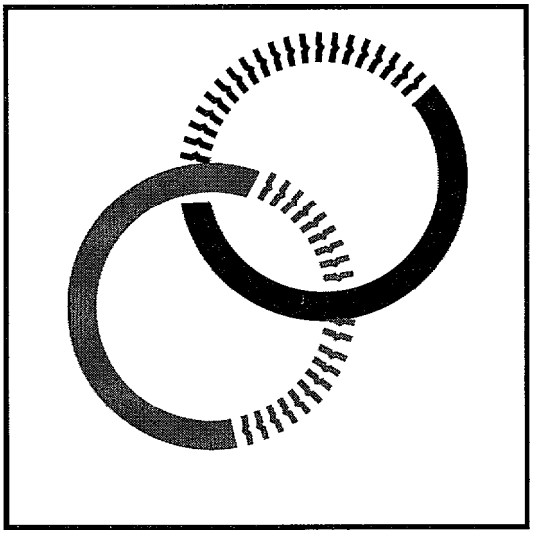
Intelligent Vehicle Highway Systems



A Public/Private Partnership

An Overview of the
IVHS Program
Through FY 1991

1 October 1991

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An Overview of the IVHS Program through FYI991

The IVHS Program has made very significant progress in transitioning from a modest Research and Development effort to a vigorous, full-scale national program with major activities in research, development, operational testing, and deployment. This report provides a brief overview of the principles upon which the program is being performed and a summary of project status.

This report was prepared by the
Federal Highway Administration
HTV-10, Washington, D.C.
202-366-2196

"... We have a strategy to unleash the creative genius of American Technology. This technology took us to the Moon and now it must make travel to space economical and commonplace. And this genius built a network of highways, and now we must support and encourage advanced technologies in the whole field of transportation from magnetically levitated trains to intelligent vehicles and highways...."

President George Bush
March 8, 1990
The White House

"...Our vision also embraces research and technology. Public/Private partnerships will make Intelligent Vehicle Highway Systems a workable reality. Smart cars and smart highways offer genuine high-tech solutions to problems of mobility, congestion, air quality and safety."

Secretary Samuel K. Skinner
U.S. Department of Transportation
February 14, 1991
New York City

"The directions for national transportation policy are captured under six major 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 safety and national security
- Protect the environment and the quality of life
- Advance the U.S. transportation technology and expertise"

The IVHS Program Has National Benefits in All Six Themes

THE NEED

Congestion

Congestion on America's roads and highways is rapidly becoming a major national problem, with penalties measured in decreased productivity, lost wages, and direct costs. The nation's international competitiveness and quality of life is adversely affected when its transportation system's efficiency is reduced. Congestion is the direct result of the continued growth in national travel, especially in urban areas, and the inability to provide adequate additional lane-miles of new capacity. The following statistics best summarize the problem:

- Total travel in the United States has more than doubled since the early 1970's
- Urban freeway delay is now 2 billion vehicle hours per year
- 70 percent of all peak hour travel on urban Interstates now occurs under congested conditions

Safety

Safety continues to present a problem on our nation's highways. While the highway traffic accident and fatality rates have been decreasing over the past several years, the number of deaths related to highway accidents still far exceeds that for any other mode of transportation. Traffic accidents cost the country an estimated $70 billion in lost wages and direct costs. Over 6.6 million police-reported collisions occur each year, resulting in 3.5 million injuries. 500,000 of which are serious or fatal. Adding to this, by the year 2020, the number of drivers over age 6.5 will increase by 20%. The special requirements for this population, dealing with reduced visual acuity. hearing loss, and reduced reaction time, must be met to safely provide for their mobility needs.

Lost Productivity

The loss of national productivity due to congestion is estimated at $100 billion annually. 1 We are a highly mobile, sophisticated society and our ability to move goods and deliver services directly affects our nation's effectiveness and well-being. If our competitors have more efficient national transportation systems, our country will lose international market share.

Energy and Environment

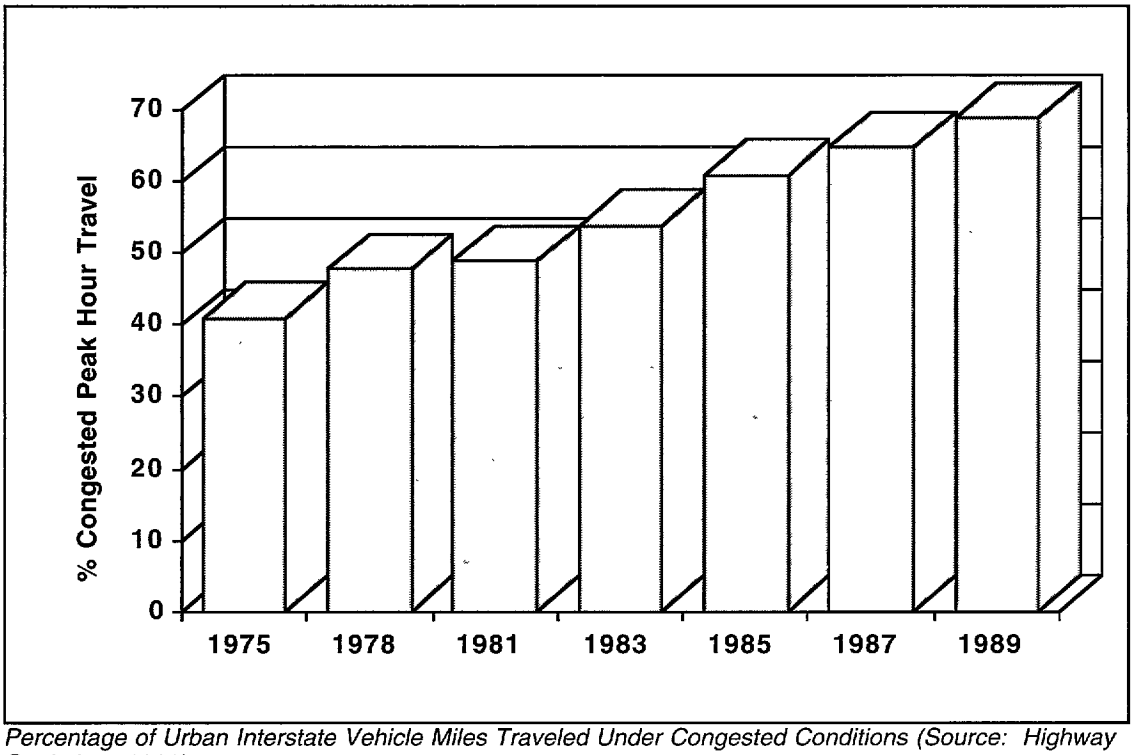
In addition to the losses in productivity while these vehicles are sitting in traffic congestion, they waste an estimated 2.0 billion gallons of fuel resulting in not only an the economic loss but also contributing to air pollution in our nation's urban areas2. A 1989 U.S. Environmental Protection Agency study reported that emissions from highway vehicles accounted for one-third of total emissions of nitrogen oxides, one-forth of volatile organic compounds, and more than one-half of carbon monoxide (CO). Currently, approximately one-half of the nation lives in areas exceeding the smog standard and one-third in areas exceeding the CO standard.

Public Transportation

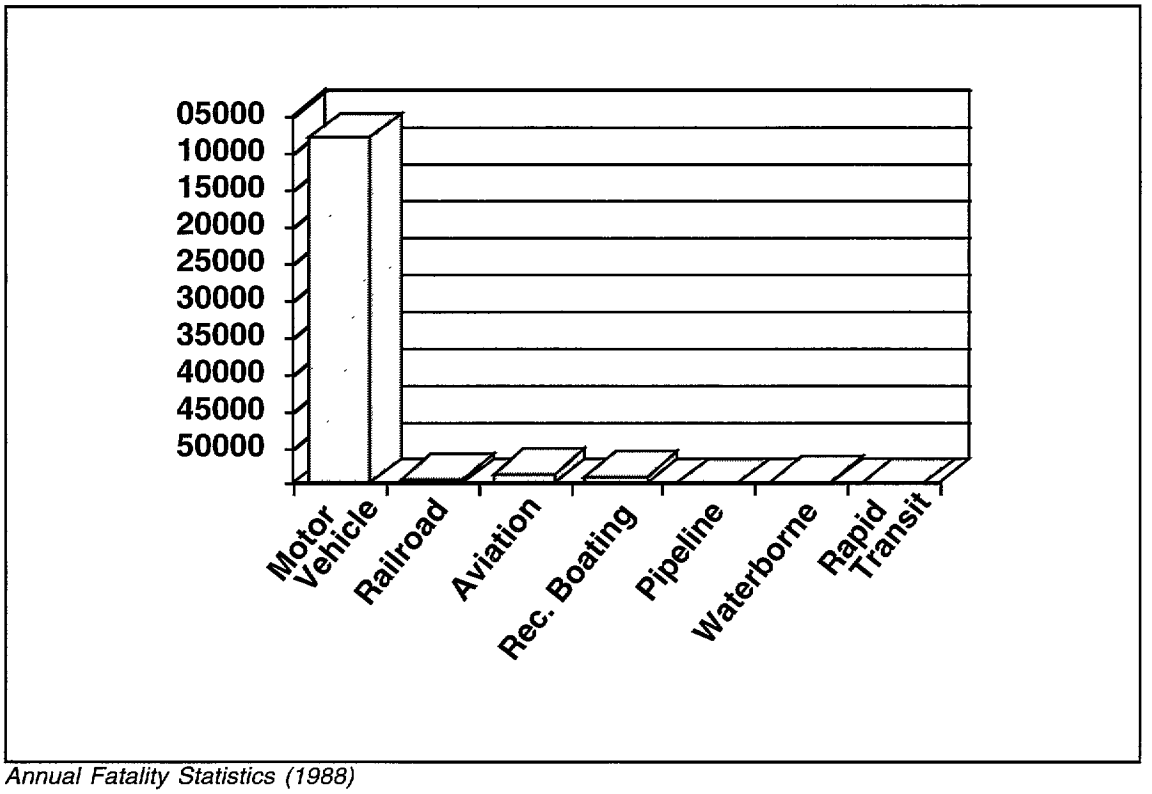
Public transportation offers some alleviation to these problems provided user acceptance can be increased. Studies have shown that use of these systems would increase if the population perceived public transportation systems as more reliable and predictable.

ISource: Robert L. French, "Safety Implications of Automobile Navigation Systems," presented for the 46th annual meeting of the Institute of Navigation, Atlantic City, N.J., June 26-28, 1990

2Mobility 2000, Reports on Maior Aspects of IVHS (College Station, Texas: Texas Transportation Institute, March 199O),p.6.



Percentage of Urban Interstate Vehicle Miles Traveled Under Congested Conditions (Source: Highway Statistics, 1990)



Annual Fatality Statistics (1988)

THE VISION

The United States is now moving from the enormously successful Interstate Highway construction program to those that will set the course of highway transportation well into the twenty-first century. These new program decisions will determine the capacity, safety, and viability of highway operations for present and future generations, just as the Interstate program did 35 years ago. As the Interstate system has become an integral part of the day-to-day activities of the population, so too will Intelligent Vehicle Highway Systems (IVHS) become a day to day part of doing business in the U.S., improving the efficiency of transport of goods, services, and travellers over the highway system and allowing this to occur at a higher level of safety.

Where appropriate, this program will involve public-private partners in joint ventures. The program will develop, test, and deploy advanced electronics technology and systems to meet the increasingly critical operational needs of the highway transportation system. IVHS will be a major complement to other highway improvement programs such as preservation and new construction. IVHS is the enabling technology which will provide our society the tools to deal with highway operational needs well into the twenty-first century.

Mobility

IVHS will significantly improve mobility in the United States. Urban areas will more efficiently manage their existing streets and freeways through improved traveler information and traffic control systems. Rural and urban area travelers will benefit from improved security, comfort, and convenience. Experience gained from better management of existing facilities will further improve the design and use of new facilities. With the time and energy saved through enhanced travel efficiency, the cost of transporting goods and services will decrease, resulting in improved industrial profitability and international competitiveness.

