longer-term AVCS concepts will initially be targeted at refining operating concept definitions and defining system architecture alternatives. Work in those areas will help refine the focus for developing required enabling technologies. Much of the work is likely to focus on adapting available technologies from other application domains to surface transportation and will serve as the foundation for more detailed system design work. That, in mm, will lead to the development of prototypes for testing and evaluation.

OPERATIONAL TESTING

Due to its greater safety ramifications, AVCS operational testing activities differ from those of other IVHS functional areas. All AVCS products and systems will require extensive simulation and evaluation on test tracks before they can be put into use in normal public road operations. The driver warning, perceptual enhancement, and assistance/control systems that do not rely on infrastructure elements can initially be tested on existing proving grounds, race tracks, or unopened sections of freeway. Later operational testing will gather data on the operation of a statistically valid sample of systems installed in vehicles operating on public roads. That testing will be used to determine system performance, reliability, costs, effectiveness of driver interfaces, and safety impacts.

National Advanced Driving Simulator

A driving simulator that provides a full range of capabilities to simulate human driving and control behavior

Realistic presentation of scenes including:
- Buildings
- Signs
- Pavement geometry and texture
- Various visibility conditions
- IVHS systems in operation
- Moving pedestrians
- Moving vehicles

AVCS systems that rely on cooperative infrastructure elements will have to be tested on special facilities. Those tests would, in a sense, become the operational tests. The important safety and human factors implications of having drivers transfer partial or complete control of their vehicles to an automated system must be explored on dedicated test facilities to ensure that problems are thoroughly resolved before they create an opportunity for injury or property damage. The first deployment of these technologies will be in public service vehicles.

Near Term

In the near term, the following AVCS target products are expected to be ready for large-scale testing:

- Backup warning
- Adaptive cruise control
- Traction (ice) warning and control
- Vehicle performance monitoring (on-board diagnostics)
- Longitudinal collision warning
- Lane change and merge warnings

large-scale tests and pilots of collision warning systems are under way. "

These tests will be used to verify the performance of the products under the full range of vehicle and road operating conditions and will be used to identify possible technical or human interface problems. They may also provide the data needed by the insurance industry and regulatory bodies to determine what incentives can be offered to encourage widespread adoption of the products offering the most significant safety improvements.

Middle Term

In the middle term, target products will evolve that have a higher degree of vehicle motion control. Some additional products that are expected to be tested in this timeframe are:

Throughout the Strategic Plan:
- *Near term means a* 5-year *iimeffame*
- *Middle term means a* 10-year *timeframe*
- *Longer* term means a 20-year *timeframe*

- Lane and road departure warning
- Lateral (steering) control
- Side collision warning
- Automated lane change system
- Automated collision avoidance (by steering or braking)
- More advanced vision enhancement
- Short-headway vehicle following control
- Rural intersection hazard warning
- Head-on collision warning

The target products listed above represent the elements of a fully automated roadway system. Combined testing of prototypes for those products in a test track environment could allow a prototype automated freeway to be demonstrated by 1997, a Congressional goal stated in ISTEA.

Longer Term

A variety of advanced AVCS concepts will be tested and put into operation in the longer term. In various combinations, those will incorporate many of the elements already described. However, some elements cannot be anticipated today because AVCS technology is changing rapidly. Automated highway concepts with varying levels of sophistication (such as long and short headway automated platoons) will be evaluated for safety, human factors, and effectiveness in reducing congestion. Those found to be most suitable will be selected for deployment.

DEPLOYMENT

Near Term

AVCS systems, products, and building blocks that will begin to be deployed during this time include the following:

- Stand-alone, electronic control systems such as anti-lock braking, electronic engine and transmission controls, and traction control under acceleration

- Simple vehicle performance monitoring (for example, tire inflation and reduced traction)
- Warning systems for side and near obstacles
- Adaptive cruise control (maintaining a safe distance from the vehicle ahead)

Middle Term

AVCS systems, products, and building blocks that are expected to begin to be deployed during this time include the following:

- Warning systems for distant obstacles (for example, frontal collision), lane departure, lane change and merge, and roadway conditions
- Electronic control systems for brake application and steering
- Vehicle performance monitoring for items such as tire condition, traction, braking capability, and acceleration capability
- Automated collision avoidance
- Vision enhancement for drivers in night, rain, and fog conditions

Longer Term

AVCS systems, products, and building blocks that may begin to be deployed during this time include the following:

- Warning systems for intersection hazards
- Automated vehicle operation on specially equipped roadways

COMMERCIAL VEHICLE OPERATIONS (CVO)

IVHS technologies that are applied to commercial vehicles will increase operational safety, reduce the amount of accidents and reduce labor costs for states, and minimize red tape for commercial operators.

Commercial Vehicle Operations (CVO)

Definition

Commercial Vehicle Operations (CVO) systems apply various IVHS technologies to improve the safety and efficiency of commercial vehicle and fleet operations. In this Strategic Plan, commercial vehicles include trucks, delivery vans, inter-city buses, and emergency vehicles. CVO systems increase safety, expedite deliveries, improve operational efficiency, improve incident response, and decrease operational costs.

"CVO systems improve the safety and operational efficiency of commercial vehicles."

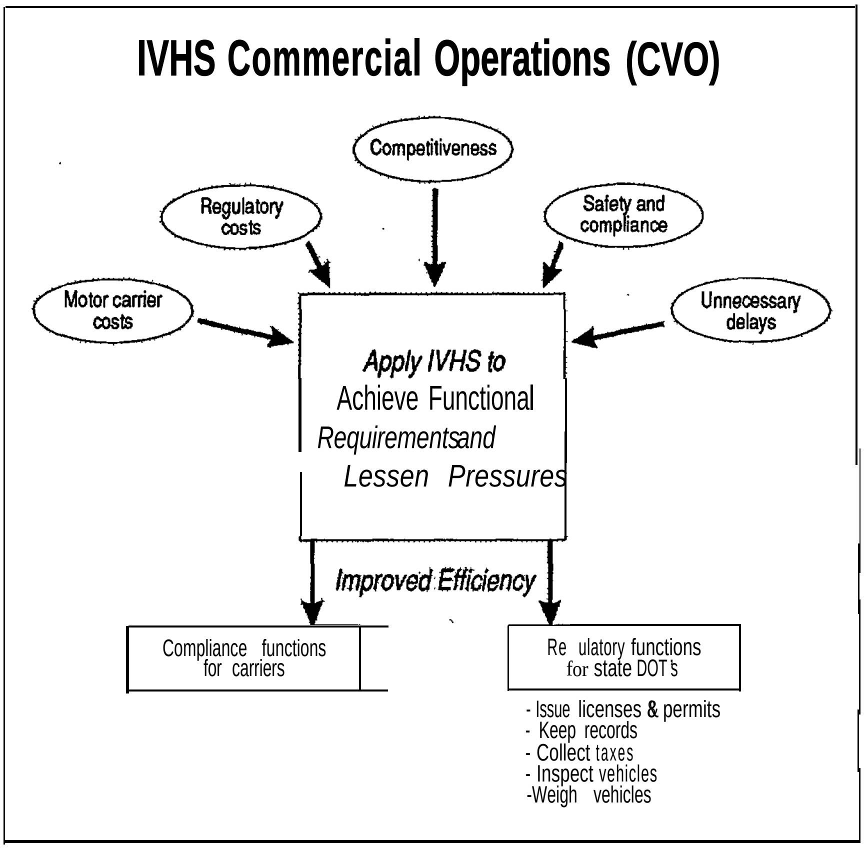
Although potential benefits from a comprehensive IVHS program in CVO are broad-based, the primary goals and most significant gains are in the areas of safety, productivity, and cost reductions. Safety is enhanced both for commercial vehicle operators and for other drivers affected by them. Productivity is enhanced because more effective fleet management tools are available to the private sector, thereby facilitating efficient fleet management and administration. Cost reductions will accrue as the result of reductions in administrative labor.

CVO builds on the functional areas of ATMS, ATIS, and AVCS. A number of primary or enabling technologies are also prerequisite to many CVO integrated functions. Advances in those technologies will be incorporated into CVO applications as they become available. The enabling technologies are listed below:

- Automated Vehicle Identification (AVI)
- Automated Vehicle Classification (AVC)
- Automated Vehicle Location (AVL)
- Automated Clearance Sensing (ACS)
- Weigh-In-Motion (WIM)
- On-Board Computer (OBC)
- Two-Way Real-Time Communications (TWC)
- Digital real-time traffic broadcasts
- Dynamic network routing and scheduling
- Roadside beacons

Characteristics and Requirements

CVO has unique needs because of the special operating requirements of commercial vehicles. Commercial vehicles are identified either by their physical characteristics (for example, heavy trucks) or by the type of function that they perform (for example, ambulance or taxi). All of those vehicles are normally operated more than a typical passenger car. Therefore, commercial vehicles may require system designs with greater safety and reliability. In many instances, the IVHS systems that are installed in commercial vehicles will have initially been



developed for ATMS, ATIS, or AVCS, but are likely to be first implemented on commercial vehicles. Much of the information IVHS can provide is useful to all drivers, regardless of the type of vehicle they use. CVO drivers, however, need more specialized data. Trucks, for example, cannot be operated on all roads for various reasons, such as low clearances, restrictive geometry, hazardous materials limitations, and bridge weight restrictions. Operators of trucks must have accurate, detailed information about any proposed alternatives to the routes they normally travel.

A key CVO goal is the creation of "transparent" (meaning unimpeded commercial traffic) state and international borders. That will, in part, be achieved by automating the collection of information required by governmental agencies. Benefits are further enhanced if the information can be shared by several states. By expanding the information collected, carriers will gain access to information essential for managing their fleets, and governmental agencies will obtain information that they can utilize for planning purposes.

"A key CVO productivity goal is transparent 'state and international borders — standardization is critical."

Standards for equipment and communications are critical to CVO. Large vehicle fleets demand equipment standardization in order to reduce the training and maintenance costs associated with part proliferation. Standards for AVI are crucial given its essential role in many CVO applications. Electronic vehicle equipment interface standards are essential if vehicle manufacturers are to be able to integrate add-on devices efficiently — a problem of particular concern to heavy truck manufacturers. Trucks that travel nationwide need to be able to receive traffic information broadcasts anywhere without having to carry several different kinds of receivers.

SAFETY

Like motor vehicle accidents in general, commercial vehicle accidents are caused by the interaction of human, environmental, and vehicle factors. Most crashes are attributed to "driver error." Yet attributing crashes to driver error often obscures the fact that safety enhancements along the roadway (such as intelligent sign systems that provide vehicle-specific information) and integrated into the vehicle (such as collision warning systems) can decrease the probability that a driver will make a serious error.

Many motor carrier safety regulations exist to reduce safety hazards. Such hazards include extreme driver fatigue, driving while intoxicated, and vehicle brake failure. A number of CVO initiatives will apply technology to improve driver and vehicle compliance with those safety regulations. The goal is to significantly reduce fatalities, injuries, property damage, monetary loss, productivity loss, and crash-caused congestion involving commercial motor vehicles.

"**The safety goal of CVO is to** significantly **reduce fatalities** injuries, and properly damage from crashes involving commercial vehicles."

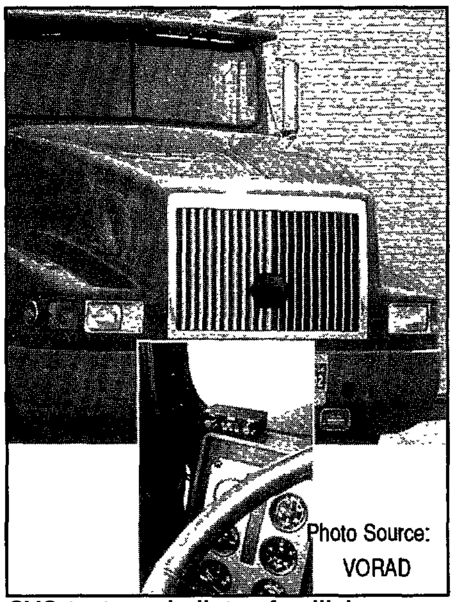
Technologies described under AVCS will also provide for enhanced safety. A variety of perceptual enhancement features (such as assisted night/fog vision), warning systems (such as out-of-lane detection and obstacle warning), and vehicle control systems (such as automated braking) provide significant safety benefits to commercial vehicle operators. Descriptions of those functions are included in the AVCS section. Some other safety-related IVHS systems that specifically address CVO issues are listed below:

- ***Driver/Vehicle Real-Time Safety Monitoring.*** A comprehensive safety system — for driver and vehicle — monitors and electronically records the status of critical safety-related factors and, as appropriate, reports on them while the vehicle is traveling. Elements pertaining to the driver could include records of duty logs, medical qualification data, and commercial driver's license information. Vehicle-related elements could include operational data and conditional information (such as status of brakes, lights, tires, and steering).

  Feedback on potentially dangerous vehicle conditions would be directed to the driver for correction. AVCS capabilities will provide additional warning information and will ultimately provide automated responses to those situations. Communication with motor carrier management or enforcement agencies could also be initiated in certain circumstances.

  The capabilities of CVO systems will be expanded when they are coordinated with in-vehicle computer systems, AVI technologies, and two-way voice/data communications. Records of key status indicators and details regarding driver/vehicle inspections performed by enforcement personnel could be maintained, and electronic safety certification systems could be included.

  Several vendors currently market systems that incorporate extensive vehicle sensor capability to measure air pressure, engine speed, idle time, brake applications, and electrical system status. These data are used to help motor carriers monitor driver perfor-



CVO tests and pilots of collision warning systems are under way.

mance and estimate maintenance needs. In addition, automated driver records (including driver logs) have been implemented by several vendors. The deployment of these systems by carriers is steadily growing. Additional work is needed to integrate components, provide road-to-vehicle communications, and resolve privacy and institutional issues (especially enforcement aspects).

- ***Hazardous Material Information Systems.*** Safe shipment of hazardous materials is of great concern to society in general, to truck operators, and to those who regulate truck movements. Electronic HAZMAT tracking technologies are being developed that hold promise as a means of providing enforcement and incident management response teams with timely, accurate information on cargo contents, enabling them to react properly in emergency situations. Early detection of cargo problems would allow time for the driver to respond and possibly prevent a serious accident. Before the use of those technologies can be implemented, however, their benefits must be quantified and compared to the costs involved. That will be accomplished by monitoring and evaluating the early operational test sites.

"Truck drivers need highway feature information that is specific to their type of vehicle."

- ***Site-Specific Highway Warning Systems for Trucks.*** Certain highway features cause difficult maneuvering for trucks due to their weight, stability, and acceleration and braking capability. Challenging highway features include steep downgrades, tight ramps, and intersections and railroad grade crossings with limited sight distances. Warning signs and other existing techniques often do not provide commercial vehicle drivers with adequate information to avoid serious accidents. Warning systems that provide information specific to the vehicle and its capabilities in relation to the highway features in question would significantly improve commercial vehicle safety.

- ***Automated May&y Capabilities.*** Technologies used for vehicle tracking and communications also provide a basis for implementing Mayday capabilities. In emergency situations, drivers would be able to communicate with their dispatchers or with local police agencies. Certain types of incidents (such as vehicle rollover and rapid deceleration that are associated with accidents) could be detected and used to automatically trigger an alert.

PRODUCTIVITY THROUGH STREAMLINING REGULATORY COMPLIANCE

Many of the proposed CVO applications and systems are directed at improving the timeliness, efficiency, and accuracy of commercial vehicle operations. Improvements are achieved by automating existing manual procedures, electronically capturing and reporting data, and improving the flow of information between carriers and regulatory agencies and between operators and dispatchers. The efficiencies come from simplification or elimination of the efforts required by the motor carrier industry to comply with various regulations — without compromising regulatory oversight — and from overall improvements in fleet management. Electronic systems, if proven to be cost-effective, will reduce the expense and effort required by a motor carrier to comply with state licensing and reporting requirements. The states will likewise benefit from more efficient program administration, better enforcement of state requirements, and a higher level of carrier compliance with state regulations.

"Cost-effective electronic systems will reduce fhe expense and effort required for carrier compliance with government regulations."

- ***Electronic Credentials.*** This will enable a motor carrier to electronically file for, obtain, and pay for all required licenses, registrations, and permits. An electronic record of the credential will be sent to the motor carrier's headquarters or other desired location. A supporting database will contain information about those transactions for access by appropriate governmental authorities. Implementation of these services is facilitated by the International Registration Plan (IRP) and the Interstate Fuel Tax Agreement (IFTA). Many states already provide this type of service for fuel taxes and registrations. The technology needed to electronically provide credentials is available, but it is not utilized. Currently, states that allow in-advance or pre-ordering of permits transmit them to carrier locations by facsimile machines.

- ***Electronic Mileage Recording and Trip Logs.*** The collection of mileage data will require road-to-vehicle communication to transmit location, date, and time information to an in-vehicle recording device. The data will be integrated with other sensor information and stored in a computerized record that will essentially replace the manual trip log typically prepared by the motor carrier. The fuel tax rates for each state and the number of vehicle miles traveled within each state can be recorded electronically if electronic beacons are provided at all state boundaries. That will provide the means to automatically create periodic fuel tax reports and calculate tax liability, as well as provide the capability to electronically file that information with carriers and state authorities.

- ***Automated Credential and Weight Checking.*** An electronic system that can automatically check carrier credentials and clear transponder-equipped vehicles through ports of entry and weigh stations at highway speeds will potentially provide substantial savings to both commercial operators and regulators. Road-to-vehicle communications allow the integration of the data (such as registration and permit data) that is needed to determine if a carrier is in compliance with state requirements. If the credentials are in order, the vehicle need not stop. Weight information from WIM devices will also be transmitted to determine if the vehicle is traveling legally. Exceptions and violations would be brought to the attention of enforcement officials for appropriate action. The technology may also be applied to international border crossings.

- ***Automated (Electronic) Toll Collection This*** expands on the technologies and facilities of automated vehicle identification and classification, enabling the electronic payment of tolls. The same enabling technologies apply here as in automated credential checking.

- ***Real-Time Information Systems.*** Establishing real-time information systems is a critical CVO goal. Those systems will provide enhanced information to drivers or dispatchers concerning congestion, incidents, and optimum routing. Areas of CVO that require special information include tracking commercial vehicles, scheduling and routing vehicles for pick-ups and deliveries, dispatching emergency vehicles, and managing fleets. New routing and scheduling models must also be developed for use by dispatchers, allowing them to manage their fleets using current congestion information.

- ***Comprehensive Data Collection for Planning.*** The automated data collection activities, which are identified in several of the above CVO functions, will be expanded to support research and planning activities by motor carriers and governmental agencies. Such information would allow better assessment of travel demand, costs, and needs. Automating data collection and integrating it with other IVHS functions will greatly reduce the overall cost for that planning information.

Current Status

BACKGROUND

Safety

Commercial vehicles are involved in a relatively small share of all motor vehicle accidents, but in a higher share of fatal accidents. When differences in travel by vehicle type are taken into account, the accident involvement rates for commercial vehicles are lower than those of passenger cars for all accidents but are higher for fatal accidents. That is partly due to the fact that a higher share of commercial vehicle travel is on rural roads — where speeds are high and accidents tend to be more severe — and partly due to the difference in size and weight between those vehicles and passenger cars.

Motor carrier safety assistance programs, commercial safety inspections, random drug testing, bans on radar detectors, and lower truck speed limits have led to steadily decreasing accident and fatality rates per mile of commercial vehicle travel. This trend had continued for a number of years. Today's heavily congested highways, with both automobile and truck traffic continuing to increase, require greater attention to safety issues and concerns. Deployment of IVHS technologies that check vehicle condition, avoid hazardous material spills, and assist in congestion management can lead to improved safety for all highway users.

Productivity

Changes in domestic and global competition are compelling U.S. companies to change their methods of operation. The use of overseas parts suppliers, the introduction of just-in-time manufacturing and distribution, and the increased emphasis on quality and consumer service are having a direct impact on the way commercial carriers operate. Local and interstate carriers are being asked to provide faster, more reliable, and more cost-effective services.

Regulation

Federal, state, and local governments regulate commercial vehicle operations in an attempt to ensure public safety, protect roads and bridges, maintain economic competition, promote fair business practices, and generate funds for highway construction and maintenance. The cost of regulation is substantial to both government and the trucking industry. States spend $5 billion annually to license vehicles, collect fuel taxes, and issue permits. Carriers spend another $2 billion annually for the paperwork associated with those tasks. States spend more than $100 million annually for truck weight enforcement alone. The interstate motor carrier industry spends millions of hours annually waiting for weight and safety inspections, toll collection, and port-of-entry checks. Productivity gains from improved fleet management and efficient traffic management are essential to the quality and competitiveness of U.S. transportation, business, and industries at the local, national, and international levels.

CURRENT IVHS USAGE AND TESTING

Commercial vehicle operators and governmental agencies have already recognized the potential of IVHS technologies to overcome industry problems — commercial operators and public safety departments are presently using IVHS technologies such as static network routing and AVL. Operational tests of specific technologies for individual vehicles are either currently proceeding or will soon begin for several functional areas, including automated toll collection, remote driver/vehicle inspections, and safety warnings. IVHS technologies that are currently in widespread use include automated toll collection (with over 30,000 commercial vehicles already tagged), automated vehicle identification, automated vehicle location and tracking using satellite technology, automated dispatching, and real-time, on-demand driver-to-dispatcher communication of both voice and data. More importantly, major efforts are now under way in which several technologies are being integrated and tested on a system-wide basis. Two notable projects are ADVANTAGE I-75 and HELP/Crescent.

Two notable CVO projects now under way are AD VANTAGE I-75 and HELP/Crescent. "

ADVANTAGE I-75 is a multi-year effort along I-75 that extends through Florida, Georgia, Tennessee, Kentucky, Ohio, Michigan, and Ontario. The project is testing CVO information gathering, processing, reporting, and sharing concepts. The system's design involves decentralized processing in which each state remains responsible for its own data processing and regulatory checks, but information is passed from state to state as a vehicle travels along the corridor.

The Crescent project of the Heavy Vehicle Electronic License Plate (HELP) program is an extensive integrated system test, under day-to-day operating conditions, of WIM, AVC, and AVI. The project is essentially a cooperative effort between state governments and the interstate carrier industry. It is located along I-10 and I-20 from central Texas, west through New Mexico, Arizona, and California to the greater Los Angeles area, then north along I-5 through California, Oregon, and Washington to the international border, continuing into British Columbia along portions of both the trans-Canada and Alaska highways. Data will eventually be monitored at more than 30 locations.

The Crescent project encompasses the use of approximately 4,000 heavy commercial combination vehicles for one year. An evaluation report of Crescent is due in 1993. As currently planned, Crescent will do the following:

- Demonstrate one potential response to the motor carrier industry's desire to have transparent state borders and "one-stop shopping" — for all permits, registrations, and the like. It will provide automated checking of license plate registration and fuel tax use registration and will help reduce the number of required stops.
- Show that the primary technologies — WIM, AVC, and AVI — will work reliably from a system standpoint in the highway environment.
- Demonstrate the potential for increased efficiency in highway planning and governmental administration of selected motor carrier regulations. Specific areas include vehicle weight information for highway planning, design, and pavement management. The latter information will be obtained from all trucks in the Crescent corridor, not just those equipped with AVI transponders.

Projects like Crescent and Advantage I-75 present an important early opportunity to test operational concepts and equipment common to many IVHS program areas. These projects are expected to show that technologies can be successfully combined in a system, that institutional barriers can be addressed, and that both commercial operations and public agencies can share successfully in the collection and use of data.

Plan Elements

The capabilities of CVO included in IVHS are built upon a broad range of technologies and applications under development, many of which also address non-CVO vehicles and operators. The program plan described here expands on the underlying, more general IVHS requirements and presents the integration of IVHS technologies into CVO-specific functions.

Commercial vehicles will benefit not only from the technologies and applications discussed here, but also from the research, operational tests, and deployment activities proposed by other IVHS efforts dealing with ATMS, ATIS, and AVCS. Conversely, the early application of IVHS technologies to CVO offers the U.S. a unique opportunity to accelerate the development of IVHS systems for non-commercial drivers.

RESEARCH AND DEVELOPMENT

The research and initial testing of equipment has been completed for many of the applications required for CVO. However, additional research is needed to optimize the potential of the applications. A description of required CVO R&D follows. Specific projects are listed in Appendix A.

Safety

Research in the area of CVO safety includes the following:

- ***Driver/Vehicle Real-Time Safety Monitoring.*** Future efforts will build on current work in the development of vehicle diagnostic and monitoring systems and driver status/performance monitoring systems. Concerns such as motor carriers' competitive data, driver privacy, and the degree of direct communication to enforcement and oversight agencies will be evaluated carefully.

- ***Driver Warning Systems.*** A number of AVCS technologies will probably be initially deployed on commercial vehicles. Research is needed to identify opportunities for improving truck safety through deployment of AVCS systems and to develop systems that address the particular needs of commercial vehicles.

"CVO benefits must justify costs in order for products to attract commercial users."

- ***Hazardous Material Information Systems.*** Technical issues to be resolved include data formatting, communications, relation to overall AVI and AVL, data management architecture, and design of cargo detection sensor technologies. Institutional and economic issues (privacy, who pays, and whether safety benefits justify costs) must be carefully considered. The scope and method of data management (for example, centralized data tracking versus stand-alone placards) will greatly affect cost and coordination requirements. Access to databases by state and local emergency response personnel also needs to be evaluated.

- ***Site-Specific Highway Warning Systems for Trucks.*** Research and testing are needed to develop the hardware and software for these systems and to determine the information required to accurately relate highway features to truck performance. Autonomous warning systems (such as those keyed to ramp radii) can be developed and deployed immediately. Warning systems requiring road-to-vehicle communication and data processing or display capabilities will require simultaneous adoption by commercial fleets and deployment of the related infrastructure.

Productivity

Research in the area of CVO productivity includes the following:

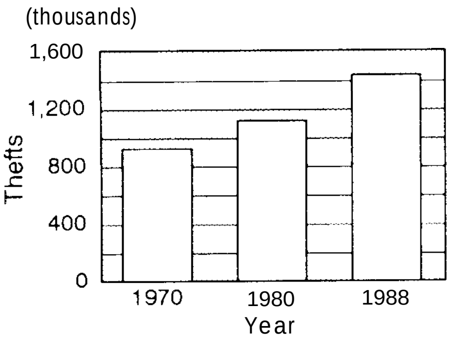
- ***Electronic Credentials.*** Additional work is needed to develop and integrate existing state and regional information systems and procedures with the institutional and program requirements of a national electronic system.

- ***Electronic Log Book.*** A cost-effective and feasible approach to solving the road-to-vehicle information and communication requirements must be determined. Formal procedures also must be developed to meet electronic auditing requirements. Procedures must be developed to efficiently handle the transition period when only partial roadway coverage exists.

- ***Automated Credential and Weight Checking.*** A variety of enabling technologies (AVI, AVC, WIM, OBC, and communications) are required to electronically clear vehicles through ports of entry and weigh stations. Efforts are needed to develop practical systems that integrate these technologies in order to provide automated clearance. Leadership and standardization will be needed at the national level to ensure nationwide compatibility of affordable systems. Operational tests are in progress, both as part of the HELP/Crescent project and as a major part of the ADVANTAGE I-75 project.

- ***Automated (Electronic) Toll Collection.*** The same enabling technologies apply here as in automated vehicle identification and classification. In addition, research is needed on appropriate designs for toll collection facilities to allow properly equipped vehicles to pass safely at highway speeds. Operational tests are occurring under the TRANSCOM program in northern New Jersey and metropolitan New York. Large-scale deployment of automated toll collection has taken place in several areas, notably on turnpikes in Texas and Oklahoma. The Oklahoma Turnpike Authority has attempted to meet the needs of the trucking industry by

Motor Vehicle Thefts in the U.S.



Data Source. MVMA

installing equipment that is compatible with the American Trucking Associations' standards for AVI. Conventional toll facilities have been removed from the mainline roadway and have been replaced with automated highway-speed toll collection.

- *Comprehensive Data Collection for Planning.* Research is required to determine specific data requirements for planning, as well as the means by which proposed facilities can be used to collect this data.

- *Stolen Vehicle Alarm Capability* The ability to read vehicular AVI readily enables the potential for correlation with a Stolen vehicles Register. On detection, communication with the proper authorities will be activated. To be effective, supplemental AVI devices hidden on the vehicle will probably he rcquircd. Research is needed to establish the mechanics and procedures that would enable this capability without impacting other AVI functions.

Human Factors

CVO requires that human factors research be expanded to include information processing by commercial vehicle drivers. Although some research is currently under way. additional efforts will focus on the way drivers interact with more complex on-board computers. Technology can give drivers the opportunity to obtain real-time highway and vehicular system information The optimum way to display the information needs to be determined so that a commercial driver is not overloaded and will react in a safe, predictable manner.

OPERATIONAL TESTING

Much of the operational testing of technologies described in this section will occur in conjunction with work being conducted in new and existing corridors. That is of particular value, since the corridor tests are closely tied to the objective of unimpeded flow of freight — transparent borders. Implementing operational tests in additional corridors -- especially those that arc along part of the nationwide network of major commercial vehicle routes ---- would contribute greatly to the implementation of the tested systems. To obtain maximum benefit, all states in the continental U.S. need to egin resolving the institutional problems both within states and among them.

Other operational tests. Such as real-time CVO driver information systems can be conducted as part of a more general investigation of integrated ATIS and ATMS systems. Functions that are specialized in nature. Such as emergency vehicle dispatching will require separate testing.

Early testing will be required in high-visibility or high-risk CVO corridors for hazardous material data tracking. Specialized monitoring programs relating to Department of Energy transport of nuclear waste materials should bc incorporated into some corridor tests. The IVHS Integration section of this Strategic Plan further addresses those tests. Specific operational tests are listed in Appendix B.

DEPLOYMENT

Near Term

CVO systems that will begin to be widely deployed during this time include the following:

- Automated weight reporting (WIM)
- Automated vchiclc identification reporting (AVI)
- Automated (electronic) toll collection at tollbooths (AVI and AVC or ETTM)
- Automated fleet vehicle location (AVL) systems
- Static network routing and scheduling

Middle Term

CVO systems that arc expected to begin to be deployed during this time include the following:

- Vehicle safety monitoring systems for driver use
- Highway speed toll collection (AVI and AVC or ETTM)
- Automated vehicle and driver credential reporting (AVC)
- Highway safety warning systems (including ramp radii. height limits, and grade speeds)
- Computerized fleet tracking and dispatching
- Automated HAZMAT identification and location
- State-line beacon network
- Dynamic or combined static/dynamic network routing

Throughout the Strategic Plan:

- *Near term means a 5-year timeframe*
- *Middle term means a 10-year timeframe*
- *Longer term means a 20-year timeframe*

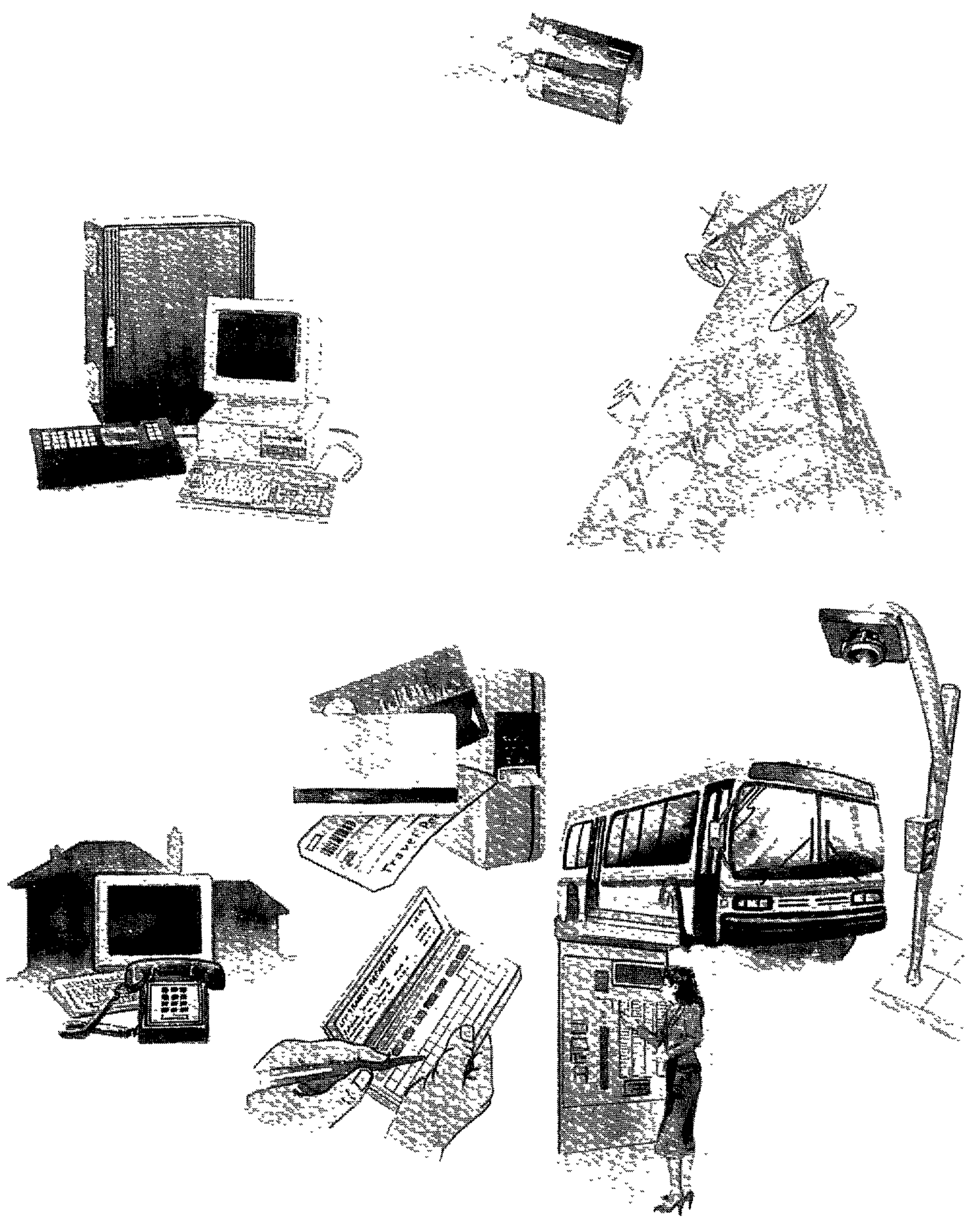
Longer Term

CVO systems that may begin to be deployed widely during this time include:

- Electronic tax and permit systems
- Automated vchiclc and driver condition monitoring and reporting

ADVANCED PUBLIC TRANSPORTATION SYSTEMS (APTS)

IVHS technologies applied to public transportation will provide information to systems operators and users, increasing the use and productivity of high occupancy vehicles.



Advanced Public Transportation Systems (APTS)

Definition

Advanced Public Transportation Systems (APTS) encompass the application of advanced electronic technologies to the deployment and operation of high occupancy, shared-ride vehicles, including conventional buses, rail vehicles, and the entire range of para-transit vehicles. The IVHS technologies of communications, navigation, and advanced information systems are being developed for ATMS and ATIS. They hold immense potential for improving mass transportation services and will be used to inform travelers of the alternative schedules and costs that are available for any given trip, including the most advantageous routing. AFTS can also automatically handle trip fees. APTS will keep the traveler informed, in real time, of any system changes that occur and will respond to changes in the traveler's plans. APTS technologies will help vehicle system administrators manage a safe and efficient fleet and plan services to meet a broad range of consumer needs: they will allow the community to manage its roadways with special accommodations for high occupancy vehicles. They will, in essence, enable transit authorities to provide a more flexible, cost effective, user-friendly service to their customers.

*"**APTS** holds immense potential for improving mass transit services."*

Characteristics and Requirements

Applying ATMS, ATIS, and AVCS technologies to APTS will make transit and ride-sharing options more efficient and, therefore, more attractive to the traveling public. That, in turn, is expected to increase the utilization of both public transit and ride-sharing. Specific APTS features and products include the following:

- Mass transit and ride-sharing information that is thorough, accurate, up-to-date, readily accessible, easily understood, convenient, and tailored to users' needs

- Ride-matching information that allows the flexibility to change arrangements on short notice, even during travel

- Mass transit and ride-share services that eliminate the inconveniences of exact change cash requirements and complex reservation and payment methods

- Traffic control measures that provide preferential treatment (such as traffic signal timing and separate lanes) for high occupancy vehicles (HOV's), thus reducing delays for mass transit and shared-ride vehicles operating in congested areas

- Convenient user fare methods that allow fast loading and unloading while automatically maintaining records for third party billing, marketing, and planning functions
- Automated monitoring and enforcement of specialized lane use
- Planning activities for fleet operations that are enhanced and supported by a wide range of data availability
- Fleet operations that are optimized by the application of real-time monitoring
- Fleet control techniques that are flexible and responsive to user demands
- Fleet monitoring information that integrates computer-assisted dispatching, customer information, and passenger security
- Electronic data communications for mass transit fleets (replacing voice communications) that expand driver assistance and security functions
- Automated vehicle controls (longitudinal and lateral), leading to fully automated operations
- Use of vehicles as traffic probes

Current Status

Mass transit and ride-sharing are increasingly available strategies for reducing traffic congestion and improving management of existing facilities. Use of transit and ride-sharing will reduce traffic congestion, but only in proportion to their level of use. There is an urgent need to encourage greater public use of transit system and ride-sharing options.

Efforts to expand conventional transit coverage into areas with lower population densities during the 70's and 80's were very expensive. Since then, financial problems in many areas have reduced the availability of this type of transit. The challenge remains to develop attractive alternatives to single occupancy vehicles.

There have been rapid advances in technology, especially in the fields of communications and information. These advances facilitate lower-cost operating methods that can make mass transit and ride-sharing more convenient and less costly. That in turn encourages more people to choose to use those transportation methods. It has been estimated that the diversion of just one out of every five solo drivers would save the U.S. $30 billion in congestion costs each year. Through APTS, the Federal Transit Administration (FTA) will support and coordinate the development and application of advanced communication and information technologies to both mass transit and ride-sharing. APTS will provide innovations that promote a unified, coordinated effort and that develop standards for product interchangeability. Those actions will reduce the overall cost of the program.

Operational tests are already being designed and implemented in several cities, including such projects as Smart Bus and Smart Traveler. Early implementation opportunities will be identified, and detailed implementation planning will be completed for more complex operational tests.

The Smart Bus concept is patterned after a European program that integrates regular fixed-route transit, dial-a-ride minibus, and contract taxi services to provide for a more efficient system that covers a larger geographic area. Evaluation is currently being carried out to determine the applicability of this approach to the United States. FTA is cooperating with the AM Arbor Transportation Authority (Ann Arbor, Michigan) to develop an operational test.

"Numerous APTS projects fur public transit and ride-sharing are under way."

Real-time travel and ride-sharing information is the focus of the Smart Traveler projects. The information is used by customers in planning travel and choosing modes and by dispatchers in directing services. The Smart Traveler program will be tested in Houston, Texas; Bellevue, Washington; and in several cities in California. In an effort to encourage transit and ride-sharing use, the Houston project will utilize IVHS technology to disseminate transit and ride-share information to users. The Bellevue project will demonstrate the use of mobile communications and information services to increase the attractiveness, and, it is hoped, the market share of ride-sharing. The California project will test both audio-text and video-text information services for providing real-time ride-share matching information to travelers in both residential and business environments.

Mobility Manager is a program concept that is similar to the Smart Traveler program. Its goals are to provide alternatives to single-occupant auto travel and to provide greater mobility for special population groups (those who may have limited transportation options due to age or disability). It operates as a clearinghouse for several different transportation modes, including bus, taxi, car-pool, van-pool, and other shared-ride modes. It provides a single point of contact for arranging the details of a journey. Funds are collected by the Mobility Manager, including fares and operating assistance from employers and social service programs. The funds are then distributed to the various service providers. The concept provides the benefits of increased convenience for the users and increased ridership and operational efficiency for service providers. FTA is currently working with potential demonstration sites for this program. One operational test has already been funded for Medford, Oregon and includes all of the Mobility Manager features.

In addition to the above projects, a number of operational tests and implementations are being planned in other cities for various types of systems. Those include automated vehicle location (AVL) systems, passenger information systems, smart card systems, and HOV operations. They will all be evaluated through the program. In Anaheim, California, a concept and project will be developed to integrate the traffic management center with local transit operations. That project will demonstrate the ability to provide information to travelers at bus stops, at transfer centers, and on transit vehicles. An automated billing service using smart card technology will be tested and evaluated in Minneapolis. In Denver, Colorado, an AVL system will be tied into a telephone information center for providing real-time fleet status information. The information will be displayed at an intermodal transportation center. Users can obtain it via telephone.

The sharing of information has already begun. "Advanced Public Transportation Systems: The State of the Art," a 1991 report, provides an example of information sharing. The information sharing process will not only supply information to users, but will also help gather that information.

As experience is gained, a database of user requirements will be developed. These data will be used in the development of formal specifications for equipment. The specifications will focus on what is needed, rather than how to design it — allowing room for innovation on the part of the manufacturers. As operational tests are conducted, user requirements will become more apparent. Once sufficient information has been gathered, a cooperative effort among users, manufacturers, experts, and government will establish performance specifications for the systems and will establish the standards and protocols that are required to facilitate interchangeability.

Plan Elements

"The goal of APTS is to decrease travel in sing/e occupant vehicles by encouraging widespread public transit and HOV use."

The goals of APTS are as follows:

- To decrease congestion by using new high occupancy vehicle concepts to encourage increased use of HOV's
- To improve traveler safety and security
- To assist transit systems in reducing unit operating costs and increasing system revenues
- To support legislative mandates (such as the Clean Air and Energy Acts)

With proper application, APTS technology can improve public transportation operations, including providing the following:

- More dependable operation
- Better system information
- Real-time updates of transit and ride-sharing information using changeable message signs
- More convenient fare payment methods
- Greater flexibility in making ride-sharing arrangements

All of this will encourage widespread transit use and will reduce the number of trips made in single-occupant vehicles. This will in turn reduce urban area congestion and its associated costs.

To accomplish these goals, ARTS technologies must be utilized by agencies that provide services, even though they often represent both significant initial expense and a degree of risk. To eliminate some of the uncertainty connected with the introduction of new technologies, a database needs to be developed that lists products currently being offered by manufacturers. It should include a listing of the technologies, along with their characteristics and capabilities. After being refined through operational tests and evaluation, the resulting database should be widely disseminated.

The development of ARTS will consist of program support and operational tests as summarized in the following components:

- Technology assessments
- Research on technology adaptations
- Evaluation of projects
- Technology sharing
- Development of user requirements and equipment standards
- Operational testing

TECHNOLOGY ASSESSMENTS

"A database will be established to track APTS technologies, products, and systems."

