The Intelligent Vehicle Highway Systems: The Federal Highway Administration R&D Program

Alberto J. Santiago
Federal Highway Administration

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Background

The level of mobility on which we have come to depend can no longer be taken for granted. As the backbone for the social and economic development of any country, a sound transportation system can promote business and facilitate communication by ensuring the proper movement of people and goods. Over the last few years, however, demand for the use of transportation facilities in the U.S. has increased at a rate much higher than that which can be absorbed by current systems. This phenomena, coupled with the lack of funding to construct new facilities and accommodate this additional demand, has been a major contributor to traffic congestion.

Recognizing the economic impossibility of constructing new facilities which would satisfy current and future travel demand while preserving the environment, the U.S. Department of Transportation (USDOT) is pursuing the concept of Intelligent Vehicle/Highway Systems (IVHS).

Congestion on the Nation's highways continues to increase, particularly in urban areas and along heavily-traveled intercity corridors. The annual cost of congestion to the Nation in lost productivity alone is about $100 billion, exclusive of the costs of wasted fuel and environmental damage. In addition, more than 40,000 persons are killed and another five million injured each year in traffic accidents, at an additional annual cost of over $137 billion to the Nation's economy.

Even though highway facilities have been declining in recent years, the loss of so many human lives is unconscionable in an era when technology would permit us to save many of them. Additionally, in many areas of the country we cannot financially or environmentally support the building of enough additional roads to solve congestion problems. What is needed is a "smarter" surface transportation system, one that actually functions as an integrated intermodal system that offers increased performance in many respects while offering improved safety, more efficient use of infrastructure, and enhanced user choices through the application of IVHS technologies and services.

IVHS is an ambitious multi-year, multi-billion dollar

research and demonstration program which aims at improving vehicle-highway system operation and management techniques for the post-interstate construction era. The main goal of the IVHS program, which will carry the Federal Highway Administration (FHWA) into the 21st century, is to develop state-of-the-art vehicle-highway management techniques and control systems that will effectively reduce congestion through optimizing the use of the existing infrastructure. If successful, we will provide an increased level of safety, mobility, driver convenience, and environmental quality for both rural and urban areas.

Vision

FHWA's vision for the future of surface transportation is one of improved use of the infrastructure and enhanced user choices through the application of appropriate IVHS technologies and services. While not a panacea, these technologies have considerable potential for addressing transportation problems. Of course, other technologies will also contribute to the solution of our transportation problems.

This is a future of safer and better informed travellers. Accurate and timely information on traffic conditions and transit services will be available to travellers before they begin trips. Navigation and route guidance and improved traffic control systems, as well as systems aimed at increasing the efficiency of commercial vehicle and transit operations, will provide assistance once a trip is underway. The safety of highway travel will be significantly increased through products which ensure the driver's own state of fitness, enhance driver perception on a continuous basis, give warning of impending danger, and eventually intervene with emergency control to prevent accidents from occurring.

This vision also includes automated highways that improve the safety, efficiency, and convenience of the highway system, while simultaneously extracting greater productivity out of the infrastructure.

IVHS technologies and services will significantly enhance the efficiency of transit and commercial vehicle systems by providing accurate information on the location and status of the vehicles and traffic conditions, and two-way communication with the drivers. This information will also help make transit systems more user-friendly to passengers. Still other technologies will aim to reduce the motor freight paperwork burden associated with the issuance of State permits and the monitoring of size and weight compliance.

While these technologies and others will be introduced gradually, over the long term they will have dramatic and enormously beneficial implications for our Nation's surface transportation system and the safety of the traveling public.

The basic components of IVHS technologies, and their interaction are: private, commercial, transit, public service, and emergency vehicles

of all kinds; roadways and traffic monitoring and control devices; communications systems; transportation system controllers and operators; collision avoidance systems; and informed travellers and users.