All vehicle operators will benefit from more efficient and less stressful travel. Through IVHS, drivers will be able to access routing information that allows them to select a route based on speed, fuel efficiency, scenic views, or points of interest. Older drivers will have more mobility because advanced technologies can augment vision and judgment, for instance at night or during bad weather. Significant improvements in level of service and schedule reliability will increase the attractiveness of public transit, car and van pools, and other multiple-occupancy vehicle systems.3

Safety

IVHS will also improve the level of safety of travel on urban and rural highways. Anti-lock braking systems, already available on the market, combined with new collision avoidance systems will help reduce the number and severity of accidents. Automated "Mayday" assistance for stranded motorists unable to call for help will speed emergency services to an incident. Information systems warning drivers of hazardous road conditions or road blockages will provide sufficient warning so as to allow the driver to be prepared, well in advance, for the incident. And, tracking of hazardous material transport on the nation's highways will ensure prompt, appropriate response to HAZMAT incidents, protecting both the traveling public and the communities in which the incidents occur.

Staged Implementation

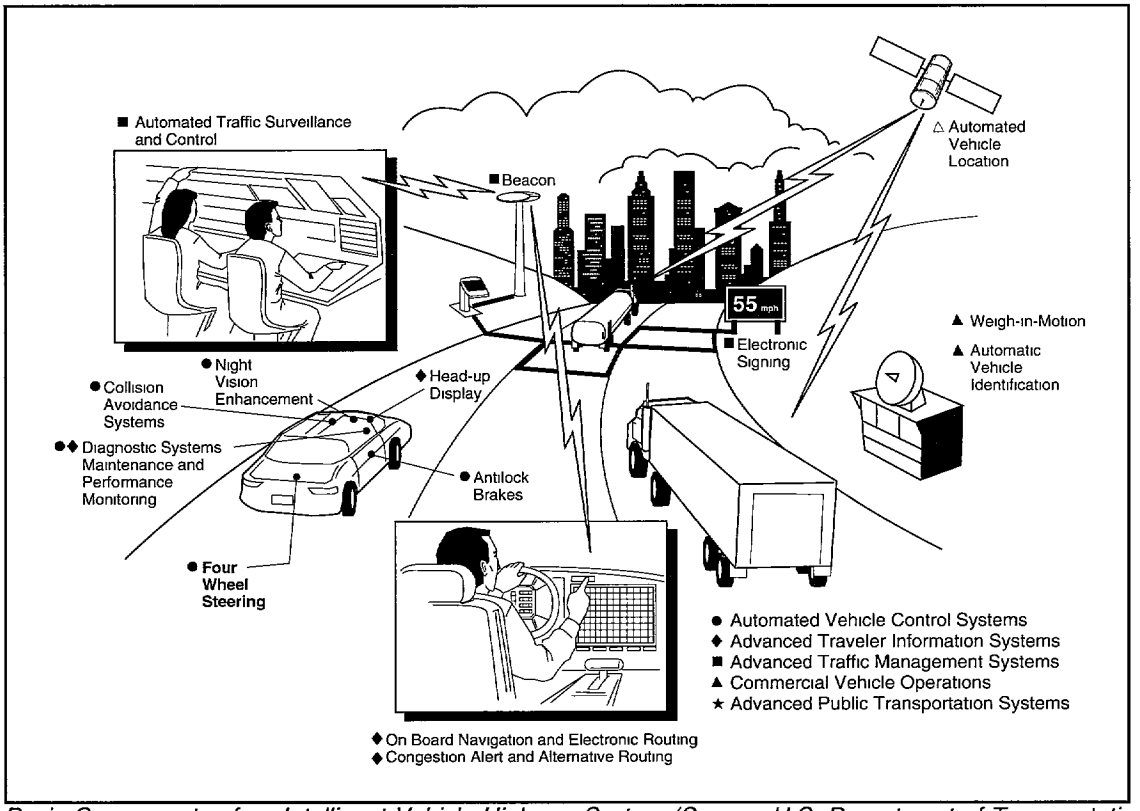
Tied directly to the need for IVHS is the fact that the program must provide incremental benefits to

3Source: Proceedings of a National Workshop on IVHS Sponsored by Mobility 2000 March 1990

the public, in much the same way as the Interstate highway system did. Starting in the late 1950's, the Interstate system was opened to traffic in stages as small sections were completed, giving taxpayers real benefits long before the overall system was completed this year. This approach was enormously successful in terms of both delivering a usable system and maintaining public and Congressional support over a period of 35 years for expenditures that reached $127 billion. IVHS needs to follow that same model, which suggests how IVHS systems will be defined, designed, and built. We cannot wait many years for the more advanced concepts to mature technologically before IVHS begins to show results. We need to aggressively apply the technology that is already available in order to produce IVHS subsystems that can start delivering benefits in the *next few years*. To do this, the IVHS program must focus on system architecture refinement, operational field tests, and communications, surveillance, and control system infrastructure acquisition.

Current Systems

IVHS is much more than a vision. At present, thousands of large trucks in the United States are equipped with electronic automated location systems, along with two-way digital satellite communications systems linking drivers to their dispatch offices. Automatic Vehicle Identification (AVI) systems are being used to automate toll collection, reducing delays and providing more efficient processing of fees, benefitting both users and toll agencies. Along the Oklahoma turnpike, over 63,000 vehicles have purchased AVI tags during the first year of operation, more than double the anticipated demand. Advanced signal control systems such as the Advanced Traffic Surveillance and Control system in Los Angeles have reduced vehicle delay, and have paid for themselves several times over in just a few years.



Basic Components of an Intelligent Vehicle Highway System (Source: U.S. Department of Transportation National Transportation Strategic Planning Study - March 1990)

GOALS AND BENEFITS

IVHS offers an effective, realistic means of addressing the problems previously identified. While IVHS is not a silver bullet. and will not eliminate congestion or accidents in the U.S. by itself, it can make a substantial contribution in several areas. It is estimated that if IVHS were fully deployed, the following benefits would accrue:

- Improved safety
  - By 2000, approximately 1000 lives, 35,000 injuries, and $1.8 Billion saved
  - By 2010, over 11,000 lives, 440,000 injuries, and $22 Billion saved

- Improved efficiency of the highway in terms of capacity and speed of travel
  - Reduction of congestion-caused delays by 25 to 40 percent by 2010
  - Almost complete elimination of vehicle congestion on fully-automated highways

- Reduced energy consumption and improved air quality
  - 2.2 billion gallons of fuel saved per year by 2000
  - 6.5 billion gallons of fuel saved per year by 2010

- Improved efficiency/profitability of the commercial fleet and public transportation providers

- Improved incident response
  - Approximately 60 percent of urban freeway congestion is due to crashes and disabled vehicles
  - Improved incident response can dramatically improve highway capacity

Benefits of IVHS will not be limited to any one section of the population but, rather, will be seen by all facets of the population. While congestion is the primary traffic problem in urban areas, the number of traffic fatalities is actually higher in rural areas due to road conditions and higher rates of speed. The increased margins of safety provided by IVHS have the potential to reduce rural traffic crashes. Moreover, when crashes occur in remote or isolated locations, the communications capabilities of IVHS will allow faster notification of authorities, resulting in faster response by emergency crews.

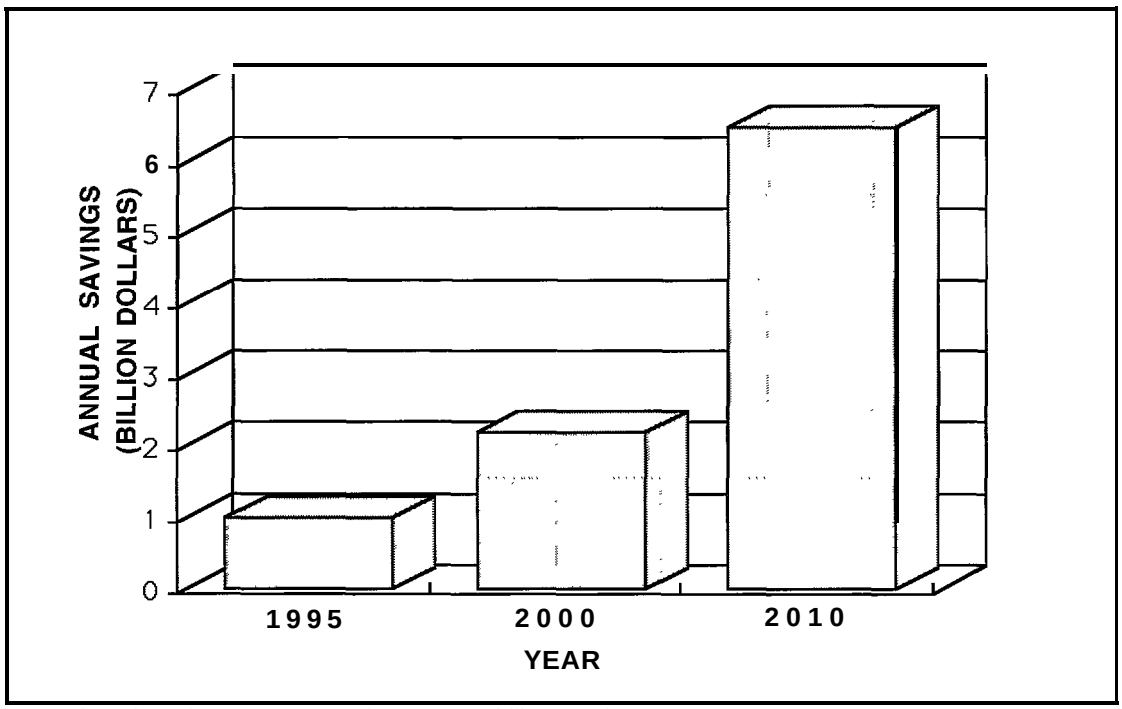
Productivity improvements, primarily for the commercial operating fleets, will benefit all segments of the population as well. All goods bought and sold within the United States are, at one time or another, shipped via the commercial fleet. Improvements in fleet efficiency will result in a lower cost of providing goods and services. Further, improvement in the productivity of the American work force through reduced traffic delay will be reflected in overall economic improvement.

Additional benefits of the improved mobility that can be brought about by IVHS include reduced congestion, enhanced safety, accommodation of increased travel demand and higher trip speeds, reduced motorist confusion and aggravation, reduced driver fatigue and frustration, and augmented and enhanced driver capabilities.

Since a large fraction of urban freeway congestion is caused by incidents, improvements in the response to accidents and other capacity-reducing events can produce significant benefits. IVHS can support improved incident management through capabilities such as emergency vehicle approach warning systems in cars, automated lane closures (especially in opposing direction) to expedite arrival of emergency vehicles and debris-clearing equipment, and rapid re-opening of all traffic lanes. In conjunction with in-vehicle monitoring and warning systems which will aid in crash avoidance, improved incident response will also save lives.

Beneficiaries		Benefits	
General Public	Commuters Shoppers Public transportation users Tourists	**Travel**	Decreased travel time Increased safety Increased comfort and convenience Increased security Decreased cost
Private Sector Ooerators	Trucking companies Bus companies Taxis Small package delivery Emergency services	Economic	Increased productivity Improved international competitiveness Product innovation On-time delivery
Industry	Automotive manufacturers Electronics manufacturers Traffic systems suppliers Researchers	Environmental	Decreased air pollution Decreased noise pollution Increased fuel savings
Public Sector Operators	State DOTs Traffic departments Transit agencies	Information	Increased trip efficiency More uniform and effective traffic enforcement Improved trip planning

I'VHS Beneficiaries (Source: Mobility 2000)



annual Fuel Savings from *IVHS (Source: Mobility 2000)*

THE PROGRAM

The aim of the IVHS program is to apply advanced concepts and technology in the areas of communications, navigation, and information systems to provide solutions to traffic congestion problems and, at the same time, to improve highway safety and reduce the harm that automobile traffic does to the environment. This involves a substantial commitment to a program that will span 20 or more years over its development cycle.