There are many advanced technologies already in use in ARTS applications. Many more are either available or are undergoing near-term development. An important component of the program is identification of the technologies and determination of their capabilities. To increase the knowledge base, assessment should include literature searches and interviews with researchers, practitioners, and manufacturers. A list of technologies that need to be investigated has already been established. Assessments will consist of in-depth research — possibly including laboratory testing — to determine the full capabilities of the technologies. Such assessments will be valuable in determining the utility of specific technologies. They will also identify the technologies that require operational testing in order to determine appropriate applications and actual costs and benefits.

Currently, technology assessment is proceeding in three areas — vehicle location, communications, and smart cards. Each is an important area with numerous ARTS applications.

Vehicle Location

Technology assessments and operational tests will be performed on promising technologies (for example, GPS) for application to transit operations. Some of the recent installations wilI be evaluated to gain insights into how readily technologies, management decisions, and customer information are being enhanced and institutionalized.

Communications

Communication systems are crucial for the operation of APTS. Options for voice and data communications include cellular radio, optical and ultrasonic methods, and a host of other technologies. Many of those are being or will be demonstrated in various operational tests. For example, cellular radios are the communication focus of the Bellevue Smart Commuter Project. Greater use of data communication in lieu of voice communication will be evaluated along with mobile data networks and private radio systems.

Smart Cards

User interface with the system is a prime concern. A major technological advance that could greatly improve user interface is the smart card — a plastic card the size of a credit card, containing a microchip with programmable memory. In a mass transit application, the microchip would contain information on the ownership of the card and the monetary value or account to be debited. The smart card is already in use in some European cities and is being tested for para-transit operations by the Regional Transit Authority in Chicago. The Ann Arbor (Michigan) Transportation Authority plans to test a conventional application of smart cards in its APTS program. The AM Arbor program is also evaluating methods for improving security for both transit and ride-share travelers. To further determine applicability of smart card technology for operations in U.S. cities, two firms were recently selected to assess the relative capabilities, costs, and benefits of various smart card technologies and to design an operational test for public transportation applications.

RESEARCH ON TECHNOLOGY ADAPTATIONS

In addition to researching and evaluating available technologies, innovative adaptations of new technologies to transit and ride-share applications wilI be examined. Although the private sector will primarily be relied upon for technology innovations, there is considerable work to be done in adapting those innovations to useful public transportation applications. Technical requirements, human factor characteristics, user needs, and institutional issues must all be researched. The IVHS Integration section of this Strategic Plan further addresses that R&D, and specific projects are listed in Appendix A.

EVALUATION OF PROJECTS

"Evaluation is the key to properly choosing APTS applications".

The evaluation component is the key to the APTS program. Transit agencies will use evaluations made by other technology applications to access information that will assist in determining which technologies can help meet transportation system operational objectives. With information concerning costs, accuracy, market response, reliability, power requirements, data outputs, and the like, transit agencies can more appropriately choose the technological applications that meet their objectives and requirements.

More evaluation will be done as operational tests are initiated; early efforts to prepare for those tests will establish procedures and criteria for evaluation. Work on actual evaluations will increase as data from operational tests increases. Some immediate opportunities exist for evaluating local initiatives already under way. Such opportunities include the Chicago introduction of smart card use for para-transit services.

TECHNOLOGY SHARING

Information will be shared and disseminated during the entire development and testing process. There are many ways to present such information, including reports, technical documents, and research papers that will describe program results and indicate future activities. Technical briefs can be produced on specific topics. How-to materials for technology implementation, such as equipment manuals and general guidelines, can be developed and distributed to users. Workshops can also be held, involving participants with experience in using various technologies.

Information can be shared on a more personal level. Direct contact can be fostered through the development of peer networks and resource lists. Peer networks will grow out of workshops as participants become better acquainted with available transit services and begin to share information with each other. The sharing of information will be enhanced by the publication of resource lists that include names, addresses, and telephone and fax numbers of those involved with the production, evaluation, and use of relevant technologies. Consultants and academicians involved in the program will share insights gained through their ongoing activities.

DEVELOPMENT OF USER REQUIREMENTS AND EQUIPMENT STANDARDS

Standards are especially important to a relatively small market application like the U.S. transit industry. Standards might encompass specifications that will allow for mass production of key components, including standardized units, plug-in installation, and modular construction.

OPERATIONAL TESTING

Operational tests provide the opportunity to measure the actual performance of various APTS technologies in real-world applications. The acceptance of various technologies by fleet operators — with differing technical and management abilities — as well as acceptance by riders of the systems, will be carefully evaluated in different sections of the country. Feedback on system requirements will come from evaluations of the requirements. Research on the possibilities of adopting new technologies and updating system requirements will guide the development of new and revised operational tests.

The majority of the APTS effort throughout the next five years will concentrate on operational testing and evaluation. That will require installation, maintenance, and monitoring of equipment, as well as capital outlays. Operational testing will be conducted in locations throughout the country and will require the assistance of experts in the areas of transit operations management and in various technologies. The testing is necessary to determine how various technologies are affected by the environment in which they are applied.

Operational tests will involve joint ventures with state and local governments and, when appropriate, private sector suppliers. They will typically require one or two years to develop implementation plans, and one year to implement those plans. It will then take an additional two or more years to operate the test and fully evaluate both equipment performance and market impact. Some agencies already employ advanced transit technologies in their regular operations. Those installations may be evaluated to further develop the knowledge base that is under development in APTS.

Operational testing for APTS is further defined by the following four program elements:

- Market development
- Customer interface
- Vehicle operations and communications
- HOV facility operations

Collectively, these elements are designed to increase the utilization and operational efficiency of HOV's — encompassing both mass transit and ride-sharing. Each will be thoroughly tested on real-world transit systems. The IVHS Integration section of this Strategic Plan further addresses those tests, and specific tests are listed in Appendix B.

Market Development

The goal of market development is to increase ride-sharing and mass transit use by making those options more appealing and giving them greater visibility. There are two major focuses for this area. The first is to increase the distribution and availability of information, making shared travel more flexible and convenient. The second focus is to provide more fare payment options, especially options that reduce customer fees based on an increased number of trips or on certain trip characteristics.

Customer Interface

Customer interface strives to increase the efficiency and convenience of shared mode travel; its aim is to gain new customers and keep them satisfied. One type of service enhancement is to provide information to travelers either prior to starting a trip or while en route. With transit arrival information on roadside monitors, travelers could respond to transit system delays by altering their routes or by otherwise changing their travel plans. Transit operations will also be faster and more attractive because of increased use of cashless fare transactions.

Vehicle Operations and Communications

The goal of this element is to improve fleet operations by increasing reliability and efficiency. Chief among the innovations in this area is automated vehicle location (AVL). AVL takes measurements of each vehicle's position at various intervals and reports them to a traffic control center. With appropriate software, that information can be used to improve system efficiency and operational reliability. AVL provides inputs for market development and customer interface activities. It wilI also improve emergency response. The information will greatly aid police in quickly finding a particular transit vehicle when a panic button is pressed or a silent alarm is activated.

Enhanced communication is a key element of APTS. Digitally transmitted information can be sent and received more efficiently and will be more clearly understood. Improved communication also aids centralized dispatching by providing greater control of operations from a central location.

HOV Facility Operations

This element improves transit, car-pool, and van-pool operations by providing their vehicles with preferential routing treatment. In the long term, AVCS technology will be applied to transit vehicles, giving them fully automated operation. The provision of these facilities is gaining momentum across the U.S. For several years, improvements have been provided through HOV and bus-only lanes that allow HOV's to bypass congestion and, in some cases, avoid paying tolls. Using advanced technology approaches, the utility of HOV lanes can potentially be increased either by deterring violators (for example, with a barrier that opens only to rightful users) or by making enforcement easier (such as using cameras with image processing). One way to identify a registered HOV — bus, car or van — is to use an electronic transponder tag which emits a specific signal. Such a tag would also make a number of other HOV preferential treatment strategies possible. Among those are automated (electronic) toll collection (ATC), preferential parking (providing more convenient or,lower-cost parking or both), and signal preemption.

DEPLOYMENT

Near Term

APTS services and systems that will begin to be deployed during this time include the following:

- In homes and offices (via TV, cable TV, telephone, and PC): Static transit schedule information and route displays
- At transit access points: Changeable message signs with scheduled arrival times

- On transit vehicles: Automated next and current stop information
- Electronic billing through smart cards for limited transit costs
- Automated vehicle location systems for fleet tracking
- Automated fleet maintenance tracking

Middle Term

APTS services and systems that are expected to begin to be deployed during this time include the following:

- In homes and offices (for example, via interactive cable TV): Route displays showing current location of vehicles, real-time ride-sharing connection information, and traffic conditions
- At transit access points: Interactive kiosks for traveler guidance and presentation of actual expected arrival times
- On transit vehicles: Automated announcement of projected actual arrival times and automated route guidance with electronic vehicle position determination
- Computer-aided dispatching and fleet control
- Additional traveler fare payment options with area-wide integrated fares
- Traveler information systems to provide interactive, personalized multi-modal routing, taking into account current traffic conditions
- Dynamic, real-time ride-share matching
- Automated HOV lane use verification

Throughout the Strategic Plan:
- *Near term means a 5-year timeframe*
- *Middle term means a 10-year timeframe*
- *longer term means a 20-year timeframe*

Longer Term

Listed below are APTS services and systems that may begin to be deployed during this time:

- Transit dispatching that is coordinated with ATMS and takes into account actual and projected traffic conditions and traveler loading
- Personalized‘ passenger pickup services
- Electronic reservations, ticketing, and billing for all transit services
- Automated transit vehicle Mayday services
- Automated transit vehicle operation on specially equipped (HOV) lanes

IVHS Integration

Looking at IVHS as five individual functional areas aids in understanding the key components of IVHS. Yet many of the tasks necessary to achieve development are common to all five areas. Moreover, as development proceeds, there will be increasing interaction among traffic management, traveler information, and vehicle control systems. Indeed, the whole of IVHS can be much more than the sum of its parts — IVHS should be regarded from the start as a set of integrated capabilities. The goal is an integrated multi-modal surface transportation system serving the public.

IVHS as a whole can be much more than the sum of its parts."

This section focuses on those issues that cut across all areas of IVHS development and underlie the integration of applications. The topics are as follows:

- Applications integration
- Rural transportation
- System architecture
- Standards and protocols
- Safety and human factors
- Communication
- Integrative research and development
- Operational tests
- Evaluation criteria
- Development projects summary

Applications Integration

IVHS progress will be achieved by successfully integrating advanced technology and information with conventional infrastructure to provide an expanding set of services, and by covering a growing geographic area. This evolution is likely to proceed in three major stages.

The first stage has already begun. It is characterized primarily by deployment of a set of stand-alone products and applications that function more or less independently. For example, computer-controlled traffic management systems, vehicle navigation devices, and commercial vehicle position tracking services are operating independently today. In parallel with this, basic enabling technologies are being developed and tested as prerequisites for many future applications.

In the second stage, independent products will be combined into more powerful applications, which are then integrated into systems. These systems are made possible, not only by advances in technology, but also by the collection, processing, and sharing of information — allowing coordination of transportation operations. For example, traffic management and traveler information systems can share data about current traffic conditions to control traffic or help drivers to select alternative routes or shift to public transportation — supporting the common objective of faster and more convenient travel.

In the last stage, advanced technology will be in place, continuing to increase its market penetration. As benefits of scale are achieved, applications will be integrated as fully as possible. Facilities can be planned so that their most effective performance depends on IVHS capabilities.

A scenario focusing on public transit development provides a useful example of systems integration. Its purpose is to present an outline of how IVHS is likely to proceed. The steps described here are, in practice, not completely distinct and separate — some activities identified in one step may begin at the same time as those in another step.

"A scenario of integrated public transit development."

STEP 1: ***Automate transit system internal operations. The*** focus is on supporting operations, maintenance, and general system management. It includes specifics such as vehicle diagnostics, scheduling, operator assignments, and vehicle identification and location technology.

STEP 2: ***Integrate traveler and transit usage information. The*** focus remains on internal operations, but now includes travel data that can be used in day-to-day operational and planning decisions. That includes passenger counting and fare collection and involves real-time communication from vehicles to dispatch centers.

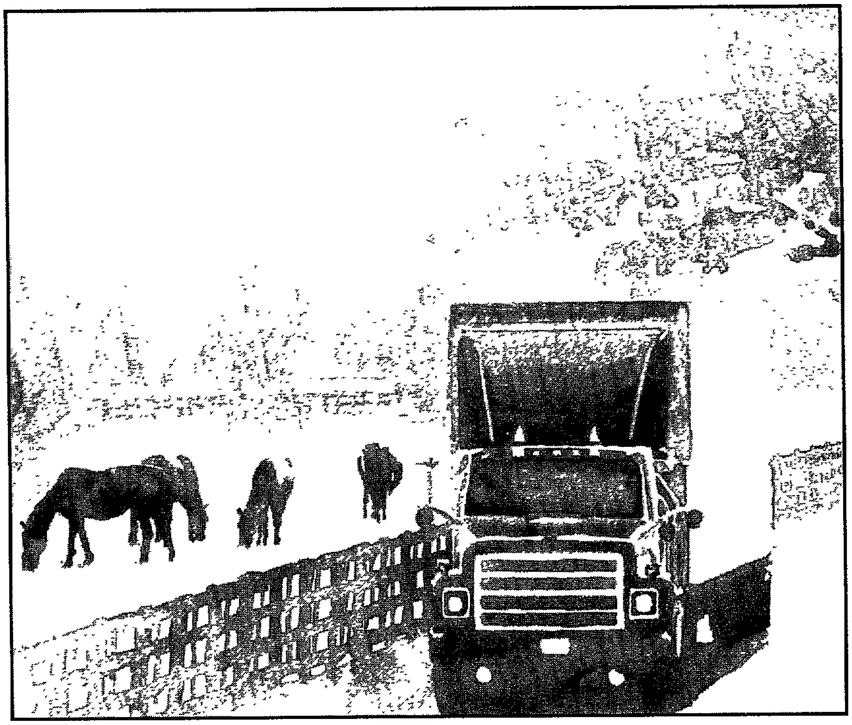
STEP 3: ***Provide information to travelers.*** Initially, travelers will gain access to services and schedules for distinct modes of travel. With further development, information will be integrated for complete trip planning, using one or more modes of travel.

STEP 4: ***Integrate with advanced traffic management systems.*** Traveler and management decision making will be greatly enhanced by information regarding current traffic conditions.

STEP 5: ***Integrate advanced vehicle control capabilities.*** A variety of AVCS functions will be incorporated, including collision warning to improve safety, lateral guidance for accurate docking at bus stops — to facilitate ease and safety of wheelchair use — and automation of vehicle operations in special facilities — such as HOV lanes — to improve safety and productivity.

STEP 6: ***Provide demand-responsive capabilities.*** The most sophisticated systems will adjust the operating characteristics of the transit system to current conditions. Two-way communication will be necessary to allow travelers to make reservations and to allow dispatch centers to maintain contact with their vehicles.

Rural Transportation



Rural transportation is an example of an area where a number of IVHS technologies can be integrated to produce substantial benefits.'

Application of IVHS to rural transportation systems will improve their safety, increase the efficiency of maintaining and operating them, and provide recreational travelers with improved navigational aids. It can include or can build upon the products and technologies developed for all of the functional areas — ATMS, ATIS, AVCS, CVO, and APTS. Technologies specifically tailored for rural applications will also have to be developed.

RURAL TRANSPORTATION CHARACTERISTICS AND REQUIREMENTS

Rural transportation systems must be uniquely tailored to the requirements of low volume rural highway systems and the vehicles that use them. Rural highways have a number of key characteristics:

- They are multi-jurisdictional, including state highways, county roads, and rural city streets.

- They frequently have limited sight distances and numerous opportunities for driver misjudgment because they are often built on existing terrain — including mountainous areas.

- Many of them have long travel distances between communities, thus fostering motorist inattention and dozing.

- They have animals — farm and ranch animals, wild game — crossing the roadway in various areas, whose presence creates serious problems for unsuspecting drivers.

- Rural highways are difficult to keep clear of snow and pavement ice. That can be a serious safety problem.

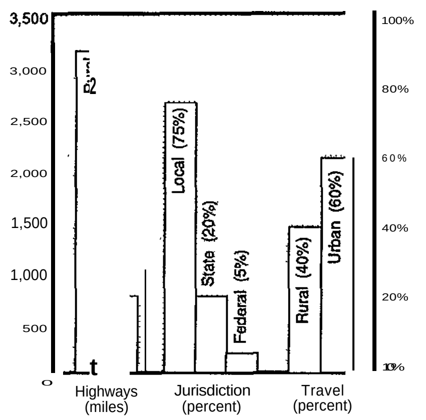
- They are not always able to provide adequate (and safe) locations for transit vehicles and school buses to load and unload passengers.

- They frequently receive considerably less maintenance attention than their urban counterparts.

"Rural IVHS focuses on safety, navigation, and maintenance."

The focus of IVHS in the area of rural safety must be the application of new technologies to age old problems — overtaking vehicles, driver dozing, vehicles leaving the road, animals and slow moving vehicles on the road, slippery pavement, and entering or crossing the roadway with limited sight distance. IVHS technologies will also bring major improvements in the areas of pavement and roadway maintenance, snow removal, and traveler navigation — both commercial and recreational.

Highways in the U.S. – 1990



Data Source:
National Transportation
Strategic Planning Study, 1990

Automated (electronic) vehicle location (AVL) and navigation systems could be enormously beneficial to rural areas, for both emergency services and public transportation. In many cases, a rural road network is not fully known or understood even by local residents, and directions are frequently given by imprecise landmarks: "Take the fork to the left, just past the large oak tree."

If callers were able to give their locations by referencing a standard coordinate system (WGS-84, for example), service vehicles could be more easily dispatched to them. That includes emergency vehicles, rural taxi services, and transit vans and small buses (frequently staffed by volunteers). In-vehicle navigation systems would further enhance such operations.

CURRENT STATUS

There are currently several efforts under way in the U.S. that focus on the unique requirements of rural transportation. However, within those projects, there is a very limited amount of research related to applying IVHS technologies.

"There has been very little research on rural IVHS applications."

The Mountain-Plains Consortium at the North Dakota State University Transportation Center was created by the 1987 Surface Transportation and Uniform Rehabilitation Act. Universities in six states participate. The focus of the effort is to develop rural transportation systems, yet it has only one active IVHS project. The National Rural Transportation Study Center at the University of Arkansas was just created by the Inter-modal Surface Transportation Efficiency Act of 1991. It is currently being organized. The Enterprise Consortium — states of Arizona, Colorado, Michigan, Minnesota, Iowa, and Washington, and Province of Ontario — is considering initiating rural IVHS programs.

Many IVHS products and systems that will initially be developed for urban use are readily adaptable to rural situations. Others must be developed primarily for rural use. Table 111-l describes those products and systems.

'Many urban IVHS products are *easily adapted* to rural use. "

DUAL-USE APPLICATIONS
– Automated maintenance systems
– Collision avoidance or warning systems — especially longitudinal (rear-end) and intersection
– Navigation systems with route guidance and traveler information
– Stranded vehicle (Mayday) signaling
– Vision enhancement (improved vision in fog, snow, blowing sand, etc.)
– Road-to-vehicle and vehicle-to-vehicle communication
– CVO technologies (for example, weigh-in-motion, automated permits)
■ Systems that alert drivers when they are about to leave their lane or go off the roadway
PRIMARILY RURAL APPLICATIONS
– Systems that alert drivers to the presence of cattle and other animals on the roadway
· Systems using sound, light, or other methods to keep animals off the roadway
– Systems that allow driiers to pass slow-moving vehicles in areas with limited sight distance
– Systems that transmit information to vehicles with on-board communication or by using advanced (variable) warning signs. That includes focal weather conditions (rain, snow, high winds, tornados), low visibility (fog, dust, snow), flash flooding (canyon and desert), special tourist information, and roadway limitations (height, width, and weight)
– Systems for snow and ice detection and removal
· Driver warning for advanced awareness of stopped transit vehicles and school buses
– Systems to safely stop runaway commercial vehicles on rural highway grades

Table Ill-l

Automated highway-speed trash removal.

Appendices A and B of this Strategic Plan list numerous research projects and operational tests for developing, testing, and demonstrating a large variety of IVHS technologies, systems, and products that can be utilized in rural settings.

"Rural IVHS *must be* affordable for rural areas."

IVHS research must account for and accommodate the specific needs of rural transportation systems. The systems must be appropriate for rural areas. That includes requiring that both the infrastructure and vehicle portions be affordable to rural users. In many cases, it will require that a new level of less expensive transportation infrastructure be developed for rural applications, since there are fewer motorists to share those costs.

"State and local *governments must get involved to assure rural applicability. "*

The adaptation of current IVHS technologies to rural areas and the development of new technologies for rural applications requires a cooperative research effort carried out by interested states, local jurisdictions — cities and counties — and private industry, with support from the federal government.

The operational test plan (Appendix B) in this Strategic Plan proposes that testing and demonstrations of IVHS systems be undertaken in both rural and urban settings. That will encourage owners and operators of rural systems to accurately judge the effectiveness of applying various IVHS products.

RURAL TEST BEDS

Rural test beds provide a means to accurately evaluate rural IVHS benefits and costs. Several rural test bed and demonstration projects are currently being proposed for use in cooperation with interested states. The test beds would be used to test and demonstrate rural systems and technologies, ranging from application of current off-the-shelf technologies to future new technology systems. Two of the sites under consideration are Route 191 between West Yellowstone and Bozeman, Montana, and Route 299 between Redding and Alturas, California.

System Architecture

Significant amounts of technology and information must be merged in IVHS systems — the greatest benefits will be achieved from a very high degree of integration and compatibility. Communications are involved in almost every area; data will need to be gathered from diverse sources, assimilated, and used in many different information and management services; technologies will be developed in five-, ten-, and twenty-year stages. All of this requires a framework on which flexible and economical systems can be built.

A system architecture, defining the relationships among system components, provides the needed framework and gives essential guidelines to designers and product developers. A system architecture can do the following:

- Foster evolutionary development of IVHS that readily accommodates new products

- Reduce overall system costs by defining a proper balance between infrastructure and in-vehicle capabilities

- Help reduce the cost of individual components by clearly defining their functions

- Allow new technologies to replace old ones as costs and capabilities change

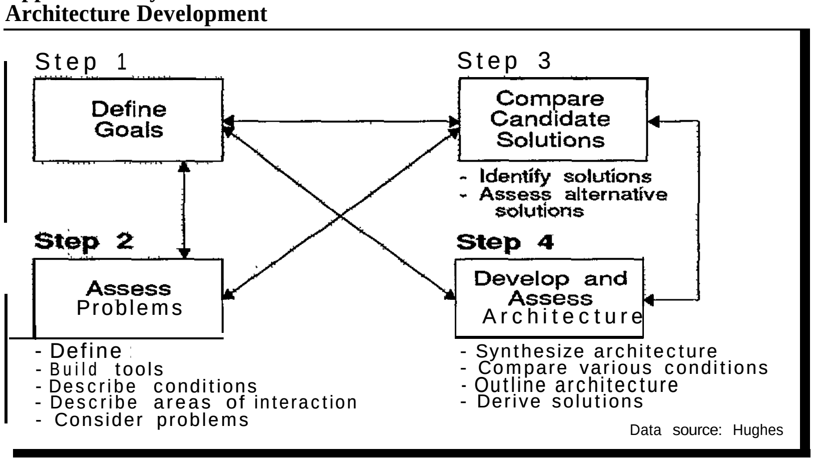
- Identify necessary interfaces between components — an essential step toward defining standards and protocols

- Provide a mechanism for evaluating specific products

- Indicate how products and technologies can accomplish common functions and thus encourage competition by the private sector

The objective is to define an open architecture that can accommodate components from multiple vendors. It should be "robust" — that is, able to incorporate new functions and technologies as the system evolves over time. New devices and new operational needs will engender change. Different goals must be supported across many regions — for example, different features will be important to rural and urban areas. A well-defined system architecture should accommodate different levels of implementation so that jurisdictions can acquire only what is important to them. In addition, a well defined architecture will provide guidance in integrating or upgrading existing systems in order to preserve current investments.

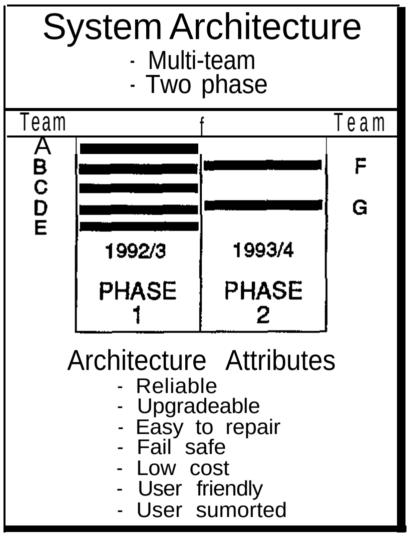
Approach to System Architecture Development



Data source: Hughes

IVHS development is moving rapidly and products are already coming to market. Requirements for some areas are evolving in parallel with developments in others. The goal, nonetheless, is a well-integrated system in which traffic management, traveler information, and vehicle control functions are all linked practically and cost-effectively to provide greater capabilities than could be achieved separately.'

A high-priority task is to create an overall IVHS system architecture; although small scale efforts have begun, a more concerted effort is needed.



IVHS AMERICA has formally recommended a system architecture development methodology to DOT that utilizes several concurrent multidisciplinary public/private/academic teams. It will require contributors from many disciplines, including transportation analysts; systems engineers; and specialists in communications, infrastructure technologies, vehicle dynamics, data management, simulation, and modeling. Simulation and modeling are especially valuable for providing early indications of a technology's cost/benefit ratio, and thus early indications of the desirability of continuing to pursue it.

DOT is the only organization with both the motivation and the funds to carry out this effort — by and large, industry's focus is on individual elements, because it cannot directly derive revenue from such integrative tasks. DOT should initiate a collaborative program involving many parts of the private sector, teamed with academia and appropriate public sector agencies. Mechanisms and funding for enhancements to the architecture will be needed over the long term.

Standards and Protocols

The hardware, software, and communications industries — all suppliers of IVHS technology — know from hard experience that standards and protocols play a crucial role in successful long-term product development and broad-based customer acceptance. Given the variety of system components and intercommunication requirements, how and when standards and protocols are established will have a great effect on the success of IVHS.

Setting standards too early can potentially stifle innovation. If they are set too late, industry cannot realistically be expected to curtail IVHS product development while waiting for nationwide standards to be defined. Yet there are very real benefits to be gained from standardization at the appropriate time. Standards can:

- Eliminate unnecessary product development costs caused by changes in the way products interconnect or the need to create multiple versions to interact with other products
- Allow system components to be interchangeable
- Help ensure system reliability, availability, and maintainability
- Foster area-wide deployment and thus enhance the utility to the consumer
- Promote application stability and hence the attractiveness to potential developers
- Establish a basis for liability limitation

The standards process for IVHS systems and technologies has already begun. Standards are needed in a variety of key areas. Current efforts address industry, regulatory, design, and performance issues, including system interfaces, communications, map databases, information systems, control systems, human factors, and hazard analysis.

Existing standards-setting organizations will be relied upon in promulgating IVHS-related standards. Three kinds of standards-making bodies are discussed below:

- ***Umbrella organizations with wide-ranging areas of interests. These*** include the American National Standards Institute (ANSI) in the United States, and, on a worldwide basis, the International Standards Organization (ISO) and the International Electrotechnical Commission (IEC).

- ***Organizations with focused areas of interest, that are accredited by*** ANSI. Typically, standards created by those organizations become ANSI standards. ANSI also serves as a gateway for those organizations to submit standards to IS0 and IEC for adoption as international standards. Organizations in this category include the American Society of Civil Engineers (ASCE), the Institute of Electrical and Electronics Engineers (IEEE), the Society of Automotive Engineers (SAE), and the American Society for Testing and Materials (ASTM).

- ***Certain trade and professional associations, as well as associations of public and quasi-public agencies, that develop and adopt voluntary standards.*** This is done under a due process confined to their own memberships and does not extend to the full community of manufacturers, fabricators, suppliers, and users as required under ANSI "community consensus" procedures. Such non-ANSI standards-setting organizations include the Institute of Transportation Engineers (ITE), the American Trucking Associations (ATA), the American Petroleum Institute (API), the International Bridge, Tunnel and Turnpike Association (IBTTA), and the American Association of State Highway and Transportation Officials (AASHTO). The due process of such non-ANSI standards-setting organizations must conform to federal anti-trust laws; it therefore is open and seeks comments and input from affected non-member groups and individuals.

Parties seeking a standard from any of these organizations must define a need and request formation of a standards committee. The procedure involves due process, forming consensus, and exposing the standard to review by the community at large. A number of standards initiatives are already under way. SAE has established an IVHS Standards

Division and an IVHS Program Office. The IEEE Standards Board has formed a new Standards Coordinating Committee for IVHS.

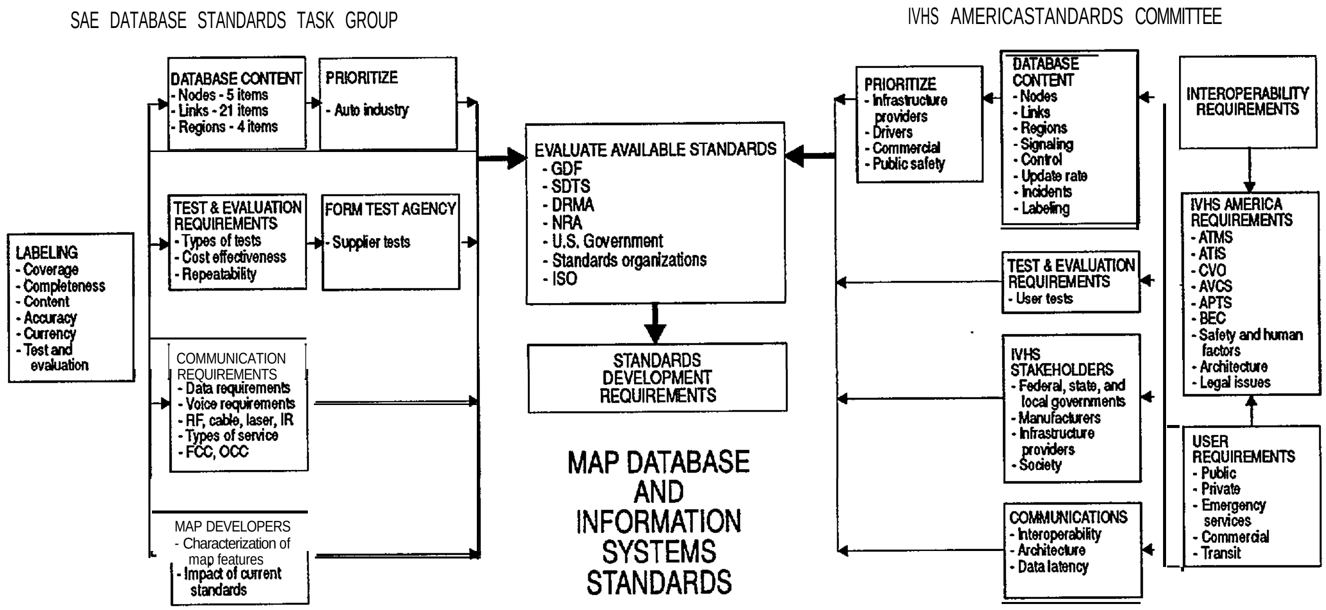
IVHS AMERICA has established a Center for IVHS Standards to work in conjunction with its Committee on Standards and Protocols. This Center, in liaison with IVHS AMERICA's technical committees, will take a proactive role in driving the overall process. This effort is especially important because of the interdisciplinary nature of IVHS and the number of standards-making bodies involved. The Center will help the Committee on Standards and Protocols to:

- Identify IVHS subsystems, interfaces, and elements that need standards
- Determine the most appropriate group to set a given standard
- Adopt or upgrade existing standards wherever possible
- Establish ad hoc groups to set standards — but only as a last resort, in the absence of other alternatives
- Act as a liaison in international standards efforts
- Review planned and in-progress operational tests to identify areas of utility for standards development, and also assist the organizations responsible for the tests in defining, acquiring, and analyzing standard-related data
- Encourage the inclusion of standards and protocols dimensions in the definition of future operational tests
- Serve as a conduit for standards-related information between operational tests and standards-making organizations

This process is already under way. As the example in Figure III-2 illustrates, the IVHS AMERICA Standards and Protocols Committee is already working with the SAE Map Database Standards Committee.

Safety and Human Factors

IVHS brings a wealth of information and enhanced capability to travelers, drivers, traffic managers, and fleet operators. Information is used by travelers to select travel alternatives; by drivers to make immediate driving decisions or as warnings of potentially unsafe conditions: by traffic managers to control traffic flow; and by fleet managers in the planning, operation, and maintenance of fleets. If these systems are to accomplish their goals, then they must provide this information in an effective, reliable manner that the user can comfortably employ.



Source: Working document of the IVHS AMERICA Standards and Protocols Committee

Figure 111-2. Development of standards for map databases and information systems.

Therefore, research on safety and human factors issues in IVHS applications must be an integral part of the strategic plan. The research should determine:

- Exactly what information is needed to provide assistance to the user and how that information will be used
- How to present information so that actions can be taken in a timely fashion, so that the information doesn't put undue stress on the user, and so that the presentation itself doesn't create an unsafe condition
- How to warn drivers of unsafe conditions in a manner that will elicit a safe and proper response.
- How to provide control assistance in a way that drivers will readily accept
- How best to construct physical devices and place them in a vehicle
- How to safely switch between manual and automated operations
- How to get information or responses from the user without jeopardizing safety — including how people react when a system is not performing properly

- How all the above issues are affected by differences among drivers (particularly older and physically handicapped drivers) and vehicles

In the traffic management area, systems must synthesize large amounts of data, potentially covering area-wide traffic conditions. Moreover, traffic flow prediction, traffic control, and incident management require working with many complex variables and require quick responses. Expert systems may offer good solutions in these areas, so considerable research and testing on those systems are called for by the Strategic Plan.

IVHS will provide sensory assistance to the driver and will eventually automate control of vehicle operations. Systems will be introduced that will greatly change present-day driving habits. Those who develop and deploy these systems must determine effective ways of introducing them into the marketplace. Incremental implementation is a likely approach. It would start with voluntary use of relatively limited functions and would later move to greater complexity with more complete automation. That method allows developers to learn from actual results and affords users the opportunity to gain greater comfort with automation as they use the partially automated systems. Many issues must be resolved relating to the transition from assisted driving to automated control, including clarifying the division of responsibility between the driver and the system. There also is a potential difference between actual safety and occupant perceived safety while operating under automatic control. If the occupant feels unsafe, the system will not be accepted, whether it is safe or not. Conversely, if a driver over-estimates the capabilities of an automated or partially-automated system, it may put the vehicle into an unsafe situation.

It is important to stress that safety and human factors must be fully integrated into research and development, not merely added afterwards. There are specialized safety and human factors research needs, design standards, and evaluation requirements for field trials. Specific funding should be allocated for those purposes. Yet safety and human factors must be the concern of all IVHS designers. As part of this effort, IVHS AMERICA has established several subcommittees to focus on the following safety and human factors issues:

- Safety and human factors ***design guidelines*** for design engineers

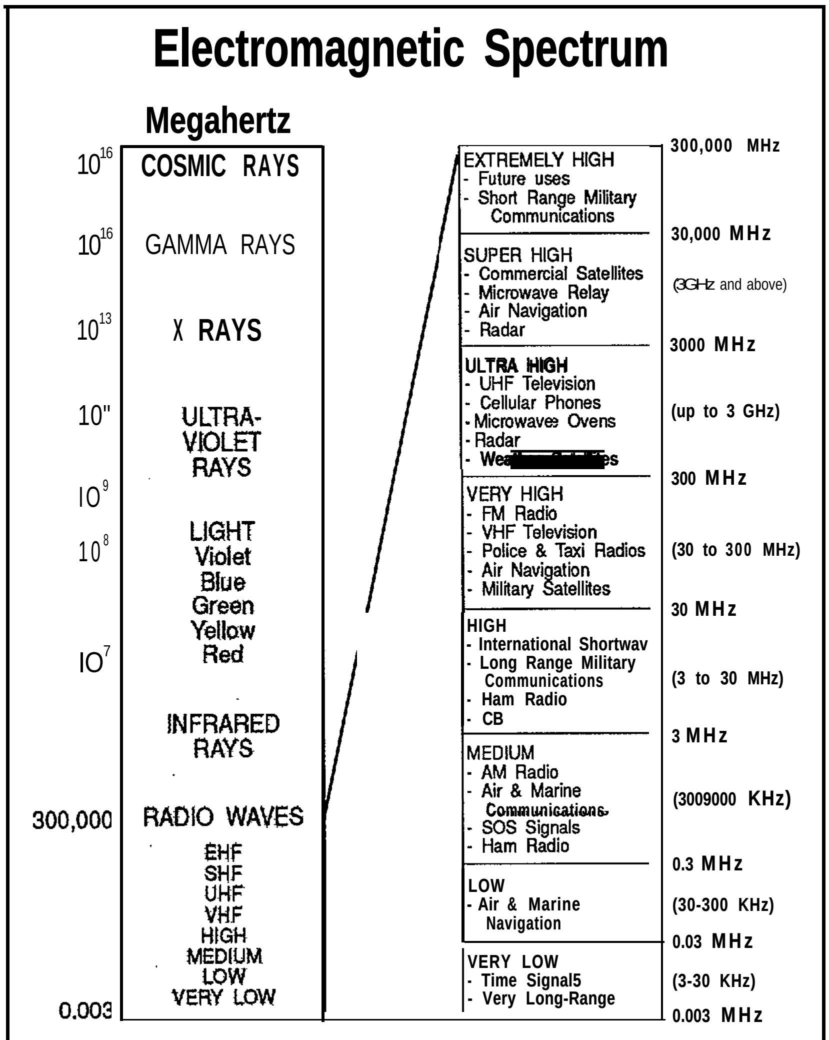
- ***Evaluation of field studies*** from a safety and human factors perspective

- Databases for safety and human factors research and for accident analysis

- Research on substantive engineering questions

Communication

Virtually every IVHS product either requires communication or would be enhanced if information were available to it through communication facilities. The needs are quite diverse, ranging from low-power roadside transmitters and receivers to satellite communications. That range requires vastly different circuitry, electronic components, antennas, frequencies, bandwidth, and data capacity. More importantly, specific IVHS functions may be achieved by alternative communication methods.



SOURCE: The Spectrum Report

For the above reasons, analysis is needed to determine communication-related requirements for IVHS product areas. Designs can then be selected to minimize the number of different communication technologies or to make use of the most cost-effective approach for specific conditions. That will also minimize the number of communication systems to be carried by a single vehicle. Communication technologies should be carefully analyzed early in IVHS development, not just for individual product needs, but for a broad cross-section of communication uses.

The focus of analysis must go beyond U.S. boundaries. To facilitate the operation of vehicles across national borders in North America and to reduce the problems associated with having the same frequencies used for different purposes in the areas adjacent to these borders, every effort should be made to use the same set of frequencies for IVHS systems in the United States, Canada, and Mexico. Although it is nearly certain that a single communication system will not meet the needs of all IVHS functions, it is important that each function that requires communication (AVI, for example) use the same frequencies throughout North America. Because radio-frequency (RF) spectrum matters usually involve extensive analysis as well as political negotiation, it is imperative that spectrum management issues receive early, coordinated, and persistent attention from all IVHS interests.

For many years, the staffs of the U.S. National Telecommunications and Information Administration (NTIA) and the Canadian Department of Communications have routinely coordinated frequency assignments in several bands for the U.S. and Canada. The two countries periodically convene the "Niagara Commission" to discuss matters more related to policy, as would be the case with IVHS frequency allocation discussions. The U.S. and Mexico have recently established the "Bi-National Commission" to develop basic RF spectrum policies and to establish procedures for frequency coordination between the two countries.

The three countries could elect to standardize IVHS frequencies throughout the Western Hemisphere by bringing in Central and South America (which, with North America, comprise International Telecommunications Union [ITU] Region II). If so, a body within the Organization of American States exists that could assist in the development of proposals for presentation to the next World Administrative Radio Conference for a permanent change in the International Table of Frequency Allocations. That would also address the issue of international frequency standardization.

Besides frequency coordination, North American countries should concur on IVHS standards and protocols for interfaces to communication systems and for the data that will be passed over them. That, again, is a long lead-time item that requires prompt attention.

Integrative Research and Development

Given the technological underpinnings of IVHS, much of the research and development effort is directed at refining technology and reducing related product costs. Yet the Strategic Plan is much more extensive — in keeping with the clear need to integrate many sources of information, support multiple transportation modes, and address institutional and legal issues.

This section summarizes the integrative and cross-cutting perspective needed in the IVHS R&D effort; a detailed list of research projects is presented in Appendix A. The following is a summary of integration topics:

- ***System analysis and system architecture.*** Determine user and applications requirements and identify the relationships among IVHS component functions from an overall system perspective.

- ***Transportation systems analysis. Analyze*** the operation of transportation systems and define strategies for maximizing their efficiency using IVHS. Develop tools for predicting the effects of IVHS on transportation operations.

- ***Modeling and simulation.*** Develop modeling and simulation capabilities for multi-purpose, multi-modal transportation network analysis.

- ***Databases and database management. Analyze*** opportunities to combine data for individual IVHS functions into integrated databases for greater utility and easier maintenance. Determine the database architectures and management functions needed to support such integration.

  Develop supporting databases on subjects of general interest, such as traffic safety and accident causes.

- ***Communication.*** Identify communication needs, analyze the capabilities of communication alternatives, and identify requirements for communication standards, protocols, and spectrum allocations.

- ***Software*** Research general software subjects pertinent to IVHS applications, such as expert systems, artificial intelligence, failure-tolerance, and virus protection.

- ***Safety and human factors.*** Determine how information and warnings should be presented and how travelers, drivers, and operators (for example, in traffic management centers) respond to them, as well as how users respond to automated systems.

- ***Institutional and legal issues.*** Conduct studies regarding institutional issues, including cross-jurisdictional concerns, state/federal relations, and public/private arrangements. Also conduct studies on legal issues, including tort liability and privacy.

- ***Socio-economic issues.*** Evaluate the potential impact of the overall IVHS program and specific issues such as public acceptance, privacy, distributional equity, environmental effects (including land use), alternative user fees, and congestion pricing.

- ***Privacy as a design issue.*** In addition to studying privacy issues from a socio-economic perspective, privacy should also be considered an essential design issue in product and system development.