The types of innovations envisioned include:

- Traffic management systems that monitor current conditions and adjust lane usage, speed limits, traffic signals, and roadway ramp access based on actual traffic conditions rather than on historical patterns;

- Public transit enhancements, such as smart cards and real-time displays of service status, and systems to make dynamic ride-sharing possible;

- Electronic devices that permit motor freight, emergency vehicle, transit, and hazardous material transporters to track their vehicles on a continuous basis and to communicate with their drivers, resulting in more responsive services;

- Devices that permit the electronic collection of tolls, transit fares, and other transportation user fees;

- Systems that can electronically weigh and inspect commercial vehicles in motion, enable the electronic issuance and monitoring of permits, or track a container throughout a multi-modal shipment;

- A variety of innovations within and outside of the motor vehicle to supplement the driver's efforts at vigilance and control, including new products which ensure the driver's own state of fitness, provide on-board road signing and visual enhancements, augment driver perception on a continuous basis, give warning of impending danger, intervene with emergency control if a crash is imminent, and over time, automate the driving process on specialized roadways;

- Devices that alert authorities to the need for dispatching emergency vehicles to the site of a collision;

- Information, available from numerous sources (home TV, radio, personal computers at home and at work, public kiosks, handheld devices, and others), that advise travellers and drivers about current and expected traffic conditions, as well as transit locations and timetables, allowing them to make informed choices about when to leave, how to travel, and what route to take; and,

- On-board navigation devices that help drivers plan and follow safe and efficient driving routes, coupled with "electronic yellow pages" that make

it easy to find local services and attractions.

Mission

In providing leadership for development of the national IVHS program, the FHWA's program will be governed by the following four principles:

1) Support research and development to solve problems of surface transportation safety, congestion, productivity, and mobility.

2) Ensure that newly developed applications are safe and produce public benefits commensurate with costs.

3) Promote and support deployment of a nationally compatible system that reduces risk and cost to users as well as the public and private section providers of products and services.

4) Support development of a domestic IVHS industry by maximizing private sector involvement in all aspects of the program.

Goals

The goals of the IVHS Program are:

1) To improve the safety of surface transportation.

2) To increase the capacity and operational efficiency of the surface transportation system.

3) To enhance personal mobility and the convenience and comfort of the surface transportation system.

4) To reduce the environmental and energy impacts of surface transportation.

5) To enhance the present and future economic productivity of individuals, organizations, and the nation as a whole.

6) To create an environment in which the development and deployment of IVHS can flourish.

Program Organization

To implement the IVHS Program, USDOT has established a coordinating mechanism including representatives from the Office of the Secretary of Transportation (OST), the Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), the National Highway Traffic Safety Administration (NHTSA), and the Research and Special Programs Administration (RSPA).

Program Delivery

The program delivery process involves research and development, operational testing of promising technologies and system concepts, a special focus on far-term IVHS development under the Automated Highway System program, and fostering the deployment of systems nationwide. Special emphasis is placed throughout on exploring institutional and legal issues surrounding IVHS deployment, promoting cooperation among public agencies, and investigating

creative financing mechanisms for IVHS.

Milestones

The Department of Transportation has established a set of discrete milestones to be accomplished during the next five years of the IVHS program (1993-1997):

Tools and Knowledge Bases
System Architecture
Radio Frequencies
Traveller Information Systems
Route Guidance and Navigation Systems
Transit Fleet Management
Fare Collection and Smart Cards
Transportation Demand Management
Transportation Management Database
Traffic Control Systems
Rural Applications
Commercial Vehicle Applications
Commercial Vehicle Network
Collision Avoidance
Automated Highway System (AHS)
Benefits and Costs
Institutional and Legal Issues
IVHS Deployment

Beyond 1997, deployment of a nationally compatible IVHS system will become FHWA's primary concern. Work will shift towards supporting deployment of IVHS user services, and continuing progress on long-term IVHS goals, especially the Automated Highway System.

The FHWA believes that it is moving in the right direction, guided by the framework provided by the National Transportation Policy, the Intermodal Surface Transportation Efficiency Act, and the *Strategic Plan for Intelligent Vehicle-Highway Systems in the United States* prepared by IVHS AMERICA.

Current Direction of IVHS

The transportation technologies that will develop under the IVHS program are divided into five interrelated components: Advanced Vehicle Control Systems (AVCS), Advanced Traveller Information Systems (ATIS), Commercial Vehicle Operations (CVO), Advanced Public Transportation Systems (APTS), and Advanced Traffic Management Systems (ATMS).