IVHS is a program with national importance and criticality. It will be developed through the participation of government, industry, and academic institutions and international automotive and electronics standards-setting organizations, acting independently and in concert.

The national public and private partners in IVHS are already working through the Intelligent Vehicle Highway Society of America (IVHS America); a new national, non-profit organization. IVHS America provides the national forum for communication, consensus building, national program coordination, and related national and international activities. Recognizing its importance, the U.S. DOT has chartered IVHS America as a Utilized Federal Advisory Committee.

IVHS will be implemented in phases, and will evolve over time. Some elements are currently being implemented while others require further research. As newer technologies mature, they will be tested for technological soundness, safety, benefits, and market demand, when implemented.

The challenge for the forthcoming decade is to maximize the benefits which will come from IVHS, by developing a clear plan for selecting appropriate implementation paths, easing institutional and legal obstacles to deployment, and conducting research.

DOT has major technical responsibilities for the underlying research, concept development, technology demonstration, testing and evaluation, and operational implementation for IVHS. The DOT is participating with IVHS America in developing the IVHS National Strategic Plan to coordinate these elements. The DOT is also sponsoring and conducting basic research, field operational tests, systems engineering and standardization efforts to ensure the successful implementation of IVHS.

IVHS DOT Program Participants

A number of Administrations within DOT are involved in the IVHS Program:

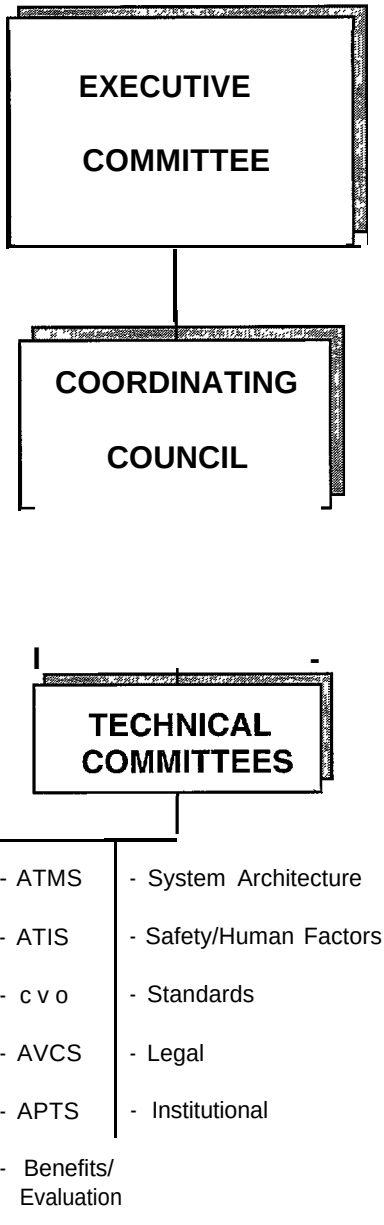
- **Federal Highway Administration (FHWA):** is particularly concerned with improving the operational efficiency and safety of highway transportation. Their focus is on the development of traffic management and traveler information systems, the development of advanced automated highway systems, and safety and productivity issues related to highway operations and motor carriers. FHWA is the lead agency for DOT's program.

- **National Highway Traffic Safety Administration (NHTSA):** is concerned with the safety aspects of IVHS, especially as related to the performance of advanced driver warning, perceptual enhancement, and vehicle control systems, and driver interaction with IVHS technologies. NHTSA is also concerned that no loss of safety occurs from driver overload or distraction as IVHS systems for enhancing traveler mobility and travel efficiency are introduced.

- **Urban Mass Transportation Administration (UMTA):** is interested in using IVHS to encourage high-occupancy vehicle travel, including conventional bus transit. carpools, and highway-related transit operations. The IVHS technologies will also improve the efficiency and effectiveness of transit fleet operations

- **Research and Special Programs Administration (RSPA):** is interested in landside applications of radionavigation technology and in supporting them directly through the Volpe National Transportation Systems Center (VNTSC).

IVHS America



- Overall governing body of IVHS America
- Representation includes one-fourth private sector members of, or designated by the Highway Users Federation for Safety and Mobility (HUFSAM); one-fourth private sector, not members of, or designated by HUFSAM; and one-half public sector members

- Administers IVHS America technical functions
- Reviews and approves IVHS products
- Representation includes 40 “at large” members who are appointed by the Executive Committee; the chairpersons of the Technical Committees; and five U.S. Department of Transportation representatives, one of whom serves as Secretary
- Sub-committees: Strategic Planning, International, and Clearinghouse

- Administers specific technical and program objectives
- Provides national coordination and identifies/prioritizes needs within technical areas
- Representation includes chairpersons who are appointed by the Coordinating Council: U.S. DOT representatives as secretaries; steering groups of approximately twenty individuals selected by the chairpersons of the committees; and IVHS America members

Ivhs America Organization Chart

MAJOR PROGRAM ELEMENTS

Research and Development

The goal of the DOT IVHS R&D program is to support and leverage technology and systems that show considerable promise of substantial benefits, but for which research problems still exist. DOT research efforts are devoted to areas where a strong federal interest and role exists. These include both technology areas and "soft" research areas, such as human factors and policy-related research. DOT funds are not used to develop production hardware systems, since this area is the appropriate domain of the private sector.

Operational Tests

IVHS operational tests are, in general, joint public/private ventures that serve as the transition between R&D and full scale deployment of IVHS technologies. Operational tests are conducted in a "real-world" operational highway environment under "live" transportation conditions. This distinguishes operational tests from research projects or other kinds of testing, such as simulation testing, or tests on test tracks or on facilities that are temporarily closed to the public. Also, the joint venture aspect distinguishes an operational test from normal contract procurements for specific tasks or activities fully funded by the federal government.

An operational test integrates existing technology, R&D products, and institutional arrangements to test one, or usually more, new technological, institutional, or financial elements in a real-world test bed. A test is designed to provide progress towards operational deployment of one or more technologies or institutional or financial arrangements. An operational test also examines market support for a particular system or for some element of that system, and evaluates the market readiness of given technologies and/or institutional arrangements. Operational tests are needed to determine whether a promising technology or system is ready for deployment, *and whether the expected benefits can be achieved at the expected cost.* In other areas, especially for the IVHS program, these tests will be used to gather data on the real-world costs, benefits, and operational impact of proposed IVHS concepts such as reliability and performance. The results of these tests will be used to make decisions on future development and deployment. These decisions will be reflected in the IVHS National Strategic Plan and the IVHS System Architecture.

An IVHS operational test typically involves a carefully crafted partnership that is negotiated among federal, state, local, private, and other institutions. Funding, technical, and administrative responsibilities are shared among the partners in the operational test. A major federal responsibility is always to ensure an acceptable evaluation of the system or technology. Funding may be "pooled" or not, depending on the nature of the relationship and agreed-upon approach.

Deployment

The goal of the IVHS program is to deploy operational systems that substantially reduce congestion, and improve safety and productivity. IVHS R&D, and operational test funds will lay the groundwork for deployment; however the actual deployment will be funded by regular federal aid funds. not IVHS research and test funds. Limited amounts of IVHS research and technology funds may be used to fund state and local planning studies prior to deployment.

Summary of Key Program Areas

The following are the areas DOT is emphasizing in managing the IVHS Program:

- **Partnerships/cooperative agreements** with industry, universities, and state and local jurisdictions to develop and evaluate IVHS technologies. In most of the cooperative agreements, DOT serves as a financial and technical oversight participant in the project, with the states and local jurisdictions contributing funds and taking a leadership role in the activity.

- **Research and development** is being conducted in areas where existing technologies do not meet the requirements or where requirements need to be established.

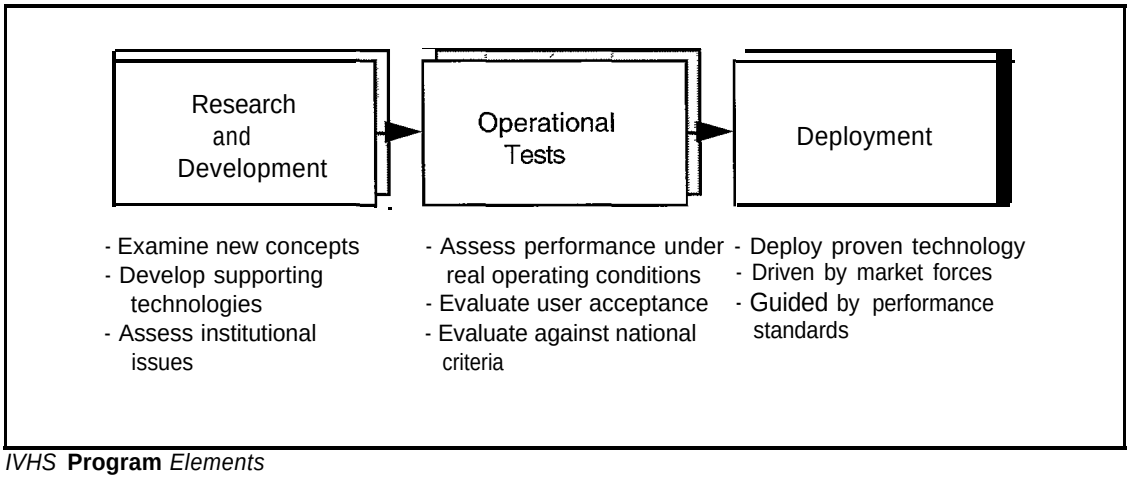
- **Operational tests** are being organized and conducted, and *national evaluation criteria* are being used, to ensure that there will be a means of comparing individual operational tests.

- **Deployment of proven technologies** is being emphasized in the IVHS Program. Much of the basic technology needed to develop and implement IVHS (except for some Advanced Vehicle Control System functions) currently exists.

- **Market forces** have largely driven the development of IVHS technology and standards are being developed to ensure interoperability among systems and across jurisdictional boundaries.

- **Multimodal implementation** will foster a systems view of IVHS, ensuring that the advantages of individual transportation modalities combine and contribute to an overall transportation solution

- **Incremental Implementation** will hasten the delivery of benefits to travelers and the national interest.



IVHS **Program** *Elements*

PROGRAM DELIVERY

DOT IVHS program delivery activities fall into two categories: management of activities external to DOT and management of internal IVHS projects.

External Activities

- **Public/Private Coordination:** DOT is working to ensure that IVHS Program activities are coordinated among program participants, other branches of government, industry, academia, and the public. This is being accomplished through participation in conferences and symposia, publication in the open literature, and sponsorship of IVHS America. IVHS America will serve as an IVHS Program information clearinghouse, making IVHS technical and program information available to the public. In addition, DOT maintains cognizance of activities occurring in the private sector, primarily regarding new technology developments and standards.

- **Strategic Plan:** DOT is working with IVHS America to develop a National IVHS Strategic Plan. The purpose of the Strategic Plan is to focus IVHS R&D, testing, and deployment, avoiding counterproductivity and overlap. R&D, operational tests, and deployment requirements are identified over five, ten, and twenty year time frames. The plan identifies and discusses the basic institutional, organizational, financial, and economic issues regarding IVHS, and presents a plan of action for using the IVHS Program to address these issues. A draft will be circulated in early calendar year 1992.