Operational Tests

Operational testing is an indispensable step in the creation of products and the integration of services into larger systems. It is the transition between R&D and full scale deployment — an opportunity to conduct tests in a “real-world” environment under “live” transportation conditions. Tests are used to integrate existing technologies and R&D products, to experiment with various institutional arrangements, and to determine cost/benefit relationships. Tests also allow a chance to evaluate the market-readiness of products and services.

An IVHS operational test typically involves a carefully crafted partnership, which is negotiated among federal, state, local, private, and other institutions. Funding and technical and administrative responsibilities will be shared among those partners.

A list of proposed operational tests is presented in Appendix B.

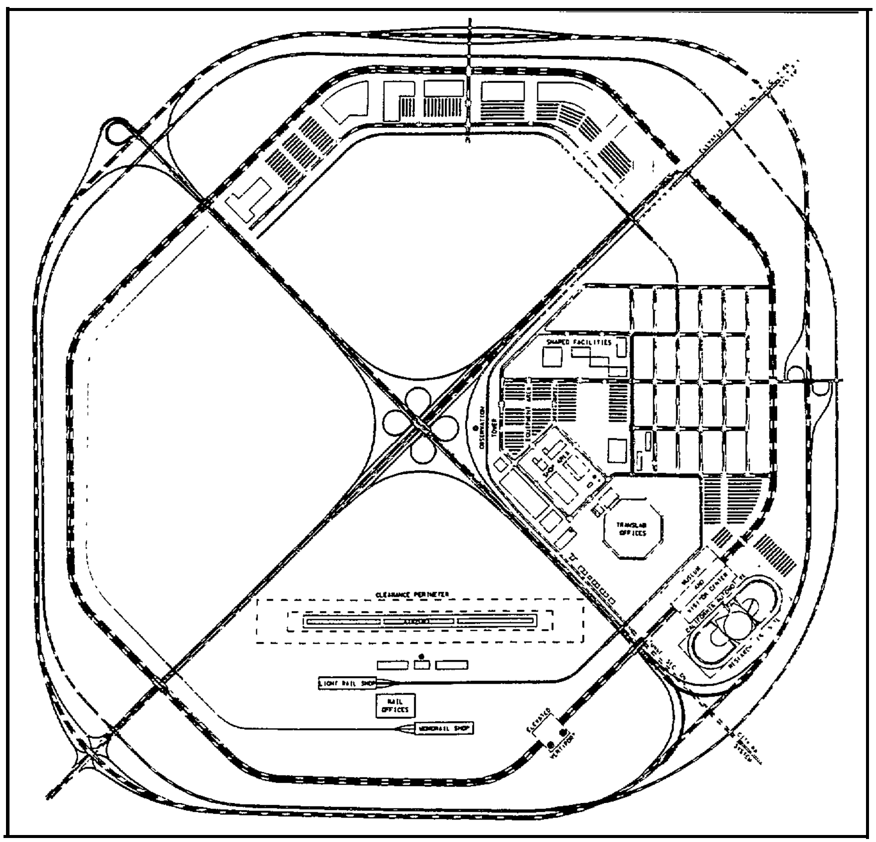
OPERATIONAL TEST SELECTION

Criteria must be established for selecting test components and for ensuring proper experimental designs. Such criteria provide a basis for judging the outcomes of the tests. An essential aspect of evaluation is the analysis and quantification of costs and benefits. The overall review must be superimposed on the existing array of controls, data gathering techniques, and information presentation methods.

NATIONAL TEST SITES

Federal, state, local, and private sectors may make substantial investments in facilities, infrastructure, and monitoring apparatus to conduct operational tests for a particular technology or approach. For the sake of efficiency and technical comparability, a number of test sites will be used for multiple experiments. That will allow testing of a variety of sensors, communication devices, and user interfaces without requiring new site investment and development time for each. Once test sites are developed, the required communication, instrumentation, and observation infrastructure will be in place to carry out multiple tests under similar conditions. That will enhance the direct comparison of various technological alternatives, either in sequence or simultaneously. The test sites will also be useful for increasing public awareness and acceptance of IVHS. Dedicated HOV facilities may be particularly useful for that purpose.

Designation of a facility as a national test site will warrant additional federal funding and will require additional attention in the design of both technical arrangements and institutional arrangements for administration of the test site. That will require a commitment from local authorities to allow the use of their facilities for additional test purposes.

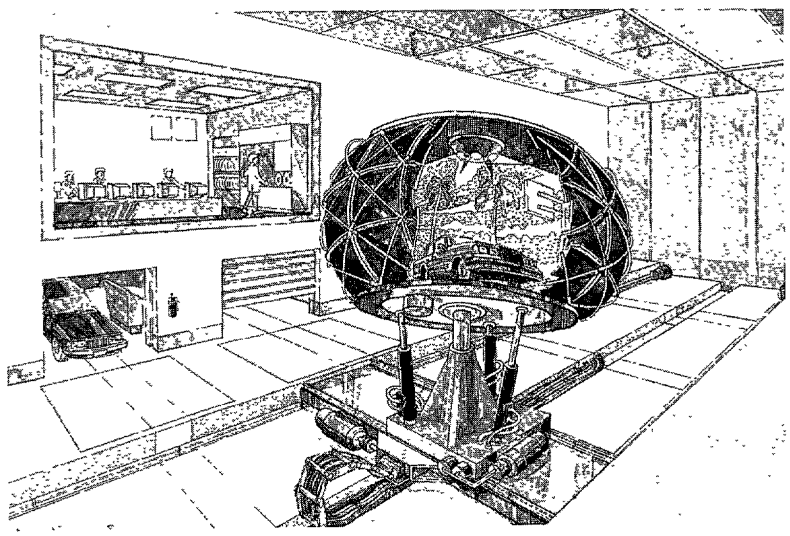


Transportation Research Center

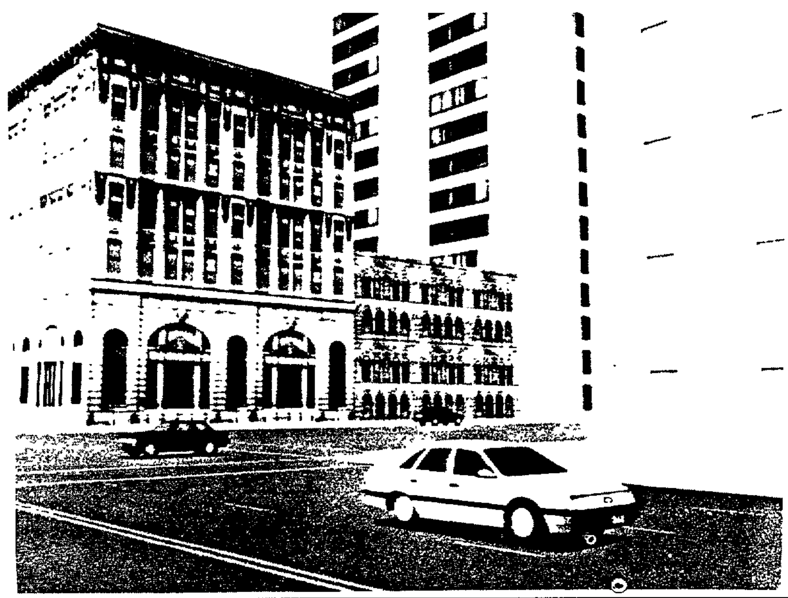
ADVANCED TESTING CENTERS

Development of many of the more advanced technologies will require extensive controlled site testing to ensure safety and reliability. Thus, transportation research and development centers will need to be adapted or established, although some existing facilities could be augmented for this purpose. The state of California is considering establishment of a new facility in an ambitious public/private collaboration. Such centers will bring together the resources and expertise of the private sector; federal, state, and local governments; and academia. They will include research labs and testing facilities for highway and mass transportation R&D projects, with full-scale test facilities, including several miles of freeways, arterial roads, and city-type streets with interchanges and intersections. The centers could be used to gauge acceptance of the technology by the public via human factors studies, or they could even be used by the private sector to perform market testing.

Artist's rendering of the National Advanced Driving Simulator (NADS). (Source: University of Iowa)



Textured graphics used in simulator scenes. (Source: University of Iowa)



Evaluation Criteria

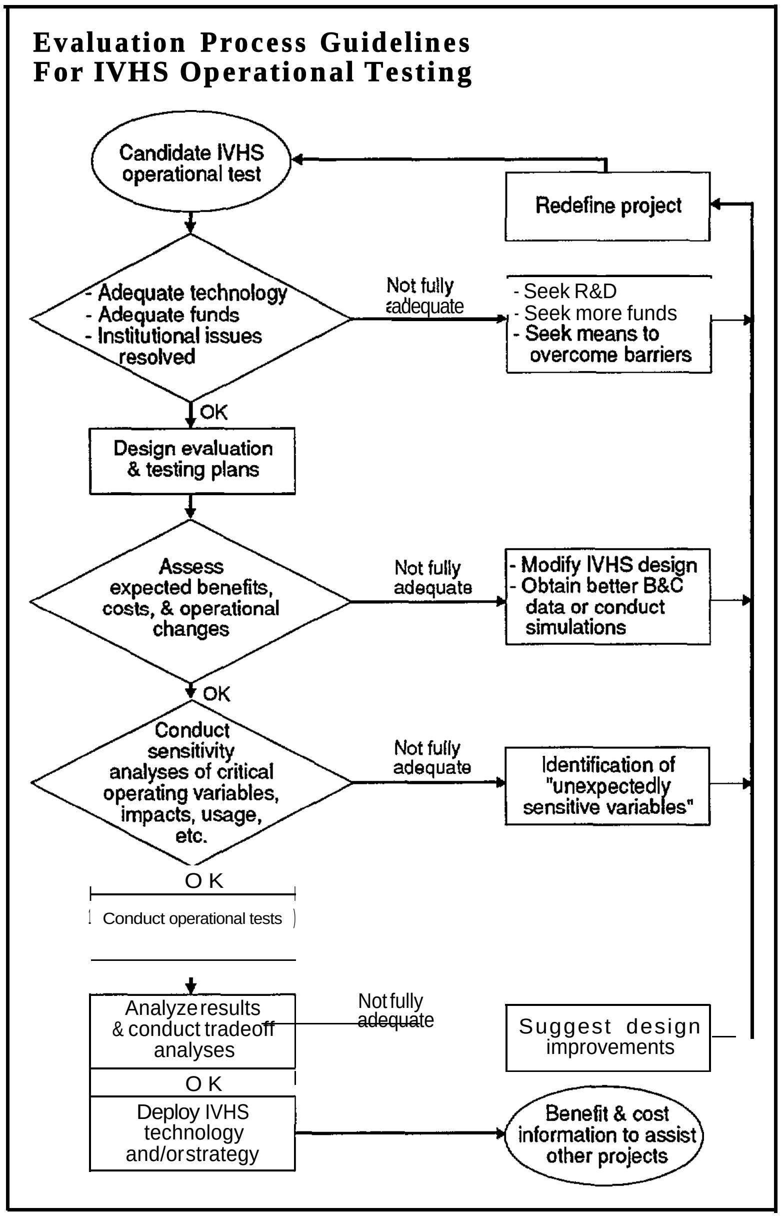
Building on existing efforts of FHWA, DOT will develop uniform evaluation criteria that can be applied to all operational tests. That can be accomplished by working through IVHS AMERICA or through other forums. Information gained by employing standardized evaluation methods during early operational tests will guide in establishing requirements for later tests. The information from all tests can be easily compared and therefore will facilitate accurate estimates of the benefits that can be gained by deploying the systems and by effectively marketing the products.

The operational tests are expected to provide the first concrete evidence regarding the viability and acceptance of various IVHS technologies. The outcomes will, in large part, determine the form and pace of IVHS deployment.

It is anticipated that large-scale IVHS deployment will have a significant beneficial impact on individuals, on the economy, and on society as a whole. Because of the large effect possible, it is important that operational tests be conducted and evaluated in a manner that gives an accurate projection of the costs, user acceptance, and individual and societal benefits of the various systems and products. To accomplish that, a structured framework must be provided for evaluating the assorted IVHS technologies, systems, and products. Use of such a framework facilitates consistent and comparable information that allows reliable comparisons to be made between alternative approaches. Such information will aid the private sector in effectively marketing products and will assist all areas of the country in determining how various IVHS systems can meet their individual needs, while still maintaining essential nationwide uniformity.

Planning for benefit assessments must be incorporated into operational tests from the beginning. Good baseline data is essential in assessing the changes that result from adding IVHS operations. Large-scale operational tests must initially obtain baseline data for accident rates, congestion levels, time-of-day travel times, mobility measures and the like. Once baseline conditions have been established, changes in the conditions can be appraised as different aspects of the tests are implemented. When multiple technologies and strategies are tested concurrently, sensitivity tests should be conducted to determine which generate the greatest benefits and which are most valued by users.

User acceptance is an extremely important factor. If users do not value the potential benefits of an IVHS product or service, they will not purchase or use it and, therefore, any safety or mobility improvements offered by it will be forfeited. In the early stages of IVHS deployment, when technologies are unproven and IVHS products and services are unfamiliar, users may be especially reluctant to try them.



If, for example, motorists do not follow the routes provided by an ATMS, substantial benefits may be lost both to the motorists and to the entire transportation system. Detailed information should be gleaned from operational tests regarding factors that influence users' decision making processes — including what information they want **and** how they will use it. In the above example, that would include the factors that influence a motorist in deciding whether or not to follow an ATMS-provided route. Surveys of user responses to particular IVHS features should be included in as many operational tests as possible, and they should include an assessment of the amount users are willing to pay for the features being evaluated.

The costs for partial or full-scale deployment of IVHS systems and services should be estimated for different sized metropolitan and rural areas. When implementation can be staged, the costs of various increments should be estimated.

Operational tests additionally provide an opportunity to study institutional factors that help or hinder deployment. Among those are the roles of the public and private sectors in deployment. Many potential benefits of IVHS relate to the provision of traveler information that, although not essential for optimized traffic flows, makes motorists' trips more enjoyable and more productive. Such information may be provided by the private sector. That information, although not provided for the primary intent of managing traffic flow, may effectively fulfill that purpose, thereby relieving the public sector of the responsibility. Various mixes of public and private sector responsibilities will be tested to determine which best meet the overall needs for aiding motorists and for preventing accidents, reducing congestion, decreasing air pollution and lessening fuel consumption. Various arrangements for sharing information among a multitude of public and private organizations will also be explored.

IVHS AMERICA's Committee on Benefits, Evaluations, and Costs is developing guidelines that can be used in establishing the process for evaluating operational tests. The committee will recommend a structure that ensures uniformity and maximizes sharing of information among the public and private sector organizations involved in research, development, operational tests, and deployment of IVHS.

The evaluation guidelines will reflect the considerations discussed above and will include the following components:

- Definition of evaluation requirements for various classes of IVHS operational testing. This ensures that standardized evaluations can be conducted, thus maintaining consistency in representing results, in reporting results, and in interpreting the outcomes of both public and private sector IVHS testing.

- Use of a common analysis framework that serves as a basis for establishing evaluation plans for individual operational tests and for guiding prospective deployment. The framework must take into account geographical and demographic characteristics; the institutional environment; expected short-term and long-term benefits; simulation and modeling; surrogate use (when important measurements cannot be taken directly); training needs; installation, operating, and maintenance costs; and hierarchical relationships between planning, operational, and policy procedures.

- Establishment of methods to determine the data required to accurately measure effectiveness and costs, to set priorities for taking measurements, to establish minimal data needs for models that extrapolate results, and to establish the data needed to perform various types of statistical analyses.

- Establishment of national database requirements for obtaining information from individual operational tests that provide consistent results from different test environments.

- Definition of a consistent set of planning and implementation steps that ensure that legal and regulatory requirements have been and will continue to be met.

- Identification and classification of public and private sector measures of effectiveness, with trade-offs between competing deployment goals for various IVHS products, systems, and subsystems.

It is essential that funds available for operational tests be used efficiently. Early results must be used to guide cost-effective deployment of initial IVHS technologies and strategies. Accordingly, evaluations must include the means to optimize the broad set of safety, environmental, economic, operational, and other public benefits that IVHS technologies promise.

Format should not stifle creative and inventive means of harnessing new IVHS technologies and assessing their benefits. Yet discipline is required in the design of evaluation plans and in reporting of results. Progress will be greatest if information on payoffs and costs is shared, both among participants in a specific test and among those who are conducting similar tests throughout the world.

Development Projects Summary

An integrated program of R&D projects and operational tests is shown in the following table. The projects and tests are arranged by time period in each of the five functional areas. Complete information on R&D and operational tests is contained in Appendices A and B, respectively.

Selected IVHS Development Projects

		1992-1996	1997-2001	2002-2011
ATMS Advanced Traffic Management Systems	Research and Development	– Traffic monitoring hardware and software ■ Traffic control systems logic – Database specification – Traffic management center user interfaces	– Multi-source traffic data fusion · Predictive traffic modeling ■ Dynamic optimal routing strategies – Adaptive traffic control	– Site-specific refinement of applications and technologies
	Operational Tests	– Traffic monitoring systems ■ Vehicles as probes – Traffic control systems – Incident detection and management – Traffic modeling ■ Traffic management center operations	– Network-wide traffic optimization – Area-wide traffic management	– Multiple transportation mode information integration
ATIS Advanced Traveler Information Systems	Research and Development	· Navigation software – Map and business/tourist services databases – Communication alternatives	· Dynamic, optimal route guidance ■ Portable information systems – In-vehicle signing	· Multi-modal trip planning
	Operational Tests	– Navigation route planning and guidance – AVI and AVL in various applications ■ Alternative presentation and delivery modes	– Dynamic route guidance – Emergency Mayday – Safety/warning systems	❑ Demand-responsive system capabilities

Selected IVHS Development Projects (Continued)

		1992-1996	1997-2001	2002-2011
AVCS Advanced Vehicle Control Systems	Research and Development	– Sensors – Collision warning – Driving simulators	- Perceptual enhancement systems – Vehicle/driver monitoring systems	- Collision avoidance systems – Obstacle avoidance systems – Automated network operations
	Operational Tests	– Roadway/environment safety warning systems - Intelligent cruise control – Test facility development	– Collision warning systems – Automated highway demonstration - Lane departure control - Intersection hazard warning	– Automated freeway lane operation ■ Automated HOV
CVO Commercial Vehicle Operations	Research and Development	– Weigh-in-Motion – Electronic toll collection ■ Driver warning systems - Electronic record-keeping	- HAZMAT cargo information systems – Automated vehicle and driver safety inspections	
	Operational Tests	– AVI/AVL in multiple applications - Electronic credential checking ■ Electronic permitting	– Electronic record keeping	– Automated heavy vehicle lane testing
APTS Advanced Public Transportation Systems	Research and Development	– Customer interfaces – Customer service systems – HOV verification - Electronic fare collection	– Interactive displays – HOV guide controls – Smart Cards	
	Operational Tests	- Kiosks - Audio/video text - Portable traveler information – Fleet management systems – Maintenance tracking systems	- Interactive customer service systems ■ Integration of customer and fleet management information	- Automated transit vehicle operation on specially equipped (HOV) lanes

IVHS Deployment

Introduction

"Deployment is the heart of this Strategic Han... *the result that justifies all other actions."*

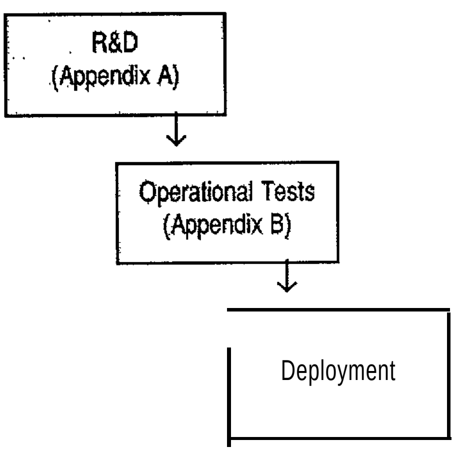
Product deployment is the heart of this Strategic Plan. It is the result that justifies all of the foregoing actions. Without widespread, large-scale deployment of products that apply a broad spectrum of technologies, the vision and benefits of IVHS cannot be realized. IVHS deployment will be an evolutionary process, stretching, extending, and building upon existing technologies and products. This section presents a practical, rational estimate of future IVHS product evolution and deployment.

In order to accomplish scheduled deployment goals, timely R&D is needed to develop technologies, reduce technology costs, study human reactions, define issues, and quantify benefits and drawbacks. The R&D projects that must be carried out in order to accomplish the deployment in this section are listed in Appendix A.

"IVHS deployment will stretch, extend, and build upon existing technologies and products."

Operational tests must be carried out in order to demonstrate and quantify the effectiveness of applying various technologies and products to real-world situations. The tests will also quantify market acceptance. Listed in Appendix B are the operational tests that must be carried out in order to bridge the transition between the required R&D and the deployment shown in this section.

The estimated costs for achieving the deployment levels shown in this section are provided in the tables in Appendix D. The *Costs* section of Chapter III integrates the costs required for deployment with those of R&D and operational testing.



Building on many ongoing activities, IVHS deployment will proceed throughout the U.S. Cooperation between the public and private sector is a pre-condition for successful and rapid deployment. Public and private investments in IVHS, occurring in tandem, can achieve more than independent investments. This is in much the same way that public investment in the Interstate and private investment in vehicles have been complementary over the last 35 years.

One key expectation is that DOT will manage its portion of the IVHS infrastructure deployment in a manner similar to their management of the deployment of the Interstate Highway System. DOT will provide a major part of the funding for the public sector components of the IVHS infrastructure. As a result, they can strongly influence state and local governments and private industry in their decisions regarding the types of infrastructure that will be deployed, the geographic sequence of deployment, and the rate of deployment. The introduction and use of IVHS technologies in public transportation will be a cooperative effort at all levels of government, with DOT acting to facilitate efforts. DOT will evaluate and disseminate technical information to assist in wise procurement actions by local transit and highway authorities and others involved in the deployment process.

'Public commifmenf to infrastructure deployment will encourage private enterprise to develop the IVHS market"

The private sector side of deployment will be market-driven. For private organizations, this deployment plan can only be viewed as a guide book or road map. However, the expenditure of federal funds for infrastructure deployment will encourage private enterprise — large corporations and small innovators -to undertake the design, development, and marketing of products, systems, and services that complement the infrastructure.

The key goal is a consistent, nationwide IVHS system that can be quickly and efficiently deployed.

Advanced Traffic Management System (ATMS) Deployment

NEAR-TERM PROJECTION

During this period, the U.S. will deploy partially-featured, non-area-wide ATMS systems in ten to twenty cities and two to five inter-city corridors. Key characteristics of those systems will be as follows:

7hroughouf the Strategic Plan:
- Near *ferm means a* 5-year *timeframe*
- *Middle term means a IO-year timeframe*
- Longer term means a 20-year *timeframe*

- Real-time traffic monitoring in local areas (several cities or part of a county)
- One-way transmission of digital traffic congestion information
- Local area coordination of traffic signals based on current traffic demands as defined by multiple monitoring sources
- Rapid incident detection and response
- Local area coordination of multi-modal information

MIDDLE-TERM PROJECTION

During this period, the U.S. is expected to deploy full-featured, area-wide ATMS systems in thirty to fifty metro areas and 15 to 30 inter-city corridors. Key characteristics of those systems will be as follows:

- Metropolitan area-wide or wide corridor monitoring for coordination of traffic signals and transit vehicles
- Use of traffic control and management strategies to rapidly detect and respond to incidents, efficiently manage saturated flow, and control traffic in an integrated, real-time fashion, including transit priorities

- Management of freeway and street networks in an integrated and adaptive manner
- One-way, real-time digital data transmission of link travel times for current traffic conditions
- Improved automated sensing of traffic flow (for example, video imaging, sonar, or doppler radar)

LONGER-TERM PROJECTION

During this period, the U.S. may see area-wide ATMS systems deployed nationwide in large urban areas, in important rural corridors, and in other areas with specific needs — examples are tourist areas, large industrial areas, and chemical stockpile disposal sites. At this time there may be more than 200 sites.

It is expected that by the end of this timeframe, ATMS systems will be fully integrated, interactive, and adaptive systems that offer the user a seamless surface transportation system.

ATMS PRODUCT EVOLUTION

INFRASTRUCTURE	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
Traffic Monitors	- Local area (several cities or part of a county) - Loop detectors - Voice reports	- Improved automated sensing (video imaging, sonar, doppler radar)	- Vehicles as traffic probes - Vehicles send their destination information
Communication (Data)	- 1-way, digital - Traffic congestion	- 1-way, digital - Link travel times	- P-way, digital - Predicted link times - Destination and progress reports
Traffic Management	- Real-time, local area coordination of traffic signals - Ramp metering - Multi-source traffic congestion processing	- Real-time, metro area-wide coordination of traffic signals (limited access and arterial) with transit priorities - Real-time link travel time calculations	- Fully integrated with all modes of transportation - Interactive with user - Unified, national data structure
Incident Management	- Rapid incident detection and response using artificial intelligence (AI)	- Rapid management of traffic in area of incidents	- Fully automated incident management
Traffic Management Software	- Signal control based on present traffic demands	- Signal control based on congestion forecasting (downstream demand) - Saturated flow strategies with upstream diversion	- Fully automated traffic management that can handle all types of traffic situations - Fully predictive

ATMS DEPLOYMENT EVOLUTION

INFRASTRUCTURE	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
Traffic Monitors	- 5-10% of major urban intersections	– 10-30% of major urban intersections	– 40-70% of major urban intersections
Traffic Management Centers (TMC's)	– Local sites in 10 to 20 metropolitan areas – Electronic signal controllers at 2-10% of all signaled intersections	– Area-wide operation: 10-30% of large metro areas – Limited area operation: Additional 10-30% of urban areas	– Systems operating in 60-80% of large metro areas throughout the U.S. – Control of 20-40% of both arterial and limited access roadways
Incident Management	– Rapid detection: 1030% of sites with TMC's – Rapid response: IO-50% of urban areas	– Rapid detection: 40-60% of sites with TMC's – Rapid response: 30-80% of urban areas – Incident traffic management: 10-20% of urban areas	– Rapid detection: All areas with TMC's – Rapid response: 75-90% of urban areas – Incident traffic management: All areas with full featured TMC's

Advanced Traveler Information System (ATIS) Deployment

NEAR-TERM PROJECTION

Vehicle navigation and route guidance capabilities are core building blocks for the most beneficial aspects of ATIS during this time period. These provide present vehicle location and static and dynamic route selection and guidance. They can also automatically filter a large volume of real-time traffic information and provide the driver with only that information which is relevant to the current driving situation. In order to deploy the systems as autonomous in-vehicle systems, a route guidance quality map database must be available. A map database with broad geographic coverage must be accurate and up-to-date in order to encourage automobile manufacturers to install such a product in their vehicles. Currently, several U.S. companies are developing map databases that are intended for vehicle navigation purposes. Standards dealing with database format, content, completeness, and accuracy are required and are being developed. Successful deployment requires that an adequate number of users be acquired quickly enough to justify financial support for the infrastructure.

MIDDLE-TERM PROJECTION

Deployment of ATIS systems during this period requires little additional equipment on board the vehicle. The only major pieces of new hardware are the “position fixing” receiver and a device for “reading” cooperative road signs for in-vehicle signing. Most of the additional features are implemented in software.

The market penetration of ATIS features into the new vehicle fleet is expected to be large enough to begin to have a measurable effect on traffic flow. During this stage, congestion peaks will reduce as traffic gradually spreads out in time and space. More equal utilization of the road network in urban areas will have begun. The consequent benefits will become measurable — fewer accidents, less fuel consumption, and improved air quality. Commercial fleets using ATIS will realize noticeable savings in fuel and improvements in on-time delivery. Stress on individual drivers will be lessened, not only because of less congestion and reduced travel time, but also because of reduced uncertainty about travel times.

The role of the infrastructure will greatly increase during this stage. The traffic information centers must develop networks of sensors, communication channels, and information sources in order to acquire traffic data for an entire metropolitan area. Communication and data fusion software must be developed to digest all of the data, produce incident notices, calculate link-times, and transmit information to ATIS-equipped systems in the network. In addition, the required passive or cooperative technologies for in-vehicle signing must be implemented and a determination made regarding which traffic signs will be available for this purpose.

The increased volume of information that must be transmitted to vehicles for these functions may render RDS-like transmission systems unusable. A potential communication channel appears to be UHF-PM radio. If that channel is to be used, it will require the assignment of a set of frequencies, preferably world-wide, for the purpose.

LONGER-TERM PROJECTION

This stage of ATIS assumes that individual vehicles will become part of the traffic information network. As they move through the network, they will transmit data to the Traffic Management Center regarding the traffic conditions that they encounter. That requires cooperation from the driving public, first in purchasing (or leasing) the necessary equipment for their vehicles, and second in allowing information on their travel to be transmitted to the Traffic Management Center. Ideally, the information would inolude origin, destination, and route, as well as link travel times experienced during the trip.

When fully implemented, this stage of ATIS will entail massive amounts of communication between Traffic Management Centers and the vehicles in the network. That can mean communicating with and, in at least a statistical sense, tracking tens (or even hundreds) of thousands of vehicles in an urban area. It will require a significant investment in communication systems, data processing equipment, software, and communication frequency channels.

To support automated emergency (Mayday) services, either Traffic Management Centers must become involved in handling emergency calls by acting as dispatch centers, or the emergency providers themselves must invest in the necessary equipment to receive digital messages and location information directly from the vehicles in distress. That is true whether the digital communications take place over the traffic message channels or over another network (such as cellular telephone).

ATIS PRODUCT EVOLUTION

	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
VEHICLE PRODUCTS			
Navigation (With electronic position determination)	■ Autonomous – Dead reckoning – Map matching - Assisted: GPS	– Assisted: Signpost	– Traffic information centers use vehicles as probes
Communication (Voice)	- Analog and digital cellular	– Digital cellular	- Digital cellular
Communication (Data)	– 1-way, digital – Traffic congestion	– l-way, digital – Link travel times	– 2-way, digital - Predicted link times – Destination and progress reports
Man-Machine Interface (MMI)	- output – Visual: Flexible format, color displays – Audio: Digitized voice – Input: Hard/soft buttons, touch screen, trainable voice recognition	- output – Visual: Color flat panel and simple HUD's – Audio: Synthesized voice – Input: User-independent voice recognition	– Output: Sophisticated HUD's
Automated Vehicle Identification (AVI)	- Automated toll collection at low speed (booth)	- Highway speed toll collection (already implemented on Oklahoma turnpikes)	- Roadway pricing – Infrastructure vehicle tracking
Road Signs	- Static database with only road name information	– Broadcast supplement to on-vehicle data ■ In-vehicle display	– Full electronic signing

ATIS PRODUCT EVOLUTION (Continued)

	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
VEHICLE PRODUCTS (Continued)			
Routing	- On-vehicle planning and guidance with major congestion alerting	– Fastest route using real-time traffic information	- Infrastructure-assisted routing for traffic management
Warnings (Inputs supplied by AVCS)	– Vehicle conditions (e.g., tire pressure and traction) - Near obstacle	– Roadway conditions – Far obstacle – Lane departure	– All driving hazards – Driver condition
Mayday	- Manual, using cellular telephone	– Semi-automated using telephone or satellite	– Fully automated – Coordinated dispatch
INFRASTRUCTURE PRODUCTS			
Traffic Information Centers (TIC's)	– Collect traffic data in cooperation with TMC's - Transmit general congestion information	– Calculate link travel times – Macro-cell link transmission	– Track vehicles – Predict congestion – Transmit predicted link travel times
Databases	- Route guidance road network (geometry, names, restrictions) ■ Businesses - Tourist information	– Road signs ■ Historical link travel times ■ Travel information	- More comprehensive and less costly
AVI Receivers	- At tollbooths (debiting)	- Along limited access toll roads	- Along all priced roadways (charging)

ATIS DEPLOYMENT EVOLUTION

	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
VEHICLE PRODUCTS			
Navigation (With electronic position determination)	– 1-2% of new vehicle fleet – Small volume introduction of assisted navigation	– 5-10% of new vehicle fleet	- 50-90% of new vehicle fleet
Communication (Voice)	- 2-10% of all vehicles ■ Infrastructure in a few metro areas	– 5-25% of all vehicles - Infrastructure in all metro service areas	– 25-60% of all vehicles – Nationwide availability
Communication (Data)	- Available in a few metro areas	❑ Congestion in all major metro areas - Current and predicted link times in some metro areas	– Link times in most major metro areas – Predictive in 50% of areas

ATIS DEPLOYMENT EVOLUTION (Continued)

	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
VEHICLE PRODUCTS			
Automated Vehicle Identification (AVI)	– 20-60% of vehicles in toll areas	– 40-80% of vehicles using toll highways	– 85-100% of vehicles using priced roadways
Road Signs	– 20-50% of vehicles with navigation	– 30-60% of vehicles with navigation	– 60-100% of new vehicle fleet
Routing	– 50-90% of vehicles with navigation	– 75-99% of vehicles with navigation	– 45-90% of new vehicle fleet
Warnings (Inputs supplied by AVCS)	■ ATIS delivers various types of warnings in 16% of the new vehicle fleet	– ATIS delivers various types of warnings in IO-20% of the new vehicle fleet	– Various levels and types of warnings in 100% of the new vehicle fleet
Mayday	- 1-5% of new vehicle fleet	– 50-80% of new vehicle fleet	– 60-90% of new vehicle fleet
INFRASTRUCTURE PRODUCTS			
Traffic Information Centers	- IO-20% of metro areas	■ Macro transmission: 30-80% of metro areas – Link travel times: 10-60% of metro areas	- Link times: 50-90% of metro areas – Predictive: 40-80% of metro areas
Databases	– Route guidance (R.G.) and businesses: 200 largest metro areas	– R.G. and businesses: Nationwide – Link times: 50 largest metro areas – Travel info: Nationwide - Road signs: 10 areas	- Link times: Full USA where needed – Road signs: Widespread throughout the nation
AVI Receivers	– 20-50% of tollbooths	– 60-90% of tollbooths – 50-90% of toll highways	– 80-100% of all priced roadways – Vehicle tracking: 5-20% of metro areas

Advanced Vehicle Control System (AVCS) Deployment

NEAR-TERM PROJECTION

Proceeding from development of AVCS to deployment will require the active participation of both public and private sector organizations acting in concert and sharing responsibilities. The commitments of resources and distribution of responsibilities need to be considered from the start of the development process, with representation from the full range of affected constituents. Such joint activities have few precedents in the United States, although European and Japanese programs often operate in this manner.

In the near term, most of the enabling technologies required to implement AVCS systems will be tested and made available for use through product development. Some of the target products will be ready for deployment. Those products will assist drivers in performing driving tasks and will not require any off-vehicle assistance.

MIDDLE-TERM PROJECTION

During this time, testing is expected to be completed on many additional AVCS products, making those products available for deployment. Product emphasis will be on providing the driver with increased sensory perception and cooperative assistance in controlling the vehicle, with some limited availability of full automation.

LONGER-TERM PROJECTION

During this period, products may become available that completely control certain functions of the vehicle, including automatically driving the vehicle along specially equipped highway lanes.

CHARTS

The following two charts summarize (1) the evolution of each of the AVCS product areas and (2) the rate of deployment for each of those products.

AVCS PRODUCT EVOLUTION

<table>
<tr><th>PRODUCTS</th><th>5-Year Timeframe</th><th>IO-Year Timeframe</th><th>20-Year Timeframe</th></tr>
<tr><td rowspan="2">Collision/Obstacle Detection and Avoidance and Longitudinal Control</td><td rowspan="2">– Warnings
– Near obstacle

– Electronic control
– Traction under braking (anti-lock)
– Engine speed
– Transmission
– Traction under acceleration
– Adaptive cruise control (maintain safe distance from vehicle ahead)</td><td rowspan="2">– Warnings
– Far obstacle (frontal collision)
– Roadway conditions

– Electronic control
– Braking (brake-by-wire)
– Automated collision avoidance

– Vision enhancement
– CCD rear vision camera with image processing
– Night
– Fog and rain</td><td>– Warnings
– Intersection hazard</td></tr>
<tr><td rowspan="2">– Combined longitudinal and lateral control
– Automated operation on specially equipped roadways (e.g., HOV lanes)</td></tr>
<tr><td>Lateral Vehicle Control</td><td>· Warnings
– Side obstacle</td><td>– Warnings
– Lane departure
– Lane change and merge

– Electronic Control
– Steering (drive-by-wire)</td></tr>
<tr><td>Monitoring and Warning</td><td>– Vehicle performance
– Tire inflation
– Traction</td><td>· Vehicle performance
– Tire condition
– Improved traction detection
– Braking capability
– Acceleration capability</td><td>■ Vehicle performance
– Increased detection capability at reduced cost</td></tr>
</table>

AVCS DEPLOYMENT EVOLUTION

	5-Year Timeframe	1O-Y ear Timeframe	20-Year Timeframe
		VEHICLE PRODUCTS	
Collision/Obstacle Detection and Avoidance and Longitudinal Control	– Electronic controls: Increasing installation rate (30-60%) and content ($50-150) in new vehicle fleet (NVF) - Adaptive cruise in less than 1% of the NVF ■ Near obstacle warning systems in 1-2% of the NVF	– Various types of warnings in IO-50% of NVF - Various types of electronic controls in 40-70% of NVF – Vision enhancement in 25% of NVF - Adaptive cruise in 1-10% of NVF	– Adaptive cruise in 40-80% of NVF ■ Collision avoidance in 20-40% of NVF ■ Vision enhancement in 10-40% of NVF - Automated electronic control on 1-40% of NVF in areas with special roadways
Lateral Vehicle Control	– Side obstacle warning systems in 1-2% of the NVF	- Various types of warnings in 10-30% of NVF – Small production runs of electronic control	- Electronic control on 5-40% of NVF in areas with special lanes equipped for lane-following
Monitoring and Warning	– Simple systems on 5-10% of NVF	- More capable systems on 10-40% of NVF	- Still more capable systems on 20-80% of NVF
		INFRASTRUCTURE PRODUCTS	
		- 2-5 automated lane pilots with manual entrance and exit	– Automated lanes in 10-20 metro areas

Commercial Vehicle Operations (CVO) Deployment

NEAR-TERM PROJECTION

In the near term, the U.S. will see widespread deployment of CVO systems. It will occur in stages, closely following successful corridor demonstrations. During this time, several major interstate carrier corridors will be equipped to reduce both the paperwork burden and the required number of stops for interstate drivers. The corridors are anticipated to be along major National Truck Network routes. Large-scale instrumentation installation will be started in each state.

MIDDLE-TERM PROJECTION

During this time, most Interstate routes and half of the non-Interstate routes in the U.S. road network are expected to be equipped to expedite CVO traffic. There will be increased interaction between vehicles and the infrastructure; that interaction will be aimed at increasing both the efficiency and safety of operating commercial vehicles.

LONGER-TERM PROJECTION

During this period, the main improvements may come from increased deployment and coverage.

CVO PRODUCT EVOLUTION

	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
VEHICLE TECHNOLOGIES AND PRODUCTS			
Automated Vehicle Identification (AVI)	– Electronic paperwork and record-keeping – Automated toll collection – Credentials: Vehicle ID – Weight reporting	– Electronic paperwork and record-keeping – Credentials — Bill of lading (cargo tracking) — Vehicle inspections — Driver's license — **Log book** (in-vehicle reporting) – Vehicle safety records – Safety monitoring (cargo safety, etc.) for driver use – Infrastructure highway safety warnings – Ramp radii – Height limits – Grade speeds	– Electronic paperwork and record-keeping – Roadway pricing – Credentials: "One-stop shopping" (computerized permits, electronic tax) – Vehicle and driver safety records keeping and reporting to infrastructure – Safety monitoring of both the vehicle and the driver – Infrastructure highway safety warnings – Road conditions – Lane restrictions
Automated Vehicle Location (AVL)	– Assisted location: GPS or Loran C - Automated reporting to fleet management	- Assisted location: Signpost beacons	■ infrastructure location determination
Communication (Voice)	– P-way, analog mobile radio or cellular	– 2-way, digital mobile radio or cellular ■ Very low cost voice network	– Low Earth Orbit (LEO) satellites for universal coverage
Communication (Data)	– Analog mobile radio ■ Geosynchronous satellite – AVI transceiver – Two-way digital text	■ Digital mobile radio – AVI transceiver – LEO satellites	
Man-Machine interface	■ Same progression as ATIS		

CVO PRODUCT EVOLUTION (Continued)

	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
INFRASTRUCTURE TECHNOLOGIES AND PRODUCTS			
Weigh-In-Motion	– Low-speed, off-highway weigh stations	– On-highway, at-speed weigh stations	
Fleet Management	– Electronic vehicle tracking – Computerized fleet tracking and dispatching		
Hazardous Materials	· Vehicle information reporting: AVL with AVI – Automated hazard identification and communication	– Infrastructure tracking: Signposts, satellites	
AVI Transceivers	· Toll collection: Same as for ATIS	– Beacons for reporting at borders	■ General monitoring and enforcement

CVO DEPLOYMENT EVOLUTION

	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
VEHICLE TECHNOLOGIES AND PRODUCTS			
Automated Vehicle Identification (AVI)	· Weight reporting: 60-90% of interstate haulers - Vehicle ID: 30-60% of commercial haulers - Automated tolls: 60-90% of commercial vehicles in equipped toll areas ■ Vehicle safety monitors: 1-5% of vehicles	– Weight reporting: 60-90% of all haulers · Electronic credentials: 40-70% of commercial haulers – Automated tolls: 60-90% of commercial vehicles in toll areas ■ Vehicle safety monitors: IO-30% of vehicles ■ Infrastructure safety warnings: 1-5% of heavy trucks	· Weigh-in-motion: 70-90% of haulers ■ Electronic credentials: 50-60% of commercial haulers ■ Automated tolls: 70-100% of vehicles in toll areas · Driver and vehicle safety monitoring and reporting: 60-90% of commercial vehicles – Infrastructure safety warnings: 30-60% **of** heavy trucks
Automated Vehicle Location (AVL)	■ 3060% of large fleets equipped with AVL	· 60-90% of large fleets equipped with AVL	■ 60-90% of all commercial vehicles equipped with AVL
Communication (Voice)	■ 5-25% of commercial vehicles equipped	■ 60-90% of all commercial vehicles equipped	· 70-95% of all commercial vehicles equipped
Communication (Data)	■ 30-60% of large fleets equipped	■ 60-90% of large fleets equipped	■ 60-90% of all commercial vehicles equipped

CVO DEPLOYMENT EVOLUTION (Continued)

	5-Year Timeframe	10-Year TImeframe	20-Year Timeframe
	INFRASTRUCTURE TECHNOLOGIES AND PRODUCTS		
Weigh-In-Motion	- 20-50% of Interstate highways equipped - 2-5% of non-Interstate roadways equipped	– 60-100% of Interstate routes - 20-50% of non-Interstate routes	■ 80-100% of national network equipped
Fleet Management	■ 25-50% of large fleets with electronic tracking for fleet management	■ 50-80% of major fleets with electronic tracking and dispatching	- 80-100% of major fleets with electronic tracking and dispatching
Hazardous Materials	■ One state pilot project ■ I-5% of HAZMAT haulers equipped	- 5-15% of HAZMAT haulers equipped	■ 15-25% of HAZMAT haulers equipped
AVI Transceivers	■ Toll collection: Same progression as ATIS ■ Infrastructure assisted highway warning systems: I-5 pilot areas (20-100 miles total) ■ Enforcement and reporting: I-5% of stations	■ Infrastructure assisted highway safety warnings: 2000-5000 miles ■ Enforcement and reporting: IO-30% of stations - State line beacons on all major travel routes	■ Infrastructure warning: 60-90% of national network ■ Enforcement and reporting: 80-100% of stations, 40-60% of enforcement vehicles

Advanced Public Transportation System (APTS) Deployment

NEAR-TERM PROJECTION

The major focus of APTS in the near term will be on improving transportation service information for transit customers and for transit vehicle fleet operators. These improvements will encompass increased accuracy, improved timeliness, and increased ease of accessibility. Travelers will be provided with an increasing number of opportunities to have a single information source address all of their travel needs. The products that will initially be deployed will take information already in existence — such as printed transit schedules — and make it more easily accessible to the traveler in the home, the workplace, or while in transit. Many smart components, such as audio- and video-text information, changeable message signs, and smart cards wilI be adapted for use in APTS applications and will be deployed during this period, APTS will closely coordinate its efforts with those of ATIS and ATMS, looking for ways to integrate those technologies into APTS services and systems.