Advanced Vehicle Control Systems (AVCS)

The ultimate goal of Advanced Vehicle Control Systems is to develop a technology in which the driver no longer drives; he or she becomes a passenger. Without human intervention, cars could journey from one place to another on designated highways which are suitably instrumented. One example of this technology is the use of radar for steering within a lane and for sensing neighboring vehicles. Another example is a braking system which regulates vehicle speed and minimizes the time separation (headway) of platooned vehicles.

Goal and Approach

Provide, via three level of AVCS, significant benefits. With the third level, complete automation, provide major break-throughs in transportation safety, productivity, and capacity.

These three levels are:

- AVCS I In-vehicle warning and vision enhancements

- AVCS II Cooperative Driver-Vehicle-Highway Systems
- AVCS III Automated Vehicle-Highway Systems

The AVCS program addresses the needs of passenger cars, commercial vehicles and transit vehicles. It will be undertaken with the advice of IVHS AMERICA and cooperatively by the FHWA, other DOT modal administrations, States, local agencies, universities, and the private sector.

A copy of the flowchart describing FHWA's R&D program in this area is enclosed in the back of this paper. (Figure 1.)

Advanced Traveller Information Systems (ATIS)

Advanced Traveller Information Systems is the framework through which information is made available, not only to the driver, but to the general traveller. ATIS is composed of several elements. First is the development of in-vehicle route guidance systems. This includes audio-visual aids such as electronic maps and highway advisory radios, enabling the driver to select the best route. A second element is the development of models which optimize network routing and usage. Third is the dissemination of information to travellers which allows for pre-trip and/or en-route planning. An example of such information would be the message that congested highways have affected bus schedules, or that HOV restrictions have been lifted. Another element of ATIS is quantification of driver behavior. This would entail developing models which replicate how people select routes, how they react to highway incidents and how they select their mode of travel.

Goal and Approach

Enhance individuals travel and traffic network management, including route and mode choice and avoidance of traffic disruptions through Advanced Traveller Information Systems. In addition, improve overall safety through in-vehicle safety advisory and warning systems.

ATIS addresses the needs of urban and rural areas. The program is being undertaken cooperatively with the States, local agencies, universities, and the private sector. It is designed to accomplish needed research, development, and operational tests, and to bring in-vehicle information systems to a fully deployment stage by 2010 at which time they would be deployed by the States as part of the regular Federal-aid highway program.

Full maturity and deployment of ATIS would be achieved via stages of research and development, operational testing, and evaluation. It is convenient to divide the development of ATIS into three states:

- ATIS I Information Stage
  1990-1995
- ATIS II Advisory Stage
  1995-2000
- ATIS III Coordination Stage
  2000-2010

During the Information Stage, emphasis will be primarily on

providing the traveller with information to improve his own planning and decision making. Most of the capabilities will rely on the vehicle's own resources and will be largely independent of any infrastructure. Such features as dead-reckoning navigation systems, on-board information databases, and static route selection fall in this category. With limited support from the infrastructure, real-time traffic incident information could be made available to the traveller to assist him in planning his route.

The Advisory Stage will supplement the static on-board information with dynamic traffic information collected and transmitted by the infrastructure. This will include basic safety warning systems, traffic link times (the time to traverse various parts of the road network), incidents, weather, and other factors affecting traffic flow. This digital information will be received by the vehicle automatically and used to compute currently optimum routes or filtered for relevance and selected items presented to the Traveller. The vehicle will then guide the driver step-by-step over the optimum route providing critical information as needed.

The Coordination Stage will have been reached when the vehicles and the infrastructure automatically exchange information to optimize the flow and safety of traffic over the entire network. Vehicles will continually report on traffic conditions they encounter. The infrastructure will combine this information with all its other sources of information using predictive data-fusion models to provide coordinated routing and traffic signal control. Included in this stage will be complex in-vehicle safety advisory and warning systems. Additionally, individual vehicles requiring emergency assistance can summon the required service (police, medical, mechanical, etc.) which will be automatically routed to the scene.

The time periods shown for these stages are, of course, approximate and are meant to represent the time period from commercial introduction to penetration of approximately 10 percent of the new-car fleet. At any point in time there will be some localities and some vehicles operating in each of these stages.

A copy of the flowchart describing FHWA's R&D program in this area is enclosed in the back of this paper. (Figure 2.)