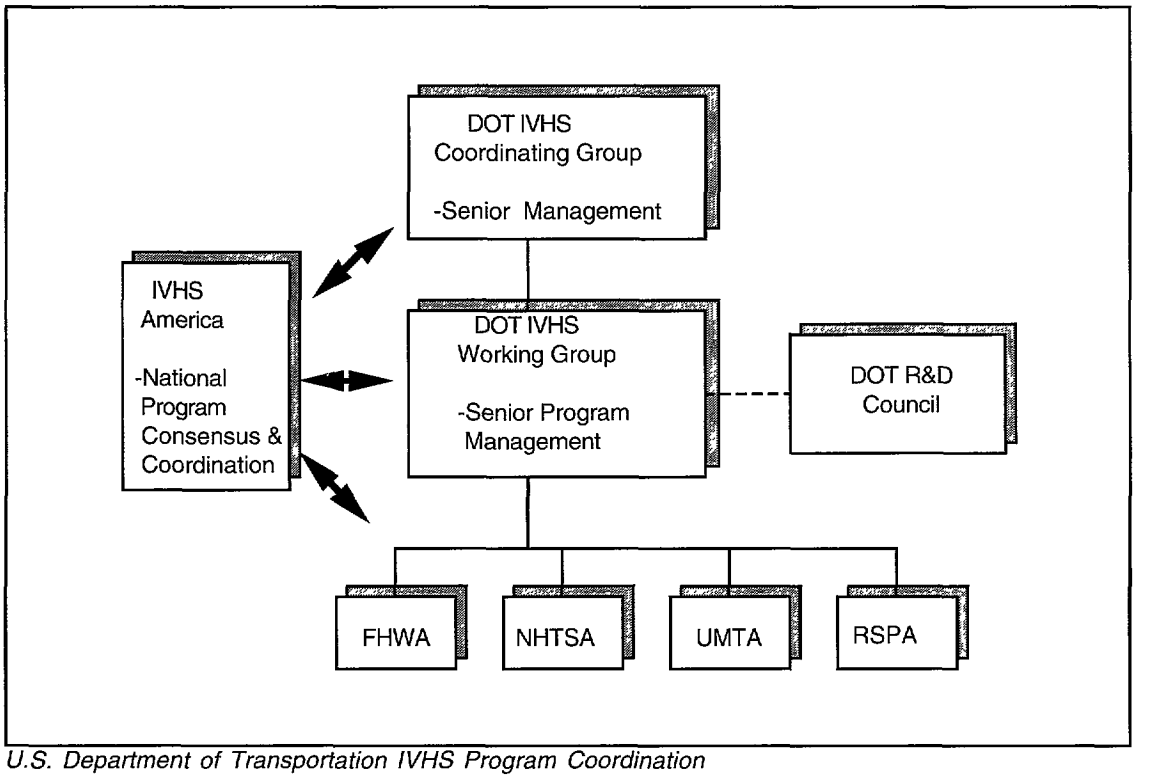
Internal Activities

- **Management Plan:** FHWA has developed a Management Plan for the IVHS program to define the functions, organization, and management process by which FHWA will advance IVHS. The plan serves both as an internal and external document and as a business plan for managing the program. LJMTA and NHTSA have developed a long term plan for their component of IVHS.

- **Program Support:** FHWA has obtained systems engineering support and program support through outside contracts. DOT is also working with the National Laboratories in various areas of IVHS research. UMTA, FHWA. and NHTSA are working with VNTSC to provide program support and several outside contracts are being developed.

- **Selection Criteria:** DOT is developing criteria by which offers for joint ventures from public and private partners for conducting operational tests will be reviewed and evaluated. The purpose of these criteria is to ensure that resources available for conducting the operational tests are used wisely and that each operational test contributes to the National Plan. Specifically, the evaluation will focus on measures such as overall contribution to the IVHS Program knowledge base, suitability of the proposed site to support overall IVHS Program test objectives, and ability of the existing infrastructure to support the test program. In addition to evaluating technical content, DOT will evaluate proposals regarding the financial and project management aspects of the proposed operational test. DOT is preparing a document that describes the evaluation process and the proposal evaluation criteria. This document will be made available for prospective offerors.

- **Evaluation Process:** DOT is developing a generic set of criteria and a standard methodology to be used in conducting evaluations of approved operational tests. The purpose of these criteria and methodologies is to ensure that a uniform basis is used in comparing the results of any IVHS operational tests. These evaluation criteria will also be made available so that they can be factored into the initial design of the evaluation methodology for any operational test.



U.S. Department of Transportation IVHS Program Coordination

SYSTEM AREAS

The IVHS Program has evolved to include five major system areas. Each of these five focus on different applications of IVHS technology to highway system needs and opportunities. While they are generally on different time lines, they all have early opportunities for deployment of individual elements. Over time, they will become more interdependent and evolve into a fully integrated total system. These five areas are:

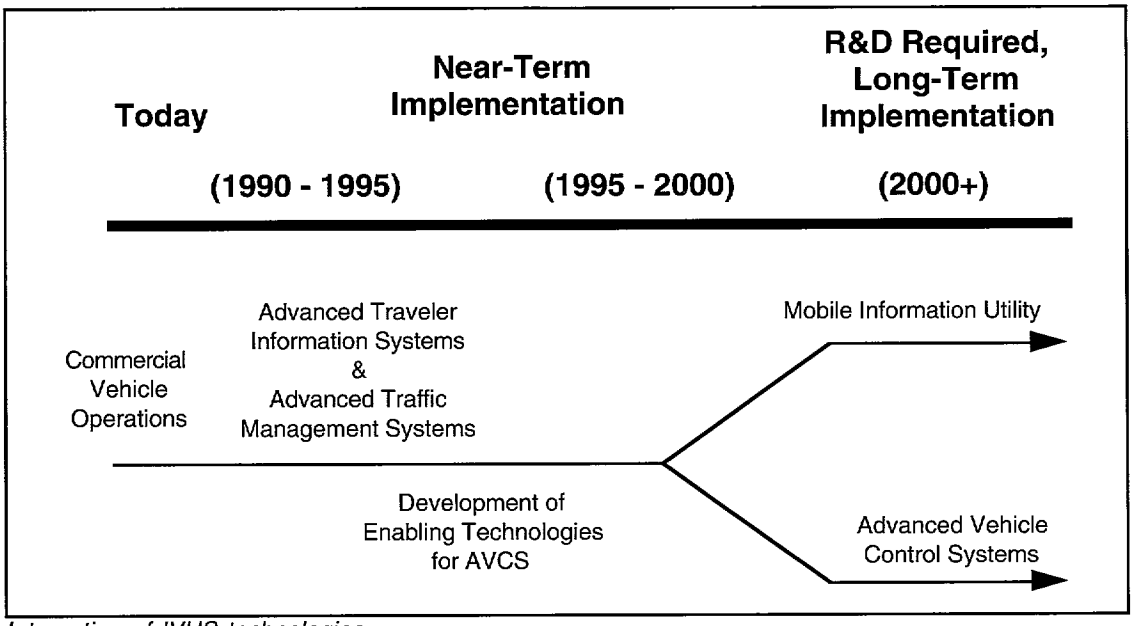
- **Advanced Traffic Management Systems (ATMS):** permit real-time adjustment of traffic control systems and variable signing for driver advice. Their application in selected corridors has reduced delay, travel time, and accidents. ATMS is being implemented using coordinated signaling systems, video surveillance of corridors, ramp metering, automated toll collection, and variable message signs (VMS).

- **Advanced Traveler Information Systems (ATIS):** let drivers know their location and how to find desired services. ATIS permit communication between travelers and ATMS for continuous advice regarding traffic conditions and alternate routes. Additionally, ATIS provides the driver with warnings regarding road safety.

- **Commercial Vehicle Operations (CVO):** expedite deliveries, improve operational efficiency, improve incident response, and increase safety. CVO makes use of ATIS features critical to commercial and emergency vehicles. A primary goal of CVO is to reduce regulatory burden and inefficiency. Many of the technologies related to CVO are already available in the marketplace. AVI devices are used in several locations to allow the electronic transfer of funds so travelers can pay tolls without stopping. Global Positioning System (GPS) and Loran-C technologies are available to track the location of individual vehicles for fleet management. Weigh-in-Motion (WIM), combined with Automatic Vehicle Classification (AVC), is available to sort vehicles for weight inspections. On-board computers are available to monitor truck performance.

- **Advanced Vehicle Control Systems (AVCS):** are vehicle- and/or roadway-based electro-mechanical and communications devices that enhance the control of vehicles by facilitating and augmenting driver performance and ultimately, relieving the driver of most tasks on designated, instrumented roadways.

- **Advanced Public Transportation Systems** work in conjunction with ATMS to provide mass transportation users and operators (e.g., buses, Vanpools, high-occupancy vehicle (HOV) lanes, carpools, taxi cabs) with up-to-date information on status. schedules, and availability of public transit systems. Automatic vehicle location and monitoring systems will provide information to improve fleet management and better inform riders of their connections. Electronic fare media will reduce the inconvenience of cash handling, provide new marketing data, and integrate third party billing for transit services. New HOV priority schemes using IVHS technologies will be devised and monitored automatically to enforce HOV facility use.



Integration of IVHS technologies

ADVANCED TRAFFIC MANAGEMENT SYSTEMS

ATMS will provide more integrated, or geographically extensive, transportation information and control than are now available with conventional Traffic Management Systems. The end-state ATMS services will be more advanced than current services, having the following functional characteristics:

- Integration of expressway and arterial traffic surveillance and control in a corridor or major area
- Real-time surveillance of traffic flow characteristics
- Unified data base containing traffic information from multiple sources
- Near-term prediction of traffic situations
- Real-time control of traffic speeds and accessibility
- Dynamic determination of best control response to normal traffic conditions
- Real-time determination of optimal responses to accidents and other nonrecurring incidents
- Integration of more than one traffic management jurisdiction
- Real-time calculation of optimal vehicle routings, which are provided to in-vehicle processors
- Integration of management of all modes, including demand management

ATMS Accomplishments to Date

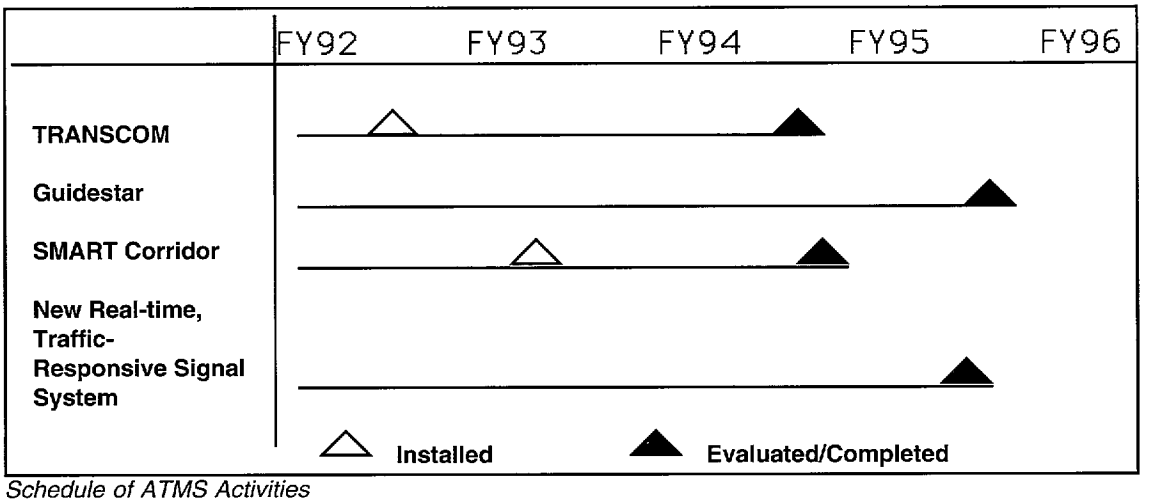
ATMS activities initiated or completed thus far include the following:

- The evaluation of the INFORM project on Long Island. New York is complete. INFORM is an operating system that integrates the operation of several parallel freeways and arterial streets. Information obtained from the evaluation indicates that motorists will divert to other routes if VMS indicate there is congestion and if the information is reliable.
- The SMART Corridor is a twelve mile long, 1 -mile wide section of the Santa Monica Freeway Corridor in Los Angeles. Installation of hardware and software is proceeding, and integrated operation is scheduled to begin in FY93. Traffic control personnel from several jurisdictions will be able to automatically monitor freeway and arterial street traffic and adjust ramp meter rates, VMS and traffic signal timing if the corridor becomes congested. Information on area traffic will be provided through VMS on the freeway, on cable TV through teletext, and through kiosks in parking garages.
- The use of television image processing for traffic detection and the side band of FM radio stations to communicate information to motorists in vehicles equipped with special radio receivers will be evaluated in fiscal year 1992 (FY92) under Minnesota's Guidestar Program, a multi-year implementation program in the Minneapolis/St. Paul metropolitan area.
- The preliminary design for a project in the New Jersey and Staten Island corridor to evaluate the use of AVI and Electronic Toll and Traffic Management technology for incident detection and congestion management will be completed in mid FY92.
- The use of satellite communications for conveying traffic data and video images from field locations to a traffic control center will be evaluated during FY92 in a Pennsylvania DOT IVHS project along I-95 in Philadelphia
- During FY92, functional specifications will be developed and laboratory and field tests will be conducted for state-of-the-art vehicle detection systems including infrared technology, image processing and machine vision.
- Also, during FY92, a state-of-the-art assessment of real-time. traffic-adaptive signal control strategies will be conducted and recommendations will be made regarding the functional requirements of the next generation of control strategies.