MIDDLE-TERM PROJECTION

During this period, the APTS program emphasis is expected to shift from smart component development to integration of those components into APTS systems. Improved versions of components will appear that better suit the requirements of APTS. The products that are deployed will enhance the management of transit fleets by providing operators with more timely information, improved accuracy of information, and improved methods and equipment for scheduling, dispatching, and controlling the transit fleets. That will also allow new types of real-time transit schedule information to be provided to travelers through the use of improved information products.

LONGER-TERM PROJECTION

During this period, the integration of information technologies may continue to blur the lines between travel modes. Surface transportation will become one integrated system that quickly and accurately responds to travelers as individuals and to society as a whole. The traveler wilI be able to obtain individualized, multi-mode routing that recognizes the traveler’s specific needs and takes into account current and predicted transit system conditions.

CHARTS

The following two charts summarize (1) the evolution of each of the APTS product areas and (2) the rate of deployment for each of those products.

APTS PRODUCT EVOLUTION

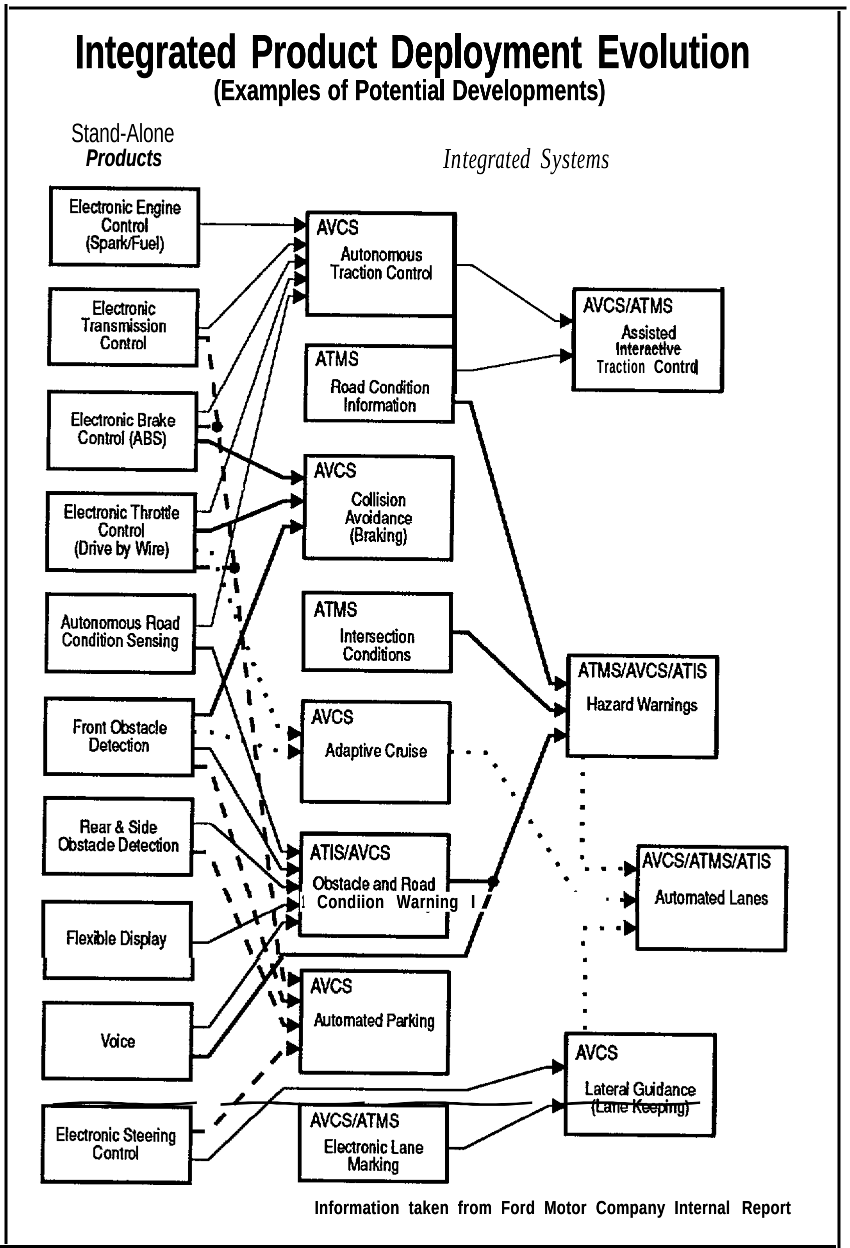
	B-Year Timeframe	10-Year Timeframe	20-Year Timeframe
TRAVELER PRODUCTS			
Traveler Information (Transit schedules and routes, ride-sharing)	- In homes and offices via TV, cable TV, telephone, and PC's – Text (audio and video) – Static route displays – At transit points via changeable message signs: Scheduled arrival times – On transit vehicles: Automated next stop and current stop information (voice and/or text)	– In homes **and offices** – Interactive cable TV – Route displays with actual current location of transit vehides – Real-time ride-sharing connection information – At transit points: Changeable message signs and kiosks show actual arrival times for transit vehicles. ■ On transit vehicles: Automated announcement of projected actual arrival times (text and/or voice) and connecting routes	– **In** homes **and offices and** at transit points: Integrated transit and roadway traffic information provided; the information is interactive and provides guidance · On transit vehicles: Projected arrival times are more accurate due to added traffic information
Traveler Guidance	– Passive guidance through better transit information	– At transit points: Kiosks provide interactive route selection · In homes and offices: Individualized, multi-modal routing	· At transit points: Kiosks automatically provide individualized, multi-modal routing accounting for current transit conditions and schedules ■ In homes and offices: PC's and cable TV's provide the same services
Traveler Financial Services	■ Electronic billing: Smart cards for debiting or charging of limited transit use costs	· Electronic billing – Handled through banks – Allows third party billing – Expanded smart card use	– All reservations, billing, and ticketing can be done electronically with automated account debiting
INFRASTRUCTURE PRODUCTS			
Transit System Operations	■ Dispatching: Digital maps with limited AVL and computer aids – Integrated transit system databases	■ Dispatching: Powerful computer aids use AVL inputs and assist operators – System management: Some computerized assistance for planning, billing, etc. – Automated verification of HOV lane use	· Dispatching: Coordinated with ATMS, uses real-time traffic information for dispatch and routing – System management: All functions integrated, full computer assistance provided (planning, billing, payroll, etc.)
Transit Vehicle Operations Center	– Automated vehicle location (AVL) on transit vehicles for use by transit management centers – Automated maintenance record tracking	■ AVL used for: – Automated route guidance – Automated schedule adherence information	· Personalized passenger pickup services

APTS DEPLOYMENT EVOLUTION

	5-Year Timeframe	10-Year Timeframe	20-Year Timeframe
TRAVELER PRODUCTS			
Traveler Information (Transit schedules and routes, ride-sharing)	– 5-15% of metro areas have in-home services available – 5-10% of metro areas have variable message signs at major transit stops - 5-10% of metro areas have automated stop information on buses	– 40-70% of metro areas have in-home services for static information, I-5% have interactive services – 30-70% of metro areas have variable message signs with static schedule information, 5-10% have actual schedules - 30-50% of metro areas have automated stop information on buses	– 60-90% of metro areas have in-home services for static information, 5-10% have interactive, real-time services, with traffic information – 50-80% of metro areas have automated stop information, 5-10% have real-time schedule information
Traveler Guidance		- 5-10% of metro areas have interactive routing at kiosks	– 20-60% of metro areas have interactive routing, 10% with real-time and predicted traffic
Traveler Financial Services	– 5-10% of traveler service transactions are accepted in 1-5% of metro areas	– 20-50% of traveler service transactions are accepted in 20-50% of metro areas	- 30-90% of traveler service transactions are accepted in 60-95% of metro areas
INFRASTRUCTURE PRODUCTS			
Transit System Operations	– 5-10% of Fleet Management Centers (FMC's) have computer- and AVL-assisted dispatch and control	– 20-40% of FMC's have computer- and AVL-assisted dispatch and control – 5-10% of metro area transit systems have integrated, computerized transit management systems	– 80-100% of FMC's have computer- and AVL-assisted dispatch and control – 30-70% of metro area transit systems have fully integrated, computerized transit management systems
Transit Vehicle Operations Center	– 5-10% of transit fleets are equipped with AVL	- 40-60% of transit fleets are equipped with AVL – 1-5% of metro areas have personalized passenger pickup	■ 70-90% of transit fleets are equipped with AVL – IO-30% of metro areas have personalized passenger pickup

Integrated Products

The following chart shows a limited number of examples that illustrate how near-term, stand-alone products can mature and be merged together to form larger systems covering various IVHS functional areas. Those systems can then mature and be combined to form highly integrated, cross-functional IVHS systems.



Milestone Summary

The IVHS Strategic Plan covers 20 years. Along the way, a number of measurable milestones gauge its progress. Usable products and services will be available to IVHS users. Major tests will be completed in a continuous stream starting early in the program. The following table shows selected technical milestones for each of the five functional areas by time period. This Strategic Plan calls for a multi-billion dollar research, development, and testing program to take place during the next 20 years. The program will shape the achievements of various milestones. Therefore, the milestones that are listed for years farther in the future are less certain than those for years closer to the present. More complete information on IVHS milestones is presented in Appendix C.

A SELECTION OF POTENTIAL IVHS MILESTONES

	1992-1996	1997-2001	2002-2011

ATMS
 	
Advanced Traffic Management Systems
	■ Traffic monitoring and control: In corridors in 15 cities and in 3 inter-city corridors
	– Incident management systems
	  – Rapid response in 10 metro areas
	  – Rapid detection in 3 metro areas
	– Communication alternatives
	  – One-way for traffic information
	  – Two-way for intersection control and monitoring
	– Transit system monitoring
		– Full-featured traffic management centers
		– Area-wide, real-time adaptive traffic control with transit priorities
		  – In major corridors in 50 metro areas
		  – In 25 major inter-city corridors
		· Incident management systems
		  – Rapid response in 150 cities
		  – Rapid detection in 25 metro areas
		– Communication alternatives: One-way for link travel times
			– Area-wide, full-featured systems to manage intermodal surface transportation nation-wide in large urban areas and major rural corridors

ATIS
 	
Advanced Traveler Information Systems
	– Transportation data available
	  – At home
	  – At the workplace
	  – At public kiosks
	  – Though hand-held devices
	· Nationwide map database
	– Static route guidance
	  – With business/tourist data
	  – In 1% of new vehicles
	  – As a vehicle aftermarket product
	· Road-to-vehicle communications: Operational tests
		– Route guidance reflecting dynamic traffic conditions in 5% of new vehicles
		– Semi-automated Mayday devices introduced
		– Real-time transportation conditions
		  – For inter-city regional/rural travel
		  – For multiple modes of transportation
		■ In-vehicle display of road signs
			· Area-wide, traffic control integrated with optimal routing in 70% of new vehicles
			– Interactive, multi-modal, demand-responsive travel assistance
			– Fully automated Mayday signaling with coordinated dispatching

A SELECTION OF POTENTIAL IVHS MILESTONES (Continued)

	1992-1996	1997-2001	2002-2011
AVCS Advanced Vehicle Control Systems	– Sensor development – Driving simulators – Lateral control experiments – Test facilities - Roadway and environment safety systems – Near obstacle detection – Adaptive cruise control	– Automated highway demonstration – Collision warning systems - Vehicle performance monitoring systems – Perceptual enhancement systems – Lane departure control demos – Intersection hazard warning tests – Far obstacle detection ■ Collision avoidance systems - Longitudinal and lateral control demos – Short-headway vehicle following tests	- Automated vehicle operation on specially equipped lanes
CVO Commercial Vehicle Operations	- Productivity management systems – Electronic credential checking in major trucking corridors – Electronic toll collection – Weigh-in-motion	- CVO infrastructure on Interstate routes and some non-Interstate principal arterial highways ■ Electronic credential checking nationwide – Electronic record-keeping	– First automated heavy vehicle lane - Transparent borders for trucks ■ All toll stations automated
APTS Advanced Public Transportation Systems	- Kiosk and workplace information systems - Automated fare collection ■ Automated maintenance tracking	– Area-wide customer service systems – Area-wide integrated fare systems - Automated HOV lane verification ■ Fleet management systems – Real-time car-pooling connection information	■ Automated transit vehicle operation on specially equipped HOV lanes
Systems Integration Tasks	■ System architecture development---------------> · **Standards and protocols** ________________-------------------------------------- **>** - Safety and human factors **design**___________________________-----------------------------------> . **Radio frequency spectrum allocation** ______________|______________--------.---------- **>**		

Organizational Program

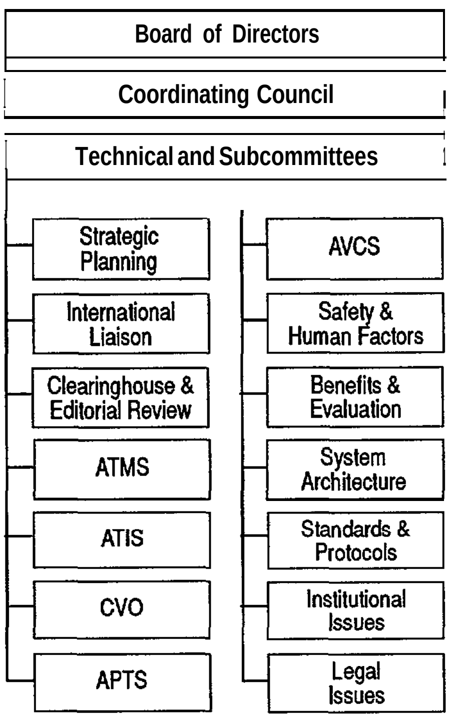
Much of Chapter III thus far has dealt with technical questions: research and development, system integration, operational tests, and deployment. Those are important issues. However, as introduced in Chapter II, there are a number of organizational, institutional, and legal issues that must be addressed in putting together a program of the complexity and scale of IVHS. The program will require organizational change, the development of new relationships among organizations, and resolution of various institutional and legal challenges. As with technical questions, the success of IVHS is predicated on effectively facing these issues.

In the following sections, key organizational roles and responsibilities are described, as are the legal and institutional issues. Recommended courses of action in response to each issue are also included.

The National IVHS Public/Private Partnership: IVHS AMERICA

The Intelligent Vehicle Highway Society of America is the institutional embodiment of the IVHS community. IVHS AMERICA's mission is to coordinate and foster a public-private partnership to make the U.S. surface transportation system significantly safer and more effective by accelerating the identification, development and deployment of advanced technologies. It provides national leadership in collaboratively articulating a vision for the IVHS transportation future, determining the means and activities by which that vision should be realized, and taking actions necessary to stimulate, encourage, and assure timely and effective program execution.

IVHS AMERICA Organization



IVHS AMERICA is a 501(c)(3) educational and scientific private non-profit organization, whose membership includes private organizations, universities, associations, federal, state, and local agencies, other public organizations, and individuals. It has a central role in the national program of research, development, and deployment of IVHS and is a focal point for national and international activities in this area; it is the principal forum for public/private coordination of national program development. For the various parties and interests involved in IVHS, IVHS AMERICA provides a platform to exchange ideas and information for the definition of the national IVHS program, to encourage a common approach to solving problems, and to issue statements on consensus views regarding various policies and technical solutions.

For the most part, IVHS AMERICA will not conduct research or sponsor studies, except as they relate to its mission. Instead, it will identify the research that needs to be done, develop evaluation criteria, recommend priorities, and propose timetables. It will provide a forum for its members to discuss the possibility of joint or shared research in particular areas. It does not have any formal power or independent authority to enact its recommendations, but it is expected that the consensus approach to establishing the recommendations and the prestige of the group will lead to adoption of most of them by the various parties who do have the authority and resources. It is expected that an IVHS AMERICA-articulated research agenda will help government agencies in securing approval and funding for their programs and will assist private sector companies in their internal program planning and budgetary processes.

Utilized Federal Advisory Committee

IVHS AMERICA is chartered as a utilized Federal Advisory Committee to the U.S. Department of Transportation on IVHS matters. As an advisory committee, it will help guide the research, development, and implementation of the federal government's IVHS activities and will provide advice to DOT on establishing program priorities.

Strategic Plan

A major function of IVHS AMERICA is to develop, through its membership, this Strategic Plan, with further responsibility for its review and modification over time. It provides the forum and opportunity for the many interests to come together and is the focal point for coordination between DOT and the other member organizations. It has coordinated the actual drafting of this document and is expediting the required consensus. Since the plan is to be a living document, IVHS AMERICA will continue to serve as the secretariat for development of future iterations.

System Architecture

IVHS AMERICA has formally recommended a system architecture development methodology to DOT that utilizes several concurrent multidisciplinary public/private/academic teams. IVHS AMERICA will assist DOT in suggesting and prioritizing architecture goals and objectives through its committee structure and will provide staff participation in a Technical Evaluation Team. As the IVHS utilized Federal Advisory Committee, it will serve as a forum for quarterly review of the teams' progress by the technical committees, Coordinating Council, and the general public.

Standards

IVHS AMERICA will coordinate with national and international standards-setting organizations to develop a consensus on a desirable set of IVHS standards and has established a Center for IVHS Standards to facilitate the standards-setting process. In conjunction with the Standards and Protocols Technical Committee, the Center will provide a secretariat role in coordinating the requests of the various committees, will identify overlapping requests, and will forward requests to the appropriate standards-setting organization. In effect, the Center will be a clearinghouse for IVHS standards and will help the Committee on Standards and Protocols coordinate between those who are seeking standards and protocols and those who will actually issue them. When possible, IVHS AMERICA will articulate the IVHS community's consensus on the appropriate standards and recommend that manufacturers conform to them and, when appropriate, that the government issue regulations. For the most part, however, the actual promulgation of the standards will be undertaken by the various government and private standards-setting organizations already in existence.

Operational Testing

IVHS AMERICA will provide advice and guidance regarding the status and efficacy of current operational tests, recommendations for additional testing and modifications or embellishments to existing projects, and suggested criteria for test selection and uniform evaluation. It will serve as a source of information and advice for parties considering creation of new tests and may, on occasion, seek to facilitate establishment of operational tests that are needed but have not been initiated. It will also enable the exchange and dissemination of current information among various test participants and to policy and opinion leaders through the clearinghouse, forums, and publications.

Institutional and Legal Issues

IVHS AMERICA will advise the federal government and its other member corporations, agencies, and institutions regarding research and analyses that are needed in the institutional and legal areas. It will serve as a clearinghouse for studies on innovative institutional solutions and will monitor activities on proposed and enacted change in legislation, regulation, and appellate law. It will utilize results of completed studies in formulating recommendations for policies to its members.

Institutional and legal changes will be required in order for IVHS to succeed, and IVHS AMERICA will serve as a catalyst for them. It will participate in, and at times, convene forums to seek consensus on appropriate institutional and legal change. It will encourage and assist in submission of comments and testimony by its membership to appropriate government executive, legislative, and regulatory proceedings which bear on IVHS development or deployment. Working with other associations, IVHS AMERICA will seek institutional and legal change to assure proper consideration of and emphasis on IVHS concerns and interests.

Clearinghouse

IVHS AMERICA is establishing a centralized repository and exchange for IVHS information — the National IVHS Information Clearinghouse — to assist the DOT in meeting its legislatively-mandated requirement of a repository for technical and safety data related to IVHS research and development. The clearinghouse will obtain and disseminate current national and international IVHS technology information to member organizations and other interested parties.

Information and Education

In its information and education role, IVHS AMERICA will advance the level of public understanding of the IVHS program and confidence in IVHS institutions that is necessary in order for this program to succeed. A wide array of tools — newsletters, speeches, conferences, and meetings with community leaders and public affairs and human factors experts — will be used to identify core concerns and problems and suggest strategies for effective response.

International Liaison

IVHS AMERICA will provide international liaison with various IVHS efforts abroad, including establishment of common standards and protocols; information and technology sharing; and conduct of conferences, workshops, and meetings.

Roles and Responsibilities

PRIVATE SECTOR

"The private sector will develop and market most of the IVHS products and services."

The private sector's role in IVHS is pivotal. Some industry officials have estimated that 80 percent of total IVHS expenditures will be private purchases of products and services using these technologies; government will account for less than 20 percent of total IVHS expenditures. The private sector will develop most of the technology and market most of the products and services that bring IVHS to reality. U.S. industry must see profit-making opportunities in the provision of new services and in the development of IVHS hardware and software for infrastructure and vehicles, if they are to make investments in developing those technologies.

Roles for private industry include the following:

- Developing base technologies for IVHS deployment
- Conducting research and development on vehicle and infrastructure hardware and software
- Identifying and exploiting market opportunities
- Providing IVHS services

The private sector will do the research and development for the technologies used in vehicles, equipment, facilities, and innovative services. Private companies are in the best position to decide which technologies are apt to be most profitable and which will be accepted by consumers. Although individual companies traditionally seek their own market opportunities, in many cases cooperative ventures may be the most effective way to develop and test new products — cooperative ventures between private sector companies may go beyond existing contractor/client relationships, and consortia of private companies will conduct certain types of pre-competitive research. It is difficult to predict how and where all of these new arrangements will occur. There is some uncertainty that existing law and public policy may not have sufficient latitude to allow the extensive cooperative arrangements that are necessary. An important element in the continuing implementation and evolution of this Strategic Plan will be to identify and address the legal and policy changes that are needed.

In addition to providing products, the private sector will provide a broad range of IVHS services, including installation and operation of traffic surveillance and detection equipment. Roles of the private sector may also include consulting, software supply, system integration, facilities management, providing ultimate service (operating IVHS infrastructures on an entrepreneurial basis), supplying secondary service (communications, maintenance, training), and acting as a value-added supplier. Private sector roles include (1) developing and marketing a variety of databases for ATMS, ATIS, and AVCS, (2) developing and marketing customized databases for commercial fleet operators, delivery services, and the like, (3) operating traveler information systems under publicly awarded franchises, under contract to public agencies, or as purely private ventures, and (4) operating area-wide traffic information and traffic management centers.

Although there are important equipment requirements, ATIS may be most appropriately characterized as an information service. A service approach suggests that traffic information may be provided via a baseline, with minimal charges overlaid with certain tiers of enhancement. The tiers may "bundle" other information service such as yellow pages, travel agency services and hotel reservations, gas station locations, banking, telephone service, paging, and the like. If travel and traffic information is one of many pre-trip and in-vehicle information services, key players may come from the electronic information industry (telecommunications, cable, financial network).

"**Private sector involvemenf requires** *defined markets, controllable* **risk, and reasonable projected return on** *investment.* "

Private sector involvement requires the existence of minimum preconditions or reductions of barriers that include:

- A market that can be dimensioned, including a well defined service, a defined geographic area, and an understanding of key characteristics of the potential market
- Reasonable, controllable risks, such as an understanding of legal liability and anti-trust risks and the establishment of an open technical architecture and standards
- Promise of a reasonable return on investment
- Resolution of certain structural barriers, such as assurance that a certain basic function will be carried out by the public sector or management of high, fixed up-front costs

FEDERAL GOVERNMENT

The federal government will provide the national emphasis and perspective on safety, congestion relief, mobility enhancement, environmental impact, energy conservation, and productivity improvements. Financial assistance should be provided where resources will induce a greater level of participation by state and local governments and the private sector in projects that have a substantial public benefit.

Department of Transportation

The U.S. Department of Transportation has the principal federal role of leadership in IVHS. Its major IVHS interests include using management and information systems to improve the operational efficiency and safety of highway transportation, establishing functional performance specifications and promoting the development of advanced vehicle control systems to improve safety and efficiency, and applying those technologies to improve highway and transit operations safety and motor carrier safety. DOT will assess the safety impacts of the collision avoidance and driver-vehicle interaction aspects of IVHS in order to be certain that no loss of safety occurs from driver overload or distraction. It is also interested in promoting the use of IVHS to encourage high occupancy vehicle travel, including conventional bus transit, car-pools, and other transit operations. Furthermore, DOT has a responsibility for coordinating federal satellite navigation activities.

‘U.S. DOT has fhe principal federal role of leadership in IVHS."

Specific participation of DOT will include the sponsorship and coordination of research and development related to its statutory responsibilities, the planning and conduct of operational tests and other evaluational programs, and the coordination of standards and protocols. DOT will assess the performance, reliability, maintainability, and life cycle costs of IVHS systems and will work with industry on the definition of the system architecture.

Within the DOT, the Office of the Secretary (OST), the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), the Federal Transit Administration (FTA), and the Research and Special Programs Administration (RSPA) are all significant contributors to the IVHS program. The primary interests of those agencies are as follows:

- The Office of the Secretary *(OST)* is concerned with overall program administration and oversight and policy development. The OST is particularly involved in preparing and reviewing proposed budgets and initiating research on institutional issues that could affect the adoption of IVHS technologies.

- *FHWA* is particularly concerned with improving the operational efficiency and safety of highway transportation. Its focus will be on the development of traffic management and information systems and on safety, productivity, and capacity issues related to highway operations and motor carriers.

- *NHTSA* is concerned with the safety aspects of IVHS, especially related to advanced vehicle control systems and driver interaction with other IVHS technologies. It is also concerned that no loss of safety occurs from driver overload or distraction as IVHS systems are introduced.

- *FTA* is interested in using IVHS to encourage high occupancy vehicle travel, including conventional mass transit, car-pools, and other highway-related public transportation operations. It is also concerned with fleet management.

- *RSPA* is interested in land-side applications of radio navigation technology, coordinating DOT R&D efforts, and providing technical research and policy analysis support through the Volpe National Transportation Systems Center (VNTSC). RSPA is particularly concerned with the safety regulation and technology of hazardous materials movements.

Staff from these and other U.S. DOT offices cooperate with officials from private sector organizations, consulting companies, associations, universities, and state and local governments through grants and contracts, cooperative arrangements, and through positions they occupy in the IVHS AMERICA organization.

Specific roles for DOT agencies include the following:

- DOT IVHS program planning and budgeting

- Managing and funding a research, development, and operational test program

- Developing a common basis for selection and evaluation of experiments and operational tests

- Assisting in development of a system architecture

- Providing leadership and support for development and adoption of open and non-proprietary national standards

- Sponsoring studies aimed at addressing constraints to IVHS advancement and deployment

- Providing financial support for deployment of public sector elements through the use of federal-aid funds

- Facilitating deployment through provision of technical assistance to state and local government agencies

- Providing seed money to induce the private sector to invest in certain key IVHS technologies

Other Federal Agencies

Other federal agencies will also have important roles to play in regard to IVHS. Those include the following:

Department of Commerce (DOC). DOC has the principal agency responsibility for issues concerned with international trade and U.S. industry competitiveness, and it may be interested in the export and import implications of IVHS products. DOC has responsibility for allocation of federal government use of the radio frequency spectrum necessary for critical aspects of IVHS operations, and also has standards responsibilities with the National Institute of Standards and Technology.

Department of Energy (DOE). The relationship of IVHS to federal energy policy and to research in energy in an IVHS environment are issues of particular interest to DOE, which is concerned with the implications of fuel conservation. DOE manages the National Laboratories, which will have technologies and skills developed that may be effectively applied to IVHS.

Department of Justice (DOJ). The Department of Justice will be concerned with pro-competition and anti-trust implications of IVHS consortia, along with policy considerations regarding issues of liability, privacy, and procurement.

Environmental Protection Agency (EPA). The EPA may be involved in the important environmental issues introduced by IVHS deployment, and it may be concerned with the relationship in many metropolitan areas between the Clean Air Act Amendments and IVHS. The EPA may wish to evaluate and monitor the potential impact that IVHS will have on air quality and will then determine the appropriate role of IVHS initiatives as part of air quality attainment strategies.

Federal Communications Commission (FCC). The FCC's regulatory function in communications will be critical to the success of the program. The FCC assigns and regulates allocation of the radio frequency spectrum necessary for IVHS operations.

Interstate Commerce Commission (KC). The ICC's interest concerns the use of certain IVHS technologies for regulatory enforcement.

STATE AND LOCAL GOVERNMENT AGENCIES

The state and local governments will select, purchase, install, maintain, own, and operate the IVHS infrastructure, or will possibly contract out or franchise some functions to the private sector. The lead responsibility will have to be carefully decided to suit the local needs of each IVHS project and its participants.

Specific additional roles will include:

- Recruiting and training engineering and operating staff
- Participating in the design and conduct of IVHS field tests, often in concert with private and federal participants
- Developing new operating procedures and protocols for integrating IVHS facilities into the local transportation system infrastructure
- Collecting and coordinating transportation data for ATMS, ATIS, CVO, APTS, and AVCS and operating those systems
- Assisting in the evaluation and dissemination of information on their IVHS experiences

"State *and local governments* will own and control operation of *the* IVHS infrastructure."

States and localities must first recognize the benefits of IVHS. Once benefits are understood, they must be balanced against transportation or other funding needs. Evaluation mechanisms and tools are being developed by the Benefits and Evaluation Committee of IVHS AMERICA to assist state and local officials in assessing public benefits against costs for particular applications of the technology. They can then address the system design, coordination, and operational issues.

Some state and local governments are now past the point of recognizing benefits: they are trying to research, develop, deploy, and operate IVHS, often in the face of budgetary constraints. They arc expanding their relationships with the private sector, seeking the benefits of partnership, and are coordinating with local and regional government. They must also coordinate among themselves and with the federal government. Some state and local governments will help lead the way in research, development, deployment, and operation of IVHS.

IVHS will become another ingredient in the nations's increasingly complex surface transportation mix. All levels of government are involved in financing, building, operating, and maintaining that system. With federal assistance, the states have been primarily responsible for the intercity highway system, as well as for major intra-urban arterials and freeways. Some states have a direct role in providing public transportation. Local governments (cities, counties, and special purpose agencies) have been primarily responsible for local streets and arterials, public transportation, and, in some cases, expressways, bridges, tunnels and toll facilities. Local governments have depended on funding from a mix of local taxes, state subsidies, and federal grants. It is the exception, not the rule, for a single authority to govern all transportation modes. It is important to recognize the challenges that exist in implementing IVHS in such a multi-jurisdictional context.

A high level of cooperation across all governmental levels will be required to develop and implement IVHS. Definition, financing, deployment, operation, management, maintenance, and staffing of IVHS projects may require entirely new institutional arrangements.

That is especially true in metropolitan areas, where multiple local jurisdictions must be involved for effective corridor and system traffic management. Even where all levels of government have every desire to work together, a history of law, regulation, precedent, and tradition may present unwelcome hurdles to cooperative IVHS projects.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) has set the stage for this new imperative for cooperation, with its emphasis on intermodalism and its definition of all large urban areas as "transportation management areas." Within each Transportation Management Area, the metropolitan planning organization (MPO) will be responsible for, among other things, the new "Congestion Management System" requirement. Further, ISTEA requires the MPO to consider relief of the traffic congestion in its long-range planning, and in "non-attainment areas" under the Federal Clean Air Act Amendments of 1990, the MPO is responsible for coordinating the implementation of "transportation control measures" to meet air quality standards. Those broad new assignments to MPO's places them in a strategic position to advance IVHS.

These new congestion management requirements, links to earlier federal air quality mandates, and new flexible multi-modal funding all focus on metropolitan area-wide solutions to transportation problems. That new federal emphasis will have a profound effect on how state and local governments work together to address transportation needs. IVHS may become a catalyst for developing those new intergovernmental relationships, but it is only one force pushing the independent entities to find new ways to work together.

State Governments

The states have traditionally been the principal actors in highway construction, maintenance, and operations, as well as highway research and planning, applying both federal and state funding. The Federal Highway Administration has had long-standing relationships with the fifty state departments of transportation. In addition, the state DOTS have long cooperated among themselves and with FHWA through the American Association of State Highway & Transportation Officials (AASHTO). ISTEA may modify those relationships somewhat by requiring new levels of cooperation between the states and the metropolitan areas. New relationships are still being defined, and they may have substantial impact on the implementation of IVHS.

States have also traditionally been the focus for regulating commercial carrier operations. The reasonable exercise of fifty independent decision-making processes has resulted in a daunting patchwork of regulation facing inter-state carriers. Early progress on IVHS (CVO) has focused on those problems.

Local and Regional Governments

IVHS projects may be nationwide in importance, but they will be implemented one local project at a time. The ultimate success of IVHS will depend on how well the localities are prepared to take on such new responsibility.

Although there is only one department of transportation in each state, transportation at the local level is provided by a vast array of institutions. Not only city and county governments, but myriad special districts, authorities, commissions, and boards will be making decisions on IVHS projects. In most cases, with chronic budget and staffing shortfalls, those local agencies may not be prepared to place IVHS very high in their priorities. Successful IVHS implementation will require commitments from local agencies, especially in the following areas:

- Finding the local match required for federal IVHS funds
- Educating local policy makers and transportation professionals about IVHS benefits
- Exchange of staff, consultants, or academics with substantive technical expertise to define project requirements and assist in procurement, installation, and testing
- Providing training programs to re-educate local agency staff in the new technologies and promoting training programs in local colleges to develop new staff
- Developing local expertise in system, rather than individual facility, operation

This may require extensive federal, state, and private sector cooperation and support.

"Successful IVHS implementation will hinge on how quickly new partnerships evolve."

In contrast with highway funding, discussed above, federal public transportation funding has traditionally gone directly from the federal agency to the metropolitan level or local governments. The Federal Transit Administration has made planning, research, and capital grants to states, but the bulk of the federal capital and operating money for transit has gone directly to the local providers of transit service or through the regional Metropolitan Planning Organizations. The FTA has traditionally had close relationships with the MPO's and individual transit operating agencies. ISTEA may require some basic changes in the nature of the complex web of local-MPO-state-FHWA-FTA relationships. Successful IVHS implementation will hinge on how quickly and effectively those new partnerships evolve.

One of the realities of metropolitan America is the intense competition for economic growth and tax revenue among local jurisdictions. IVHS projects that must span multiple boundaries may have to deal with a history of competitive, or even adversarial, relationships among local agencies. Projects will have to be sensitively defined, promoted, and executed as "win-win" ventures for all involved. As these new alliances mature, local agencies will gain more experience with each other and the other levels of government in working collectively to solve shared transportation problems.

ACADEMIA

The development and deployment of IVHS imply important issues for academia, both in research and in the education of new practitioners. The academic community has a major role to play and has already seen an opportunity in IVHS, as a number of active programs have already been initiated.

The most important function of academia is the development of educational programs and the education of transportation professionals. The deployment of IVHS implies change for transportation organizations. Rather than the traditional focus on construction and maintenance of facilities, many organizations will need to deal with system operations and management through the new technologies and concepts discussed throughout this Strategic Plan.

That will require the broader education of the transportation professional, including areas such as software systems, communications, information systems, and institutional studies. What is needed is a "new transportation synthesis" as an educational model for the 21st century transportation professional. The development of that synthesis and the education of a new kind of transportation professional will be a critical contribution by the academic community.

Academia also has an important role to play in research activities in the IVHS arena. In the development and implementation of this Strategic Plan, academia will be a major participant, both in assessing the current state of likely technological improvements and as a major participant in basic and applied research and development and operational tests.

Indeed, there is a close tie between the research programs and the new transportation synthesis noted above. IVHS research will require the talents of faculty in areas that have not traditionally been involved in transportation. The access to interesting research problems, as well as to funding, provides the pathway and motivation for new faculty to participate in transportation research in the university. From here, it is essential to engage those faculty members in transportation education and the new transportation synthesis. That approach has worked effectively in fields such as manufacturing and biomedical engineering, and IVHS is an opportunity to make it happen in transportation as well.

Success in IVHS will require progress in three areas, the "triad" of technology, systems, and institutions and management. The development and integration of advanced technology into the transportation

Expertise is needed in three areas:
- ***Technology***
- ***Systems***
- ***Institutional Management***

infrastructure are central to IVHS. Systems level activities, including network operation, economic analysis, optimization, and simulation are likewise fundamental. Finally, institutional and management issues such as public/private partnerships, intergovernmental relations, and legal questions are also of prime importance.

These three areas require a breadth of capabilities not captured by many organizations. The modem research university is best suited for such broad activities. The universities, with their dual roles in education and research, have built broad faculties in engineering, management, political science, and technology policy. They often undertake mission-oriented work that requires the broad vision and expertise described above. By addressing the triad in an effective way, the research universities have a unique role to play in the IVHS arena. The major research universities are a key national resource that is not duplicated in Japan and Western Europe to the scale that it exists in the United States. The U.S. IVHS effort should build upon that advantage.

Public/Private/Academic Research and Education Partnerships

A partnership between the public sector, the private sector, and the U.S. academic community is attractive in the IVHS context. The model suggested is that of major university centers or university consortia for IVHS being established with joint public/private funding. University centers or university consortia of IVHS excellence should be established by the competitive process, with substantial federal support (on the order of $5 million per year per center) on a multi-year basis to ensure stability. Those funds would be matched on a one-to-one basis by industry funds or non-federal public funds. Several US. universities already have major programs under way, in cooperation with industry and state and local government. In practice, that is proving to be a viable cooperative mechanism.

To achieve long-term progress for IVHS, those programs must include support for basic and applied research and for development of new undergraduate and graduate educational programs. The integration of new disciplines into the transportation research and education fabric of the university would be an essential activity. Truly joint programs are envisioned, with exchanges between industry, government, and academia through which (1) visiting industry and government people work on research and education activities on-campus and (2) faculty and students work in government and private industry labs and operating agencies. Furthermore, the universities, as partners of industry and the public sector, would provide continuing education and training subjects for practicing professionals.

The national joint public/private/academic centers of IVHS research and education should form a national network, providing coordination and reinforcement. For example, they could meet (along with other interested groups) to discuss such areas as sustaining and building interdisciplinary educational programs, IVHS manpower needs in industry and government and the skills needed to fill those jobs, and publication mechanisms for IVHS programs.

In a partnership, all should benefit. Here, the universities clearly benefit by having a vital role in developing new research and educational programs. The public and private sectors benefit by the development of transportation professionals educated for the new challenges of the field and by the research contributions produced as part of the joint ventures.

OTHER ORGANIZATIONS

Many organizations and professional societies will be involved in the IVHS program. Those groups will help to identify research needs and priorities and will do important work in defining a vision for IVHS.

The Transportation Research Board (TRB), for example, has a well-established committee structure encompassing many disciplines and is capable of dealing with those types of questions; it will make important contributions. TRB identifies research needs and conducts technical research and policy studies. It administers legal research, manages AASHTO's National Cooperative Highway Research Program (NCHRP), and will administer the Federal Transit Administration's new Transit Cooperative Research Program. TRB has been selected by DOT to administer the IVHS IDEA (Innovations Deserving Exploratory Analysis) program.

Professional societies involved in IVHS include the Society of Automotive Engineers, the American Society of Civil Engineers, the Institute of Electrical and Electronics Engineers, the American Society of Mechanical Engineers, the American Society for Testing and Materials, the Institute of Transportation Engineers, and the National Society of Professional Engineers.

The functions handled by those societies are as follows:

- Setting standards and protocols
- Collecting and disseminating information in the U.S. and internationally through journals and conferences

CONSUMER AND USER GROUPS

There is also a wide spectrum of organizations that will be involved in the development and implementation of this program through their representation of their constituents' views on what needs to be accomplished and how IVHS should be implemented. It is impossible to list all of the groups in this category, but it includes such membership organizations as the American Automobile Association, the American Association of Retired Persons, the National Safety Council, the Highway Users Federation, and the American Association of State Highway and Transportation Officials.

Legal Issues

PROCESS

There are a number of legal issues that could greatly affect IVHS research, development, and deployment. Those include product liability and other tort liability, antitrust, privacy, procurement, intellectual property, and regulation. For some issues, the law is already developed and the principal function needed is dissemination of accurate information. Some of the issues are already being addressed in a broader context, such that the IVHS community needs to ensure that the specific applications of IVHS are addressed. Some issues, however, will require specific refinement, development of legal doctrine, or change in law or regulation for IVHS application.

For many of the legal problem areas described below, along with those not yet identified, the following actions are appropriate:

1. Conduct studies to refine understanding of the problem, review the literature regarding the issue, conduct case studies, research the history and application of the legal doctrines, and generate suggestions for alternative solutions.

2. Conduct forums of representatives of the interested parties to seek agreement on appropriate solutions to the issues.

3. Conduct efforts to effect law changes or other implementation strategies.

The scope and detail of each work element, who should fund it, who should supervise it, and who should conduct it will vary from issue to issue.

Studies, analyses, or other research will be the responsibility of the federal government, state and local public agencies, private firms, associations, or academic institutions. The Transportation Research Board will often be the appropriate entity to supervise, administer, or publish such research. Special law school study projects with public and private funding may be appropriate to address a number of issues over a longer timeframe and to establish a continuing institutional expertise in such legal research.

IVHS AMERICA will advise on research needed, monitor developments and activities, participate in or convene forums, recommend policies, and facilitate its membership's participation in the legislative and regulatory process. Many activities regarding legal change will, of course, be the autonomous prerogative of individual public agencies and private firms.

ISSUES

Tort Liability

Liability doctrines and practices as applied by our court system may significantly deter private sector designers and manufacturers from the development and introduction of new technologies to our surface transportation system.