Commercial Vehicle Operations (CVO)

Commercial Vehicle Operations addresses the special needs of commercial traffic. It encompasses many of the ATIS aspects and enables dynamic fleet management. CVO also encompasses in-vehicle diagnostic systems, automated vehicle identification and certification, and driver performance systems. These systems will alert professional drivers of possible vehicle malfunctions, log arrivals at checkpoints and/or jurisdictional boundaries (for tax purposes), and measure

driver performance (such as alerting a driver who is experiencing fatigue).

Goal and Approach

The goals of the CVO program are to improve the: (1) efficiency and effectiveness of traffic management and regulatory administration by Federal, State and local governments, (2) productivity and fleet management of commercial operations, (3) safety for CVO and others affected by them, (4) and ensure that driver dependant systems are designed to address the ultimate user.

The FHWA will pursue these goals, consistent with FHWA's mission and the Secretary's National Transportation Policy in partnership with FTA, NHTSA, States and industry.

The CVO program is closely coordinated with the other IVHS programs so that they consider the unique aspects of commercial vehicles, drivers, and operators when developing the various IVHS technologies. The early application of IVHS technologies to CVO will not only help achieve CVO goals, but also offer the U.S. a unique opportunity to accelerate the development of IVHS systems for automobile drivers.

The primary technologies to be integrated and applied under the CVO are:

Automation Vehicle Identification
Weigh-in-Motion
Automatic Vehicle Classification
Electronic Placarding/Bill of Lading
Automatic Vehicle Location
On-board Computers
Two-way Real-time Communication
Automatic Clearance Sensing

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Advanced Public Transportation Systems (APTS)

APTS addresses the needs of non-drivers: people who indirectly use the highway system. This component of IVHS is concerned with the optimal utilization of mass transportation systems such as buses, light rail, subways, and any form of high occupancy vehicle, such as carpools and vanpools. APTS can make a significant difference in mobility as information on mass transit facilities will be made available to drivers to potentially reduce overall demand. For example, once the origin and destination of a trip is determined, a driver could be made aware that re-routing his or her trip to use other transportation modes could make the travel time shorter and/or safer.

Advanced Traffic Management Systems (ATMS)

Most important of all aspects of the IVHS program is Advanced Traffic Management Systems, the very backbone of IVHS. ATMS consists primarily of three aspects. One is the development of surveillance systems to monitor the operational status of a roadway network. A second is the development of real-time, traffic-adaptive control

systems which, through the feedback provided by the surveillance system, adapt network control such as traffic signals, freeway ramp meters, messages on electronic signs, etc., for optimal performance. A third is the development of system operator support systems (expert systems, simulation models, etc.) to enable and facilitate real-time control and management of the network.

Goal and Approach

Research, develop, and operationally test adaptive transportation management systems and control strategies to achieve maximum transportation efficiency on existing highway networks. Apply advanced technologies to continue to advance the state-of-the-art in traffic engineering while pushing the state-of-the-practice through aggressive technology transfer and training activities. Provide the platform by which the integration of all IVHS components (ATIS, CVO, APTS, and AVCS) will be achieved. Provide incentives for deployment and implementation of state-of-the-art traffic management systems across the United States.

ATMS is a combination of research, development, and operational tests in which Federal, State, academic, and private cooperative efforts will be merged into a strong and efficient program to combat traffic congestion.

With the goal of providing maximum efficiency of existing facilities, ATMS proposes to develop the technology necessary for their real-time, adaptive management and control. In this effort, nine major program areas will be addressed:

1) Development of the technology necessary for the real-time surveillance and monitoring of urban networks.

2) Development of real-time traffic control systems which interact with surveillance systems and system operators to implement control tactics that maximize the utility of existing networks -- not in a reactive, but rather in a proactive mode.

3) Development of support systems composed of real-time traffic simulation and optimization models integrated with artificial intelligence technology to assist traffic engineering practitioners in effectively and efficiently managing traffic.

4) Development of strategies, such as responsive transportation management, incident detection and response, malfunction management, and congestion containment, to ensure the minimal propagation of congestion and air pollution.