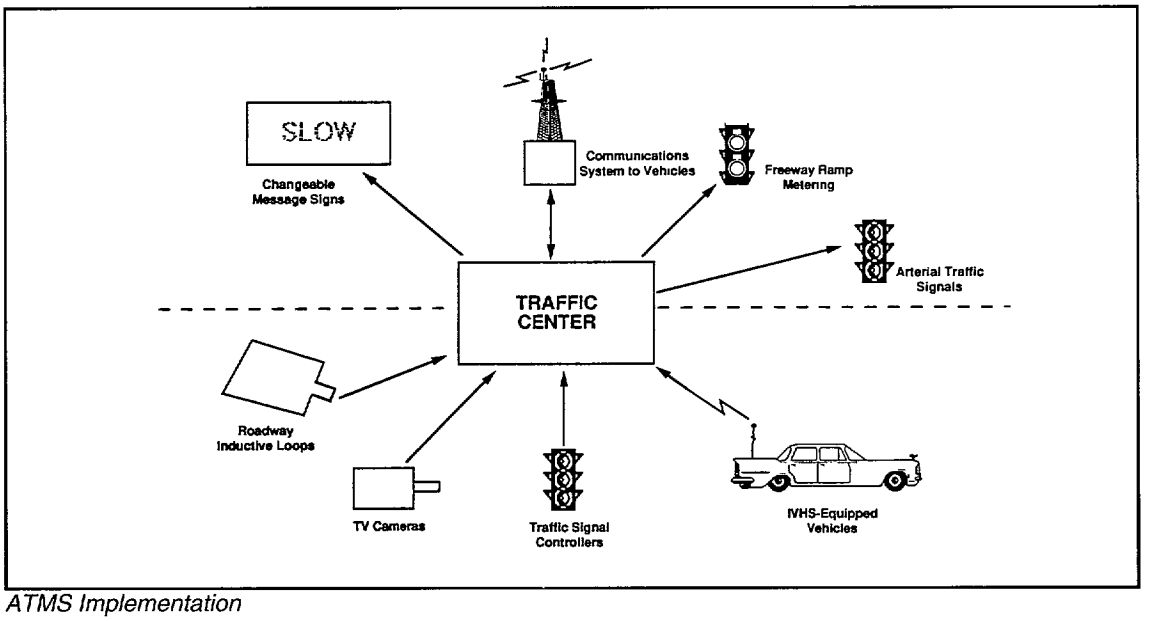
ATMS in the FY93 Budget

ATMS activities in the FY93 budget include:

- Development work on advanced strategies to integrate the operation of arterial streets and freeways on an area-wide basis will be initiated.
- Evaluations of state-of-the-art adaptive traffic control strategies will be conducted.
- Guidestar will be expanded through the addition of more image processors, and the implementation of greater radio range within Minneapolis/St. Paul and to other areas of Minnesota.
- System installation and evaluation of electronic toll and traffic management in the New Jersey/Staten Island Corridor will be under way.
- Additional operational tests of state-of-the-art traffic management features will be initiated.



Schedule of ATMS Activities



ATMS Implementation

ADVANCED TRAVELER INFORMATION SYSTEMS

ATIS will encompass a wide range of opportunities for providing the traveler with information to enhance the efficiency, safety, and convenience of their travel. These mechanisms will be designed to reach as broad a segment of the traveling population (private. public, and commercial) as possible and will include information regarding travel modes and options. Major functional elements of ATIS include:

- Instant availability of current traffic conditions
- Navigation and route guidance
- On-board availability of trip services information
- In-vehicle display (visual/audio) of trip related highway guide and warning signing
- In-vehicle safety advisory warnings
- Use of vehicles as probes to transmit traffic status and Mayday information

ATIS Accomplishments to Date

ATIS projects initiated thus far and scheduled to continue include the following:

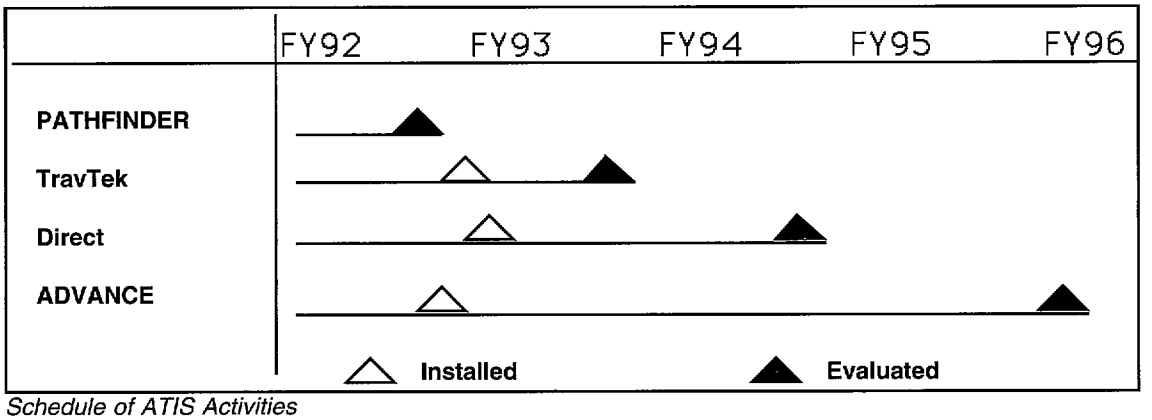
- The evaluation of PATHFINDER in the Los Angeles SMART corridor, the first U.S. test of the use of in-vehicle navigation devices to provide real-time traffic information to drivers, will be completed by mid- 1992.
- The collection of field data for a detailed evaluation of the TravTek project in Orlando, Florida will be nearing completion by the end of FY92. TravTek involves 100 specially equipped rental cars that are testing the first route guidance information system based on current traffic conditions in the United States . The in-vehicle system also includes a "yellow pages" motorist and tourist information system.
- The DIRECT project in Detroit will be operational in late-1992 and the evaluation underway. DIRECT is testing alternatives for communicating with drivers in the vehicle, including the first United States test of automatic highway advisory radio. which automatically interrupts the regular broadcast signal for traffic alerts.
- Design and initial testing of the ADVANCE project in the Chicago suburbs will be completed by mid-1992 and recruitment of local participants will begin. ADVANCE will involve up to 5000 private and commercial vehicles in the first large-scale test of an in-vehicle navigation and dynamic route guidance system. Two-way communications will allow the vehicles themselves to act as "roving traffic probes" to provide information on travel times.
- Guidelines for in-vehicle displays and controls. in both commercial and non-commercial navigation and information systems, will be developed and an evaluation under way by 1992.

ATIS in the FY93 Budget

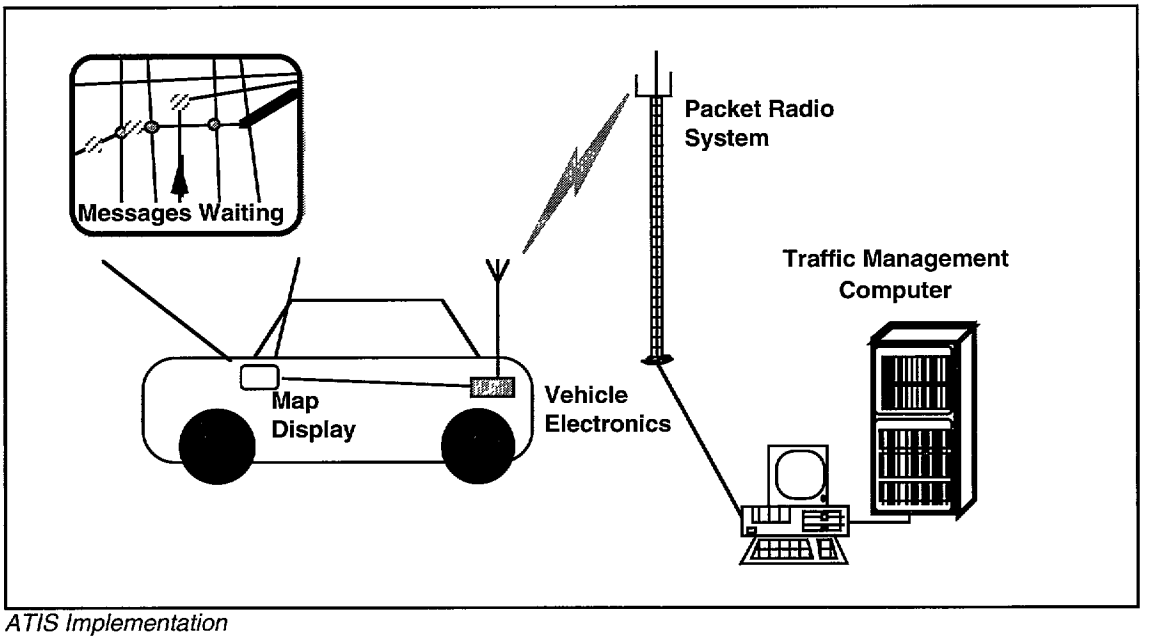
ATIS activities which will continue in FY93 include:

- Data analysis for the TravTek evaluation will be completed and the final report prepared.
- Full-scale testing and evaluation of ADVANCE will be underway.
- Operational tests of rural applications of ATIS will begin. These tests will provide information on routings, major incidents, and weather-related hazards to drivers in rural areas.
- Major operational tests featuring alternative system communications techniques and system architectures will be initiated.
- A prototype system to provide an in-vehicle warning when approaching roadway safety hazards will be completed. and initial testing and evaluation will begin.
- Recommendations on the design and configuration of displays and controls for ATIS systems will be developed. These recommendations will account for the effects of factors such as age, fatigue,and degree of training on driver performance while using these systems.

- ATIS system design architecture and communications will be refined to allow integrated operation with ATMS.
- Requirements will be developed for integrating ATIS with transit, rideshare, and parking agencies, and with in-home/workplace pretrip information systems.