"Liability law may significants deter development and introduction of new technologies."

Product liability may inhibit the willingness of private sector companies to develop products that differ greatly from existing products. It particularly looms as a major issue for vehicle manufacturers and their suppliers. There is a very real danger that some IVHS applications that are technically feasible will not come into use without substantial changes in tort and product liability law. Those changes appear unlikely given current trends in legal reform. Exposure to risk of expensive product liability suits raises the cost to the private sector of equipping vehicles with IVHS systems and could reduce the incentive to be a market leader in this area.

Presently, the primary burden of the cost of accidents on our highways is borne by the vehicle owner. IVHS can ultimately reduce the number and severity of accidents and thus improve overall safety and reduce the cost of insurance for the individual vehicle owner. However, for those accidents that do occur in an IVHS environment, the owner or operator of the infrastructure and its IVHS systems and the designer and manufacturer of the on-vehicle equipment will be likely to become more common targets of accident claims. IVHS could therefore cause a shift of liability to the infrastructure and equipment suppliers, even as it reduces the total cost to society of motor vehicle incidents.

An examination of that potential problem is required to see if those concerns are likely to be realized. If it is found that the problem is serious, there may need to be consideration of changes to federal and state tort liability law so that the potential damages arising from a malfunction or misuse of an IVHS component are limited or are shared widely.

Such problems of the tort liability system with unpredictable and occasional extraordinary damage awards are not limited to IVHS. The problems extend to many services and products, especially to those that are new. Tort reform reaching far beyond the scope of IVHS is presently being considered. In the long run, liability problems for IVHS may be resolved within the context of that more general tort reform. However, more immediate action may be required to address potential constraints to the development or deployment of IVHS in the short term.

Suggested solutions include the following:

- Establishment of innovative risk pooling arrangements, wherein coverage for potential losses attributable to IVHS is purchased as part of the fees paid for products and services

- Conditioning receipt of IVHS products, services, or both upon agreement by the user or purchaser to submit any claims to an arbitration or other alternative dispute resolution process

- Limitation on punitive damages or pain and suffering awards, either for IVHS incidents or as part of general tort reform

- Limitation of liability by legislation, government assumption of liability, or both for losses above a certain threshold, similar to precedents used for international air carriers, the commercial space industry, and the nuclear power industry

- Establishment of regulatory regimes with which compliance would trigger limitations of liability

- Extension of sovereign immunity to government contractors or suppliers, as long as they comply with government specifications or regulations

Of these approaches, those that would require significant modification to existing law and legal practice are likely to take a long time and will be difficult, if not impossible, to accomplish.

Actions Needed

Studies should be conducted to ascertain just how serious a constraint current liability laws and legal practices really are and what actions might be undertaken to resolve these problems. Such studies should include surveys, interviews, and forums of large and small companies considering development of IVHS products and services, as well as participants in current operational tests, insurance companies, federal and state regulators, and the trial bar. A review of the literature on liability and innovation, tort reform, and other relevant topics should be conducted. Federal and state statutes, case law, and practices should he reviewed.

The results of such studies should be reviewed and discussed by the IVHS community within the forum provided by IVHS AMERICA, and an appropriate course of action should be determined. Such action may include policy recommendations submitted to DOT, the Congress, or other governmental bodies; participation in broader tort reform efforts; discussions with insurance or trial bar interests; and establishment of special risk pools.

Antitrust

There has been some uncertainty about the extent to which antitrust law places a cloud over collaborative research in this country. Although the U.S. is more concerned with industrial collusion than the Japanese or Europeans, in reality there is wide latitude in the types of research activities that can now be undertaken. The National Cooperative Research Act of 1984 (15 U.S.C. 4301 *et seq.)* explicitly limits antitrust liability for research activity and provides that joint research and development ventures are subject to a test of reasonableness. If a joint R&D venture has no anti-competitive effects, or if any such effects are outweighed by the pro-competitive effects, then the venture does not violate the antitrust laws. Furthermore, recovery for violations that do occur is limited to actual damages for joint R&D ventures that have been properly disclosed to the U.S. Department of Justice and the Federal Trade Commission.

Some companies may be concerned about the extent to which such cooperative work is legal and not subject to treble damage penalties. Although there is increased flexibility for U.S. companies to work cooperatively, both among themselves and with state, local, and federal governments, consideration of additional changes may be needed to allow U.S. firms to compete more effectively internationally.

Actions Needed

Research is needed to determine the degree to which antitrust concerns are a constraint to IVHS development, along with work to make sure that both industry and government agree on the delineation between pre-competitive and competitive activity. Drawing on such work, IVHS AMERICA should publish guidance alerting its membership to problem areas regarding compliance with anti-trust laws.

Privacy

"Safeguards for the control of IVHS information must be provided fo protect individuals' interests and privacy concerns."

One major concern that had to be addressed early in the operational test design of the HELP/Crescent project was privacy safeguards for the drivers and owners of commercial vehicles participating in the project. Such concern required use of a private contractor to manage data as a buffer between public and private participants, with limitations placed on public access to the data. Similar concerns will surface from participants in other projects.

Appropriate safeguards and guidelines on the control and use of IVHS information must therefore be built into the process in order to alleviate concerns over the inappropriate use of the data and in order to protect the privacy of individual vehicle users. Such protection must be considered at every stage of design, development, and deployment of the technology to assure program integrity and credibility and to secure public acceptance and support.

The law of privacy regarding information that is collected through electronic means is undergoing rapid change. The Electronic Communications Privacy Act (ECPA) was adopted in 1986 to protect wire or electronic communications from illegal interception by unauthorized third parties. It creates standards and procedures for court-authorized electronic surveillance, regulates when electronic communications firms may release the contents of communications during the transmission process, and provides legal protection of the privacy of stored electronic communications, from both outside intruders and unauthorized government officials. Due to changes that have occurred in the last five years, a major revision of the ECPA is under consideration. Such revisions may encompass privacy protections for IVHS travelers. Limitations and protections on the use of data collected in IVHS that might help in the finance of programs could, however, limit opportunities for its beneficial use, both for public sector planning and for commercialization.

Actions Needed

Studies should be conducted assessing the impact of the present ECPA on projected IVHS applications and evaluating the potential impact of proposed changes to the legislation. Review and analysis should be conducted on other privacy laws, cases, and doctrines concerning IVHS. Studies or surveys that have been conducted regarding privacy laws across jurisdictions should be identified.

Survey, opinion, and market research should be conducted on public attitudes and concerns for privacy and on mechanisms that might provide acceptable protection.

IVHS AMERICA should develop and adopt a policy statement regarding privacy issues and IVHS, based on information derived from the studies recommended above. It should include guidelines regarding information use by its membership, along with principles to be considered in design of systems, standards, tests, products, and services.

The IVHS community should monitor and participate in the process of federal and state legislative consideration of privacy laws, including establishment of informal relationships and submission of comments and testimony where appropriate.

Procurement

The difficulty of doing business with the government is of great concern to private sector firms. Although it is understood that the government must have procedures for its dealings with private interests in order to assure fairness and receipt of full value for the expenditure of public funds, it is still widely believed that procurement and government contracting requirements are far too complex and timeconsuming, often constraining effective and timely achievement of program aims.

One example, an issue of immediate concern, is the potential for perceived or real conflicts of interest among private sector technical experts assisting IVHS AMERICA and DOT in defining the scope of work for the system architecture project. The work will be contracted by DOT, with the same experts wanting to bid for such contracts. They are concerned as to when they must separate themselves from the collaborative, pre-competitive, system architecture work-scoping process, so that they will be legally eligible to compete for the work. Conversely, competitors will want assurances that those who have provided technical assistance will not have an unfair competitive advantage.

Another issue concerns how DOT may effectively fund productive, creative research and development and whether current contracting and procurement practices support or inhibit that goal.

Actions Needed

Studies should be conducted identifying alternative models for procurement, especially regarding technology research, development, and deployment. NASA, the Department of Defense, the Department of Energy, and the Department of Health and Human Services may provide instructive models.

A paper should be prepared describing the issues regarding conflict of interest, procurement integrity, and the development of the IVHS system architecture.

Intellectual Property

Many cooperative arrangements among government, the private sector, and universities are envisioned as part of the development process of IVHS. They include research consortia and operational test joint ventures. It is important that understandings and agreements regarding rights to intellectual property be reached at the beginning of each project.

The federal government now has fairly broad latitude regarding the intellectual property rights it may grant to recipients of federal funds. Such arrangements may go as far as, but do not always extend to, granting to the non-federal party rights to inventions developed in performance of an agreement, as long as the federal government retains a nonexclusive, nontransferable, irrevocable, paid-up license to use the subject invention.

The policy for copyrighted material (which includes computer software) is similar. The non-federal party generally may copyright the material developed under the funding agreement, as long as the federal agency reserves a royalty-free, nonexclusive, and irrevocable license to reproduce, publish, or otherwise use, as well as to authorize others to use the copyrighted material for federal government purposes.

When federal funding is to be used as part of a cooperative project, federal requirements should be formulated and stated early in the discussions or at the earliest possible stage of pre-procurement activity if a formal procurement is required. Arrangements for separating federal and non-federal funding in the project may be appropriate in order to safeguard proprietary concerns.

Policies regarding intellectual property have been changing, and they continue to change. Efforts are needed to monitor new developments and to provide guidance to the IVHS community.

Actions Needed

A paper should be prepared discussing the application of federal (and state) intellectual property laws and regulations and procurement requirements to IVHS research and development programs. IVHS AMERICA should monitor developments in this field, advise its membership, and, where appropriate, provide advice to the federal government.

Regulatory Structure

A number of regulatory agencies, processes, and requirements could affect the rate of IVHS deployment. The relationship between various IVHS functions and products and the multitude of regulatory influences must be considered and understood. For example, there is a complicated process for determining the use of portions of the radio spectrum. If an already dedicated portion of the spectrum is needed, a relatively long process may be required before IVHS interests receive approval. Moreover, regulatory authorities will be faced with other competing interests and therefore may not give the same weight to IVHS use as transportation experts would.

There is a wide assortment of safety and economic regulations that may lead to a longer gestation period for development. Such regulations are imposed for valid public policy reasons. The impact of such regulations must be understood and included in developing reasonable and rational planning schedules.

The need to meet air quality goals may focus attention on the ability of IVHS to improve traffic flow. Local officials, faced with an obligation to exert greater control over traffic flows, may find the investment expenditures on IVHS less burdensome than draconian traffic curtailment measures.

Safety regulations bearing on IVHS may vary from state to state, and coordination through IVHS AMERICA or federal preemption by NHTSA may therefore accelerate deployment.

Actions needed

A study should be conducted to identify all of the regulatory programs, agencies, and jurisdictions that will bear on IVHS and to assess the impact of those on timing and alternative courses of action.

DOT should take the lead in coordinating with other federal agencies in the course of administering the federal IVHS effort.

The Radio Technical Commission for Aeronautics, which was used as a model in defining the role of IVHS AMERICA as a utilized Federal Advisory Committee, advises and includes in its membership eight federal agencies, with the Federal Aviation Administration serving as the lead agency. IVHS AMERICA should explore adding to its membership additional federal agencies that have interest in or jurisdiction over elements of the national IVHS program.

Jurisdictional Authority to Delegate Traffic Management

The principal institutional challenge to deployment of ATMS, as discussed in the Institutional Issues section of this document, is the need for the multitude of local governmental and modal jurisdictions within a metropolitan area to coordinate and consolidate their traffic management policies, controls, and management. In many cases, such consolidation may be constrained by state laws that mandate the responsibility and control of local streets, and the traffic on them, to local municipalities. Such local governments may not be legally able to participate in ATMS initiatives.

Actions needed

Studies should be conducted, surveying the laws of the states, as to what legal authority local jurisdictions have to delegate or otherwise participate in traffic management coordination and consolidation activities. Recommendations of needed state or federal legislation should be included along with consideration of other approaches, such as the applicability of intergovernmental agreements or compacts. Furthermore, an assessment should be conducted of the ability of private companies to provide service on public roads.

Institutional Issues

This section identifies the major institutional issues regarding IVHS development and deployment and recommends immediate actions that should be taken to begin their resolution.

"The technical interconnection of transportation system parts requires the interconnection of the associated institutions."

Most institutional issues arise from the integration of different components of the transportation system into a single system. That interconnection of parts requires the interconnection of the institutions associated with those parts, and it also requires related change to institutional responsibilities and capabilities. Thus, each description of IVHS technology is implicitly a description of new institutional interconnection and change. In light of this, some system architectures may be superior to others because of their institutional implications.

- ATMS will require institutional interconnection within a local geographical area such as a metropolitan region. The main interconnections would be between government agencies.

- ATIS will require interconnection between public and private institutions, and between the highway owners and operators and the automobile manufacturers, equipment suppliers, and owners.

- AVCS will require very close cooperation between public infrastructure organizations and private vehicle manufacturers and equipment suppliers, due to the high degree of technical integration. Cooperative efforts will operate primarily on a national scale in the development stage, especially regarding architecture and standards, and in development will shift to greater emphasis on coordination among state and local agencies.

- CVO will require public and private cooperation across the multitude of state and federal regulatory and taxing jurisdictions and among the many private service providers and users operating on the national highway network (for example, interstate trucking).

- APTS will require the continued metamorphosis of transit agencies into providers of mobility services to travelers, applying new technology to encourage increasing vehicle occupancy.

New forms of public/private partnerships, public/public intergovernmental arrangements, and private/private joint ventures will be required to develop and deploy the national system of IVHS facilities, vehicles, and services. Furthermore, existing institutions will be faced with the challenge of internal reformation and change. All must be concerned with the expectations, perceptions, and needs of the citizens, customers, and constituents who will experience the impact of IVHS on their mobility and quality of life. Fiially, each partnership sector, be it public — at the national, state, or local level — or private, will face special financial concerns and challenges made even more critical by the interdependence of the parties.

INTERGOVERNMENTAL/ INTERAGENCY COORDINATION

Federal Interagency Coordination

Within DOT, the federal IVHS program has already brought FHWA, FTA, NHTSA, and RSPA together with the Office of the Secretary to work closely and cooperatively in pursuit of the potential opportunities and benefits of IVHS. As IVHS matures, it is likely that the traditional boundaries that have historically separated these administrations will continue to blur.

Successful national deployment of IVHS will require participation and support from other federal departments, such as the DOC, the DOE, the Department of Justice, the EPA, and the FCC. Organizational coordination arrangements among those agencies within the federal government will evolve. The appropriate role for each agency in relation to IVHS AMERICA must still be determined.

Metropolitan Area Surface Transportation Operational Management

As noted above, the responsibility for transportation management and supervision in a metropolitan area is typically spread over a number of governmental jurisdictions and departments. States (and in some regional areas, more than one state) own interstate and primary freeways and highways and generally control ramp metering and signalization on those systems. Counties own and operate county roads, and cities do the same for streets in their jurisdictions. Different agencies within each level of government arc responsible for construction, maintenance, signalization, law enforcement, regulation, and incident management. Transit and toll authorities may also be involved in some areas.

"Metropolitan area transportation management and supervision is typically spread over a number of jurisdictions and depatimenfs."

The introduction of new IVHS technology into this mixture will increase the need for cooperation while adding to its complexity. Just as technological change encouraged regional integration in such areas as public utilities, technology deployment may drive integration of traffic management responsibilities.

National IVHS policy should encourage and facilitate institutional interconnection and coordination at the metropolitan level. Special ATMS categorical funding or regular federal-aid highway IVHS capital funding could be made contingent on appropriate metropolitan cooperative arrangements. Research should be conducted to determine the extent to which there needs to be closer agency and community cooperation. As a first step, there should be an analysis to determine the extent of current cooperation.

TRANSCOM, which serves as a clearinghouse for traffic information in the New York-New Jersey area, illustrates this. Operated under the auspices of the Port Authority of New York and New Jersey, more than fourteen organizations and jurisdictions participate in the program. TRANSCOM's mission is to develop and improve interagency responses to traffic incidents. Programs include incident notification, incident management, construction coordination, and transit development. The following agencies participate in the TRANSCOM program:

- New York State Thruway Authority
- Metropolitan Transit Authority
- New Jersey DOT
- New Jersey Highway Authority
- New Jersey State Police
- New Jersey Transit Corporation
- New Jersey Turnpike Authority
- New York City DOT
- New York DOT
- New York State Police
- Palisades Interstate Park Commission
- Port Authority of New York and New Jersey
- Port Authority Trans-Hudson
- Triborough Bridge and Tunnel Authority
- Many local police departments

The complexities of linking these organizations are significant, even without any major technological innovation. The introduction of new technology into the TRANSCOM association through IVHS greatly increases the complexity and need for coordination.

CVO Inter-jurisdictional Coordination

Similar to the interjurisdictional challenges facing metropolitan areas is the need for coordination among multiple states and other governmental levels in deployment of the IVHS technologies associated with Commercial Vehicle Operations (CVO). Among the greatest benefits associated with CVO is the concept of paperless, transparent borders, eliminating the delay associated with licensing and registration, examination of credentials, weighing, and payment of taxes for each state a vehicle enters. That can only be achieved, however, through often arduous negotiations among numerous agencies to reconcile the statutes, regulations, practices, policies, and control needs of the many jurisdictions through which an interstate commercial vehicle passes. Indeed, the oldest CVO operational test, HELP/Crescent, has found resolving institutional issues to be more challenging and significant than answering technical questions.

NEW MISSIONS AND TECHNICAL CAPABILITY, CHANGING ORGANIZATIONAL CULTURE

Many organizations whose role until now has been primarily construction and maintenance of highways and traffic control systems will now need to place greater emphasis on system operations.

"The transportation sector will have to develop personnel wifh new skills."

The introduction of new technologies into the field of transportation will require that members of existing institutions learn new skills and accept new missions. Institutions that are extremely competent in their traditional tasks will have to become expert in new technologies and functions. In general, the transportation sector will have to develop people with different skills than those needed today.

Local transportation agencies may lack sufficient expertise for sophisticated technology. Maintenance and operations crews that work today with well-established technology (such as traffic lights) may be faced with new, delicate, and sophisticated technologies (for example, computer vision systems for incident detection).

In general, the transportation sector may find itself with both a shortage of skilled personnel and a gap in professional culture. Transportation has traditionally been a field of civil and mechanical engineering, not electrical engineering. Civil engineers skilled in road building and mechanical engineers skilled in vehicle design and operation may neither understand nor welcome telecommunications and computing. Public agencies may have difficulty attracting and paying for expert personnel, as well as difficulty in integrating them into their organizations.

PUBLIC/PRIVATE COOPERATION

The relative roles of the public and the private sectors will evolve over time. Indeed, it is an essential part of the IVHS development strategy to cause them to evolve.

Partnership arrangements will be tailored to a specific need and will be developed for specific purposes, often for limited periods. The forms of specific collaborations proceed from the identification of purpose and need. Those collaborative arrangements are shaped by the following:

- A determination of the appropriate source or sources of funding
- The location and availability of the skills and technologies required
- The contractual or other relationships of the individual players that will best motivate the desired outcome

Collaborators Versus Adversaries

In many cases both government agencies and private companies have each considered the other to be more a problem than an ally in addressing transportation needs and problems. Much of our traditional attitude about public/private relations is adversarial. The key to deployment of IVHS and to national competitiveness in an international realm will be to work cooperatively, on the basis of consensus. Unwillingness to participate in such collaborative institutional processes may represent a major barrier to success.

Private Transportation Operations

One deployment scheme that may be feasible would be to privatize many of the transportation management functions currently undertaken by local public agencies. That can be done either by direct private provision of the service or by franchising or contract.

Whatever approach is tried or chosen, there will have to be identification and analysis of the legal constraints involved in' allowing private companies to provide highway and other services. If franchising or contract services are considered, there will need to be consideration of the need to provide access to people who cannot afford potentially high costs for such services.

The implications of private IVHS services need to be evaluated. Models such as regulated monopoly, limited competition under franchise, or open markets in information should be explored in terms of viability, impact, benefits, and risk.

SOCIETAL IMPACTS OF IVHS

"transportation is an integral part of modern day existence."

Although much of IVHS will be driven primarily by technology, it is inevitable that the program will have major impact on, and, in turn, be affected by, other societal factors. Some of those, such as environmental concerns, have already been identified, even if the extent of the impact cannot be fully understood at this time. However, the major changes wrought by IVHS may also have other consequences that are presently unforeseen, much as the development and implementation of the Interstate Highway System over the past 35 years had major societal consequences that extended well beyond those originally envisioned.

IVHS should facilitate not only safe and efficient movement of people and goods, but should also provide opportunities for people to develop their potential in a healthy productive environment that is enhanced by the implementation of the new technology. Transportation is an integral part of modern day existence. It can facilitate or inhibit one's opportunities to participate as a full-fledged member of society. Access to transportation is needed to access education, health care, employment, recreation, family relationships, and virtually every other endeavor. IVHS must be developed and implemented in a way that guarantees access to the system by all segments of the population and by all communities wishing to participate. Market forces alone, in absence of attention to the larger societal interests and impacts, cannot guarantee such an outcome.

Although the Interstate Highway System has been an immense success in what it was intended to accomplish, an ongoing broader vision of how that system interfaced with the larger society would have enabled earlier recognition of some potential problems and possibly earlier preventive measures. As we lay the foundation for the next thirty or forty years in transportation, we have the opportunities to use what we have learned from the past and to create a process for integrating IVHS into the larger fabric of society. IVHS can then contribute to solutions for problems that extend well beyond transportation per se.

While breaking new ground in establishing public/private/academic partnerships to develop and deploy IVHS technologies, broader partnerships should also be established to examine and monitor how the projected changes in the transportation system will interact with and affect virtually every other aspect of our society,

IVHS will have different impacts on different economic, demographic, and social groups. The impacts on various groups must be assessed and actions taken to assure equity in the distribution of benefits versus the sharing of costs. Furthermore, government must assure that the effect of IVHS deployment will not cause reduced mobility for any group.

ACTIONS NEEDED

Operational Tests

Experiences with institutional issues in operational tests conducted to date should be documented — such as the process by which agreements were reached on the public/private joint ventures, why they were structured the way they were, and lessons learned that can improve or expedite the process for future such arrangements.

Criteria and methodologies for evaluation of every operational test should include the institutional issues that arose during the course of the project and the manner in which they were addressed.

Reports on the institutional problems and success of each operational test should be maintained as part of the IVHS AMERICA Clearinghouse.

The primary focus of some operational tests should be on experimenting with alternative arrangements for use of the private sector in development or deployment of IVHS technologies, or both.

New Skills

Studies should be conducted to determine the new skills and institutional competencies that will be required within various organizations that will have developmental or operational responsibilities for IVHS. Changes required in organizational structure should be identified, along with educational qualifications for personnel and additional training required.

Organizations and individuals with expertise in conflict resolution/process management should study this Strategic Plan, the IVHS AMERICA organizational program, and other IVHS-related public-private, public-public, and private-private ventures, initiatives, and needs and should make recommendations for improvements on the consensus process.

Private Sector Services

Studies should be conducted analyzing alternative mechanisms for private sector provision of services in the collection, processing, and beneficial use (and sale) of information related to IVHS technologies. Arrangements to be evaluated would include unregulated markets, limited competition through government-issued franchise, regulated monopolies, and provision of service as a contractor to government. There also need to be guarantees of public access to facilities developed with public funds.

Societal Impact, Users, and Customers

Research should be conducted to explore the broader societal impacts of IVHS. Opinion or market research should also be undertaken to ascertain public attitudes regarding projected IVHS deployments and the mechanisms by which they are expected to take place. Attitudes and concerns should be identified and analyzed regarding privacy, use of new public/private arrangements, concerns and perceptions regarding impacts on safety and congestion, the balance between public and private responsibilities and funding, general versus dedicated versus user fee public finance, the relative importance of public investments in those technologies as compared to other public needs and services, and the willingness to pay taxes to support such operations. A study of national scope should be conducted creating a baseline for subsequent follow-up studies. Similar work should be conducted in local markets, often in conjunction with, but not limited to, operational test sites.

Methods should be identified and pursued to include additional user representation in IVHS AMERICA activities and other IVHS projects.

IVHS Costs

It is difficult to estimate costs for a long-term technology development program at its startup stage. Different sets of assumptions can produce large differences in cost estimates. Given these caveats, this section estimates 20-year program costs using one set of assumptions. Funding levels in the ISTEA 1991 are not used as a constraint.

These cost estimates, which were estimated by the IVHS AMERICA technical committees, do not imply funding levels or funding priorities. Those will be determined after operational tests determine the relative benefits of the systems. Actual funding levels could vary widely without serious consequences. If higher levels of funding are provided, the program can be accelerated, or if lower levels of funding are provided, the program time frame will be likely to be lengthened.

Funding for the development and deployment of IVHS in the United States will be provided by government at all levels, by private sector companies, and by the public/private partnerships now developing. Funding levels will depend largely on the benefits that could accrue for each partner. The combination of user service and societal benefits must be high enough to generate a willingness on the part of the consumer to pay the full private cost of the additional technology, and a willingness on the part of the public sector to pay for the associated infrastructure and regulatory costs. Vehicle manufacturers have limited engineering and financial resources to invest in improving their products and meeting regulatory goals. Investments in IVHS will therefore come at the expense of other programs in both the private and public sectors. Coordination is vital in order to ensure that products and technologies are both cost-effective for the public and profitable for the private sector.

Government expenditures will be focused on the infrastructure, which is publicly owned and operated; the private sector will focus on IVHS products and services that it will sell to consumers and to transportation system operators. Development work needed for interface between the infrastructure and the IVHS-equipped vehicles should be financed by the partnership.

The total level of spending for IVHS will depend on the degree of public acceptance and market penetration of IVHS products and services. Estimates of private sector participation and deployment were based on a set of assumptions that are delineated in Appendix D.

Development Cost Requirements and Funding Sources

The level of development funding will be determined by the many public-private partnerships that will form to pursue different aspects of IVHS development. Where and how these partnerships will form or what contributions the private participants will make cannot be determined precisely. This increases the importance of stable federal funding at the development stage.

Because most IVHS infrastructure and vehicle-based technology will benefit surface transportation systems throughout the country, the federal responsibility as a percentage of total public development responsibility will likely be similar to other federal transportation programs (up to 80 percent federal share). However, it is important to leverage federal IVHS program funds to the maximum possible, as well as to assure full participation and commitment of the non-federal partners and operators/users. Federal Highway Administration policy requires a 20 percent non-federal cash match and allows a 30 percent match from other federal sources for an overall 50 percent match. To meet the objectives, state and local government and private participants will match the federal share. Within the overall funding framework, it is recognized that the federal share for specific projects will vary, depending on various factors.

Development cost assumptions were made for the purpose of estimating public-private funding levels. Those assumptions are as follows:

PUBLIC SECTOR

- Development of infrastructure-based technology wilI primarily be the responsibility of the public sector.

- Public responsibility could be increased to 100 percent for funding of critical development products with very long lead times and for technology development where public funds could be used early to leverage private participation later in the development process. As an example, fully automated AVCS may have the potential to greatly increase the efficiency of public and private systems, but the 20-year development cycle is much too long for private sector investment consideration. Without long-term public support, these important parts of IVHS development would not be likely to proceed beyond the planning stage.

- System architecture development should be the responsibility of the federal government, since it cuts across all levels of the surface transportation system, relates the various components of IVHS, is a precursor to many development and deployment activities, and would provide the overall framework for public investment in IVHS.

- Development expenditures will vary during the development period, ramping up initially, leveling off at mid term, and presumably diminishing toward the end of the twenty-year period.

PRIVATE SECTOR

- The calculus for private sector funding is conceptually simple: there must be a reasonable prospect of future profitable return. Investment is inhibited if risk is high or if the payoff has a long timeframe. The assumption used in these estimates is that vehicle-based, product-oriented, proprietary development should be primarily the responsibility of the private sector. The costs generally will not be assigned to IVHS development costs under this plan. They are estimated to more accurately show private sector participation.

- As different elements of the system mature and risk is reduced, the climate for entrepreneurial activity using private capital will improve. It is assumed that during the later stages of the development cycle, formation of consortia, principally funded by private sector participants, will become the funding mechanism of choice.

- Public funding share for overall IVHS research and development activities was assumed to be 80 percent (20 percent private), since its nature is high-risk and long-term. Public share of the operational testing portion of development was assumed to be 70 percent, since the work is generally tied more closely to product development.

- Test facility costs are assumed to be 70 percent public, 30 percent private. However, much higher private participation is possible for those facilities if a shared use lease arrangement could be worked out between the facility developers and some major users.

- ATMS and APTS are public responsibility, but at least 5 percent of the development costs of IVHS technologies in those areas can be assigned to the private sector, due to its relationship to products that will be marketed by the private sector for use in the public infrastructure. In addition, as mentioned elsewhere in the plan, traditional roles and responsibilities may be reversed via privatization during the IVHS deployment stage.

LOCAL FINANCIAL IMPLICATIONS OF IVHS

Even though it is anticipated that IVHS will be very beneficial, there will be development, maintenance, and operating costs associated with deployment. Much of the burden of increased operating costs may have to be borne by state and local governments. That burden comes at a time, however, when governments are finding themselves faced with declining tax revenues. While it may be difficult for those communities to shoulder the increased financial commitments of large, sophisticated IVHS systems, those systems will still be significantly less costly than alternative approaches for improving the operation of surface transportation systems. Also, the use of existing communications systems, investment by the private sector in surveillance networks, and the use of IVHS for crime detection or tracking hazardous substances could reduce local government costs.

Funding studies necessary to clarify funding relationships during the development process include the following:

- Research in assessing the capital and operating costs of systems intended to be operated at the local levels
- Research to establish ways to quantify the local benefits to be derived from IVHS applications.
- An assessment of the appropriate arrangements for federal/ state/local cost sharing for IVHS capital and operations costs, including the evaluation of the appropriate application of user fees or other beneficiary payment methods
- Analysis of the funding alternatives and trends open to local communities to pay for the systems
- Analysis to identify impediments to private IVHS R&D support and to determine how to better encourage private R&D

The following table shows estimated development cost by function, time frame, responsibility, and development stage.

Public/Private Sector Research and Development and Operational Testing Cost Estimates (It is noted that the cost estimates in this table do not imply funding levels or priorities.)											
			Cost Estimates in Millions								
Research and Development	Assumed Share		5 years 1992 - 1996		5 years 1997 - 2001		10 years 2002 - 2011				
	% Pu	% Pr	Pub	Prv	Pub	Prv	Pub	Prv	Pub	Prv	TTL
System Architecture[1]	100	0	20						20	0	20
Organizational Program[2]	**100**	**0**	**7**	**0**	**5**	**0**	**8**	**0**	**20**	**0**	**20**
ATMS	**95**	**5**	**57**	**3**	**67**	**3**	**19**	**1**	**143**	**7**	**150**
ATIS	**80**	**20**	**80**	**20**	**60**	**16**	**30**	**8**	**170**	**44**	**214**
CVO	**80**	**20**	**16**	**4**	**8**	**2**	**8**	**2**	**32**	**8**	**40**
AVCS	**80**	**20**	**320**	**80**	**540**	**130**	**400**	**100**	**1,260**	**310**	**1,570**
APTS	**95**	**5**	**28**	**2**	**38**	**2**	**28**	**2**	**94**	**6**	**100**
Total R&D			**528**	**109**	**718**	**153**	**493**	**113**	**1,739**	**375**	**2,114**
Operational Testing[3]											
ATMS	**95**	**5**	**170**	**9**	**320**	**17**	**330**	**18**	**820**	**44**	**864**
ATIS	40-75	2560	200	51	230	120	120	180	550	351	901
CVO	70	30	70	30	28	12	21	9	119	51	170
AVCS	70	30	70	30	230	100	530	220	830	350	1,180
APTS	95	5	115	6	160	9	115	6	390	21	411
Test Facilities[4]	70	30	305	130					305	130	435
Total Operational Testing			930	256	968	258	1,116	433	3,014	947	3,961
TOTALDEVELOPMENT R&D AND TESTING			1,458	365	1,686	411	1,609	546	4,753	1,322	6,075

Note:
- Estimates have not been rounded, but only first or second significant digit accuracy can be assumed.
- Costs estimated by IVHS AMERICA technical committees.
- The private costs are for joint public/private efforts. Proprietary private development expenditures are estimated in Appendix D.

1 Estimated public sector requirements. The private sector is working on system architecture questions as well, but estimates have not been made to date.

2 Organizational program, including studies, conflict resolution, regulatory legislation, and work on institutional legal and standards issues surrounding IVHS development and deployment.

3 Operational test estimates include pretest planning, test selection evaluation, and post-test evaluation.

4 Test facilities included cold and warm weather full-scale operational test centers that replicate the existing and future ground transportation systems. Two sites at $2OOM; one national driving simulator (NADS) at $35M.

Deployment Cost Requirements and Funding Sources

The deployment of IVHS products in the U.S. will primarily be market-driven, and therefore the consumer will pay the largest portion of the cost directly. The government's share of the overall funding will be highly leveraged. Government funding (federal, state, and local) will be directed toward providing infrastructure that encourages consumer acceptance of products by greatly increasing the value of the products; thus, it must lead the deployment process. Both the individual consumer and society as a whole will benefit.

PUBLIC SECTOR

Deployment of the public IVHS infrastructure, although representing only 18 percent of the total cost of IVHS deployment, is pivotal because in many cases it will enhance the value of the private product and provide the purchase incentive. Assumptions are as follows:

- Planning and engineering for infrastructure-based IVHS is public responsibility.
- The federal/state partnership that developed for the construction of the Interstate highway system should be continued for IVHS deployment, and local governments and the private sector should be added as full partners.
- The Federal Transit Administration will likely continue its funding relationship with local governments for the deployment of IVHS technology. Federal share of 80 percent is typically allowed for both vehicle and infrastructure capital expense. Because of federal funding limitations, a higher local match would be desirable to extend deployment opportunities to additional transit systems.
- Since many of the benefits of the IVHS are likely to be public, it is appropriate that the initial users do not bear the full cost of the system. Public subsidy for some part of the private cost of equipping a vehicle with IVHS technology may be needed in order to get sufficient participation for the realization of public benefits, such as reduced congestion.

PRIVATE SECTOR

Successful implementation of IVHS requires increased technology in vehicles. The extent and speed of penetration of IVHS is dependent on the market. Consumers choose between different vehicles and different levels of content. Manufacturers seek to meet consumer demand by providing vehicles with the best mix of features and options, given consumers' willingness to pay. Experience repeatedly has shown that consumers are only willing to pay for features with a private benefit at least as high as the additional cost. Furthermore, some consumers are very price conscious and will postpone buying a new vehicle or will drop out of the vehicle market altogether when vehicle content and prices increase.

The challenge to manufacturers is to develop cost-effective packages of IVHS technologies that consumers will find valuable, at the same time meeting the social need for the vehicle portion of the IVHS to mesh with the infrastructure. That clearly means there are a number of important implications for the successful introduction of IVHS.

- Standards and protocols for vehicle-highway communication must be worked out in a process that allows for low cost access to the technology. Otherwise, consumers will not choose to purchase the vehicle side of the system.

- In the near term, most IVHS applications will be concentrated in those urban areas where the benefits are the greatest. If the vehicle portions of the system are expensive, they will be offered as optional equipment. In order for IVHS to penetrate the market, those technologies will need to provide benefits to the driver that are sufficient to justify the additional cost.

- IVHS represents a clear profit opportunity, and it therefore is only likely to attract development resources and investment if the private benefits are sufficient to cover the additional vehicle cost plus a market return on the investment. Given the variable nature of driving conditions in the country, the appropriate level of IVHS technology is unlikely to be uniform. One challenge to the private sector will be to find and coordinate the appropriate base level of technology that should be standard on every vehicle.

Private sector contribution to deployment of IVHS is composed of three parts in the following table:

- Private contributions to public/private partnerships for IVHS deployment and IVHS deployment costs for specific products (partnership costs)

- Proprietary private sector costs for product manufacturing

- Consumer purchase of IVHS products and systems (proprietary private sector costs are included in those costs)

Because these cost estimates are based on assumptions about market penetration, they should be regarded as only suggestive of the levels and distributions of expenditures likely to be required.

DEPLOYMENT COST ESTIMATES

Total deployment cost estimates for the three periods can be estimated by assuming gradual increases in sales of IVHS products and a matching gradual increase in public expenditure for the required infrastructure. Deployment costs totals can also be assigned to the public sector, private company, and private consumer, depending on the expenditure types and assumptions. Typical cost calculations and specific assumptions are in Appendix D.

IVHS Deployment Cost Estimates

(it is noted that the cost estimates in this table do not imply funding levels or priorities.)

Proposed Funding Responsibility	Technical Function	Near term 1992 to 1996	Mid term 1997 to 2001	Long term 2002 to 2011	Total
		Cost Estimates in Millions			
Public Sector	ATMS	985	6,231	17,725	**24,941**
	ATIS	70	415	1,511	**1,996**
	AVCS	0	200	4,120	4,320
	CVO	825	960	3,201	4,986
	APTS	225	600	2,030	2,855
Planning and Engineering for IVHS		60	130	150	340
Total Public Sector		**2,165**	8,538	28,737	39,438
Private Company Partnership with Government	ATIS	150	330	997	1,477
	AVCS	160	339	**1,299**	1,798
	CVO	150	210	775	1,135
Total Private Sector Partnership		460	879	3,071	**4,410**
Proprietary Manufacturing Costs[1]		2,716	12,890	69,588	**85.194**
Total Private Sector Company		**3,176**	**13,769**	**72,659**	89,804
Consumer Costs	ATIS	1,432	14,680	86,250	102,362
	AVCS	1,500	6,400	38,350	46,250
	CVO	2,500	4,700	14,575	21,775
Total Consumer Cost[2]		5,432	25,780	**139,175**	**170,387**
Total Deployment Cost[3]		**7,597**	**34,316**	**167,912**	209,625

Note: Estimates have not been rounded, but only second significant digit accuracy can be assumed.

1 Non-infrastructure.

2 Estimated market for M-IS products (includes private sector costs).

3 Includes public sector and consumer costs, but excludes private sector company costs, since they are included in the consumer costs.

IVHS TOTAL COST PERSPECTIVE

This $215 billion twenty-year program is one of the largest transportation programs in history. The program is different than previous major transportation programs in that it is consumer-led. Less than 20 percent of the overall cost will be public. The total public and private cost is only 1 percent of the 18 trillion dollars that will be spent on transportation in the U.S. during the same twenty-year period. Total development costs for the new program seem high at 18 to 24 percent of total cost, but most of those costs are private sector proprietary development costs covered by product sales. Public sector development costs are only 11 percent of total public cost — about what might be expected of any new public sector program. Public sector development expenditure of $5 billion will leverage $30 billion in private sector development expenditure. Similarly, the $39 billion public sector 20-year deployment investment will leverage $89 billion in private company investment. Both public and private investments are base investments. Secondary economic impact of these investments will be substantial.

20-Year Plan Estimates

	Cost Estimates in Millions					
		Private Company[1]				
Phase	Public	Joint[3] Partnership	Proprietary	Total Private (Products and Services)	Total User Market (Non-Public)	Total Program[2]
Development	5,000	1,000	30–45,000[4]	31–46,000		6,000
Deployment	39,000	4,000	85,000[5]	89,000	170,000	209,000
TOTAL	44,000	5,000	115–130,000	120–135,000	170,000	215,000

Note: Estimates rounded.

[1] Private sector costs estimates are not included in total costs since they would be counted twice with user or market estimates.

[2] Excludes private sector proprietary costs, since they are included in user costs.

[3] Private sector development and deployment costs for M-IS products with government and private sector deployment costs for specific projects.

[4] Proprietary private sector development costs for IVHS products (most non-specific.) They are assumed to be 10 to 15 percent of gross sales and are considered maximum supportable development costs.

[5] IVHS product manufacturing costs (non-public products and services).

TOP-DOWN REALITY CHECKS

The cost estimates presented represent bottom-up estimates by the technical committees and estimates of individual market penetrations and product costs. Those need to be double-checked to make sure they are realistic — a "reality check."

ISTEA RECONCILIATION

The FY91 reauthorization contains $660 million, 6-year IVHS funding for research and the Corridor programs (IVHS testing and demonstration). Annual authorization is $94 million for FY92 and $113 million/year for FY93 through FY97. FHWA's actual authorization is $234 million for FY92 ($94 million from the reauthorization plus $140 million general operating expense for IVHS activities).

Intelligent Vehicle-Highway Systems (IVHS) FY 1992 FHWA Program Budget Summary

Category	Total
1. Program support	6,678,005
2. Institutional issues program	1,500,000
3. Deployment program	7,700,000
4. ATMS	19,575,000
5. ATIS	17,150,000
6. CVO	6,100,000
7. APTS	2,500,000
8. AVCS	1,275,000
9. Additional operational tests	6,000,000
10. Automated highway system	2,000,000
11. Earmarked activities	
A. Academic institution	1,000,000
B. Accelerating planned projects	26,750,000
C. New projects	65,000,000
Total IVHS Program	163,228,005

Source: FHWA

A ramp-up period will be required during the early years of the program due to normal staffing and organizational problems. For example, FHWA is proposing an IVHS operating budget of $163 million for N92 and $178 million for N93. If FHWA continues to provide similar budgets during the 6-year ISTEA, approximately $1 billion would be allocated for IVHS development activities, in comparison to the $1.8 billion development costs estimates in the plan for the same period.

These gross estimates indicate that adequate funding should be available during the first 6 years of the program. It is federal policy to fund the activities with a 50 percent match from non-federal sources (maximum of 80 percent). State and local governments are beginning to increase funding for IVHS programs. They will be likely to have similar start-up problems and will only be able to contribute higher matching percentages toward the end of the ISTEA period. For example, the California Department of Transportation submitted a $35 million IVHS program to the California Legislature for FY92/93 after starting their program with only five hundred thousand dollars in 1986.

One serious question is then, are the IVHS budgets (federal, state, local, and private) being spent for research, development, and testing to satisfy this Strategic Plan? For those budgets established prior to this plan's adoption, the answer is to some extent no. Some projects were budgeted for implementation of IVHS systems currently available off the shelf. Those projects should be budgeted from implementation, rather than from research and development funds, since they would not benefit the IVHS development process. Another problem with the ISTEA allocation is that it places emphasis on operational testing in the early program years, instead of research and development. Much applied research needs to be done on the enabling technologies prior to field testing.

This plan and its companion tactical plan (due in September) should begin to remedy the R&D need versus actual budget problems in subsequent budget cycles.

IVHS PRODUCT MARKETS — REALITY CHECK[2]

Clearly, IVHS technologies represent an important component of future improvements in vehicle content. Along with greater comfort, performance, and conventional features, future motorists are likely to demand an enhanced ability to exchange information with the highway IVHS infrastructure and to take advantage of the improved safety options offered by remote sensing. Gauging the potential size of that market is an important undertaking for manufacturers and has implications for the proper timing and mix of infrastructure investments.