5) Develop the technology which ensures the proper integration of surveillance systems with freeway and surface

street control systems such that real-time, traffic-adaptive control is provided on a network-wide basis. This integration will also provide the common platform needed to incorporate ATIS, CVO, APTS, and AVCS. This development will also address issues related to the integration of mass transit, fleet management, emergency vehicles, and multi-modal travel into network-wide control systems.

6) Investigate and resolve institutional barriers which may hamper the rapid and effective deployment of these systems together with the development of procedures to adequately plan the implementation of these systems while maintaining an adequate level of performance.

7) Determine the need and develop the technology necessary for the implementation of advanced transportation management in rural environments.

8) Engage in aggressive technology transfer and training activities to promote professional development, entice recruitment of professionals into this technical area, and continue to push the state-of-the-practice to the extent where adequate staffing and expertise is available for IVHS development and implementation. This initiative will also address the transitional issues related to moving from existing technology to advanced systems.

9) Investigate human factors issues such as information needs for control, system/operator interfaces, control center design, etc., to maximize the utility of these systems.

A copy of the flowchart describing FHWA's R&D program in this area is enclosed in the back of this paper. (Figure 4.)

Benefits of IVHS

IVHS can be an important part of the solution to the surface transportation problems facing us in the future, just as the Interstate Highway System was in the past. Applications of cost-effective IVHS technologies have the potential to help save lives, save time, and save money. It will also multiply the effectiveness of future spending on highway and transit facility construction and maintenance, increase the usefulness and attractiveness of public transportation, and provide new tools for managing travel demand. Of course, these benefits will not be achieved without considerable costs. The trade-offs between benefits and costs will be assessed in making public investments in the technology.

The benefits of IVHS will likely be experienced by all segments of the population. For example, measurable

reductions in traffic congestion are attainable through better network surveillance and management, and a better-informed travelling public. While these results in obvious advantages for the traveller, the indirect consequences are also significant. These include reduction of "secondary" or congestion-related accidents, improved transit service, less fuel wasted from sitting in traffic jams, and fewer emissions from idling engines. Productivity gains result not only from workers who waste less time commuting, but also from lower commercial trucking costs and greater returns on capital investment in public transportation.

While congestion is the primary traffic problem in urban areas, rural areas suffer from a higher traffic fatality rate due to road conditions and higher rates of speed. The increased margins of safety provided by IVHS crash warning and avoidance technologies have the potential to reduce the number and severity of both rural and urban accidents. Additionally, IVHS communications capabilities will improve rural emergency response times and improve levels of rural public transportation service.

Improved vehicle management systems will assist transit in operating more efficient and attractive services. Ride-sharing arrangements will be made more convenient. Electronic fare collection will reduce the exact-change barrier to the convenient use of transit.

Increased collection and creative use of information will assist travellers in making informed decisions to use transit and other ride-sharing arrangements. Less vehicle-miles of travel will result, with associated environmental and energy conservation benefits. Personal mobility will be enhanced by making services better understood and more accessible, especially to the transportation-disadvantaged, including the elderly and disabled, and residents of geographically remote communities.

Electronic toll collection, a convenience in itself, also provides the necessary technology base for congestion pricing, a demand management tool for which ISTEA has authorized research and development, and which may be an important part of the long-term solution to many transportation problems. Commercial vehicles also stand to gain from systems which replace hand-to-hand document transfer with electronic information transfer, minimizing stops for tolls, weighing, safety inspections, and other delays. These same technologies can lead to similar benefits for passengers using public transit by electronically integrating fare and billing systems.

Although there are substantial risks, an entirely new plane of benefits may be realized with the complete automation of certain highway facilities. An automated highway could provide a nearly accident-free driving environment and result in an increase of two or three times

the capacity of present-day facilities, while possibly encouraging use of more environmentally benign propulsion methods.

IVHS technologies and systems also promise to remove much of the uncertainty, aggravation, frustration, fatigue, and general stress associated with travel that many of us experience today.

Roles and Responsibilities

Implementing a nationally compatible system of IVHS technologies and services in the United States will require the successful integration of a wide range of technologies and engineering and operating skills, and the resolution of non-technical issues as well. The Federal government does not have the only role to play in this effort. It will be necessary to establish unprecedented levels of cooperation and coordination among hundreds of entities and thousands of individuals representing:

- The private sector, including manufacturers of goods, construction firms, and providers of legal, financial, communications, operations, and maintenance services;
- Organizations representing scientists, engineers, and the users of surface transportation systems;
- The academic community; and,
- Federal, State and local governments.