Schedule of ATIS Activities



ATIS Implementation

COMMERCIAL VEHICLE OPERATIONS

The objective of CVO services is to increase the productivity of commercial vehicle regulatory agencies and commercial vehicle operators, and to enhance the safety of CVO drivers and vehicles. IVHS activities related to CVO have focused on refining technologies for use by the highway industry. Efforts are addressing standardization, institutional problem solutions and consensus building among States to ensure success in areas such as uniform vehicle licensing, registration. tax reporting, and safety. Areas in which CVO services can be automated and improved include the following:

- Automated permit and registration acquisition
- Pretravel verification
- Law enforcement
- Road use information collection
- Automatic toll collection
- Vehicle/cargo tracking
- Vehicle routing
- Passenger/cargo/vehicle scheduling
- Driver fatigue monitoring and impairment countermeasures
- Vehicle performance monitoring
- CVO-unique ATIS services

CVO Accomplishments to Date

CVO activities initiated thus far and planned to continue include the following:

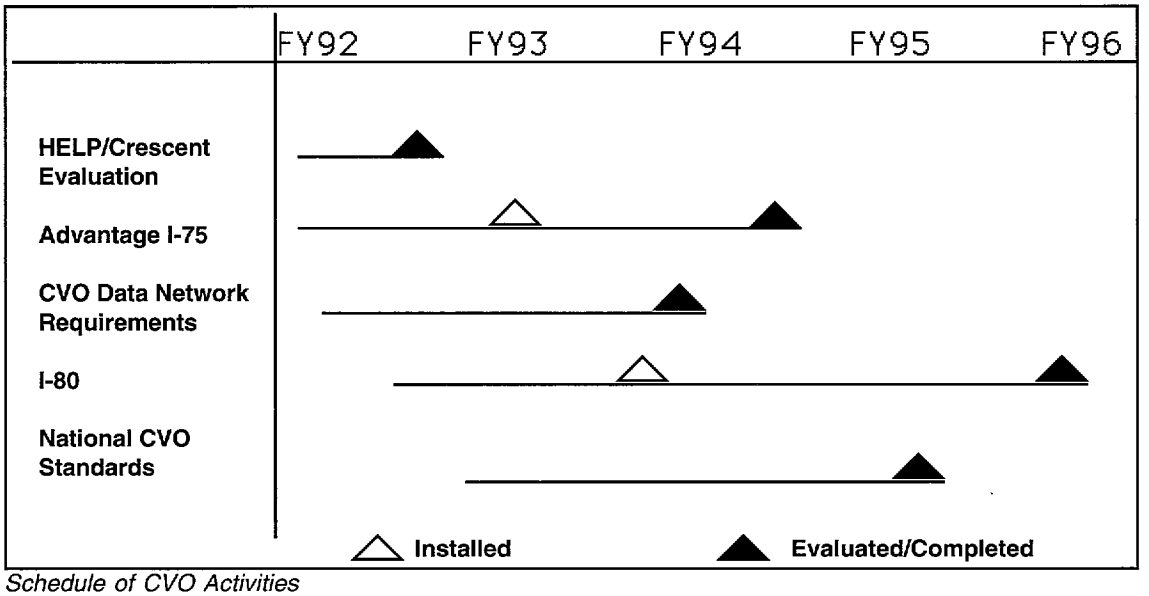
- An evaluation of the Crescent Project, which is the operational testing phase of the Heavy Vehicle Electronic License Plate (HELP) program, is scheduled for completion. HELP has been actively involved in integrating AVI, automatic vehicle classification (AVC), and weigh-in-motion (WIM) technologies, using a centralized management approach. Results will include generic AVI and WIM specifications, and equipment and system performance information.
- System design and installation for the Advantage I-75 operational test will be complete. Its initial goal is to use off-the-shelf AVI technology to allow transponder-equipped, properly documented trucks to travel along I-75 at mainline speeds, with minimal stopping at enforcement stations. Advantage I-75 will test a decentralized management approach, with each State retaining its constitutional and statutory authority relative to motor carriers.
- Basic planning for a major east/west corridor CVO effort along I-80, will be complete and the system design will be under way. This project will physically connect all three CVO test efforts and further national goals by focusing on resolving institutional and uniformity issues related to the large-scale deployment of IVHS technologies.
- Functional requirements for a computer-based, in-vehicle management system to monitor various commercial vehicle systems and communicate with external sources will be complete. Potential functions of the management system include: automatic mileage reporting, remote driver and vehicle inspections, fatigue monitoring, automatic toll collection, and navigation information.

CVO in the FY93 Budget

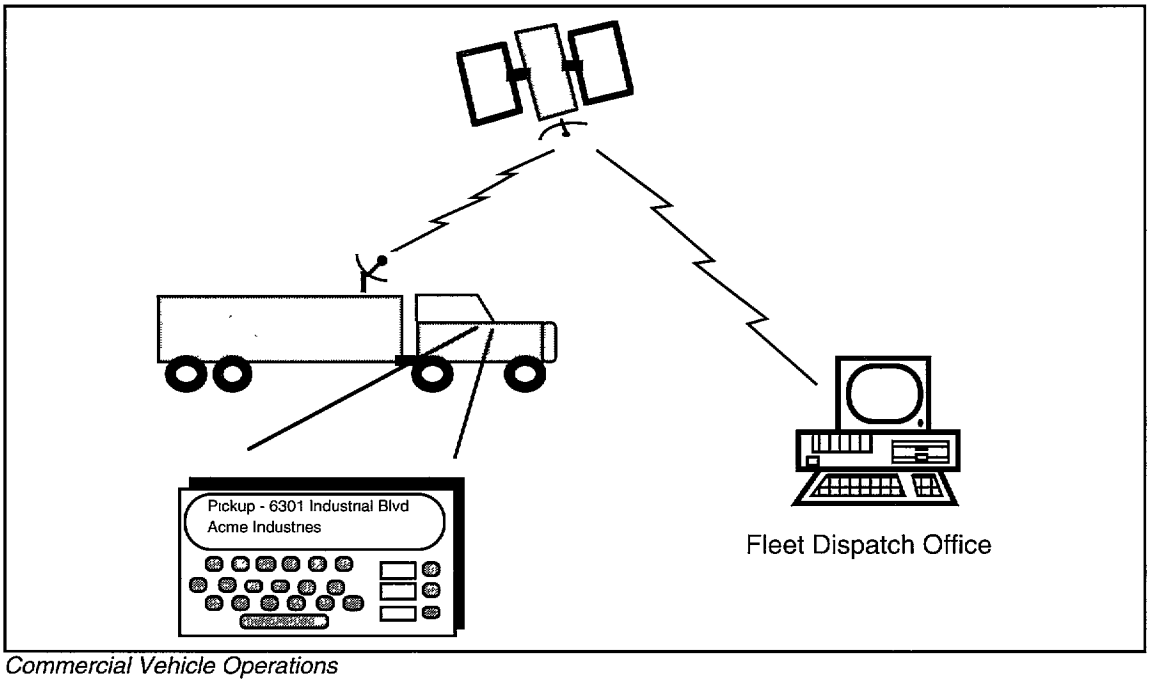
CVO activities in FY93 include the following:

- The HELP/Crescent, Advantage I-75, and I-80 operational tests will continue.
- Electronic systems to allow carriers to make advance purchases of necessary permits and to verify adequacy of licenses and permits from their home bases will tested.
- Functional requirements for a data network for CVO safety enforcement agencies will be defined.

- Needed actions to explain IVHS technology to commercial drivers in order to stimulate its use will be identified and initiated.
- The compatibility of automatic toll collection systems with regard to interstate carriers will be assessed.



Schedule of CVO Activities



Commercial Vehicle Operations

ADVANCED VEHICLE CONTROL SYSTEMS

AVCS encompasses a range of technologies, from driver aides such as collision warning systems through fully automated roadways. Initial AVCS systems will be self-contained within individual vehicles, and will not require the existence of roadway or roadside equipment. These perceptual enhancement, warning, and collision avoidance systems will improve safety by helping drivers better sense impending danger, sense and alert drivers of lapses in their judgement or skills, aid them in performing the driving task, and eventually even compensate for some of their errors.The development of vehicle-to-vehicle and roadway-to-vehicle communications systems will allow implementation of cooperative systems whereby safety will be improved by addressing collisions at intersections and where vehicle lateral and longitudinal position is controlled when suitably equipped vehicles are operated on dedicated instrumented lanes. Vehicles would enter and exit such lanes voluntarily and under manual control, but would be under full or partial system control while in the lanes. The culmination of the AVCS initiative would be complete automation of the driving function for suitably equipped vehicles operating on urban and inter-city freeway facilities. It provides “automatic chauffeuring”of vehicles from arrival at one freeway on-ramp to departure from another freeway off-ramp. This will provide enhanced levels of safety and will allow vehicles to automatically operate with closer spacing.

AVCS has the potential to dramatically decrease traffic crashes and congestion, particularly on urban and intercity freeways. The ultimate success will depend upon our ability to match the advanced systems to the capabilities and limitations of the drivers who must use them. Achievement of these goals will require scientific, engineering, institutional, and socio-political initiatives that will be of great magnitude and scope, but small compared to the benefits.

AVCS Accomplishments to Date

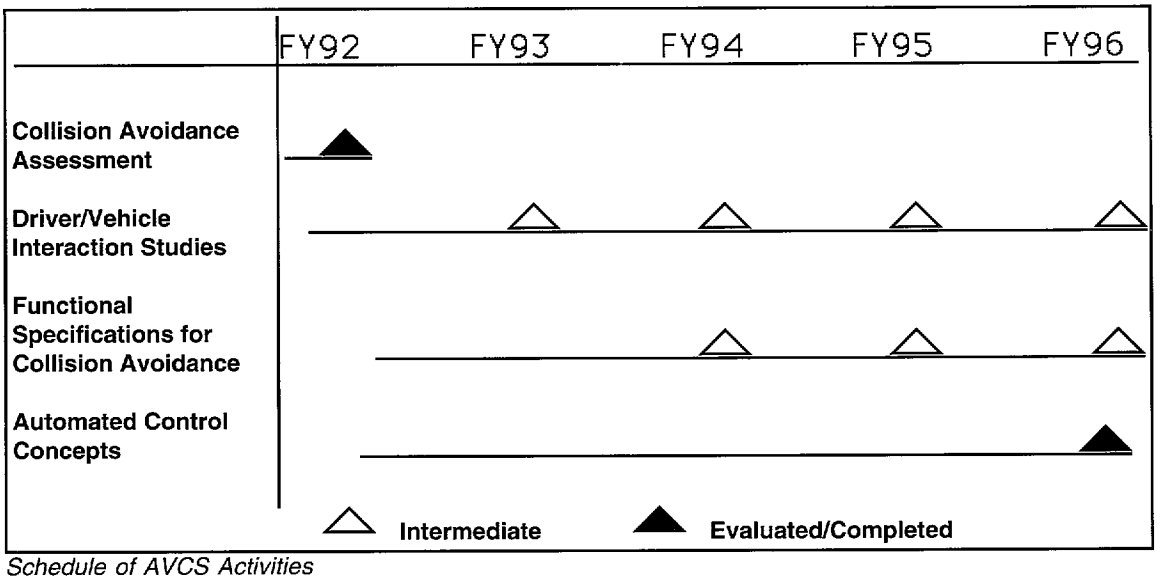
AVCS projects initiated thus far and which are scheduled to continue include:

- Completed analytic assessment of collision avoidance IVHS technologies and potential benefits.
- Initiated efforts to define functional specifications for AVCS systems which address:
  - rear-end collisions. This includes consideration of adaptive cruise control and automatic braking systems
  - collisions that occur due to blind spots, while changing lanes, and backing
  - collisions that occur at intersections.including special consideration of communication needs and the interaction of these needs with other IVHS communication needs
  - rollover and other off-road single vehicle crashes
- Initiated development of a method and a prototype system for monitoring driver performance using non-intrusive techniques that combine measures of driver control inputs with behavioral and/or physiological state.
- Initiated development of standardized methods for assessing workload demands placed upon drivers as a function of increasing amounts of secondary IVHS-driven tasks that must be performed.
- Initiated investigation of AVCS human factors requirements and initiated development of a standardized method of assessing the appropriateness of various warning signal display formats, singly and in groups. Initiated development of hierarchies for handling multiple signals and standardized guidelines for presenting real-time warning signal information to drivers.
- Began evaluating the feasibility of developing a lane position monitoring system.
- Began development of an instrumented variable performance test vehicle for evaluating IVHS countermeasures performance and driver/vehicle interaction on the test track.
- Initiated development of a standard “battery” of measures and a hardware package for assessing driver control behavior/performance and psychophysiological state .
- Initiated development of a vehicle motion environment characterization system
- Began work on developing baseline data and magnitudes and ranges of various driver groups’ driving control behavior
- Provided support for the Program on Advanced Technology for the Highways (PATH)