EVALUATING THE AFFORDABILITY OF IVHS[2]

The potential cost of implementing IVHS is significant. Sometime after the year 2000, IVHS could add $1000 (in 1990 dollars) to the cost of the average new vehicle. To put that in perspective, it would raise today's vehicle price by about 6 percent, and it would increase the average car payment by about $22 a month (financed over 5 years) or $26 a month (financed over 4 years). It is not a trivial expense; on a per mile basis, the cost of the technology is about half the present average gasoline cost per mile.

The increase in vehicle cost that may be associated with IVHS is constrained by the willingness of consumers to spend money on new vehicles. Spending on new vehicles has averaged 4.35 percent of GNP since the early 1960's, with no discernable trend (although there is considerable variation over the business cycle). Assuming that relationship continues, future increases in income, vehicle pricing, and volume growth provide a basis for estimating the average expenditure per vehicle that will be affordable by consumers in some future years.

In addition, vehicle cost assumptions must also account for the cost of regulations that have been passed, but have not yet gone into effect. Preliminary estimates indicate that safety and air quality regulations presently enacted into law will be likely to increase the cost of a 2001 vehicle by 10 to 15 percent. Countering the higher cost of regulations is the anticipated continued improvement in productivity and cost control in the automobile industry. Adjusted for content, vehicle prices can be expected to increase about 1 percent less than prices in general on an annual basis.

QUANTIFYING CONSTRAINTS ON IVHS EXPENDITURE

The average 1991 expenditure per vehicle is about $15,900 (in 1990 dollars — 1990$). Providing the same level of vehicle content in 2001 could be expected to cost about $14,450 (1990$), given continued improvements in manufacturing productivity. However, the 2001 vehicle price must also cover the cost of mandated safety and environmental changes. Assuming cost increases due to regulation of

12 percent, raises the price for the average vehicle about $1,750 (1990$) for a total of about $16,200 per unit. That price is based on assumptions that the next 10 years would not bring any average improvement in vehicle content, luxury, or performance beyond that required by law.

Assuming expenditure on cars and trucks at the historical average of 4.35 percent of GNP, trend growth in GNP, and industry volume of 17 million units implies that there will be about $18,700 spent (1990$), on average, per vehicle. The difference of $2,500 is what wilI be available in 2001 for consumers to increase vehicle content above 1991 levels or to increase volumes above trend. That suggests that an average per-vehicle expenditure of $500 to $1000 to add IVHS content could be supportable, as long as there is no further increase in regulatory requirements.

In fact, however, a number of proposed increases in fuel economy standards could easily require technological improvements to vehicles that would cost $2000 per vehicle, effectively using most of the potential voluntary increase in vehicle content that could be devoted to IVHS.

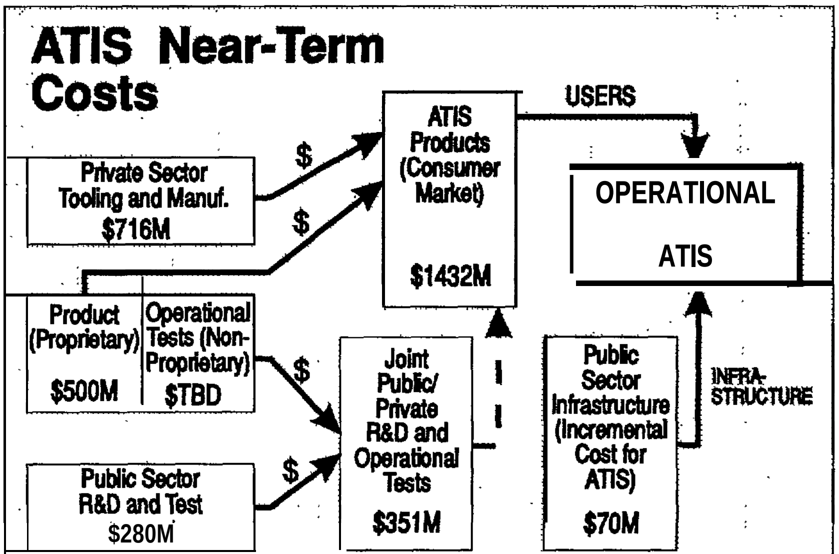
However, as noted elsewhere in this Strategic Plan, consumers will buy IVHS hardware and software if they see clear personal benefits. Reduced travel time, improved travel time reliability, enhanced mobility, fuel savings, improvements in the ease and convenience of driving, and increased safety are examples of IVHS benefits that can be translated into economic terms for consumers as well as for commercial fleets. If these private benefits of IVHS are substantial, consumers might well decide to buy an IVHS feature strictly on its economic merits, justifying the purchase on a cost/benefit basis.

In particular, consumers might choose to buy less expensive cars with IVHS, rather than more expensive cars without IVHS. Or, consumers might spend a larger fraction of income on automobiles in order to purchase IVHS, if IVHS were viewed as cost-effective solutions to their transportation needs.

Given the ongoing competition between manufacturers, consumer choice will determine the pace and extent of IVHS penetration into the vehicle fleet. This will depend on consumers' perceptions of the private benefits of the technologies, the cost of these systems, and, the ability of consumers to afford new vehicles and the additonal content.

USING THESE COST ESTIMATES

Reviewers who are interested in isolating a functional area or public or private sector estimates by function, or who want to look at the near-term estimates in more detail can do so by combining parts of the cost estimate charts in this section with the charts and spreadsheet in Appendix D.



SOURCE: Jim Rillings, Chairman, ATIS Committee

For example, the near-term ATIS estimates could be tracked as follows:

- Private sector tooling and manufacturing estimates (spreadsheet, p. D-8- estimated as one half of consumer costs) and the proprietary development costs (spreadsheet, p. D-8 — estimated as 10 to 15 percent of ATIS market) must be covered by the ATIS products market.

- Private sector R&D plus public sector R&D (from the first table in this section) are combined for the total research and development and field testing estimates.

- Public sector infrastructure cost estimates (spreadsheet, p. D-8) plus ATIS market costs (spreadsheet, p. D-8) are combined to provide an estimate of what an operational ATIS might cost.

COST ESTIMATE WEAKNESSES AND FUTURE CONSIDERATIONS

Much of IVHS is consumer goods and services, not infrastructure, and is therefore thought to be primarily in the private sector. As products and services are developed and deployed, the boundaries between what is now considered public and private may blur and there may even be role reversals. Those roles and relationships will be shaped in time, following the emergence of the systems architecture and the market studies that precede product introduction. Future revision of this plan can bring those considerations into focus. Many issues have not been fully discussed in the report, including:

- How IVHS will be marketed and by whom.

- Private sector companies not currently involved in IVHS development, but who would clearly benefit from IVHS deployment, for example, insurance companies, information entrepreneurs, and infrastructure companies.

- The extent to which public sector costs could be recovered from users of IVHS services. A key in recovering costs will be identifying and segmenting the many different markets for IVHS services.

- What parts of the infrastructure now in the public domain may be privatized during IVHS deployment.

Near-Term Actions

The "Course of Action" has detailed a wide-ranging set of tasks that constitute the IVHS Strategic Plan. This concluding section focuses on a key set of actions to be accomplished in the near-term that will provide a vital impetus to the program and ensure its success.

From R&D Through Deployment

- Provide consistent, dedicated public funding

  A dependable source of funds is essential for effective planning within DOT, as well as for administration and support of activities initiated by federal and state departments of transportation. Furthermore, consistent, predictable public funding can stimulate larger private sector investments. Funding should come from federal, state, and local governments.

- Provide resources for research and development

  Although no major scientific breakthroughs are required to accomplish stated goals, substantial R&D and operational testing are needed to develop practical systems and demonstrate their safety, effectiveness, and marketability. Resources will be needed from all IVHS participants.

- Deploy advanced transportation management centers

  Transportation management centers will contribute to the integration of traveler information services for public, private, and commercial use. A variety of public and private arrangements can be used to create and operate these centers.

- Test and deploy a prominent set of services and applications, including

  - Traveler information provided in the home, at the workplace, and at convenient public locations
  - In-vehicle safety systems
  - In-vehicle route guidance systems.

  IVHS will be accepted through the development and availability of products and services useful to the consumer. The private sector should take the initiative in devising, testing, and bringing products to market. Public and private cooperation will be needed to make systems a reality.

- Conduct operational tests for vehicle fleet operations

  Priority should be given to products and systems that promote increased productivity and more effective and safe vehicle fleet operations. All IVHS developers and users will benefit from early testing and implementation of technologies. These operational tests will be achieved through partnerships of state authorities, DOT, and fleet operators.

Integration

- Create well-defined procedures for operational tests and establish test sites

  Guidelines must be established for selecting technologies to be tested, for experimental designs and for evaluation of test results and quantification of benefits. DOT should play a primary role in establishing these guidelines, with major contributions from IVHS AMERICA technical committees.

  Specially selected sites should be identified for operational testing of alternative technologies in multi-modal applications. This can be done using medium- and long-term test projects, instrumenting test beds, and establishing a small number of shared operational test facilities.

- Develop a system architecture

  Effective integration of the various components of IVHS requires a system architecture — its design will take time and must draw from multiple disciplines. It must be an open architecture, able to accommodate different system implementations in diverse settings. The architecture should be developed largely by the private sector and academia, with requirements from the public sector, and with primary funding from DOT.

- Promote standards and protocols

  Standards and protocols play an important part in product development and in ensuring compatibility among systems. Existing organizations should be relied upon in this standards-setting effort. Existing standards should be adopted or adapted wherever possible. IVHS AMERICA should take a proactive role in defining needs and fostering the overall process.

- Define RF spectrum needs and get appropriate allocation

  Many current and proposed tests and several major applications and architectures employ radio frequency (RF) communications. RF spectrum matters often involve extensive analysis as well as political negotiation. IVHS AMERICA should coordinate efforts to define requirements and work with DOT and private industry to seek appropriate RF spectrum allocation from the FCC. Coordination with Canada and Mexico is needed for continent-wide spectrum allocation for IVHS.

Organizational Program

- Address key institutional issues. Challenges to the success of ivhs involve important institutional issues. Development of effective public/private partnerships is essential. Establishing IVHS AMERICA was a key step. Institutional arrangements should be developed for combining public and private resources in joint programs.

  Cooperation among state and local jurisdictions in the implementation and deployment of ivhs facilities is also of prime importance.

- Seek resolution of key legal issues and procurement procedures

  Several legal issues present important challenges to the success of IVHS. Special effort should be initiated now to address two of these, tort liability and privacy issues. DOT should commission studies in these areas and the IVHS AMERICA Legal Issues Committee should continue to address them.

  Government agencies should recognize the significant costs and complications for the private sector in doing business with the federal government. Changes to procurement procedures are needed to avoid undue restraint on development.

- Pursue international cooperation

  Representatives from all sectors should engage in discussions and exchange of information with international IVHS groups concerning standards, research and development, and testing. The private sector should give consideration to participating in international consortia for the development of IVHS technologies. IVHS AMERICA should continue to foster a global perspective — sharing information and seeking members from around the world.

Education and Training

- Establish university-based IVHS research and education centers

  Centers for IVHS research and education should be established in the academic community. Substantial funding should come from the federal government, with monetary and in-kind contributions from state and local governments and industry.

- Develop the human resources needed to support IVHS

  New skills are required for the deployment, operation, and maintenance of IVHS facilities. State departments of transportation and local bureaus of public works will need to provide appropriate training of existing personnel and seek different kinds of professionals.

- Inform the public about progress

It is important that the public and those responsible for and concerned with IVHS be kept fully informed about its development. IVHS AMERICA, through its publications, clearinghouse, and media relations, should report on the progress of the IVHS program.

Planning

- Update the Strategic Plan and provide advice to DOT

Significant effort in the development of IVHS is taking place and progress is rapid. IVHS AMERICA should institute a mechanism to update the Strategic Plan annually to incorporate the results of IVHS activity as well as the knowledge gained from continuing R&D, operational tests, and deployment.

- Make tactical plan recommendations to DOT

Annual program planning advice to the DOT should be provided to meet federal budgeting requirements for the next two federal fiscal years.

Endnotes

1 The information in the Rural Transportation section was developed in conjuction with CALTRANS and Montana State University, with consultation and comments from several other states.

2 This section supplied by Paul D. McCarthy, Ford Economics Office, and reviewed by MVMA for its concurrence.

APPENDICES

Appendix A. Research and Development Projects

Research and development are required to support the product evolution and deployment projected in Chapter III of this Strategic Plan. The projects listed in the integrated IVHS R&D plan presented in the following charts will supply the required support. The charts show the research projects that are required for each technical area. For each project they rate the level of applicability of that research to each IVHS area. The charts call out who is expected to provide the leadership to initiate and manage the project, and they provide the timing required for the research to be carried out, including showing how it will be phased in over the next 20 years.

'R&D is required to support the product evolution and deployment projected in Chapter III."

It should be noted that the term "project leadership" as used here means the organization that initiates the project, gets the required parties to agree to work together, and possibly manages the actual project. The project leader is not necessarily the organization that provides the majority of the funding. For example, a university (private) could define a project, initiate a consortium of industry participants, solicit funding, and then completely manage and implement the research. However, all of the funding could be provided through a research grant from some government agency. In that case, the project leader would be listed as private.

The R&D projects are classified as predominantly belonging to one of the following categories. No ranking is implied by the order.

1. Human Factors
2. Information Flow
3. Architecture
4. Communication
5. Legal and Institutional Issues
6. Socio-Economic Issues
7. Benefits Analysis (Evaluation and Prediction)
8. Software
9. Modeling and Simulation
10. Databases
11. Failure Mode Analysis
12. Safety
13. Traffic Monitoring
14. Vehicle Performance
15. Sensors
16. Planning

Throughout the Strategic P/an:

- *Near ferm means a 5-year timeframe*
- *Middle term means a 40-year timeframe*
- *Longer term means a 20-year fimeframe*

ATMS	ATI	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						1. HUMAN FACTORS			
						Driver interface: Analyze, define and quantify the human requirements for a safe and friendly interface between the driver and the vehicle. That includes:			
H	H	H	H	H	Jo	– For various types of information (for example, navigation, route guidance instructions, traffic information, in-vehicle signs, perceptual enhancements, hazard warnings), define and evaluate the benefits of various: – Display characteristics: Color, monochrome, HUD's – Formatting of information: Wording, content, density, symbols – Communication methods for information and instructions – Voice output characteristics – Sensory channel tradeoffs	A	A	
H	H	L	H	H	Jo	– Determine the best methods for providing in-vehicle sign information, including guidelines on when to use visual and auditory modalities. Quantify the benefits that are achievable to increase the safety and mobility of various special groups.	A	a	
L	H	H	H	H	Pr	- Analyze and quantify the benefits and drawbacks of various in-vehicle equipment layouts, including vehicle-to-vehicle commonality standards.	A		
M	M	M	H	H	Pr	- Analyze the benefits of various approaches to "no hands" message receipt and transmission for various types of vehicle operators.	A		
H	H	H	H	H	Jo	■ Driver education/training: Define the specific knowledge, skills, and attitudes that are required to operate various IVHS devices. Recommend how to accomplish the training most efficiently.	A	A	

NOTES: 1. Technical area ratings are: H = Strong application to this area; M = Moderate application to this area; L = Little application to this area.
2. Project LEADership: Pr = Private sector; G = Government; Jo = Joint action by private and public sectors.
3. NEAR = 5-year timeframe; MID = IO-year timeframe; LONG = 20-year timeframe.
4. Timing marks: A indicates primary Action period for the project.
a indicates a period of minimal action while building up or winding down.

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						1. HUMAN FACTORS (Continued)			
H	H	H	H	H	Jo	Driver information: Analyze driver information needs (for example, types, amounts, detail, timing) and their effects on driving performance for: – Vehicle guidance – Vehicle control - Interactions between visual and auditory sensory modes – Driver capacity to assimilate information – Route selection - In-vehicle display of roadway signs – Warnings – Vehicle condition - Driver condition (fatigue and other) – Voice communication – Motorist services (nearby hotels, restaurants, etc.)	A	A	a
						Behavioral issues: Analyze, define, and quantify each of the following:			
H	H	H	H	H	Jo	– Factors affecting the perceived benefits and risks of various IVHS products.	A	A	a
H	H	H	H	H	Jo	– Drivers' reactions to various types of instructions (for example, a warning generates a panic reaction, or an instruction generates unquestioning compliance).	A	A	a
H	H	H	H	H	Jo	- Drivers' reactions to failure modes in various types of IVHS systems (for example, in the event of temporary loss of automated control in a platooning system, will drivers revert safely to normal highway spacing).	A	A	a
H	H	L	L	H	G	– Travelers' methods and criteria for making transportation modal choices. Types of information that will influence these choices.	A		
H	H	M	H	H	G	– Travelers' perceptions of time-savings thresholds to make rerouting desirable.	A	a	
H	H	M	H	M	Jo	– Travelers' perceptions of the suitability of various types of routes.	A	a	
H	H	M	H	M	Jo	■ Factors affecting perceived risks for various types of routes.	A	a	
H	H	M	H	H	Jo	■ Types of routes that travelers perceive to take more (or less) time than actual (subjective time metrics).	A	a	
H	H	M	H	M	Jo	- Drivers' preferences for complete routing or only routing around congested areas.	A		

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						1. HUMAN FACTORS (Continued)			
H	H	M	L	H	Jo	– Drivers' methods and criteria for route and departure time selection for a trip. Types of information that will influence those choices.	A	a	
H	H	L	H	H	Jo	– Types of information that promote driver compliance with system generated routing.	A	a	
H	H	H	H	H	Jo	User demographics: Define various user groups – for example, age groups (young and elderly), physically impaired/handicapped, and alcohol or drug-impaired. For each group, define, analyze, and quantify the following: – Performance attributes – Preference and attitude attributes - Cognitive attributes - Special product requirements to enhance the utility and acceptability of the various IVHS products.	A	A	A
H	H	L	H	H	G	Traffic management centers (TMC): Analyze TMC operator information needs and the man-machine interface requirements for efficiently conveying the information to the operator. Also evaluate how those same needs apply to fleet management centers.	A	A	
						2. INFORMATION FLOW			
M	L	L	H	H	Jo	*Information exchange* requirements: Analyze information exchange between transit and commercial fleet vehicles and between fleet control centers and traffic information centers. Determine and quantify the information needs of each.	A		
H	H	L	H	H	Jo	In-vehicle signing: Analyze tradeoffs between passive & cooperative approaches to in-vehicle signing. Define the information requirements of the various approaches.	A	a	
H	H	H	H	H	Jo	Basic *information* needs: Identify and quantify the information needs of private drivers, commercial vehicle operators, traffic management centers, and fleet managers. Quantify those needs for each IVHS function.	A	a	
						3. ARCHITECTURE			
H	H	H	H	H	G	*Overall system architecture:* Perform analysis to define overall IVHS system architectures and evaluate the effectiveness, cost, performance, adaptability, reliability, fault tolerance, etc., of each.	A	A	A
H	M	M	H	H	Jo	Distributed processing: Analyze various architectures for distributed processing and control. Quantify benefits.	A	a	
H	H	H	H	H	Jo	Empircal analysis: Refine architectural concepts by comparing field test results with the analytical work.	A	A	A

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						4. COMMUNICATION			
H	H	H	H	H	Jo	Architecture: Define communication architectures and technologies for handling various IVHS tasks.	A	A	a
H	H	H	H	H	Jo	*Communication capabilities:* Analyze the capabilities of various communication technologies (RF, 1R, beacons, satellites, etc.) versus the data transmission requirements for various IVHS functions. The technologies must be assessed in terms of their performance, cost, and a variety of potential constraints, such as availability of radio frequencies, cost, size, and packaging location requirements of various components.	A	A	a
M	M	H	M	H	Jo	Vehicle-to-vehicle *communication:* Evaluate the alternative architectures and technologies for vehicle-to-vehicle communication versus the information requirements of various IVHS functions. Quantify the capability of each approach to handle each type of transmission, operate in a real-world environment, and handle various weather conditions. Determine the performance (average burst rate for data transmission, channel capacity, etc.), reliability (error tolerance), data coding requirements, and operating protocols for each approach.	A	A	a
H	H	H	H	H	Jo	Standards and protocols: Develop communications standards and protocols for the various IVHS communication tasks. Identify which areas require the early development of standards and protocols to encourage the development of low-cost standardized systems without stifling creativity. That includes: – One-way, from infrastructure to vehicle (wide area or limited area) – Two-way between infrastructure and vehicle – One-way from vehicle to either infrastructure or another vehicle – Two-way from vehicle to vehicle		A	a

A T M S	A T I S	A V C S	C V O	A P T S	L E A D	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	N E A R	M I D	L O N G
						5. LEGAL AND INSTITUTIONAL ISSUES			
						5a. LEGAL ISSUES			
						General **Analysis**			
H	**H**	**H**	**H**	H	Jo	– Legal: Analyze various types of IVHS system implementations to determine the areas in which existing laws would hinder their deployment. Define the types of hindrances that exist and quantify the level of hindrance that each presents. For major impediments, propose realistic legal changes that would remove them.	A	A	
H	H	H	**H**	H	Jo	– Communication Systems: Technical research will identify the communication needs of IVHS. This project will analyze the institutional and legal changes that have to be made in order to obtain the required frequency spectrum allocation. That allocation will be for the U.S., but it must also be coordinated with both Canada and Mexico, and it must take into account other international considerations.		A	A
						Tort Liability			
H	H	H	H	H	G	- Conduct a literature review on liability laws and tort reform.	A		
H	H	H	H	H	G	– Conduct surveys, interviews, and/or forum discussions with both large and small companies in order to identify their tort concerns.	A		
H	H	H	H	H	Jo	- Analyze liability doctrines and practices to determine if they inhibit private sector participation.	A		
H	H	H	H	H	Jo	– Make policy recommendations on which liability laws or legal practices are problems and how to resolve them.	A		
H	H	H	H	H	G	■ Review application of sovereign immunity principles to both government contractors and suppliers.	A		
						Antitrust			
H	H	H	H	H	G	– Research antitrust concerns to identify constraints in IVHS development.	A		
H	H	H	H	H	Jo	- Define appropriate roles for industry and government on delineation of pre-competitive and competitive activity.	A		
H	H	H	H	H	Jo	■ Provide guidance as to when legal counsel is needed to advise IVHS AMERICA membership at meetings.	A		

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						5a. LEGAL ISSUES (Continued)			
						Intellectual Property			
H	H	H	H	H	Jo	– Analyze the application of federal (and state) intellectual property laws and regulations and procurement requirements to the research and development programs projected for intelligent vehicles and highways. IVHS AMERICA is to monitor developments in this area, advise membership, and, where appropriate, provide advice to the federal government.	A		
						Privacy			
H	H	H	H	H	G	– Assess the impact of the present Electronic Communications Privacy Act (ECPA) on projected IVHS applications and evaluate the potential impact of proposed changes to the legislation.	A		
H	H	H	H	H	G	– Conduct surveys, opinion polls, and/or market research on public attitudes and privacy concerns and make recommendations for acceptable protection.	A		
H	H	H	H	H	Jo	– A policy statement for IVHS AMERICA needs to be developed and adopted on privacy issues and IVHS. That statement is to include a code of ethics and a set of principles that are to be considered in the design of systems, standards, tests, products, and services.	A		
						Procurement			
H	H	H	H	H	G	– Conduct studies identifying alternative models for procurement regarding technology research, development, and deployment.	A		
H	H	H	H	H	G	– Identify issues regarding conflict of interest, procurement integrity, and the development of an IVHS system architecture.	A		
H	H	H	H	H	Jo	- Develop a government architecture procurement strategy.	A		
						Regulatory Structure			
H	H	H	H	H	G	- Identify regulatory programs and agencies and assess their impact on timing and alternative courses of action.	A		
H	H	H	H	H	G	– Coordinate with other federal agencies in administering the federal IVHS effort.	A		
H	H	H	H	H	Jo	- Determine other federal agencies to which -IVHS AMERICA should act as a Utilized Federal Advisory Committee.	A		

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						5a. LEGAL ISSUES (Continued)			
						Jurisdictional *Authority to Delegate Traffic Management*			
H	H	H	H	H	G	– Conduct studies to survey laws of the states as to legal authority for local jurisdictions to delegate or participate in traffic management coordination and consolidation activities. Recommend state or federal legislation along with consideration of other approaches such as the applicability of inter-governmental agreements or compacts.	A		
						5b. INSTITUTIONAL ISSUES			
						Operational Tests			
H	H	H	H	H	Jo	– Document institutional issues in the current operational tests. – Processes by which agreements were reached on the public/private joint ventures – Document how they were structured and why – Identify lessons learned – Maintain institutional problems and successes of operational tests as part of the IVHS AMERICA Clearinghouse.	A		
						New Skills			
H	H	H	H	H	Jo	– Conduct studies to determine the new skills and institutional competencies that will be required within various organizations that will have developmental or operational responsibilities for IVHS. – Identify and document required changes in organizational structure, educational qualifications for personnel, and additional training requirements.	A		
H	H	H	H	H	Jo	■ Research and recommend improvements in the consensus process.	A		
						Private Sector Services			
H	H	H	H	H	Jo	– Conduct analysis of alternative mechanisms for private sector provision of services in the collection, processing, and beneficial use of information related to IVHS. Evaluate unregulated markets, limited competition through government issues franchise, regulated monopoly, and provision of service as a contractor to government.	A		

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						5b. INSTITUTIONAL ISSUES (Continued)			
						Users and *Customers*			
H	H	H			Jo	– Conduct national opinion and/or market research of public attitudes and concerns regarding projected deployment of various types of IVHS systems (including increased preferential treatment of HOV's).	A		
H	H	H			Jo	- Identify and analyze attitudes and concerns regarding: - Privacy -Use of new public/private arrangements -Concerns and perceptions regarding impacts on safety and congestion – Attitudes regarding the balance between public versus private responsibilities and funding – The importance of public investments in technologies – The willingness to pay taxes to support such operations – Expanded HOV priority use acceptance	A		
H	H	H			Jo	- Conduct opinion/market research studies at the local test site level.	A		
						Funding *Studies*			
H	H	H	H	H	G	– Assess the capital and operating costs of systems intended to be operated at the local level.	A		
H	H	H	H	H	G	- Assess cost-sharing alternatives among federal/state/local agencies for IVHS capital and operations costs.	A		
H	H	H	H	H	G	– Evaluate user fees or other beneficiary payment schemes.	A		
H	H	H	H	H	G	– Analyze funding alternatives and trends open to local communities.	A		
H	H	H	H	H	Jo	– Identify impediments to private IVHS R&D support and recommend ways to encourage private R&D.	A		
						6. SOCIO-ECONOMIC ISSUES			
H	H	H	H	H	G	Public acceptance: Evaluate how various individuals may react to various IVHS concepts. Consider the public's reaction to perceived inconveniences, a sense of gain or loss of personal freedom and privacy, difficulty of device use and/or understanding, increases or decreases in the enjoyment of driving, incorrect assessment of risks. Identify methods to maximize acceptance of IVHS products through public education, system design, driver training, or other means.	A	A	
H	H	H	H	H	G	*Environment* Analyze and quantify the impact that the implementation of various types of IVHS systems would have on the environment (for example, pollution and natural resources).	A	A	

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						6. **SOCIO-ECONOMIC ISSUES (Continued)**			
H	H	H	H	H	G	*Land* use. Analyze the impact of various IVHS systems on specific site locations. Quantify the benefits and drawbacks of implementing each system.	A	A	
H	H	H	H	H	G	Geographic distribution: Assess the long term effects of IVHS on growth development patterns in metro areas. Evaluate the impact on urban sprawl and moving (versus eliminating) bottlenecks.	A	A	
H	H	H	H	H	G	Collection *of fees:* Analyze and quantify the benefits (economic and acceptability) and drawbacks of utilizing IVHS technologies to collect various types of user fees (for example, in place of fuel taxes).	A	A	A
						7. BENEFITS ANALYSIS (Evaluation 81 Prediction) **Most of the following research is intended to establish what benefits would** result from various actions. That will facilitate intelligent decision making.			
H	H	H	H	H	G	*Productivity benefits:* Analyze and quantify the productivity improvements and travel time savings that are potentially achievable by using IVHS technology to make various changes in the transportation system.	A	A	
H	H	M	H	H	G	*Pre-trip information:* Analyze and quantify the benefits that are potentially achievable by employing various concepts for increasing the availability of real-time travel condition information and link times to potential transportation network users (for example, people at home who may defer travel or use public transit).	A		
H	M	H	M	H	G	**Traffic management strategies:** Analyze and quantify the potential benefits that HOV priority, traffic restraint strategies, deterministic routing of automated vehicles, and parking restrictions could provide when used in traffic management. The various conditions under which those benefits are achievable must be tied into the benefits.	A	A	
H	L	H	H	H	Jo	*Rapid response:* Analyze and quantify the potential benefits and drawbacks of various rapid incident response strategies. Those include dynamic traffic assignment technologies for private, commercial, and transit vehicles.	A		

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						7. BENEFITS ANALYSIS (Continued)			
H	H	H	H	M	G	Congestion prediction: Analyze the capabilities of various forecasting techniques to predict where congestion will occur in the near-term. Those techniques would use: Real-time origin-destination data provided by vehicle probes, traffic information from other sources, time-of-day databases, and traffic simulation techniques.	A		
L	M	H	M	M	Jo	*Vehide-to-vehicle* **communication:** Analyze and quantify the benefits achievable through direct communication between vehicles. Define the types of information that can potentially be communicated and then quantify the benefits that would be derived from each type of communication.	A	A	
H	H	H			G	High **traffic demand:** Analyze the benefits of various strategies for managing the traffic network when the demand requirements are near or exceed the capacity of the road network. Those considerations include strategies for anticipating demand, restricting flow into bottleneck areas through the use of upstream diversion, and restricting control techniques. Quantify the various approaches versus their overall effect on optimal network flow.	A	A	
H	H	H			G	Allocation of routing: Analyze and quantify the benefits and drawbacks of various approaches for partitioning the allocation of coordinated vehicle routing tasks between individual vehicles and a Traffic Management Center.	A	a	
H	H	H			G	*Benefit ramp-up:* Analyze and quantify the benefits achievable for the traffic network (congestion, incidents) and society (safety, productivity, emissions) versus the proportion of the total vehicle fleet equipped with various IVHS products.	A	A	A
H	H	H			G	Real-time *routing:* Analyze and quantify the benefits achievable by using the real-time traffic, origindestination, and routing information for planning and managing a multi-modal urban transportation system.	A	a	
M	M	H			Pr	Driver condition: Analyze various approaches (both passive and interactive) for evaluating and monitoring the drivers condition and ability to perform various tasks. For commercial vehicles, that could include pre-trip testing.	A	A	

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						8. SOFTWARE			
						Traffic management: Develop traffic management algorithms and software utilizing new approaches (for example, artificial intelligence [AI] and expert systems) for:			
H	M	M	L	M	G	Area-wide traffic control.	A	A	A
H	H	L	H	H	G	– Multiple source traffic data fusion and integration into traffic control algorithms. Include traffic probe reports, origin-destination data, manual reports, and infrastructure traffic information monitoring devices.	A	A	
H	M	H	H	H	G	- Incident detection: Develop algorithms for implementing rapid-response incident detection. Those require the integration of the latest detection technologies with software approaches to rapidly detect when an incident occurs.	A	A	
H	H	H	H	H	G	– Predictive traffic control with efficient algorithms for rerouting vehicles while traffic link travel times are continually changing. Incorporate congestion leveling employing modulation of predicted link times.	A	A	a
H	H	L	H	H	G	– Real-time demand management: Develop software algorithms for managing demand when congestion is predicted to be near or above the road network capacity. Incorporate the use of real-time origin-destination data provided by vehicle probes, traffic information from other sources, time-of-day databases, and traffic simulation techniques. Employ AI techniques. Implement strategies for anticipating demand (congestion prediction), restricting flow into bottleneck areas through the use of upstream diversion, and restricting control techniques.	A	A	a
H	H	H	H	H	Pr	Database *management:* Develop information and data management algorithms and software for each type of database that is required to perform the various IVHS functions.	A	A	
H	H	H	H	H	Jo	*Computation:* Develop algorithms and software for fault-tolerant real-time computational capability that is high speed, reliable, rugged, and low cost. Various approaches are required to handle the requirements of different IVHS functions. The software and/or firmware must be matched to the various types of hardware that will be used.	A	A	A
H	H	H	H	H	Jo	*Distributed processing:* Develop algorithms and software for various types of distributed processing and control.		A	A A
L	L	H	L	L	Jo	*Advanced vehicle control systems:* Develop algorithms for collision warning systems and for automated vehicle control.	A	A	A

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						8. SOFTWARE (Continued)			
H	H	H	H	H	Jo	Real-time vehicle routing: Develop algorithms and software for real-time routing of vehicles, providing near-minimum travel times for all vehicles in the network.	A	a	
H	H	H	H	H	Jo	Real-time traveler routing: Develop algorithms and software for real-time routing of non-private vehicle travelers, providing near-minimum travel times.		A	a
L	H	H	M	L	Jo	System safety: Develop procedures and protocols for verification and validation of safety-critical software.		a	A
H	M	H	H	H	Jo	*Driver monitoring:* Develop algorithms and software for analyzing the condition of the driver (for example, fatigue or impairment) and for taking appropriate actions (for example, driver warning or limited vehicle operation).		A	a
						9. MODELING AND SIMULATION			
H	M	H	H	H	G	Urban traffic *networks:* Develop traffic models for specific urban traffic networks that can be used to quantify the potential benefits of various IVHS strategies.	A	A	
H	H	L	M	M	G	Traffic system models: Develop traffic system models that can be used to facilitate the analysis of optimal allocation of tasks between vehicles and the infrastructure.	A	a	
L	L	H	L	L	Jo	**Vehicle/road** *models:* Develop detailed dynamic models of vehicle/road interaction to support automated highway system development.	A	A	a
L	H	H	M	M	Jo	*Driver/vehicle models:* Develop driver/vehicle models that account for lateral and longitudinal vehicle control and attention sharing among control and monitoring tasks, which can be used in the design and evaluation of proposed in-vehicle information systems and vehicle automation systems.	A	A	A
H	M	L	M	M	G	**Traffic** *modeling and dynamic traffic assignment:* Develop traffic models that can anticipate where congestion will occur and predict the effects that various control and management strategies will have on travel patterns and traffic operations. Methods will include real-time traffic simulation, area-wide and corridor optimization techniques, and dynamic traffic assignment. Basic research into new traffic flow theories and optimization techniques must also be investigated.	A	A	a

A T M S	A T I S	A V C S	C V O	A P T S	L E A D	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	N E A R	M I D	L O N G
						9. MODELING AND SIMULATION (Continued)			
H	H	H	H	H	G	*Simulator driving scenarios:* Develop a set of standardized driving simulator task scenarios.	A	A	A
L	L	H	H	H	G	*Architecture simulations:* Develop simulations to address alternative AVCS architectures (for example, vehicle motions, sensor models, signal processing, threat assessment, and vehicle control).	A	A	A
						10. DATABASES			
H	H	H	H	H	Jo	**Data** *formats:* Develop minimum requirements for uniform data distribution formatting for each of the various types of databases. This is required to facilitate ease of use.	A	A	a
H	M	H	H	H	G	*Accident statistic database:* Develop a database of national accident statistics that can be used to quantify the safety benefits of various IVHS products.	A	a	
H	L	H	H	H	Jo	*Vehicle performance characteristics database:* Develop a database of vehicle performance characteristics that can be used to identify the range of vehicle responses that must be considered in designing systems.	A	A	A
H	M	H	M	H	G	*Historical roadway information database:* Develop a database of historical roadway information related to the effects of bad weather conditions, roadway construction, and incidents on the capacity and operational characteristics of freeways and arterial highways. The information will enhance the development of traffic management software.	A	A	a
H	H	H	H	H	Jo	*Map database requirements:* Analyze, define, and quantify the requirements for a nationwide digital map database that will meet the IVHS needs of both the public and private sectors in the U.S. It should include types of data, accuracy, completeness, and currency.	A		
H	H	H	H	H	Jo	*Map database strategy:* Determine the mechanisms for creation of a digital map database that meets the previously defined requirements of both the public and private sectors.	A		
H	H	H	H	H	Jo	*Map database* **development:** Develop a nationwide digital map database that fulfills all of the public and private sector requirements previously defined.	A	a	
H	H	H	H	H	G	**Highway //n/r** *time* **database:** Develop a time-of-day link travel time database and statistics for the entire U.S. highway network.	a	A	
H	M	H	M	H	G	*Origin-destination statistics database:* Develop origin-destination statistics for traffic management purposes.	A	a	

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						11. FAILURE MODE ANALYSIS			
H	M	H	H	H	Jo	**Large** *software* **program fault analysis:** Develop methods for doing failure mode analysis on very large software algorithms.	A	A	A
H	M	H	H	H	Jo	**Large** *system* **fault analysis:** Develop methods for doing failure mode analysis on specific types of very large IVHS systems.	A	A	A
H	M	H	H	H	Jo	Soft **failure methods** Develop methods for doing failure mode analysis to determine "limp home" modes for various IVHS systems.	A	a	
						12. **SAFETY**			
L	L	H	M	H	Jo	**Fault** *tree* **analysis:** Develop fault tree analyses of safety-critical systems and subsystems and use them to identify needs for redundancy and other reliability enhancing techniques.	A	A	a
L	L	H	M	H	Pr	*Software* **safety methods:** Apply methods of design for safety-critical software developed in other fields of activity for use in IVHS.	A	A	a
L	M	H	M	H	G	**Transportation safety analysis:** Develop methods for analyzing existing transportation safety data to predict the changes in safety that would result from use of IVHS.	A	A	
L	L	H	M	H	G	*Driver perceptions:* Analyze driver perceptions regarding the suitability of and tolerance to various types of automated longitudinal and lateral control.	A	A	A
L	L	H	H	H	G	**Safety benefits analysis:** Analyze the safety benefits, including collisions avoided, lives saved, injuries avoided or reduced in severity, and property damage costs reduced.	A	A	A
H	H	H	H	H	G	*Driving simulator:* Develop a National Advanced Driving Simulator.	A	A	a
H	H	H	H	H	G	*National safety statistics:* Develop a national database for safety impact evaluation.	A	A	a
L	L	H	H	H	G	*Vehicle dynamics:* Develop advanced tools, such as variable performance vehicle testbeds, systems for assessment of baseline vehicle motion, and data gathering systems.	A	A	A
L	L	H	H	H	G	*Collision countermeasures:* Develop performance specifications for countermeasures that will augment driver capabilities in avoiding collisions, both by assisting the driver and by taking control when necessary.	A	A	A
H	H	H	H	H	G	**Driver workload:** Develop programs to acquire an enhanced understanding of such driver characteristics as effect on driver workload and driver risk compensation.	A	A	a

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						13. TRAFFIC MONITORING			
H	H	M	H	H	Jo	Traffic data formats: Evaluate various approaches for formatting and disseminating traffic information. Quantify the benefits and drawbacks of each.		A	a
H	M	H	M	M	Jo	*Traffic* monitoring sensors: Evaluate and develop sensor technologies needed for traffic monitoring. Include sensors for the measurement of traffic flow, speed, occupancy, and congestion. Possible technologies include automated vehicle identification; loop detectors; sonic, infrared, or laser systems, and wide-area detection systems using radar or video image processing.		A	a
H	H	M	H	H	Jo	vehicles *as* probes: Analyze the overall system architecture and the cost/benefit balance of using infrastructure detection versus utilizing vehicles as probes. Quantify the required percent of vehicles that must be participating for the approach to be effective.	A	a	
H	H	M	M	H	Jo	*Area-wide surveillance:* Develop methods for area-wide surveillance and detection of traffic on the transportation network. They must be accurate, reliable, inexpensive, quick, and comprehensive.	A	a	
						14. VEHICLE PERFORMANCE			
M	M	H	H	H	Pr	Vehicle performance monitoring: Evaluafe various approaches to real-time vehicle systems monitoring (including status of brakes, other mechanical systems, vehicle dynamics, etc.) and for communicating that information to drivers and/or infrastructure.		A	A a
H	M	H	H	H	Jo	*Heavy* truck *limitation notification:* Evaluate various approaches for dynamic grade severity, roadway or ramp curvature and height limitation warning systems. Quantify the benefits and drawbacks of each. Develop the most promising technologies.		A	a
H	L	H	H	H	Pr	*Vehicle* dynamic models: Develop vehicle dynamic response models (software). They must have sufficient fidelity to allow their use in the design of closed-loop vehicle control systems.		A	A

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						15. SENSORS Development of sensor technology for any specific purpose starts with a broad-scope evaluation of worldwide sensor alternatives.			
H	M	M	H	H	Jo	*Vehicle* *and* classification: Evaluate various approaches and quantify the benefits of each.	A		
L	L	L	H	L	G	Weigh-in-motion: Evaluate various approaches and quantify the benefits of each.	A		
H	M	H	M	H	Jo	**Air qualify and meteorological** conditions: Evaluate various approaches and quantify the benefits of each. These must be approaches that facilitate automated incorporation of this data into the traffic control strategies.	A		
L	L	H	H	H	Jo	**Driver performance** sensing: Selection of appropriate performance characteristics that need to be measured. Selection of sensor options. Determination of the relationships between 1) driving performance and driver characteristics and 2) driver control and vehicle response (for example, action and vehicle motion).	A	A	a
L	L	H	H	H	Pr	*Vision enhancement:* Evaluate various technologies for detection including radar (active), infrared (passive), laser (active), video (passive), glare reduction, image intensifiers, and ultraviolet. Evaluate various approaches to display the information including head-up displays. Evaluate sensor technologies, perform cost reduction studies, perform fabrication feasibility studies, and define packaging requirements. Evaluate potential modifications to the infrastructure to enhance vision.	A	A	a
L	L	H	M	M	Pr	Obstacle detection: Evaluate approaches (1) that are totally contained within the vehicle, (2) that use communication between vehicles, and (3) that use communication with the off-vehicle infrastructure. Technological approaches could include: Radar, infrared, laser (active), acoustic, and video. Evaluate each alternative for range measuring performance, angular resolution capabilities, image compression and processing, and reliability. This is to include production cost reduction efforts for the required components.	A	A	a
H	L	L	H	L	Jo	**Violation** *recording:* Evaluate image processing sensors to visually record license plates as a vehicle passes. Those will be used to automatically identify vehicles (for example, toll booth or HOV lane violators).	A	A	

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						15. SENSORS (Continued)			
L	L	H	M	H	Jo	Lane sensing: Compare the use of (I) on-vehicle obstacle and headway detection system techniques adapted to provide lane sensing to (2) the use of off-vehicle techniques such as magnets, radar targets, buried wires, reflectors, special paints, and transponders placed on the road. Evaluate the performance of each alternative and quantify its benefits and drawbacks.	A	a	
M	M	H	M	H	Pr	*Road friction:* Develop sensors that meet the IVHS requirements for measuring true ground speed and surface traction condition. Evaluate the alternative approaches for cost and applicability to each of the various IVHS uses.	A	a	
L	L	H	M	H	Pr	*Distance* **and** closing **rate** sensing: Evaluate the various approaches to distance (range) and closing rate measurements. For each approach, quantify that technology's resolution, response time, transition from long to short spacing, detection of zero closing rate, and ability to reliably operate in all weather environments.	A	A	
H	H	H	H	H	Jo	**Absolute location** Quantify the benefits and drawbacks of roadside beacons, in-pavement markers satellites, and inertial guidance systems. Performance in terms of resolution, accuracy, and reliability all need to be evaluated for each alternative.	A	a	
L	H	H	H	H	Pr	**Acceleration, velocity deflection** *and angular rate:* Develop low-cost, high-performance, high-reliability sensors for vehicle control and navigation applications.	A	a	

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX A RESEARCH AND DEVELOPMENT PROJECTS	NEAR	MID	LONG
						16. PLANNING			
H	M	H	M	H	G	*ATMS site* planning: Area-wide traffic management systems are very complex. They have many different types of enhancements and impediments that are specific to a particular geographic site. Analyze traffic management systems for various specific sites utilizing computer models of the sites to quantify the benefits and drawbacks of various traffic management approaches and features of those specific sites. Design a system that is specifically tailored to the needs of each site, but which employs the standards and protocols defined for national implementation of systems.	A	A	A
H	H	H	L	H	G	Traveler decision models: Develop planning analysis models to predict effects of information availability on traveler decision making, with consequent impacts on traffic conditions and modal choice.	A		
H	H	H	L	H	G	*Transportation sensitivity models:* Develop regional transportation planning models capable of analyzing effects of major transportation system changes, such as automated freeway systems and integrated area-wide traffic management and traveler information systems.	A	A	
H	H	H	H	H	Jo	*IVHS standards center:* Create a center for IVHS standards to serve as a national clearinghouse and resource for developing and establishing U.S. IVHS standards and protocols. It will also serve as a focal point for U.S. participation in international IVHS standards activity.	a	A	A
H	H	H	L	H	G	*Land use analysis models:* Develop regional transportation/land use integration modeling capabilities to represent effects of major transportation system changes on land use.	A	A	

Appendix B. Operational Tests

"Operational tests are the transition between R&D and the product deployment estimated in Chapter III."