Each of these communities of interest has its own expertise to offer and role to play in the development, implementation, and use of IVHS systems. It is essential, however, that these disparate skills and roles be integrated in a manner that enables the development and deployment of IVHS to proceed in as smooth and effective a manner as possible. The successful integration of these communities into an effective public/private partnership

remains a key area of interest for all participants, including the Federal government.

The **private sector** has the principal responsibility for developing the technology and marketing the products that will bring IVHS to reality. The private sector will provide a broad range of IVHS services, including consulting, computer software products, systems integration, communications, and facilities management. They may also have an increasing role in providing and operating many infrastructure elements on an entrepreneurial basis.

Professional societies will help identify research needs and conduct technical research and policy studies, set standards and protocols in their area of responsibility, and collect and disseminate information through their journals and conferences.

A wide spectrum of **consumer and industry groups** have important contributions to make to this program. They will represent

particular industries and sectors of society that have an interest in IVHS.

The most important function of **academia** is the development of educational programs and the education of transportation professionals. Academia also has an important role in basic and applied research and development, technology assessments, and operational tests.

State and local government units now own and operate most roadway and public transit systems. To the extent that these facilities are the ones to which IVHS technologies will be applied, State and local governments will dictate the selection, purchasing, installation, ownership, operation, and maintenance of IVHS infrastructure. In addition, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) considerably extended the responsibilities and authority of **metropolitan planning organizations (MPOs)** in the transportation decision-making process, particularly in the areas of congestion management and air quality standards attainment. These broad new assignments place MPOs, working together with State and local governments, in a strategic position to advance IVHS.

The **Federal government** will provide the national emphasis and perspective on safety, congestion relief, mobility enhancement, environmental impact, energy conservation, productivity improvements, and system standards necessary to assure the development and deployment of a nationally compatible IVHS system. In this context it will evaluate the actual costs and benefits associated with IVHS applications. It will also represent the public interest, provide leadership, fund high-risk research, and participate with the private sector in demonstrating and evaluating technology. In addition to the Department of Transportation, Federal agencies with important roles in regard to IVHS include: the Department of Commerce, the Federal Communications Commission, the Department of Energy, the Department of Justice, the Environmental Protection Agency, the Interstate Commerce Commission, and the National Laboratories.

Within the Federal sector, the **Department of Transportation** will provide the national framework of support for IVHS, and ensure the broadest Federal integration. The Department of Transportation has the responsibility for encouraging and coordinating the development of technology and the associated knowledge base, for developing standards of system performance for meeting safety goals, and for ensuring the nationwide compatibility of IVHS systems. In addition, DOT spending on research, operational tests, and evaluations will stimulate private sector and State and local government efforts. Finally, Federal-aid funding from the Highway and Mass Transit Trust Fund, administered by the Department, will be available for implementation of IVHS nationwide.

The **Intelligent Vehicle Highway Society of America (IVHS AMERICA)** is chartered as a utilized Federal Advisory Committee to advise the U.S. Department of Transportation on the IVHS program. It also serves as the primary organizational representative of the IVHS community described above, and provides a forum to discuss the possibilities for joint or shared IVHS research and operational tests. IVHS AMERICA has also undertaken several secretariat activities to assist the Department, including establishing a repository for technical and safety data related to IVHS research and development. DOT personnel serve as *ex officio* members of IVHS AMERICA's Board of Directors, members of its Coordinating Council, and as secretaries to each of the Technical Committees. The Department is excluded, however, from participating in the internal administrative or business affairs of the organization.

Conclusions

IVHS is providing a way to ensure our social and economic well-being by enabling for the development and implementation of technologies that will ensure the viability of our future transportation needs. However, three major obstacles still remain to be overcome:

1. We must recruit and retain the talents and expertise of many professional disciplines who, jointly with the traditional traffic engineering experts, can enable the successful development of IVHS.

2. We must not attempt to apply advanced technologies with the mindset that promotes the use of procedures based on conditions and assumptions that predate the existing problems, and indeed have helped to create them.