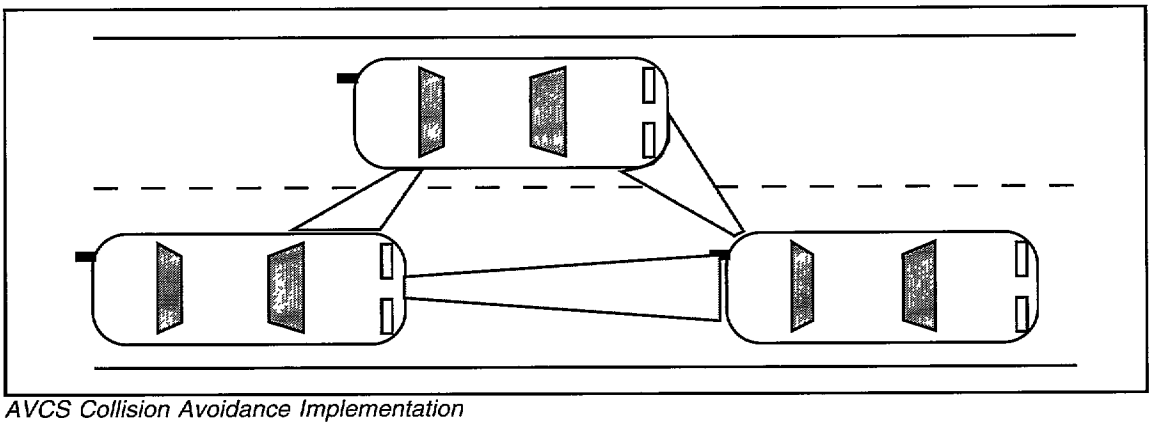
AVCS in the FY93 Budget

AVCS research areas included in the FY93 budget are as follows:

- Continued funding of programs initiated in previous fiscal years.
- Development of functional specifications for systems to address rear-end collisions, collisions related to blind spots, intersection collisions, and rollover and off-road crashes will be continued. This may include testing and evaluation of subsystems and prototypes to demonstrate proof-of-concept and to establish appropriate limits on performance.
- System specific human factors research to optimize interfaces between the driver and the vehicle subsystems (e.g., adaptive cruise control, rear object detection systems, intersection safety management systems) will be undertaken.
- Hardware and human factors assessments of vision enhancement for night and reduced visibility conditions will be conducted.
- The effects of various vehicle dynamics properties (e.g., suspension, steering, and braking properties, and tire "squeal") will be assessed as will the attendant motion, visual, auditory cues that result in driver behaviors/controlling actions.
- A program will be initiated to evaluate the feasibility of improving rural Emergency Medical Services through the application of IVHS technology.
- Continued support will be provided for PATH



Schedule of AVCS Activities



AVCS Collision Avoidance Implementation

ADVANCED PUBLIC TRANSPORTATION SYSTEMS

APTS will be involved in all facets of operations for public transportation systems (both public and privately owned and operated), including the operations of conventional bus service, school buses, carpools, Vanpools. and taxicabs. APTS will, in conjunction with the other IVHS systems, provide travelers and system/vehicle operators with a wide range of support functions and information services not generally available today.

Travelers will be provided with the following: (1) information on available transportation services, routes, schedules, and costs: (2) mechanisms for integrated and automated fare collection: and (3) in-vehicle transportation service data including safety functions, projected time of arrival, and connecting route information. This information will have sufficient detail to permit the traveler to make informed decisions regarding a preferred mode of transportation.

Operators of public transportation systems and the individual drivers will be supported by an array of services, including the following: (1) Traffic management center inputs on road and traffic status, congestion information, and segment transit times which will aid in projecting and maintaining route schedules; (2) in-vehicle navigation and route guidance equipment; and (3) communications capabilities for automatic vehicle location. reporting routine traffic/schedule status or emergencies. Other potential APTS capabilities include traffic signal preemption; HOV facilities management (such as, lane access control, lane monitoring, and violation detection); fleet monitoring and control; and vehicle diagnostic monitoring and component prefailure detection.

Technologies being considered for application in APTS include:

- Cable TV to communicate real-time transit availability
- Smart cards to improve fare handling and third party billing
- Traffic signal preemption to speed transit service
- Infrared cameras, video, and AVI to monitor HOV lane usage
- Vehicle guidance systems to expand HOV lane use
- Automated vehicle location and monitoring systems to improve transit fleet management
- Radio data systems to increase fleet communication capacity.

APTS Accomplishments to Date

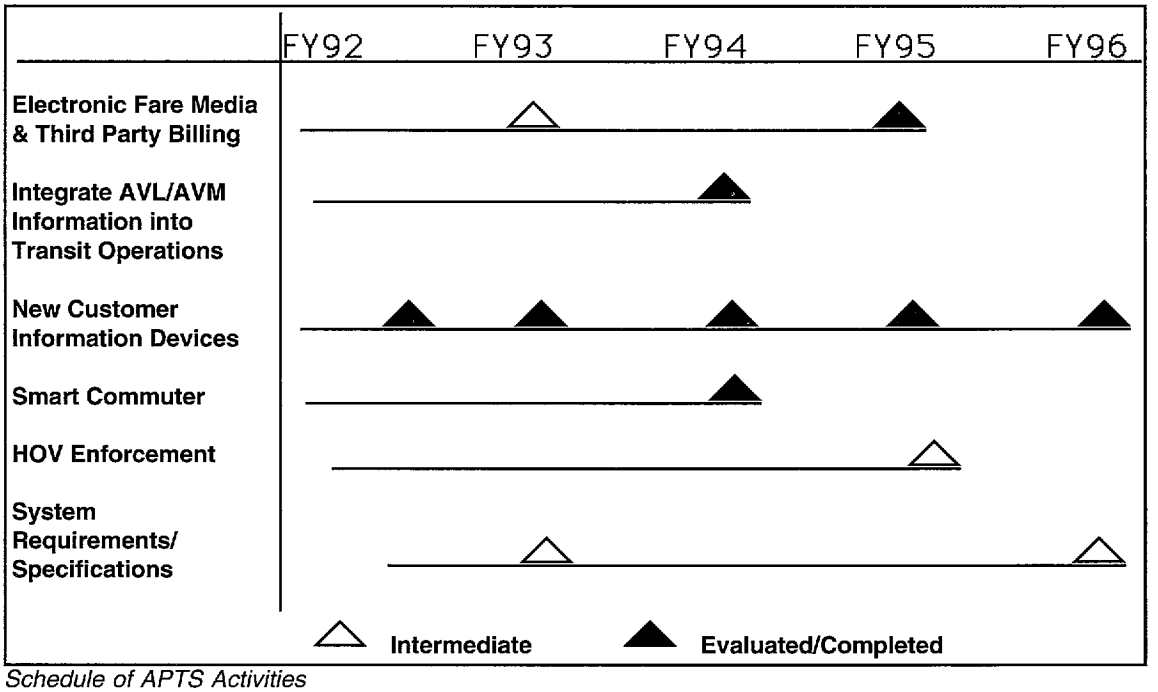
APTS accomplishments to date include the following:

- A “smart commuter” concept has been developed which provides real-time travel and ride-sharing information to travelers to help them in making mode choice decisions and in coordinating ride-sharing activities. Project development work for site-specific operational tests is under way with several states and transit organizations.
- A “mobility manager” concept to link various transportation suppliers, provide transportation information to travelers. and invoice the traveler has been developed and is currently being operationally tested. Integrated third party billing capability is being investigated for expansion to employer subsidy programs and use of smart cards.
- A European “smart bus” concept that integrates fixed-route transit, dial-a-ride minibus.and taxi services is being critically evaluated for its application in the United States. A cooperative effort is underway with one transit authority to develop a site-specific operational test.
- Specifications are being developed for an improved algorithm to provide computerized travel information to aid a telephone information agent in rapidly identifying preferred itineraries for mass transit travelers.

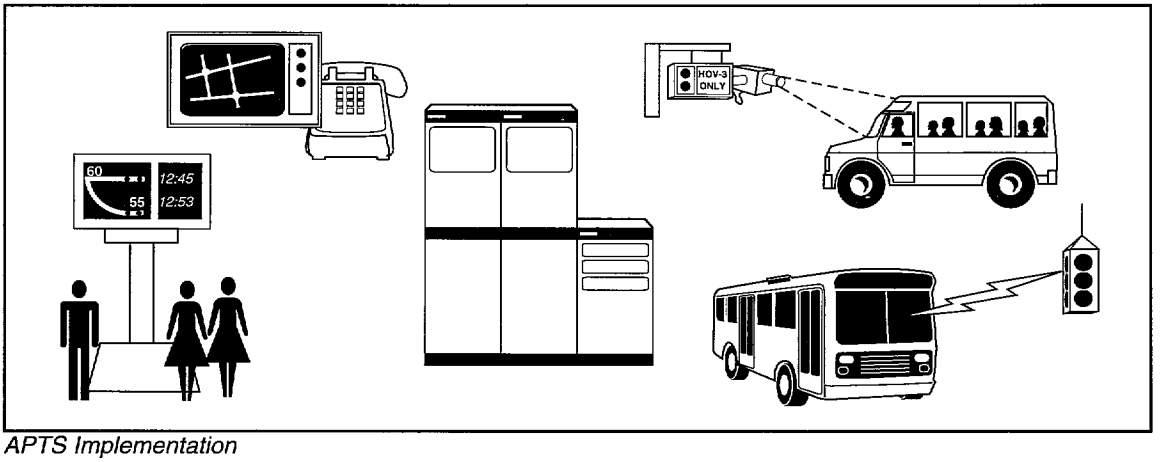
APTS in the FY93 Budget

Six elements of the APTS program are funded in the UMTA budget as follows:

- APTS technologies will be assessed by surveying existing technologies and ongoing research.
- Applications of new technologies (e.g., image processing for HOV lane enforcement) will be researched.
- User requirements will be evaluated to develop performance and interface standards
- Structured evaluations of specific technologies will be conducted.
- APTS technology information will be made available to key professionals working in the field.
- Operational tests will be conducted to evaluate the effectiveness of particular technologies which have been adapted to local transportation requirements.



Schedule of APTS Activities



APTS Implementation

OPERATIONAL TESTS

Operational tests are a major element of the IVHS Program and serve the purpose of moving IVHS technology from the realm of R&D into operational use. Following are selected operational tests which are being conducted with Federal funding participation:

- **TRANSCOM:** TRANSCOM is a consortium of 14 transportation and public safety agencies in the New York and New Jersey area whose goal is to improve inter-agency response to traffic incidents. As part of this goal, a cooperative effort has been initiated to equip approximately 1,000 commercial vehicles with transponders. Readers will be placed at selected toll booths to provide automatic toll collection for equipped vehicles. Readers will also be installed at other locations, allowing vehicles equipped with transponders 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.

- **SMART Corridor Project:** The SMART Corridor is a joint demonstration project located along 12.3 miles of Santa Monica Freeway corridor in Los Angeles. The objectives of the SMART Corridor are to provide congestion relief, reduce accidents. reduce fuel consumption, and improve air quality. This will be accomplished using advanced technologies to advise travelers of current conditions and alternative routes using communications systems such as Highway Advisory Radio (HAR), Changeable Message Signs (CMS), kiosks, and teletext, improving emergency response, and providing coordinated interagency traffic management.

- **GuideStar Project:** GuideStar is a cooperative effort that will bring together a number of on-going operational traffic management and traveler information systems efforts with a wide range of new IVHS projects and technologies designed to reduce congestion and improve safety throughout Michigan. The project will emphasize the gathering and distribution of traffic information for the use of traffic managers and motorists. The effort will include the development of the AutoscopeTM video imaging vehicle detection system. Michigan is currently establishing a major laboratory for GuideStar IVHS activities along a 3-mile corridor in the Twin Cities metropolitan area.

- **Pathfinder Project:** Pathfinder is a cooperative effort by Caltrans, FHWA, and General Motors. It is an in-vehicle navigation system project aimed at improving traffic flow. Pathfinder will provide drivers of 25 specially equipped cars with up-to-date information about accidents, congestion, highway contruction, and alternative routes as they operate in Los Angeles' SMART corridor. A control center will manage the communication. detecting traffic density and vehicle speeds via detectors and by using Pathfinder vehicles as probes, and transmitting congestion information to equipped vehicles. The information is then presented to the driver in the form of an electronic map on a display screen or via digital voice.