Throughout the Strategic Plan:
- *Near term means a 5-year timeframe*
- *Middle term means a 10-year timeframe*
- *Longer term means a 20-year timeframe*

Operational testing is an indispensable step in the integration of newly created products and services into large transportation systems. It is the bridge between R&D and full-scale deployment, an opportunity to conduct tests in a real-world environment under "live" transportation conditions. Tests are used to integrate existing technology with R&D products and to experiment with various institutional arrangements. They also provide a chance to evaluate consumer market reception of the assorted products and services.

The integrated IVHS operational testing plan presented in the following charts provides the transition between R&D (Appendix A) and deployment (estimated in Chapter III of this Strategic Plan). The charts show the operational tests that are required. For each test, they rate the level of applicability of that test to each IVHS area. The charts call out who is expected to provide the leadership to initiate and manage the test. The charts also provide the required timing for the operational testing to be carried out, including showing how it will be phased in over the next 20 years.

It should be noted that the term "test leadership" as used here means the organization that initiates the test, gets the required parties to agree to work together, and possibly manages the actual test. The leader is not necessarily the organization that provides the majority of the funding.

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX B OPERATIONAL TESTS	NEAR	MID	LONG
M	H	L	H	M	Jo	1A. Test *Information* (e.g., navigation, route-guidance, AVL and AVI) features in rental-car fleets in representative cities across North America. That will provide human factors and preference information from a broad cross section of users in real driving situations, while giving the widest possible exposure to the public, government officials, and the press of the potential benefits of ATIS.	A		
M	H	L	H	H	Jo	1 B. Extend this test to include public service vehicles and comercial fleets, such as taxis, delivery trucks, transit vehicles, police cars, and EMS vehicles. That will permit assessment of productivity gains and mission time reductions, and will allow the exploration of information exchange between commercial and transit fleets and traffic information centers.	A	A	
H	H	M	H	H	Jo	2A. Test the use of vehicles *as* traffic probes by equipping a percentage of the vehicles in OT #1 to communicate traffic conditions automatically to a traffic information center. This will be used to test various communications technologies, to determine the fraction of vehicles that must be equipped to make the traffic probe concept viable, and to determine the effectiveness of probes for rapid incidence detection.	A	A	
H	H	M	H	H	Jo	2B. Expand the test to evaluate the partitioning *of databases and software functions* between the vehicle and the infrastructure.	A	A	
H	H	M	H	H	JO	2C. Perform a *large-scale* test of the *traffic-probe* concept making heavy use of both commercial delivery and public service vehicles.	A	A	

NOTES: 1. Technical area ratings are: H = Strong application to this area; M= Moderate application to this area; L = Little application to this area.

2. Project LEADership: Pr = Private sector; G = Government; Jo = Joint action by private and public sectors.

3. NEAR = 5-year timeframe; MID = IO-year timeframe; LONG = 20-year timeframe.

4. Timing marks: A indicates primary Action period for the project.
a indicates period of minimal action while building up or winding down.

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX B OPERATIONAL TESTS	NEAR	MID	LONG
H	H	L	H	H	Jo	3. Perform an extensive test for a *real-time traffic information, route* **guidance and Mayday** system utilizing a large fleet (e.g., 100,000 vehicles) of private, transit and commercial vehicles. With that kind of large-scale test that the real benefits to congestion, safety and security can be assessed.	A	A	
H	H	L	H	H	Jo	4A. Demonstrate **and** evaluate the benefits of extended route guidance systems that include *real-time* network *link* times computed and transmitted to vehicles equipped *for minimum-time route selec-*tion and guidance in one geographic area (e.g., the Santa Monica Smart Corridor, **Chicago,** Washington, D.C., or Western Long Island).	A	A	
H	H	L	H	H	Jo	4B. If successful, extend to additional geographic areas. Include **cooperative route selection** and traffic control management using real-time traffic assignment.		A	
M	H	L	H	L	Jo	Test low-cost systems for dissemination of available *real-time* **traffic and travel information,** for example, using a FM-subcarrier or Highway Advisory Radio (HAR) *communications* channel. Evaluate the benefits that an absolutely minimal cost system can **provide.**	A		
M	H	M	H	M	Jo	6. In vehicle signing Compare various passive and cooperative approaches with respect to cost, performance, durability, and benefits. Equip electronic road signs with transmitters and a fleet of vehicles able to receive their transmissions. Compare that with alternatives such as an on-board sign database. Also evaluate the human factors of various types of audio and visual outputs as they relate to the driver.	A		
M	H	L	M	H	Jo	7. Demonstrate and test *portable traveler information units.*	A		
M	H	L	H	H	Pr	8. Vehicle *location:* Compare the long-term utility and performance of vehicles operating with and without infrastructure-assisted location correction. Use the best performing dead-reckoning, map-matching navigation systems available. Equip several hundred vehicles.	A	A	
M	M	L	H	H	Pr	9. Test the integration of public ATIS **with** *special commercial functionality* packages, developing the interfaces required to support public and private communications, databases, and other interrelated issues.	A	A	

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX B OPERATIONAL TESTS	NEAR	MID	LONG
M	H	L	M	H	Jo	10. Demonstrate various technologies (e.g., TV, RF, or telephone) for disseminating integrated **parking** *and transit information and for toll debiting.*	A	A	
H	H	L	H	H	G	11. Demonstrate **a** *multi-modal,* **in-vehicle information** system **that** provides real-time park-and-ride, transit schedule and transit route information, and informs the driver of current conditions that warrant mid-trip mode changes.		A	
H	H	L	L	H	Jo	12. In one metro area, demonstrate a **traveler information center** which evaluates collection, coordination, and distribution of multi-*mode surface transportation information.* Evaluate the benefits of private sector involvement in providing that information.	a	A	
M	H	L	L	H	G	13A. In several metropolitan corridors, demonstrate the use of *user-friendly kiosks* at major trip locations and of *changeable message signs at* bus stops *and on buses* with heavy user loads. The kiosks should provide real-time information on bus routes and schedules linking specific locations to waiting passengers. They may be user activated by pressing appropriate buttons or areas of a touch screen. The test will be used **to** quantify the value that travelers place on various types of information and of the human factors involved. Compare the results with earlier tests, e.g., Rochester, NY and Cincinnati, OH.	A		
M	H	L	L	H	G	13B. Extend these corridors to cover an entire metro area.	a	A	
H	H	M	H	H	G	14. In a large *metropolitan area* with multiple, independent traffic management and dispatch systems, demonstrate and quantify the benefits of *integrating* the *existing systems* for area-wide, multi-modal cooperative control, thus breaking down the political and institutional barriers without adding large costs to the individual communities.	A	a	

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX B OPERATIONAL TESTS	NEAR	MID	LONG
H	H	M	H	H	Jo	15A. Demonstrate a pilot urban *Traffic Management Center* that has information and control *for* **an entire metropolitan area** (including freeways), breaking down the political and institutional barriers that restrict the cooperation required to best manage congestion and incident response. Evaluate alternative **software** *and* **hardware** *control* **approaches** (e.g., powerful computers and displays, expert and AI, and variable freeway speeds) and the viability and benefits of integrating existing traffic management system equipment.	A	A	
H	M	M	M	H	G	15B. Expand that test to demonstrate and evaluate *alternative surveillance and detection capabilities* (e.g., for accuracy, reliability, cost, response time, and completeness), including rapid incident detection. Include video image processing and other technologies.	A	A	
H	H	M	M	H	G	15C. Evaluate approaches to *controlling traffic* **at and around** *incidents and special events.* Include lane control techniques and HOV priority treatment for certain sections of highway. Quantify the effectiveness of the various approaches.	A	a	
H	H	H	H	H	G	15D. Demonstrate and evaluate *area-wide, predictive traffic control and real-time traffic routing* **assignment** approaches and techniques. Include anticipative saturated flow strategies such as upstream flow diversion and restriction.	a	A	
H	H	M	H	H	C	15E. Use the test to define and *evaluate* the various approaches and situations where *road pricing strategies* would provide benefits above those attainable with other traffic control approaches. Include a major installation in an urban area. Quantify the benefits.	a	A	
M	H	L	L	H	Jo	16A. In a single corridor, demonstrate providing **real-time** *transit* **information** to travelers *utilizing telephone* (e.g., 900 lines), **interactive** *cable* **TV, and video** *terminals* (audio-text and video-text) at home, in work places, and at high user volume trip locations. The test will be used to quantify changes in transit usage patterns and in traveler value/usage of the information provided.	A		
M	H	L	L	H	JO	16B. Expand the test to include *dynamic ride sharing and trip* **matching** *information* through the use of both audio-text and video-text. Use that to quantify customer acceptance of ride sharing and willingness to participate.	**A**		

A T M s	A T I s	A V C s	C V O	A P T S	L E A D	APPENDIX B OPERATIONAL TESTS	N E A R	M I D	L O N G
M	L	L	M	H	Jo	17A. Demonstrate the use of *electronic fare collection* employing *smart* **cards.** Use a small group of "special needs" clients, and install readers in taxis and paratransit vehicles in part of a city. The purpose of the test is to quantify the improvements that are achievable both in the operations and in the level of usage.	A		
M	M	L	M	H	Jo	17B. Expand the test to include all people in the area who wish to participate. Install readers in all regularly scheduled, fixed-route service vehicles. Additionally, expand the use of smart cards to *include* multiple uses such as *parking* **fees and phone charges. Use the** test to further quantify perceived user value and to develop a volume discount system that yields increased card usage.	a	A	
H	L	L	H	H	G	18. Test the use of various alternative approaches **to signal preemption** for various types of vehicles along several major arterial streets. Use the test to evaluate methods for reducing traffic disruptions (e.g., late buses and excessive passenger loads) and to quantify the effectiveness of the integrated use of vehicle location information and traffic management information in making dynamic adjustments to traffic signal timing.	**A**		
H	L	L	L	H	**Jo**	19. Demonstrate the *integration of electronic fare collection with third party billing* systems. Quantify changes in transit usage patterns driven by user subsidy programs, including government and social service agency programs that subsidize transit costs for special needs clients and for businesses that subsidize transit costs for their employees.	**A**		
H	H	L	H	H	Jo	20A. Demonstrate alternative *technologies for automated vehicle location and passenger counting* to evaluate the effectiveness of using this type of data to assist in both vehicle dispatching and customer information systems. Use them to quantify improvements in operations and customer information services that can be achieved by incorporating AVL and APC technologies.	**A**		
H	L	L	L	H	G	208. Expand the test to include the *integration of AVL with system-wide computer aided transit dispatching* (CAD). The CAD software should propose alternative dispatching strategies to the dispatcher in order to assist in making short-term decisions for correcting immediate operational problems in the system (such as early and late buses, bunching, and breakdowns). The test will quantify improvements achievable in operational efficiency and response time to short-term operational problems.	**a**	**A**	

ATMS	ATIS	AVCS	CVOS	APT	LEAD	APPENDIX B OPERATIONAL TESTS	NEAR	MID	LONG
H	L	M	L	H	G	21. Evaluate the effectiveness of various alternative technologies (e.g., high speed cameras and image processing) for **automatically monitoring vehicle occupancy** *levels* on actual high occupancy vehicle (HOV) lanes.	a	A	
L	L	H	H	M	Pr	22A. Test various approaches to **on-vehicle moniforina of commercial vehicle safety.** Include both vehicle operating condition and cargo safety. Define and quantify the additional benefits that can be achieved.	A	a	
M	L	H	H	H	Pr	228. Expand that test to include **driver condition monitoring**	a	A	a
L	L	H	H	M	Jo	23. In several geographic areas, demonstrate various approaches to **automated commercial vehicle roadway hazard warning.** Include grade, curvature, and road condition warnings. Evaluate **and** quantify the achievable safety benefits.	A	A	
L	L	L	H	L	Jo	24. In one or more truck corridors, demonstrate various AVI technologies as they apply to the special *needs of commercial vehicles.* Include automated (electronic) record keeping, pre-clearances, and reporting for identification, bill-of-lading, safety status, log book with mileage, permits, fuel taxes, and weights.	A	a	
M	L	L	H	L	G	25. In one state, demonstrate various approaches **to hazardous cargo** *tracking* using a combination of AVI and AVL techniques. Evaluate, define, and quantify the costs and benefits of utilizing these technologies.	A	a	
H	**M**	M	H	H	Jo	26A. Test a variety of *Automated Toil Collection (ATC) and Automated* *Vehicle identification (A VI)* techniques in a large urban area that has both single point tolls (e.g., bridges) and entry/exit tolls (e.g., highways). Evaluate technologies for both toll booth (low speed) and mainline (highway speed) collection. Evaluate and quantify the benefits achievable utilizing each approach.	A		
H	L	L	H	L	Jo	268. Test various ways to automatically classify vehicles according to various criteria relevant to toll collection and CVO applications.	A		
H	L	L	H	L	Jo	26C. Test approaches to automatically record toll or state boundary violators which do not have AVI transponders. Recording techniques must produce images of the rear license plate. Evaluate technologies for both toll both (low speed) and open road applications.	A		

ATMs	ATIs	AVCs	CVO	APTS	LEAD	APPENDIX B OPERATIONAL TESTS	NEAR	MID	LONG
H	H	H	H	H	Jo	27. Test alternative infrastructure/vehicle communications architec-tures. Alternatives should include digital cellular telephones, specialized mobile radio, FM-subcarrier (e.g., RDS), local-area and wide-area radio with dedicated frequency authorization, and ultra-short range RF or infrared electronic signposts.	A	A	
M	L	H	M	M	Jo	28A. Test various approaches and techniques for Adaptive Cruise Control in a test *track* environment with a mixture of different types of vehicles (e.g., large and compact cars, and large and small trucks). Carefully evaluate both the performance of the systems and drivers' responses to them.	A	A	
M	L	H	H	M	Jo	28B. If successful, extend the test to operate additional vehicles on both urban and rural *public roadways.*	a	A	
H	L	H	H	H	Pr	29A. Test various approaches and techniques for Roadway *Traction* Detection in a test **track** environment with a mixture of different types of vehicles (e.g., large and compact cars and large and small trucks). Carefully evaluate both the performance of the systems and drivers' responses to them.	A	a	
H	L	H	H	H	Jo	298. If successful, extend the test to operate additional vehicles on both urban and rural *public roadways*	a	A	
L	L	H	H	H	Pr	30A. Test various approaches and techniques for *Lane Departure Detection* and warning in a test *track* environment under a variety of conditions. Carefully evaluate both the systems' performance and drivers' responses to the systems.	A	A	
L	L	H	H	H	Jo	30B. If successful, extend the test to operate additional vehicles on both urban and rural **public roadways.**	a	A	
L	L	H	M	M	Pr	30C. If part A is successful, extend the test to incorporate and evaluate various Lateral *Control* approaches and technologies that incorpo-rate the best lane detection techniques.	a	A	
L	L	H	M	M	JO	300. If part C is successful, extend the test to operate additional vehicles on both urban and rural *public roadways.*		A	a
L	L	H	M	H	Pr	31A. Demonstrate various approaches and technologies for *Obstacle Detection* (front, side, and rear) and warning in a test *track* envi-ronment.	A	A	
L	L	H	M	H	Jo	31B. If successful, extend the test to operate additional vehicles on both urban and rural *public* **roadways.**	A	A	

ATMS	ATIS	AVCS	CVO	APTS	LEAD	APPENDIX B OPERATIONAL TESTS	NEAR	MID	LONG
M	L	H	M	H	Jo	32A. Demonstrate and evaluate **cooperative intersection** *collision* **warning** using vehicle-to-vehicle and/or vehicle-to-road communication in a test *track* environment. Quantify the benefits of various approaches, and the concept in general.	**a**	A	
M	L	H	M	H	Jo	32B. If successful, extend the test to a 10,000 vehicle fleet operating on *public* **roadways** in a single city.		A	a
L	L	H	M	H	Pr	33A. Demonstrate and evaluate the use of frontal obstacle detection for **automated collision detection and avoidance** *(through* **brake application)** in a test *track* environment. That will build on the results of the obstacle warning operational test.	a	A	
L	L	H	M	H	Jo	33B. If successful, extend the test to operate additional vehicles on both urban and rural *public* **roadways.**		A	A
M	L	H	M	H	Jo	34A. Demonstrate and evaluate various approaches for an *automated* **lane and vehicle following** system in a test *track* environment. The system will have manual entry and exit. The test will be used to validate the combined use of longitudinal (throttle, frontal detection, and braking) and lateral (steering and lane following) control in a stable, predictable environment. Include various types and sizes of vehicles.		a	A
M	L	H	M	H	G	34B. If successful, extend the test to operate additional vehicles on a 10-*mile stretch of isolated lane roadway* (e.g., HOV). Evaluate and quantify the benefits achievable by these systems for both autos and buses.	**a**	**A**	**a**
M	L	H	M	H	Jo	34C. Combine the **individual** vehicle control elements to develop a test of *multiple* vehicles interacting with each other, including lane changing and merging operations.	a	A	
M	L	H	M	H	Jo	34D. Extend to operations of a *fleet of automated vehicles* on a comprehensive **test facility,** including *multiple lane* freeway segments with freeway-to-freeway *interchanges.*	a	A	a
M	L	H	M	H	Jo	34E. Extend to operations on connected segments of *freeway lanes* segregated from manually controlled traffic,		a	A
L	L	H	H	H	Jo	35. Combining the results of the longitudinal and lateral control and the collision avoidance OT's, demonstrate *automated* **steer-away** *collision avoidance* in a test *track* environment.		A	a

Appendix C. Key IVHS Milestones

Key milestones for the overall deployment of IVHS systems are presented in this section. The milestones represent points in time when various IVHS products, services, infrastructures, standards, and regulations are expected to either be in widespread use or be readily available for use.

This Strategic Plan calls for a multi-billion-dollar research, development, and test program to take place during the next 20 years. That program will shape the achievement of various milestones. Therefore, milestones that are listed for years farther in the future are less certain than those for years closer to the present.

A fully integrated set of key IVHS milestones is presented in the following charts. Each milestone is described and its level of applicability to each IVHS area is rated. The charts also show when each milestone is expected to be achieved.

The milestones have been classified as predominantly belonging to one of the following categories. No priority is intended by the order.

1. Functional milestones for systems on-board the vehicle
2. Technology milestones for systems on-board the vehicle
3. Milestones for services to commercial vehicles
4. Milestones for services to travelers (provided outside of private vehicles)
5. Infrastructure support milestones
6. Milestones for standards and protocols
7. Regulatory milestones

Throughout the Strategic Plan:
- Near term *means* a 5-year timeframe
- Middle term means a 10-year fimeframe
- Longer *term* means a 20-year timeframe

This chart lists various IVHS products, services, infrastructures, standards, and regulations, and shows the timing for their widespread availability.

ATMS	ATIS	AVCS	CVO	APTS	APPENDIX C KEY IVHS MILESTONES	NEAR	MID	LONG
					1. FUNCTIONAL MILESTONES ON-BOARD THE VEHICLE:			
					Navigation systems with:			
M	H	L	H	M	· Autonomous dead-reckoning and map-matching positioning	A		
M	H	L	H	H	· Infrastructure-based positioning system receiver (for example, global positioning satellite [GPS], electronic signpost, LORAN-C) for correcting errors in dead-reckoning and map-matching	a	A	
					Route planning and guidance			
M	H	L	H	H	· Autonomous (static): Route guidance and travel information	A		
M	H	M	H	H	· Dynamic: Based on minimum travel times (and other selectable criteria), taking into account real-time information – current traffic conditions and current traffic network link travel times	a	A	
H	H	M	H	H	– Predictive: Coordinated, multi-modal planning and guidance taking into account predicted traffic conditions, traffic network link travel times, and transit schedules, as well as the actions of other vehicles and travelers in the network		a	A
					Transit vehicle (bus) guidance			
M	L	L	L	H	▪ Automated route guidance instructions	a	A	
M	L	L	L	H	· Automated schedule adherence information	a	A	
					Safety warning systems			
L	H	H	H	H	· Vehicle condition and performance monitoring (for example, tire pressure, braking ability, acceleration ability)	a	A	
H	H	H	H	H	· Traction (ice) warning	a	A	
L	H	H	H	H	· Lane departure warning	a	A	
					· Lane change and merge (side collision) warning			
L	H	H	H	H	– Autonomous	a	A	
L	H	H	H	H	– Cooperative		a	A
					▪ Longitudinal collision warning			
L	H	H	H	H	– Autonomous	a	A	
L	H	H	H	H	– Cooperative		a	A
H	H	H	H	H	▪ Intersection hazard warning (cooperative)		a	A

NOTES: 1. Technical area ratings are: H = Strong application to this area; M = Moderate application to this area; L = Little application to this area.
2. NEAR = 5-year timeframe; MID = lo-year timeframe; LONG = 20-year timeframe.
3. Timing marks: A indicates that the product or service is widely used or readily Available; the milestone has been Achieved.
a indicates periods of pilots or minimal availability.

ATMS	ATIS	AVCS	CVO	APTS	APPENDIX C KEY IVHS MILESTONES	NEAR	MID	LONG
					1. FUNCTIONAL MILESTONES ON-BOARD THE VEHICLE (Continued)			
					Safety warning systems (Continued)			
L	H	H	H	H	– Roadway hazard warning (autonomous)	a	A	
					– Heavy truck			
H	H	M	H	M	– Special road conditions (height clearance, grade, curvature)	a	A	
L	H	M	H	L	– Cargo safety	a	A	
L	H	H	H	H	- Driver condition warning	a	A	
					Driver assistance *and vehicle control systems*			
H	H	L	H	M	– In-vehicle display of road signs	a	A	
M	L	H	H	L	– Adaptive cruise control	a	A	
					■ Lateral (steering) control			
M	L	H	M	H	- Automated lane following on specially equipped lanes	a	a	A
M	L	H	M	H	– Automated lane changing		a	a
					- Automated collision avoidance			
M	L	H	H	H	– Braking	a	A	
M	L	H	H	H	– Steer away	a	a	a
M	L	H	M	H	– Prototype automated highway system demonstration to support ISTEA requirement	a	A	
M	L	H	M	H	- Automated vehicles for operation on specially equipped lanes with limited access points	a	a	A
M	L	H	H	H	- Short headway vehicle following (also called platooning)	a	a	a
					- Vision enhancement systems for:			
M	H	H	H	H	– Simple obstacles (for example, rear vision camera)	a	A	
L	H	H	H	H	– Roadway image under adverse visibility conditions (for example, night, fog, and rain)	a	A	
					Automated (electronic) vehicle identification **(AVI)**			
L	H	L	H	L	– Toll debiting	A		
L	H	L	H	L	■ Toll collection	a	A	
					Emergency (Mayday) services			
H	H	M	H	H	– Semi-automated Mayday: Cellular telephone or other communication means to summon emergency assistance	a	A	
H	H	H	H	H	– Automated Mayday: Automated vehicle location and coordinated dispatch of services using traffic information transceivers	a	a	A

ATMS	ATIS	AVCS	CVO	APTS	APPENDIX C KEY IVHS MILESTONES	NEAR	MID	LONG
					2. TECHNOLOGY MILESTONES ON-BOARD THE VEHICLE			
					Color video displays used for:			
H	H	L	H	H	· Maps, traffic information, and route guidance instructions	A		
H	H	M	H	H	– Vehicle safety information	a	A	
					Digitized and/or synthesized voice used for:			
H	H	L	H	H	· Static road sign, traffic, and other travel information	a	A	
M	H	L	H	H	– Route guidance instructions	a	A	
H	H	H	H	H	– Safety warnings		a	A
					Speech **recognition systems** (user independent) for:			
M	H	H	H	H	■ User infonation input into the systems	a	A	
M	H	H	H	H	- Controlling systems	a	a	A
					Communications			
					– One-way, from infrastructure to vehicle			
					– Wide area: AM or FM radio, RDS			
H	H	L	H	H	· Wide area traffic information	a	A	
H	H	L	H	M	· Traffic network link times	a	A	
					– Limited area: RF or 1R beacons, HAR			
M	H	L	H	H	• Geographic position	a	A	
H	H	L	H	H	· Traffic information	a	A	
H	H	L	H	H	• Road signs, road condition, and other hazards	a	A	
					– Two-way between infrastructure and vehicle			
					– Wide area: Digital mobile radio, cellular telephone			
H	H	L	H	H	• Traffic information	a	A	
H	H	L	H	H	• Vehicle's destination and congestion reporting	a	a	A
L	H	L	H	M	Various personalized information and reservation services	a	A	
					– Wide area: Digital cellular telephone			
L	H	L	H	H	· Voice information	A		
M	H	L	H	H	Data transmission	a	A	
					– Limited area: RF or 1R beacons			
H	H	L	H	H	· Vehicle's destination and congestion reporting	a	a	A
H	H	L	H	L	· Individual routing by infrastructure	a	a	A
L	H	L	H	L	. Updates of local map information	a	A	
					- One-way from vehicle to either infrastructure or another vehicle			
					– Low power transmitters for:			
H	H	H	H	H	· Other vehicle warnings (very low cost "I am here" signal)	a	A	
H	H	H	H	H	· Vehicle destination and congestion reporting	a	a	A
					– Two-way from vehicle to vehicle for:			
H	H	H	H	H	– Cooperative hazard warning	a	a	A
M	H	H	H	H	– Vehicle action warning (turning, changing lanes, stopping)	a	a	A
H	H	H	H	H	– Intersection collision warning	a	a	A

ATMS	ATIS	AVCS	CVO	APTS	APPENDIX C KEY IVHS MILESTONES	NEAR	MID	LONG
					2. TECHNOLOGY MILESTONES ON-BOARD THE VEHICLE			
					Digital databases			
					■ Digital map databases for North America, including:			
H	H	H	H	H	– General road network (geometry, names, etc.)	A		
H	H	H	H	H	– Turn restrictions and freeway signs	A		
H	H	H	H	H	– Nominal link times for the traffic network	A		
M	H	L	H	H	– General traffic signs	a	A	
					- Business directory database			
L	H	L	M	H	– Integrated with map database	A		
L	H	L	M	L	– Travel information	A		
					3. MILESTONES FOR SERVICES TO COMMERCIAL VEHICLES			
L	H	L	H	L	*Commercial vehicles*			
					– Electronic vehicle identification	A		
					– Electronic bill-of-lading	A		
					– Automated, electronic mileage recording and fuel tax reporting		A	
					– Electronic vehicle weighing while in motion	a		
					– Electronic issuing of vehicle permits	a	A	
					– Electronic driver's license	a	A	
					– Electronic cargo tracking	a	A	
					– Electronic vehicle inspection and reporting	a	A	
					4. MILESTONES FOR SERVICES TO TRAVELERS (PROVIDED OUTSIDE OF PRIVATE VEHICLES)			
					Traveler **guidance information** *services*			
					– Provided in homes and offices via telephone, radio, interactive TV, and PC's (displays and audio-text or video-text)			
					– Multi-modal transportation information			
M	H	L	L	H	· Real-time ride-sharing	a	A	
L	H	L	L	H	• Static transit routes and schedules	a	A	
M	H	L	L	H	Real-time transit schedule adherence information	a	A	
M	H	L	L	H	– Multi-modal routing utilizing current traffic and transit conditions	a	a	A
					· Provided on-board transit vehicles			
M	H	L	L	H	– Predicted actual arrival times	a	A	
M	H	L	L	H	– Traveler next stop and current stop information (voice and/or text)	a	A	
					· Provided through kiosks and changeable signs			
M	H	L	L	H	– Predicted actual arrival times	a	A	
M	H	L	L	H	– Traveler route selection assistance	a	A	

ATMS	ATIS	AVCS	CVO	APTS	APPENDIX C KEY IVHS MILESTONES	NEAR	MID	LONG
					4. MILESTONES FOR SERVICES TO TRAVELERS (Continued)			
					Traveler financial services			
					- Automated (electronic) billing (in advance or following use) for transit fares, roadway tolls, vehicle parking, and transit ticketing			
M	H	H	H	H	– Using smart cards	a	A	
M	H	H	H	H	– Allowing third party billing (for example, social services)	a	A	
M	H	H	H	H	– Providing ability for travelers to easily review and update their accounts	a	A	
					5. INFRASTRUCTURE SUPPORT MILESTONES			
					Traffic management centers to:			
					- Quickly, accurately, and reliably collect, format, and transmit:			
H	H	H	H	H	– Traffic information	a	A	
H	H	H	H	H	– Current traffic network link times	a	A	
H	L	H	L	H	– Coordinate area-wide traffic controls (signal timing and split, ramp metering, etc.) with known movement of vehicle traffic (integrated freeway and arterial control)	a	A	
H	L	H	H	H	– Coordinate automated incident detection and response	a	A	
					– Forecast near-term congestion			
H	H	H	H	H	– When and where it will occur	a	A	
H	H	H	H	H	– Coordinate control actions to eliminate predicted congestion spots by diverting and/or restricting upstream traffic	a	a	A
H	H	H	H	M	– Provide real-time, dynamic traffic routing assignment	a	a	A
H	H	H	L	H	- Collaborate all modes of transportation, jurisdictions, and traffic management functions	a	a	A
H	H	H	H	H	– Support cooperative traffic routing and control	a	a	A
H	H	H	H	H	– Manage priority treatment of special vehicles such as police, EMS, transit and HOV's	a	A	
M	M	H	M	H	– Safely manage intersections (for example, with hazard warnings for cross traffic)	a	a	A
					Traveler information centers to:			
L	H	H	L	H	– Monitor transit schedules and status	a	A	
M	H	H	L	H	– Distribute information	a	A	
L	H	L	L	H	– Manage cross-mode fee collection	a	a	A
L	H	M	L	H	– Perform dynamic, multi-modal routing analysis	a	a	A

ATMS	ATIS	AVCS	CVO	APTS	APPENDIX C KEY IVHS MILESTONES	NEAR	MID	LONG
					5. INFRASTRUCTURE SUPPORT MILESTONES (Continued)			
					Vehicle identification stations to:			
L	H	M	H	H	■ Debit and/or collect tolls	a	A	
L	H	L	H	L	■ Weigh vehicles while they are in motion	A		
L	H	L	H	L	■ Charge taxes	a	A	
L	H	L	H	L	– Verify permits	a	A	
L	H	L	H	L	– Verify bills-of-lading	A		
H	H	M	H	L	- Charge and/or collect road use taxes (replacing fuel taxes)	a	a	A
H	H	H	M	H	– High Occupancy Vehicle lanes – Automated lane use verification and enforcement	a	a	A
H	H	H	H	H	*Emergency service centers to:* - Coordinate management of emergency service vehicles	a	A	
					Information *transmitters*			
H	H	L	H	H	– Wide-area traffic and travel information broadcasting	a	A	
H	H	L	H	H	– Network of local area transceivers for traffic information	a	a	A
					Automated vehicle operations			
M	L	H	M	H	- Test track for automated highway system demonstration to support ISTEA requirement	a	A	
M	L	H	M	H	– Automated lanes with limited access points (for example, HOV)	a	a	A

A T M S	A T I S	A V C S	C V O	A P T S	APPENDIX C KEY IVHS MILESTONES	N E A R	M I D	L O N G
					6. MILESTONES FOR STANDARDS AND PROTOCOLS			
H	H	H	H	H	*Center for* **IVHS Standards** – Establish and operate	A	A	A
L	H	H	M	L	*National procedural standards for:* – Hardware and software design, **verification,** and validation	a	A	
					National standards for:			
H	H	H	H	H	– Map database content, data accuracy, and data completeness	A		
L	L	L	H	L	– Electronic fuel tax reporting: Methods and protocols	A		
M	H	L	H	H	– Commercial vehicle automated vehicle identification (AVI): Equipment and protocols	A		
L	H	H	H	H	– Automated (electronic) roadway toll collection: Equipment and protocols	A		
L	M	L	H	H	– Electronic drivers' licenses for commercial vehicle operators: Equipment and protocols	a	A	
L	L	L	H	M	– Computerized commercial vehicle permits: Equipment and protocols	a	A	
L	L	L	H	L	– Electronic reporting of commercial vehicle taxes: Equipment and protocols	a	A	
H	H	M	H	M	– Hazardous material tracking: Equipment and protocols	a	A	
H	H	M	H	H	– Roadway-to-vehicle communication	A		
H	H	H	H	H	– Two-way vehicle-to-roadway communications	A		
L	M	H	M	H	– Vehicle-to-vehicle communications	a	A	
L	H	L	L	H	- Smart Traveler information systems		A	
H	L	H	H	H	– Smart Bus information systems	A		
					7. REGULATORY MILESTONES			
L	L	L	H	L	*International commercial vehicle regulation plan*	A		
L	L	L	H	L	**International commercial** *vehicle fuel tax agreement*	**A**		
M	H	H	H	H	*international Frequency* - Spectrum allocation for the wireless communication needs of IVHS	a	A	

Appendix D. Cost Calculations

Cost calculations in this section include:

- ATMS Funding
- ATIS Funding
- AVCS Funding
- CVO Funding
- APTS Funding
- Deployment Funding

Private Sector Preliminary Deployment Cost Estimates

The cost estimates (in 1991 dollars) for private sector involvement assume that: the products will be technically feasible, the products will show adequate public benefit, and IVHS products will ultimately be marketable. The market penetration assumptions seem unrealistic to some who have reviewed the data, but conservative to others. Some feel that the estimates are a reasonable first cut.

The assumption that vehicles in 2011 will have an average of $1,000 (1991 dollars) ATIS content and about $500 AVCS content assumes a wide range of actual content, from a few dollars of standard equipment to several thousand dollars for vehicles with complete systems.

Translating marketing assumption into technology development investment required some very rough “rule of thumb” assumptions that may be totally wrong for some product manufacturers. Those estimates assume 10 to 15% of gross product sales as an estimate of maximum tolerable product development costs.

To summarize, the calculations in the appendix were made as follows:

1. Gross market penetration on new vehicle production in 1996, 2001, and 2011 for vehicle-based IVHS products was assumed. (In fact, there may be considerable retrofit potential for IVHS products.)

2. Average IVHS product content was estimated for those years.

3. The market assumptions were smoothed between market levels (see the spreadsheet on page D-S).

4. Maximum development costs as percent of gross sales were assumed.

The following simple expenditure model by Paul D. McCarthy of the Ford Economics Office (reviewed by MVMA) provides a reasonable reality check of the future ATIS and AVCS vehicle content assumptions on pages D-4 and D-S.

Simple Vehicle Expenditure Model[1] (1990 dollars)

ASSUMPTIONS

Inflation	4%
Vehicle pricing	3%
Real Annual GNP Growth[2] 1991-2001	3%
Vehicle Expenditures (as a percentage of GNP)	4.35%

$\frac{\$15{,}900\,(1.03)^{10}}{(1.04)^{10}} = \$14{,}500$	Price for 1991 content at 2001 productivity
$14,500(1.12) = $16,200	Price for 1991 content in 2001, including regulations
$\$5{,}443(1.03)^{10} = \$7{,}300$ billion	Projected 2001 GNP
$7,300(0.0435) = $318 billion	2001 vehicle expenditures
$318/.017 = $18,700	Available expenditure per vehicle in 2001
$18,700 - $16,200 = $2,500	1990 dollars available in 2001 for increased content, volume, CAFE, and new regulation

Note: All numbers are rounded.

1 These calculations provided by Paul D. McCarthy of the Ford Economics Office

2 Trend GNP is about 2.5%. 3% growth is assumed to return GNP to lrend levels by about the year 2000.

ATMS Estimates

- Assume that there are traffic signals at one-mile intervals, and that half of the connecting roads have traffic signals.
- A small site is 10 miles square and a large site is 20 miles square. The control intersections include freeway ramps, and arterial intersections.
- The infrastructure costs will likely be shared by federal, state, and local governments.

ITEM	1996	2001	2011
Site Construction:			
– Number of intersections per site	150	600	150
■ Average installation cost per intersection'	$50 K	$50 K	$50 K
– Average installation cost per site	$7.5 M	$30 M	$7.5 M
■ Average TMC and communication[3]	$15M	$25 M	$20 M
– Total (average) construction cost per site	$22.5 M	$55 M	$27.5 M
– Average number of sites constructed per year	5	20	12
■ **Average annual construction cost**	**$113 M**	**$1100 M**	$330 **M**
Corporate'	9M	93 M	78 M
Maintenance & Operation?			
– Number of sites	25	125	245
· Cost per site	$3M	$6 **M**	$5 M
· **Average annual M&O cost**	$75 **M**	$750 **M**	**$1225 M**
ATMS TOTAL YEARLY COST	$197 M	$1,943 M	$1,633 M

1 The three years were selected to illustrate funding calculations. 1996 is at the end of the near-term 5-year deployment cycle, 2001 is at the end of the mid-term 5-year cycle, and 2011 is at the end of the 20-year development cycle.

2 Intersection installation costs include controller updates, intersection controls, and rehabilitation.

3 Costs include traffic management center, CCTV video (50 cameras per site), and communications infrastructure.

4 Portions of some ATMS systems will be privately developed and operated, for example, collection and distribution of real-time traffic data. These estimates assume 5% of total ATMS cost.

5 M&O costs for new systems only. For systems that are in operation, the capital costs above will be used to update and rehabilitate existing management centers.

ATIS Estimates

- The infrastructure for the Traffic Management System gathers the information that is transmitted to the ATIS users. Therefore, ATIS infrastructure costs are minimized.

- Even though the functional capabilities of the systems are increasing, the average costs are assumed to decrease as the systems mature.

ITEM	1996	2001	2011
Corporate:			
- Number of companies (product)	100	100	100
– Average yearly design and tooling cost	$1 M	**$0.5** M	$1 M
- Number of companies (database)	8	8	
- Average database development cost	$5 M	$5 M	$056 M
■ **Total annual corporate expenditure**	**$30 M**	**$90 M**	**$108 M**
Consumer:			
- Number of vehicles purchased per year[6]	**400** K	3M	12M
- Average ATIS price per vehicle	$2 **K**	$1.5K	$1 K
■ **Total annual consumer expenditure**	**$800 M**	**$4,500 M**	**$12,000 M**
Infrastructure (Maintenance, Construction and Operations):			
- Number of ATIS sites in operation[7]	5	125	**245**
- Average M&O cost per site	$0.5 M	$1 M	**$0.67** M
- Yearly database maintenance	$2 **M**	**$4 M**	$6 **M**
■ **Total annual M&O cost**	**$14 M**	**$129 M**	**$170 M**
ATIS TOTAL YEARLY COST	**$644 M**	**$4,719 M**	**$12,278 M**

Note: Communications systems in 250 metro areas.

6 These estimates assume a 2% market penetration in 1996, gradually increasing to 75% in 2011.

7 It is assumed that the ATIS sites are essentially the same as ATMS sites. (All cities over 200,000 population by 2011.) The M/O costs are for the collection, analysis, and communication facilities used for ATIS exclusively.

AVCS Estimates

- It is assumed that some physical infrastructure modifications would be needed (not only electronics), in order to avoid over-optimism in the cost estimates.

ITEM	1996	2001	2011
Corporate:			
■ Number of companies	8	16	16
- Average yearly design and tooling cost	$4 M	$6 M	$10 M
- Total annual corporate expenditure	$32 **M**	**$96 M**	**$160 M**
Consumer:			
- Number of vehicles purchased per year	1M	4 M/0.1 M	10 M/2 M
- Average AVCS price per vehicle	$500	$400/$2000	$250 / $1500
■ Total annual consumer expenditure	**$500 M**	**$1,800 M**	**$5,500 M**
Infrastructure:			
Site Construction:			
- Miles of roadway per year	0	100	300
- Cost per mile		$2.5 M	$1.5 M
– Annual AVCS construction cost	$0 M	$50 M	$450 M
Maintenance & Operation:			
– Miles of roadway	0	100	2,500
– Average cost per mile		$0.1 M	$0.1 M
- Total yearly M&O cost	$0 M	$10 M	$250 M
· Total annual Infrastructure cost	**$0 M**	$60 **M**	$700 **M**
AVCS TOTAL YEARLY COST	$532 **M**	**$1,956 M**	$6,360 **M**

CVO Estimates

- The fleet management center costs assume that centers already exist, and thus they only require the addition of the necessary IVHS equipment.
- M&O costs are assumed to be 10% of the construction costs for the total number of sites that are in existence.