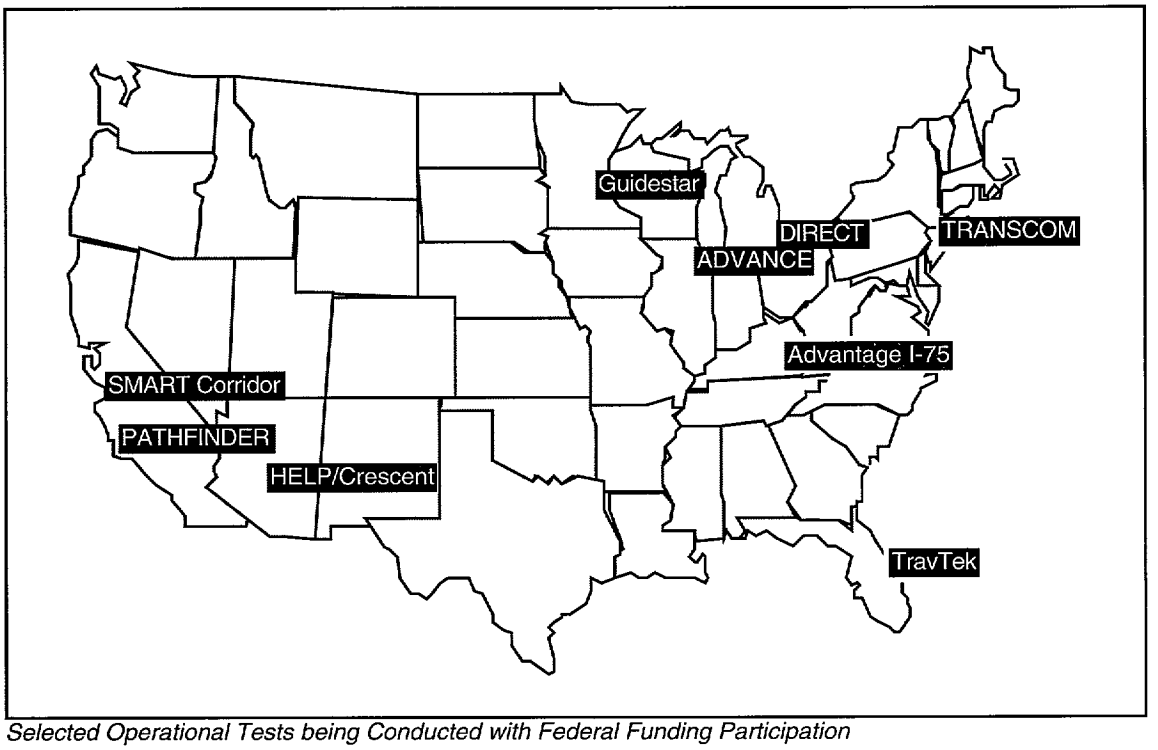
- **TravTek:** TravTek (Travel Technology) represents a public/private partnership involving the city of Orlando. Florida, the Florida DOT, FHWA, General Motors (GM), and the American Automobile Association (AAA). The goal of TravTek is to provide traffic congestion information, motorist services ("yellow pages") information, tourist information. and route guidance to operators of 100 test vehicles equipped with an in-vehicle TravTek device. Route guidance will reflect real time traffic conditions in the TravTek traffic network. A Traffic Management Center will obtain traffic congestion information from various sources and provide this integrated information, via digital data broadcast, to the test vehicles and the sources.

- **ADVANCE:** ADVANCE (Advanced Driver and Vehicle Advisory Navigation Concept) is a cooperative effort to evaluate the performance of the first large-scale dynamic route guidance system in the United States. Participants include the Illinois DOT, Motorola, Inc., the Illinois Universities Transportation Research Consortium, and FHWA. Up to 5,000 private and commercial vehicles in the northwestern suburbs of Chicago will be equipped with in-vehicle navigation and route guidance systems. Vehicles will serve as probes, providing real-time traffic information. This information will then be transmitted to the equipped vehicles and used to develop a preferred route. The routing information will then be presented to the driver in the form of dynamic routing instructions.

- **DIRECT:** DIRECT (Driver Information Radio using Communication Technologies) will deploy and evaluate four alternative low cost methods of communicating advisory information to motorists. These include Radio Data Systems (RDS), Automatic Highway Advisory Radio (AHAR), HAR using AM radio, and cellular phone. A Metropolitan Transportation Center will collect traffic information from various sources and provide traffic updates to travelers on an exception basis. Initial experimental testing will involve 30 specially-equipped vehicles; subsequent testing will involve additional vehicles using conventional equipment (AM radio and cellular phone).

- **HELP/Crescent:** HELP (Heavy Vehicle Electronic License Plate Program) is a multi-state, multi-national research effort to design and test an integrated heavy vehicle monitoring system using Automatic Vehicle Identification (AVI), Automatic Vehicle Classification (AVC), and Weigh-in-Motion (WIM) technology. Collected data will be processed by a central computer, and then be used by both government and the trucking industry for regulatory, weight enforcement, and fleet management purposes. The demonstration phase of HELP is known as the Crescent project which will include approximately 40 equipped sites ranging from British Columbia southward along I-5 to California and then eastward along I-10 to Texas, branching onto I-5. The goal is to have a system in which a truck, entering the system in British Columbia, can drive through the entire network without having to stop at other weigh stations or ports-of-entry.

- **Advantage I-75:** Advantage I-75 represents a partnership of public and private sector interests along the I-75 corridor. The project will facilitate motor-carrier operations by allowing transponder-equipped and properly documented trucks to travel any segment along the entire length of I-75 at mainline speeds with minimal stopping at weigh/inspection stations. Preclearance decisions at downstream stations will be based on truck size and weight measurements taken upstream and on computerized checking of operating credentials in each State. Advantage I-75 features application of off-the-shelf technology and decentralized and statutory authority relative to motor carriers and their operations.



Selected Operational Tests being Conducted with Federal Funding Participation

ISSUES REQUIRING INVESTIGATION

A primary focus of the IVHS Program is to ensure that all areas regarding national IVHS implementation, both technical and nontechnical, are addressed. As discussed previously. a number of operational tests have been initiated to evaluate aspects of IVHS. Various systems engineering activities are currently underway, such as standards and architecture definition, to ensure that, once deployed, IVHS will function as a *national* system and not merely a collection of locally implemented IVHS applications. Areas of particular concern that will continue to be investigated in FY93 include the following:

- **System architecture:** Fundamental to the success of a national IVHS system is the development of a flexible, open system architecture, or framework, upon which the system design and standards can be based. Elements of the system architecture include the communications system medium (e.g., terrestrial radio, satellite, infrared beacon); system data flows and protocols; message formats and data rates; database schemas and data dictionaries; and subsystem physical and electrical interfaces. The development of a system architecture is a continuing process. The architecture needs to adapt to the advent of new technologies and requirements without requiring the replacement of basic system elements such as communications equipment. In practice. several levels of system architecture may be needed to address concepts having varying "lifetimes".

- **Standards:** Development of standards will be key to widespread acceptance of IVHS technologies. Manufacturers are understandably unwilling to risk investing in components that could be made obsolete by eventual standardization. Yet standards must be carefully cast to encourage innovation and competition by stating "what" and not "how." In other words, *pe$ormance* standards are the right approach, where any of several competing technical implementations can perform the required function.

- **Evaluation:** It is incumbent on government to provide technical oversight of the IVHS Program. To do so, DOT needs objective, complete evaluation criteria for judging the outcome of research and operational field experiments. Further, to save money and time, means must be made available for assessing the applicability of the results of one set of experiments to other situations without having to fully repeat the work. The DOT develops criteria which it uses in evaluating each national operational test.

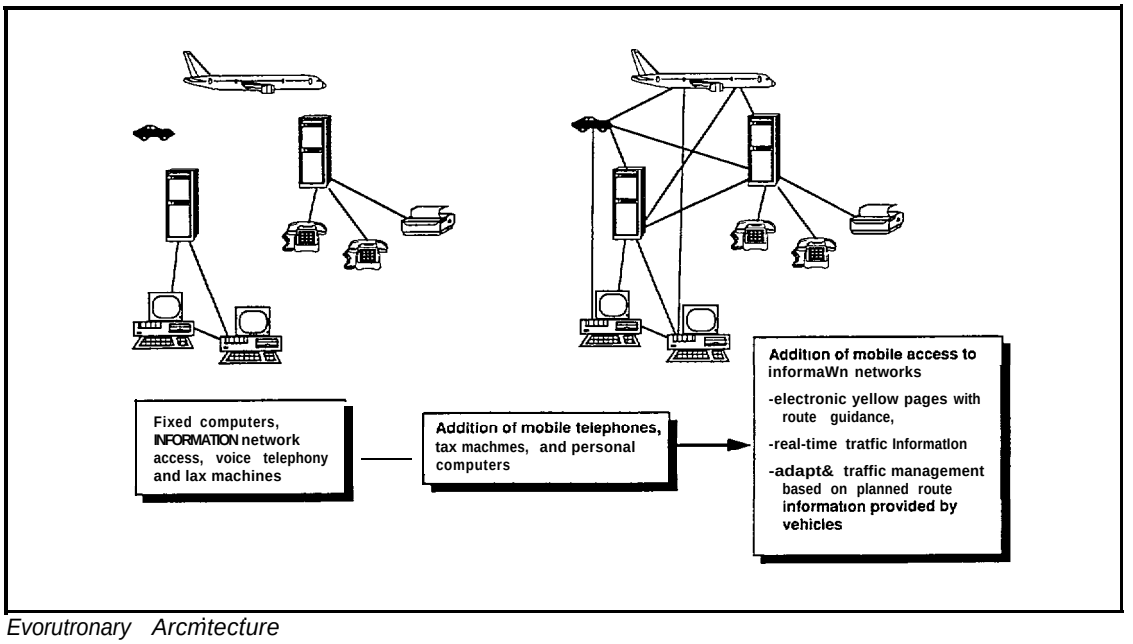
- **Human factors:** IVHS will expose the public to new technologies and procedures. This fact raises two important issues: acceptance and safety. Any candidate IVHS subsystem will need to be rigorously evaluated to assess the potential effect on safety. The ultimate success of IVHS will depend on the match between the technologies and the capabilities and limitations of the drivers. If IVHS is to succeed, it must also gain wide acceptance with the public. Systems that are difficult to use, that require extensive training, or whose "bother" exceeds their benefit, will fail. Issues such as the best way to communicate certain kinds of information to drivers (e.g., visual versus aural) depend on such things as the priority of the information and degree of distraction from driver situational awareness. Most TVHS subsystems will need extensive human factors screening *even before being funded for field experimentation.*

- **Liability:** Liability associated with vehicle control systems is an obvious issue, but the problem goes much further. It is not unreasonable to postulate that a driver who accepted alternate route guidance and subsequently was involved in an accident would sue all parties connected with the system. The same may be true of incident response enhancement systems if it could be asserted that the system designed to improve the response time to an accident had "failed," and an injured person's condition was aggravated by the delay. A fair compromise between limitation of liability and incentives for system designers, builders. and operators to act responsibly will have to be worked out.

- **Privatization Opportunities:** The development of AVI may evolve beyond toll road/bridge/tunnel applications as some states like California consider statewide electronic license plates. With such as system, it is possible to fund a variety of highway and street improvements

with user charges automatically collected as vehicles with the electronic license plates pass through the improvements. Private franchises could install and operate computerized traffic signal systems just as easily as they are now being considered for toll road development. Electronic fare media for public transportation may also evolve to where the major part of cash handling for transit may be contracted to banks. The availability of vast amounts of new electronic transfer information may open new service opportunities for entrepreneurs.

- **Access by private services:** IVHS infrastructures will probably be operated by state and local governments. However, many of the desirable services, such as "yellow pages" or availability of parking space, will probably be provided by private companies. Accounting for this arrangement in the system architecture, communications capacity, and cost/revenue planning processes is essential. For example, will private providers have access to the base IVHS communications systems for a price? What share of the system capacity would be set aside for these services? What relative priority would they have? Would the service providers be asked to share the cost of initial system installation? These and other questions need to be addressed before technical issues that depend on them are decided.



Evorutronary Arcmitecture

A Public/Private Partnership

An Overview of the
IVHS Program
Through FY 1991

1 October 1991