ITEM	1996	2001	2011
Corporate:			
Number of companies	30	100	100
Average annual design and tooling cost	$1 M	$0.5 M	$1 M
Total annual corporate expenditure	$30 **M**	$50 **M**	**$100 M**
Consumer:			
Number of vehicle systems purchased per year	1 M/200 K	1 M/300 K	1.5 M/500 K
Average CVO price per vehicle	$300/$2,000	$500/$2,000	$500/$2,000
Total annual consumer cost	$700 **M**	**$1,100 M**	**$1,750 M**
Infrastructure (Operation and Maintenance):			
Annual number of state electronic credential systems	50	50	25
Cost per system	$400 K/$20 M	$400 K/$10 M	$400 K/$10M
Annual number of automated ports-of-entry and weigh stations	400	500	1000
Average cost per site	$300 K	$300 K	$300 K
	$120 M	$150 M	$300 **M**
Annual number of truck-specific warning sites	20	40	100
Average cost per site	$10 K	$10 K	$10 K
	$200 **K**	$400 **K**	$1 M
Average annual construction cost	**$140.2 M**	**$160.4 M**	**$311 M**
Annual Infrastructure M&O cost	$25 **M**	$50 **M**	**$100 M**
Total annual infrastructure cost	**$165 M**	**$210 M**	**$411 M**
CVO TOTAL YEARLY COST	**$895 M**	**$1,360 M**	**$2,261 M**

Note: CVO-IVHS penetration estimates assume the entire CVO fleet. Trucks, taxis, emergency vehicles, and the like participate in IVHS. 1990 MVMA data suggests that there are now 56M trucks operating on U.S. highways, and that 5.3M were manufactured in 1990. However, only 300K of those trucks are over 10K GVW.

APTS Estimates

ITEM	1996	2001	2011
Transit Operator:			
· **Number** of APTS units purchased per year	10	50	100
- Average price per unit	$3 M	$2.5 M	$1.5 M
■ **Total annual consumer cost**	$30 M	**$125 M**	**$150 M**
Infrastructure (Operations and Maintenance):			
■ Number of sites in operation	30	150	400
■ Average cost per site	$0.5 M	$0.3 M	$0.2 M
■ **Total annual M&O cost**	**$15 M**	$45 **M**	$80 **M**
APTS TOTAL YEARLY COST	$45 **M**	**$170 M**	$230 **M**

Projected Expenditures for IVHS Deployment in the United States
1992-2011 (in millions of dollars)

6/16/92

Sector:		Public						Private Company			Private Consumer (1)			Total Public	Private (2) Partnership cost	Private (3) Proprietary Development	Private (4) Manufacturing Deployment	Total Private	Total Consumer	Total (5) Expenditure
Technology:		ATMS	ATIS	AVCS	CVO	APTS	P&E	ATIS	AVCS	CVO	ATIS	AVCS	CVO							
Near Term	1332	137	14	0	165	45	10	30	32	30	12	100	300	431	92				412	843
	1993	137	14	0	165	45	10	30	32	30	40	200	400	431	32				640	1,071
	1994	197	14	(6) 0	165	45		30	32	30	130	300	500	431	92				930	1,361
	1995	197	14	0	165	45	15	30	32	30	450	400	600	436	32				1,450	1,886
	1996	197	14	0	165	45	15	30	32	30	800	500	700	436	32				2,000	2,436
5 year subtotal:		985	70	0	825	225	60	150	160	150	1,432	1,500	2,500	2,165	460		2,716	3,176	5,432	7,597
Mid Term	1997	547	37	20	174	70	20	42	44	34	1,360	760	780	868	120				2,900	3,768
	1998	637	60	30	183	95	20	54	57	36	2,160	1,020	860	1,285	14s				4,040	5,325
	1999			40	192	120	20	66	69	42	2,940	1,260	940	1,702	177				5,160	6,862
	2000	[illegible]	[illegible]	50	201	145	30	78	73	46	3,720	1,540	1,020	2,129	137				6,280	8,409
	2001	1,943	129	60	210	170	40	90	96	50	4,500	1,800	1,100	2,552	236				7,400	9,952
5 year subtotal:		6,231	415	200	960	600	130	330	333	210	14,680	6,400	4,700	8,536	879		12,890	13,769	25,780	34,316
Long Term	2002	1,912	133	124	230	176	30	32	102	55	5,250	2,170	1,165	2,605	249				8,585	11,190
	2003	1,881	137	166	250	182	20	94	107	60	6,000	2,540	1,230	2,658	261				9,770	12,428
	2004	1,850	141	262	270	168	20	35	113	65	6,750	2,910	1,235	2,721	273				10,955	13,676
	2005	1,813	145	316	290	194	20	97	120	70	7,500	3,280	1,360	2,784	287				12,140	14,924
	2006	1,788	149	380	310	200	10	99	126	75	8,250	3,650	1,425	2,837	300				13,325	16,162
	2007	1,757	153	444	330	206	10	100	133	80	3,000	4,020	1,490	2,900	313				14,510	17,410
	2008	1,726	157	508	350	212	10	102	139	85	3,750	4,330	1,555	2,963	326				15,695	18,656
	2009	1,635	161	572	370	218	10	104	146	so	10,500	4,760	1,620	3,026	340				16,880	19,906
	2010	1,664	165	636	390	224	10	106	153	95	11,250	5,130	1,685	3,089	354				18,065	21,154
	2011	1,633	170	700	411	230	10	108	160	100	12.000	5,500	1,750	3,154	368				13,250	22,404
10 year subtotal:		17,725	1,511	4,120	3,201	2,030	150	997	1,299	775	86,250	38,350	14,575	28,737	3,071		63,588	72,659	139.175	167 912
Total:		24,941	1,336	4,320	4,386	2,855	340	1,477	1,738	1,135	102,362	46,250	21,775	39,438	4,410	30-45.000	85,194	69.604	170,387	203,825

Notes:

(1) These are product costs to the consumer - the total estimated market for the products by category.

(2) These are costs to deploy IVHS partnership agreements or work that private sector companies do to place IVHS technology into specific vehicles for production.

(3) Private, proprietary development cost varies by market size but averages 10 to 15% of the market in this estimate. The market considered is that between 1997 and five years beyond the plan period (2016). The estimate is for a $300 billion market for that period.

(4) These are manufacturing costs assumed to be 50% of consumer costs.

(5) Total expenditure is total public and total consumer combined - private sector company costs are assumed contained in the consumer cost.

(6) The assumption used here is: that AVCS is contained within the vehicles during early AVCS deployment. The only AVCS infrastructure placed during this time period is contained in test facilities and field operational tests covered under development funding.

Appendix E: Glossary

AASHTO	American Association of State Highway and Transportation Officials.
ACC	Adaptive Cruise Control. A cruise control system that maintains a safe distance from the vehicle ahead.
ACS	Automated Clearance Sensing. A CVO technology used to help large vehicles negotiate low or limited clearance objects such as bridges and viaducts.
ADIS	Advanced Driver Information Systems. Vehicle features that assist the driver with planning, perception, analysis, and decision-making.
ADVANCE	Advanced Driver and Vehicle Advisory Navigation Concept. A large-scale project being conducted in the northwestern suburbs of Chicago, ADVANCE will evaluate the performance of a dynamic route guidance system that uses vehicles to gather traffic information. Up to 5000 private and commercial vehicles will be equipped with in-vehicle navigation and route guidance systems and will serve as probes, providing real-time traffic information to the traffic information center. Processed traffic information is then transmitted to the vehicles, where it is used in developing preferred routes. The routing information is presented to the driver in the form of dynamic routing instructions.
ADVANTAGE I-75	A CVO operational test along Interstate 75, this project represents a partnership of public and private sector interests along the I-75 corridor. ADVANTAGE I-75 improves the efficiency of motor-carrier operations by allowing properly documented, transponder-equipped trucks to travel any segment of I-75 with minimal stopping at weigh and inspection stations. Most information transfer is carried out while the vehicle is traveling at mainline speeds. Once weight and truck size measurements are taken at any point along the corridor, the information is passed along to all upstream inspection points, where it is used for computerized credential checking and pre-clearances in each state. ADVANTAGE I-75 features both decentralized control and the application of off-the-shelf technology. Each state retains its constitutional and statutory authority relative to motor carriers and their operations.
AHAR	Automatic Highway Advisory Radio.
AI	Artificial Intelligence. A computer software programming technique in which a computer "learns" from past experience, allowing it to make more intelligent decisions with greater program use.

ALI	Autofahrer Leit- und lnformationssystem. A route guidance system that was tested on the German autobahn beginning in 1979 and continuing until 1982. The system was jointly developed by Blaupunkt and Volkswagen. It used inductive loops to both detect traffic and communicate with the vehicle. Equipped vehicles could transmit and receive information using the loop antennas. Testing was sponsored by the West German Government. See also ALI-SCOUT.
ALI-SCOUT	A route guidance system that uses infrared beacons to transfer navigation and route guidance information from the infrastructure to equipped vehicles. On-board displays provide the information to the driver. The system was developed in West Germany by Bosch/ Blaupunkt and Siemens. It combines features of both the Blaupunkt AL1 system and the Siemens AUTOSCOUT system. The system was extensively tested in West Berlin. See also LISB and EURO-SCOUT.
AMTICS	Advanced Mobile Traffic Information and Communication Systems. A Japanese traffic information system demonstration project under the direction of Japan's National Police Agency with support from the Ministry of Posts and Telecommunications.
ANSI	American National Standards Institute.
APC-	Automated Passenger Counting.
API	American Petroleum Institute.
APTS	Advanced Public Transportation Systems.
ARI	Autofahrer Rundfunk Information. A European traffic information broadcasting system that alerts users to tune their radios to a specific station in order to receive the traffic information transmissions. It is similar to American HAR systems.
ARTT (or ATT)	Advanced Road Transport Telematics. Also called DRIVE II, ARTT (or ATT) is the second phase of DRIVE. It will focus on field trials involving local and regional transportation agencies throughout Europe.
ASCE	American Society of Civil Engineers.
ASTM	American Society for Testing and Materials.
ATA	American Trucking Associations.
ATC	Automated (electronic) Toll Collection.
ATIS	Advanced Traveler Information Systems.

ATMS	Advanced Traffic Management Systems.
ATSAC	Automated Traffic Surveillance And Control.
Autoguide	A British route guidance system that uses infrared beacons to transfer navigation and route guidance information from the infrastructure to equipped vehicles. On-board displays provide the information to the driver. A test of the technology is being planned for a corridor between central London and Heathrow Airport.
Autoscope™	A system that uses a video camera and computer software to analyze roadway images and extract traffic flow information. It was developed by the University of Minnesota and is undergoing testing on Interstate 394 in the Minneapolis/Saint Paul area.
AVC	Automated Vehicle Classification. Used in CVO, AVC electronically identifies a vehicle's type. Using this system decreases the amount of time required at border crossings by reducing the amount of paperwork drivers have to process.
AVCS	Advanced Vehicle Control Systems.
AVI	Automated Vehicle Identification. A system that combines an on-board transponder with roadside receivers to automate identification of vehicles for purposes such as electronic toll collection and stolen vehicle recovery.
AVL	Automated Vehicle Location system. A computerized system that tracks the current location of vehicles in a fleet. It is used to assist in applications such as dispatching.
Beacon	See proximity beacon.
CACS	Comprehensive Automobile Control System. A six-year, $52 million Japanese project guided by the Ministry of International Trade and Industry (MITI). Completed in the 1970's, it established that vehicle/road information systems with dynamic route guidance could yield significant benefits.
CAD	Computer-Aided Dispatching.
CALTRANS	The CALifornia department of TRANSportation.
CARIN	CAR Information and Navigation system. Autonomous route guidance system developed by Philips Electronics.
CARMINAT	CARIN+MINerve+ATlas. A EUREKA project, that developed an in-vehicle electronic system for communication, navigation, route

guidance, and car performance monitoring. It combined features of the Philip's CARIN system (route guidance and navigation) with the information system concepts of Sagem's MINERVE and Renault's ATLAS projects. The system gains information via an RDS receiver, a CD-ROM, and various vehicle sensors.

CCD — Charge-Coupled Device, an optical-electrical sensor.

CDL — Commercial Driver's License.

CD-ROM — Compact Disc – Read Only Memory.

CIDER — Communication Infrastructure for DRIVE on European Roads. A DRIVE program with the objective of recommending the optimum communication infrastructure. It concluded that DRIVE should not have a dedicated communications infrastructure, but instead should employ a mixture of public and private networks.

CMS — Changeable Message Sign. Used in ATIS and ATMS to display real-time information to drivers.

Corridors — Parallel roadways or transportation facilities, that generally serve major metropolitan areas.

c v o — Commercial Vehicle Operations.

CVSA — Commercial Vehicle Safety Alliance.

DACAR — Data Acquisition and Communication techniques and their Assessment for Road transport. A DRIVE project, DACAR is a consortium of 11 companies from five countries organized to conduct R&D in the field of advanced data communication and acquisition technologies for RTI. Pilots are under way for infrared (850 nm), microwave (60 GHz), and inductive cable communication approaches.

Dallas North Tollway Project — An ETTM system operated by the Texas Turnpike Authority on 18 miles of urban tollway.

DART — Dallas Area Rapid Transit. A project that uses GPS, AVL and Computer-Aided Dispatching, DART is cooperating in a $17 million GPS fleet management application.

Database Standards Task Group — A subcommittee of SAE's IVHS Division. The Task Group's purpose is to develop standards for digital street map databases. That includes standardization of terms and the use of that nomenclature to facilitate evaluation and comparison of the completeness and content level of various databases.

Dead-Reckoning	Dead-reckoning is a technique that calculates the current location of a vehicle by measuring the distance and direction that the vehicle has traveled since leaving a known starting point.
DEMETER	Digital Electronic Mapping of European TERritory. A EUREKA project started by Bosch and Philips in 1986. Its objective is to create a standardized European digital road map at 1: 10,000 scale. The project has resulted in the development of GDF, a proposed standard for the acquisition and representation of the highly detailed digital map data that is required by dead-reckoning/map-matching navigation systems.
Differential correction	A technique for overcoming GPS position determination errors. A GPS receiver is placed at a precisely identified control location. The difference between the indicated GPS position and the actual position is calculated. Correction information is then broadcast for other GPS systems to use in making their position determinations.
DIME	Dual Incidence Matrix Encoded files. Computer-based map files created under contract to the U.S. Census Bureau and used for the 1980 census. The comparable files for the 1990 census are called the TIGER files.
DIRECT	Driver Information Radio utilizing Experimental Communication Technology. A Michigan Department of Transportation operational test in Wayne County, Michigan, that will deploy and evaluate various low cost methods for communicating traffic advisory information to motorists. The approaches include RDS, AHAR, HAR, AM Radio, and cellular phone. The Metropolitan Transportation Center in Detroit will collect traffic information from various sources and provide up-to-date traffic information to travelers.
DOT	Department Of Transportation.
DRIVE	Dedicated Road Infrastructure for Vehicle safety in Europe. A European Community program to find ways to alleviate road transportation problems through the application of advanced information and telecommunications technology. DRIVE has more than seventy projects, including CIDER, DACAR, IMAURO, INVAID, PAMELA, PANDORA, SIRIUS, SMART, SOCRATES, TARDIS, and VIC. The ultimate target of the DRIVE effort is to produce an integrated road transport environment (IRTE).
DRIVE II	See ARTT.
ECPA	Electronic Communications Privacy Act.

EGT — European Geographical Technologies B.V. European consortium formed to create and manage digital street map databases in Europe. Its initial focus is on defining and fulfilling the needs of traffic and transport related applications.

ENTERPRISE — Evaluating New TEchnologies for Roads PRogram Initiative in Safety and Efficiency. U.S. IVHS cooperative initiative to facilitate the rapid development and deployment of IVHS technologies. Intended to be a consortium of public and private organizations with compatible IVHS goals that will identify and exploit opportunities for cooperative ventures.

ERGS — Electronic Route Guidance System. A 1968 to 1971 route guidance project supported by the Federal Highway Administration. The system provided in-vehicle directional guidance to the driver. Although it was not implemented in the U.S, the Japanese CACS project established the feasibility of the ERGS technology.

ERTICO — European Road Transport Information and COmmunications systems. A EUREKA project with the objective of deploying systems that automatically communicate motor freight information to commercial drivers. ERTICO is a $2.7 million, three-year project to develop a common road information and communications system for motor carriers across Europe.

ETTM — Electronic Toll and Traffic Management. Uses AVI to electronically collect tolls, enabling vehicles to pay tolls without stopping at tollbooths.

EUREKA — European REsearch Coordination Agency. A European program designed to stimulate cooperative research and development between industries and governments in Europe. The EUREKA program includes projects such as CARMINAT, DEMETER, ERTICO, EUROPOLIS, PROMETHEUS, and TELEATLAS.

EUROPOLIS — A EUREKA research project to design automated road systems and develop technologies to automate driver functions while considering environmental control and fleet management. EUROPOLIS is a $150 million, seven-year project with Danish, French, Spanish, and Italian participation.

EURO-SCOUT — An infrastructure-based information, navigation, route guidance and traffic management system. Developed by Siemens, EURO-SCOUT is a derivation of the previously demonstrated ALI-SCOUT system. Like ALI-SCOUT, it also uses infrared beacons to transfer information between the infrastructure and equipped vehicles.

FAME	Freeway and Arterial Management Effort. Sponsored by Washington DOT, FAME includes the Incident Management and Integrated Systems project. Its purpose is to develop a framework for establishing and implementing an incident management system and to demonstrate the benefits of an integrated system. That will be accomplished by designing and implementing a control system for I-5 that automatically modifies arterial roadway traffic signal timings and ramp metering in response to changes in freeway conditions.
FAST-TRAC	Faster And Safer Travel through Traffic Routing and Advanced Control. A demonstration project that integrates ATMS and ATIS, FAST-TRAC utilizes the SCATS adaptive, coordinated traffic control system with video image processing for vehicle detection and is linked with the Siemens's ALI-SCOUT technology.
FCC	Federal Communications Commission for the U.S.
FHWA	Federal Highway Administration. A branch of the U.S. Department of Transportation.
FTA	Federal Transit Administration. A branch of the U.S. Department of Transportation.
GDF	Geographic Data Format. A transfer file specification for digital roadway and topological map databases produced by Bosch and Philips under the DEMETER project of DRIVE. The format includes specifications for database encoding.
Geocode	A code representing a political or geographic unit (for example, a city, county, or zip code area) incorporated into a GIS.
Geodetic Coordinates	A system of geographic position referencing. Angular measurements of latitude and longitude are projected onto a well-defined reference ellipsoid that approximates the earth's irregular shape.
GIS	Geographic Information System. A computerized data management system designed to capture, store, retrieve, analyze, and report geographic and demographic information.
GPS	Navstar Global Positioning System. A government-owned system of 24 earth-orbiting satellites that transmit data to ground-based receivers. GPS provides extremely accurate latitude and longitude ground position in WGS-84 coordinates. However, for U.S. strategic defense reasons, deliberate error (called selective availability) is introduced into the code that is provided for civilian users.
GSM	Groupe Speciale Mobile. European digital cellular radio standard.

HAR — Highway Advisory Radio. A traffic information broadcasting system used in the U.S. Drivers are alerted to tune their car radios to a specific channel in order to receive transmitted information. HAR is similar to the European AR1 system.

HAZMAT — HAZardous MATerial(s).

HELP — See HELP/Crescent.

HELP/Crescent — Heavy vehicle Electronic License Plate program. CRESCENT is a demonstration project within the HELP program. It includes a multi-state, multi-national research effort to design and test an integrated, heavy vehicle monitoring system using AVl, AVC, and WIM technologies. The project will take place along I-10 and I-20 from central Texas, west through New Mexico, Arizona, and California to the greater Los Angeles area, then north along I-5 through California, Oregon, and Washington to the international border, continuing into British Columbia along portions of both the trans-Canada and Alaska highways. Data will eventually be monitored at more than 30 locations.

HOV — High Occupancy Vehicle. Any vehicle — bus, van, car — with multiple riders. An HOV lane refers to a roadway lane reserved for use by HOV's.

HUD — Head-Up Display. A type of display that projects information in front of the user.

HUFSAM — Highway Users Federation for Safety And Mobility. A Washington-based coalition of 400 corporate and association members (plus some 2,000 individual members) with affiliated groups in each state and 14 regional offices around the country. Its main goal is to serve the common interests of business and industry in advancing highway transportation safety and efficiency. HUFSAM was instrumental in the formation of IVHS AMERICA. The Highway/Vehicle Technology Committee of HUFSAM, composed of representatives from major U.S. transportation companies, has been charged with identifying the value of IVHS and defining how such systems can be effectively utilized.

IBTTA — International Bridge, Tunnel and Turnpike Association.

IDEAS Program — Program for Innovations Deserving Exploratory Analysis.

IEC — International Electrotechnical Commission.

IEEE — Institute of Electrical and Electronics Engineers, Inc. A professional society and standards-making body, IEEE is composed of some 30 individual societies, including the Computer Society and the Vehicular

Technology Society. It has established an IVHS Standards Coordination Committee.

IFTA — Interstate Fuel Tax Agreement.

IMAURO — Integrated Model for the Analysis of Urban Route Optimization. A DRIVE project for developing dynamic traffic simulation models for small urban areas. The models will account for behavioral changes arising from information received and will incorporate the effects of various types and penetration levels of RTI installations. The models are expected to be powerful tools for evaluating various RTI approaches from the viewpoints of road safety, transport efficiency, and environment.

INF-FLUX — A French vehicle guidance project that combined a commercial infrastructure-based route guidance system with RDS communication of traffic data. The project was promoted by a consortium that included Urba 2000 (a group made up of several government ministries and individual operators such as CGE), CGA-HBS, Siemens, CGE (Compagnie Des Eaux), and the City of Paris. It may be integrated with SIRIUS in the future.

INFORM — INFORmation for Motorists. A computerized traffic management and information system operated by the NY State DOT in the highly congested Long Island Corridor. INFORM gathers traffic information from roadway sensors, processes it, and then communicates it to motorists using variable message signs and commercial radio broadcasts. It also adjusts traffic signals and entrance ramp metering signals in response to current traffic patterns. It has $30 million of funding.

INMARSAT — INternational MARitime SATellite organization.

INRETS — National Institute for REsearch in Transportation and related Safety, a French institute.

Intelligent Vehicle-Highway Systems Act of 1991 — IVHS Act. Included in the ISTEA, this act proposes the establishment of a national IVHS program to include evaluation and implementation of IVHS technologies; development of standards; establishment of an IVHS information clearinghouse; utilization of advisory committees (one of which is IVHS AMERICA); and funding of an IVHS research, development, and testing program.

INVAID — INtegration of computer Vision techniques for Automatic Incident Detection. A DRIVE project for the use of computer vision techniques in automatically detecting traffic incidents on both motorways and urban roadways.

In-Vehicle Signing	On-board display of roadside sign information. The information can be obtained either by short-range transmission from roadside beacons or from on-board data storage. In-vehicle signs are utilized to improve driver effectiveness, especially when driving at night or during inclement weather conditions.
IR	Infrared.
IRP	International Registration Plan .
IRTE	Integrated Road Transport Environment.
ISATA	International Symposium on Automotive Technology and Automation. A yearly symposium held in Florence, Italy.
ISO	International Standards Organization.
ISTEA	Public Law 102-240, Dec. 18, 1991 (H.R. 2950 [early Senate version, S 12041). The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 provides the primary federal funding for highway programs in the U.S. It contains the Intelligent Vehicle-Highway Systems Act of 1991 (Title VI, Part B).
ITE	Institute of Transportation Engineers, an international scientific and educational association. ITE's 10,000 members are transportation professionals — from over 70 countries — who are responsible for the planning, design, and operation of surface transportation systems.
ITU-Region II	International Telecommunications Union-Region II (consists of North America, Central America and South America).
IVHS	Intelligent Vehicle-Highway Systems.
IVHS AMERICA	Intelligent Vehicle Highway Society of America. A nonprofit, public/private scientific and educational corporation that is working to advance a national program for safer, more economical, energy efficient, and environmentally sound highway travel in the U.S. IVHS AMERICA is a utilized federal advisory committee for the U.S. DOT.
JSAE	Japanese Society of Automotive Engineers.
JSK Foundation	Japanese Association of Electronic Technology for Automotive Traffic and Driving.
LCD	Liquid Crystal Display
LED	Light Emitting Diode

LEO	Low-Earth Orbit satellite system. A system that uses satellites positioned in low-altitude earth orbits to provide inexpensive, low frequency, low power positioning and two-way messaging services.
Liaison Council for IVHS/RTI Japan	A council formed by representative members of the IVHS community in Japan to smoothly carry out information interchange inside and outside of Japan. Membership includes personnel from the Japan Traffic Management Technology Association, the Highway Industry Development Organization, and the Association of Electronic Technology for Automotive Traffic and Driving (JSK Foundation).
Lincoln Tunnel	Location of an ETTM system operated by the Port Authority of New York and New Jersey, in which 2800 buses are equipped with AVI tags.
LISB	Leit- und Information System Berlin. A full-scale trial of the ALI-SCOUT system that was conducted in West Berlin. The trial was completed in 1991, but the system remains operational. The project was carried out by Bosch/Blaupunkt and Siemens with funding from the West German government and the Senate of West Berlin.
LORAN-C	Land-based radio navigation system operated by the U.S. Coast Guard as a public service. This hyperbolic system uses signals broadcast from land-based radio towers.
Map-matching	A technique to enhance and correct in-vehicle dead-reckoning. Computer software follows the progress of the vehicle through an on-board digital map and matches the dead-reckoned estimate of the current position to the closest point on the map in order to correct for accumulated sensor errors.
MDTRS	Mobile Digital Trunked Radio Systems. A standard for pan-European public and private digital trunked mobile voice and data networks.
MITI	Japan's Ministry of International Trade and Industry.
MM1	Man-Machine Interface (or Interaction). The interface between the system hardware and the person who is using the system. This general term includes touch (for example, buttons, levers, or touch screens), vision (such as lights or various displays), and auditory effects (such as chimes, beeps, voice synthesis, and voice or speech recognition).
Mobility 2000	An informal assembly of government agencies, automotive companies, electronics suppliers, communications companies, large fleet operators, universities, and private individuals. Mobility 2000 served to define and promote IVHS in the late 1980's.
MPO	Metropolitan Planning Organization.

MVMA	Motor Vehicle Manufacturers Association.
NeGHTS	Next Generation Highway Traffic Systems. A Japanese program that is directed by the Ministry of Construction, NeGHTS is a spinoff of the RACS program. It begins development of the next generation of infrastructure-related vehicle-highway communication technologies and systems.
NHTSA	National Highway Traffic Safety Administration. A branch of the U.S. Department of Transportation that focuses on safety and standards.
NIMC	National Incident Management Coalition. NIMC was created to serve as a focus for consensus-building, and for promotion and wider implementation of incident management programs. Sponsors include AASHTO, American Trucking Associations, and FHWA.
NTIA	National Telecommunications and Information Administration of the United States.
NVF	New Vehicle Fleet. All of the new vehicles sold in the United States during a particular year.
OBC	On-Board Computer.
Oklahoma Turnpike System	An ETTM system that was installed in January 1991; it has dedicated lanes that can handle all classifications of vehicles.
OS	Ordinance Survey. British mapping agency that is equivalent to the USGS in the United States.
OST	Office of the Secretary of Transportation for the U.S. Department of Transportation.
PAMELA	Pricing And Monitoring ELectronically of Automobiles. A DRIVE project that is investigating two-way microwave communications between vehicles and roadside equipment. Its purpose is to facilitate automated toll collection that does not require vehicles to stop.
PANDORA	Prototyping A Navigation Database Of Road-network Attributes. A digital mapping project of DRIVE, this is one of two DRIVE projects under way to test GDF. The project will develop a comprehensive digital map for a 7000 square km trial area between Birmingham and London. It integrates road network geometry and street name data from the Ordinance Survey with traffic-related attributes from the Automobile Association. It will confirm the correctness of the integrated data through field trials of CARIN and TravelPilot systems.

PATH — Programs on Advanced Technology for the Highway. More recently referred to as Partners for Advanced Transit and Highways. PATH is a California state-wide program of IVHS research, development, testing, and evaluation headquartered at the University of California/ Berkeley's Richmond Field Station. It is sponsored by the California DOT.

Pathfinder — An operational test of an in-vehicle urban freeway navigation and information system. Sponsored by CALTRANS, FHWA, and General Motors, it is being carried out in conjunction with the development of a Smart Corridor in the Los Angeles area.

PEGASUS — PEople, Goods And Services Urban Systems., A concept for incorporating demand-responsive traffic management with advanced traffic control. PEGASUS was developed by the Texas State Department of Highways and Public Transportation.

Platooning — The technique of electronically coupling vehicles together in small groups that follow a lead vehicle. It generally refers to high-speed, high-density travel on limited access highways under the control of AVCS.

Predictive Data Fusion — A technique for processing real-time traffic information.

PROMETHEUS — PROgraMme for a European Traffic system with Highest Efficiency and Unprecedented Safety. A EUREKA project, PROMETHEUS is primarily a private sector initiative aimed at developing a uniform European traffic system that incorporates IVHS technology.

Proximity beacon — A short range transmitter of radio, microwave or infrared location-coded signals. It can also be used as a communication link for traffic information, road sign information, and other localized information.

PVS — Personal Vehicle System. A Japanese program coordinated by the Ministry of International Trade and Industry (MITI).

Q-Free — An ETTM system operating in Norway, Q-Free uses a camera system for enforcement and has passive AVI tags.

Quad Sheets — A series of maps produced by the U.S. Geological Survey and available to the general public. The entire United States is included.

RACS — Road/Automobile Communication System. An experimental Japanese ATMS effort being carried out under the direction of the Ministry of Construction. RACS was integrated with AMTICS to form the VICS program.

R&D — Research and Development.

RDS	Radio Data Systems. An information transmission system that was defined by the European Broadcasting Union.
RDS-TMC	Radio Data Systems incorporating a Traffic Message Channel.
Roadside Beacon	See proximity beacon.
Route Guidance Database	The detailed information that is required to enable a computer to generate a high quality driving route between two locations. The information includes items such as road geometry, street names, addresses, speed limits, turn restrictions, one-way restrictions, road levels, and roadway connections.
RSPA	Research and Special Programs Administration. A Branch of the U.S. Department of Transportation.
RTA	A Regional Transit Authority.
RTI	Road Transport lnformatics.
SAE	Society of Automotive Engineers.
SAGACE	An in-vehicle information system that was developed by SAGEM for the CARMINAT project. It provides traffic-related information — such as parking availability — and on-board vehicle diagnostics. Information is relayed to the vehicle via RDS.
SCANDI	Surveillance, Control, ANd Driver Information System. A Michigan DOT program started in 1978 that now covers parts of four Detroit freeways. Surveillance from a traffic operations center is accomplished via video cameras and traffic detector loops. Variable message signs provide drivers with delay/backup warnings, locations of accidents, suggested bypasses and alternative routes, parking availability, and other information as warranted. Beginning in 1991, SCANDI operations will be managed from the Metropolitan Transportation Center, which will also be used to monitor future IVHS projects.
SECFO	The Systems Engineering and Consensus Formation Office of DRIVE.
Selective Availability	A technique of deliberately introducing inaccuracy into GPS broadcasts for civilian applications.
SHRP	Strategic Highway Research Program. A $35 million research program for highway materials, pavement performance, structures, and operations. SHRP is funded by the FHWA and AASHTO and is administered by the TRB.

SIRIUS

1. Systeme Integre de Regulation et d'Information des Usagers. A French ATMS system operating in Paris that integrates traffic data collected by loop detectors and video cameras. The system will detect incidents and formulate responses. It also serves as a test bed for studying driver responses to improved information and for refining the application of image analysis in traffic monitoring. The principal objectives of SIRIUS are improvements in road safety and in rush-hour and yearly vacation traffic movement. Regional and central governments contributed $130 million to initiate this program, which may be integrated with INF-FLUX.

2. Socio-political Implications on RTI Implementation and Use Strategies. A DRIVE project to identify sensitivities that affect (positively or negatively) RTI implementation and to identify the socio-political impacts of RTI adoption. This information will aid in making recommendations for introduction and phasing-in of RTI policies in various European communities.

SMART

A DRIVE project aimed at developing an intelligent information carrier (such as Smart Card) for use in various transportation applications and to develop specifications for the most promising applications.

Smart Card

An electronic information carrier system that uses plastic cards — about the size of a credit card — with an imbedded integrated circuit that stores and processes information.

SMART Corridor

The SMART Corridor is a joint demonstration project located along 12.3 miles of the Santa Monica freeway corridor in Los Angeles. The objectives of the project are to provide congestion relief, reduce accidents, reduce fuel consumption, and improve air quality. Those will be accomplished using advanced technologies to advise travelers of current conditions and alternate routes (using communication systems such as HAR, CMS, kiosks, and tele-text), thereby improving emergency response and providing coordinated inter-agency traffic management.

SOCRATES

System Of Cellular RAdio for Traffic Efficiency and Safety. A DRIVE project that is developing techniques for using GSM digital cellular radio as the basic communication medium for dynamic route guidance within IRTE. SOCRATES, the largest of all DRIVE projects, concluded with the West Sweden Field Trial in 1991.

SSVS

Super-Smart Vehicle Systems. A Japanese program coordinated by the Ministry of International Trade and Industry. The project emphasizes driver control assistance. It includes systems for accident recognition and avoidance and systems for other direct aids to vehicle operation.

TARDIS Traffic And Roads-Drive Integrated Systems. A DRIVE project to establish common functional requirements for systems that are not wholly vehicle-based and that depend on communication between vehicles and a roadside infrastructure. It includes investigating the possibility of combining communication for route guidance with that for automated toll debiting. It also plans to specify the functional requirements of the IRTE in order to provide a common framework for technical developments.

TELEATLAS A Dutch and Belgian EUREKA project for developing and electronically publishing digital map databases that include geographic and economic information together with traffic-related information.

Teletrac An AVL system undergoing operational testing by Los Angeles Rapid Transit. Teletrac provides vehicle locations for emergency vehicles, corporate vehicles, and stolen vehicle tracking systems. Communication is limited to location and vehicle status information.

TIGER Topologically Integrated Geographic Encoding & Referencing files. Computer-based map files created for the Census Bureau in support of the 1990 census. They contain DIME file data augmented with information for new suburbs and small cities (as of 1987) that were not included in the DIME files.

TMC
1. Traffic Management Center.
2. Traffic Message Channel. See RDS-TMC.

Trafficmaster Trafficmaster is a General Logistics PLC information system for drivers. It is licensed under the United Kingdom's 1989 Road Traffic Act, and has been in operation since September 1990. The system is installed on Britain's M25 London Orbital Motorway and interconnecting motorways within a 35-mile radius of central London.

TRANSCOM TRANSportation operations coordinating COMmittee. TRANSCOM is a consortium of 14 transportation and public safety agencies in the New York and New Jersey area. Its goal is to improve inter-agency response to traffic accidents. In order to accomplish that goal, a cooperative ETTM effort has been initiated for managing a heavily traveled corridor between northern New Jersey and New York City. The project will equip approximately 1,000 commercial vehicles with electronic transponders. Readers will be placed at selected tollbooths to provide automated toll collection for equipped vehicles, Additional readers will allow transponder-equipped vehicles to serve as traffic probes. The test will evaluate the use of this data to determine real-time traffic information such as speed, travel time, and the occurrence of incidents.

TravTek — Travel Technology. A public/private partnership involving the City of Orlando, the Florida DOT, FHWA, General Motors, and the American Automobile Association. TravTek provides traffic congestion information, motorist services ("yellow pages") information, tourist information, and route guidance information to drivers of vehicles that are equipped with TravTek in-vehicle systems. The route guidance that is provided reflects the real-time traffic conditions in the TravTek network A Traffic Management Center obtains traffic congestion information from various sources, integrates the data, and then provides the integrated information, via digital data broadcasts, both to the TravTek vehicles and back to the various data sources.

TravelPilot — An enhanced version of the Etak Navigator system that was developed by Bosch/Blaupunkt. TravelPilot uses a CD-ROM for map data storage. The system is used in both the PANDORA and Pathfinder projects.

TRB — Transportation Research Board. Under the direction of the National Academy of Science's National Research Council, TRB serves to stimulate, correlate, and make known the findings of transportation research.

TSWS — Test Site West Sweden. TSWS is a test site in the Gothenburg, Sweden area that is the primary test bed for SOCRATES. Operated by the Swedish National Road Administration, it provides a systems environment for testing RTI products and systems in a realistic traffic context. Testing has included in-vehicle signing systems and automated toll debiting.

TTI — Technology Transfer Institute. TTI was established as a private company in 1969 in order to develop international cooperation in the fields of science and technology. It is affiliated with the Japan Technology Transfer Association.

TWC — Two-Way real-time Communication. TWC is used to transmit information and guidance from the infrastructure to vehicles and vice versa. Various methods are being considered and/or tested. Those include RDS-TMC, infrared beacons (ALI-SCOUT), and GSM cellular telephone systems (SOCRATES).

ULIISE — French version of EURO-SCOUT.

UMTA — Urban Mass Transportation Administration. Former name of the U.S. Federal Transit Administration.

USGS — United States Geological Survey.

VIC — Vehicle Inter-Communication. A DRIVE project that is utilizing a "top-down" approach to specify requirements and protocols for real-time vehicle-to-vehicle communication — such as that required for certain AVCS applications.

VICS — Vehicle Information and Communication System. A Japanese IVHS program. It is a combination of RACS and AMTICS and is overseen by the Japanese Ministry of Posts and Telecommunications.

VORAD™ — Vehicle On-board RADar. A vehicle detection and driver alert system that uses a low-power radar unit. The VORAD system is being tested in 2,400 Greyhound buses, with U.S. DOT participation in evaluation of system performance and effectiveness.

VRC — Vehicle/Roadside Communications.

WARC — World Administrative Radio Conference.

WAVM — Wide-Area Vehicle Monitoring.

WGS-84 — World Geodetic System 1984. A widely accepted, standardized system of geodetic coordinates of latitude and longitude. The system is used by the Navstar Global Positioning System (GPS).

WIM — Weigh-In-Motion. A technology for detennining a vehicle's weight without requiring it to stop on a scale. WIM uses automated vehicle identification (AVI) to identify the vehicles, employs technologies that measure the dynamic tire forces of the moving vehicle, and then estimates the corresponding tire loads for a static vehicle.

NOTE: Valerie Shuman of SE1 Information Technology provided a document that solidly contributed to the formation of the Glossary.

APPENDIX F: IVHS AMERICA Organizational Membership List

Abratique & Associates
Alpine Electronics Manufacturing of America, Inc.
ALTA Technology, Inc.
Allied Signal
American Association of Motor Vehicle Administrators (AAMVA)
American Association of State Highway and Transportation Officials (AASHTO)
American Automobile Association (AAA)
American Consulting Engineers Council
American Council of Highway Advertisers
American Honda Motor Co., Inc.
American Public Works Association
American Telephone & Telegraph (AT&T)
Ameritech Mobile Communications, Inc.
AMTECH Corporation
Ann Arbor Transit District
Arizona Department of Transportation
Association of Electronic Technology for Automobile Traffic and Driving (JSK)
AT/COMM, lNC.
Autostrade SPA (Italy)
The ATA Foundation, Inc.
AWA Traffic Systems America
Michael Baker Jr., Inc.
Barton-As&man Associates, Inc.
Battelle
Bell Atlantic Mobile Systems
Bosch Corporation
British Columbia Ministry of Transportation & Highways
BRW, Inc.
California Department of Transportation
Cambridge Systematics
Castle Rock Consultants (CRC)
Center for Urban Transportation Research (University of South Florida)
CERT — Centre d'Etudes de Recherches de Toulouse (France)
Charles River Associates Inc.
Chrysler Motors
City of Anaheim, California
City of Atlanta, Department of Public Works
City of Irvine, California
City of New York Department of Transportation
Clarion Corporation of America
COFIROUTE (France)
Colorado Department of Transportation
Command Systems Group, Inc.
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Computer Communications and Graphics (CCG) Associates, Inc.
Computer Methods Corporation (CMC)
Computran Systems Corp.
Comsis Corporation
Control Technologies, Inc.
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Cubic Toll Systems
Cue Network Corporation
Danish Ministry of Transport
Delaware Transportation Authority
DKS Associates
Edwards & Kelcey, Inc.
ENO Transportation Foundation
ETAK, Inc.
Farradyne Systems, Inc.
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Fiberoptic Display Systems
Florida Department of Transportation
Ford Motor Company, Inc.
Frederic R. Harris, Inc.
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Fujitsu Ten Liited
Galaxy Microsystems, Inc.
GEC Traffic
Geico Philanthropic Foundation
General Motors Corporation
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George Mason University
Georgia Institute of Technology
GTE
Harris Corporation
Haugen Associates
Highway Industry Development Organization
Highway Users Federation
Hyundai America Technical Center, Inc.
Ian Catling Consultancy Liited (United Kingdom)
IBI Group
Illinois Department of Transportation
IMRA America, Inc.
Indiana Department of Transportation
INRETS (France)
Institute of Transportation Engineers (ITE)
Institute of Transportation Studies/Partnership for Advanced Transit and Highways (PATH), University of California Berkeley
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Inter-metrics, Inc.
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International Municipal Signal Association
Iowa State University
IVHS Technologies, Inc.
Japan Traffic Management Technology Association (Japan)
Jet Propulsion Laboratory
JETRO New York
JHK & Associates
Kentucky Transportation Cabinet
Kessman & Associates
Kiewit Network Technologies, Inc.
Kiiey-Horn and Associates, Inc.

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KSI
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Lee Engineering, Inc.
Leica Technologies, Inc.
Lockheed Information Management Services Company
Los Angeles City Department of Transportation
Louisiana Transportation Research Center
3M Company — Traffic Control Materials Division
Mark IV Transportation Products
Marketing Resource Concepts
Maryland Department of Transportation
Massachusetts Institute of Technology
Matsushita Electric Industrial Co., Ltd. (Panasonic Industrial)
Mazda Motor Corp.
METRO (Municipality of Metropolitan Seattle)
Metropolitan Transportation Commission (Oakland, CA)
Michigan Department of Transportation
Microwave Sensors, Inc.
Minnesota Department of Transportation
Missouri Highway and Transportation Department
The MITRE Corporation
Mitsubishi Electric Corporation
Mitsubishi Motors Corporation
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Motor Vehicle Manufacturers Association of the U.S., Inc. (MVMA)
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National Private Truck Council (NPTC)
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New Jersey Institute of Technology
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New Mexico Taxation & Revenue Department
New York State Department of Transportation
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OKI Telecom
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Virginia Department of Transportation
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Westinghouse Electric Corporation
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Wisconsin Department of Transportation
Xanavi Informatics Corporation (Japan)
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Appendix G: IVHS AMERICA Committees

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