3. Although we are focusing on advancing the state of the art, we must pay enough attention to the state of the practice. That is, we must develop systems and solutions that can be implemented.

We must pay attention to these obstacles and overcome them effectively. If we do, there is no question that IVHS will be a viable solution.

Figure 1

AVCS Research Program

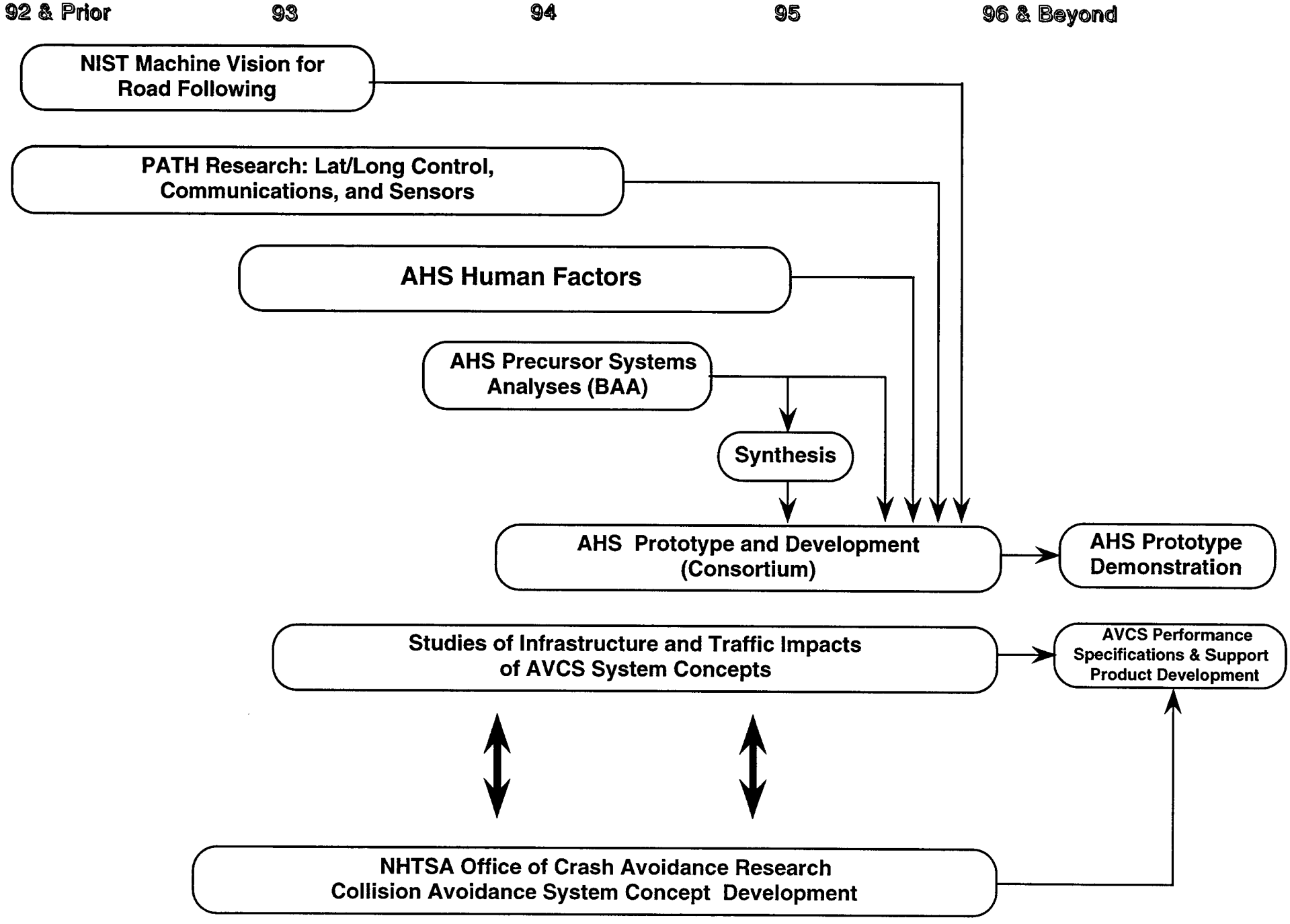

Figure 2

Advanced Traveler Information Systems

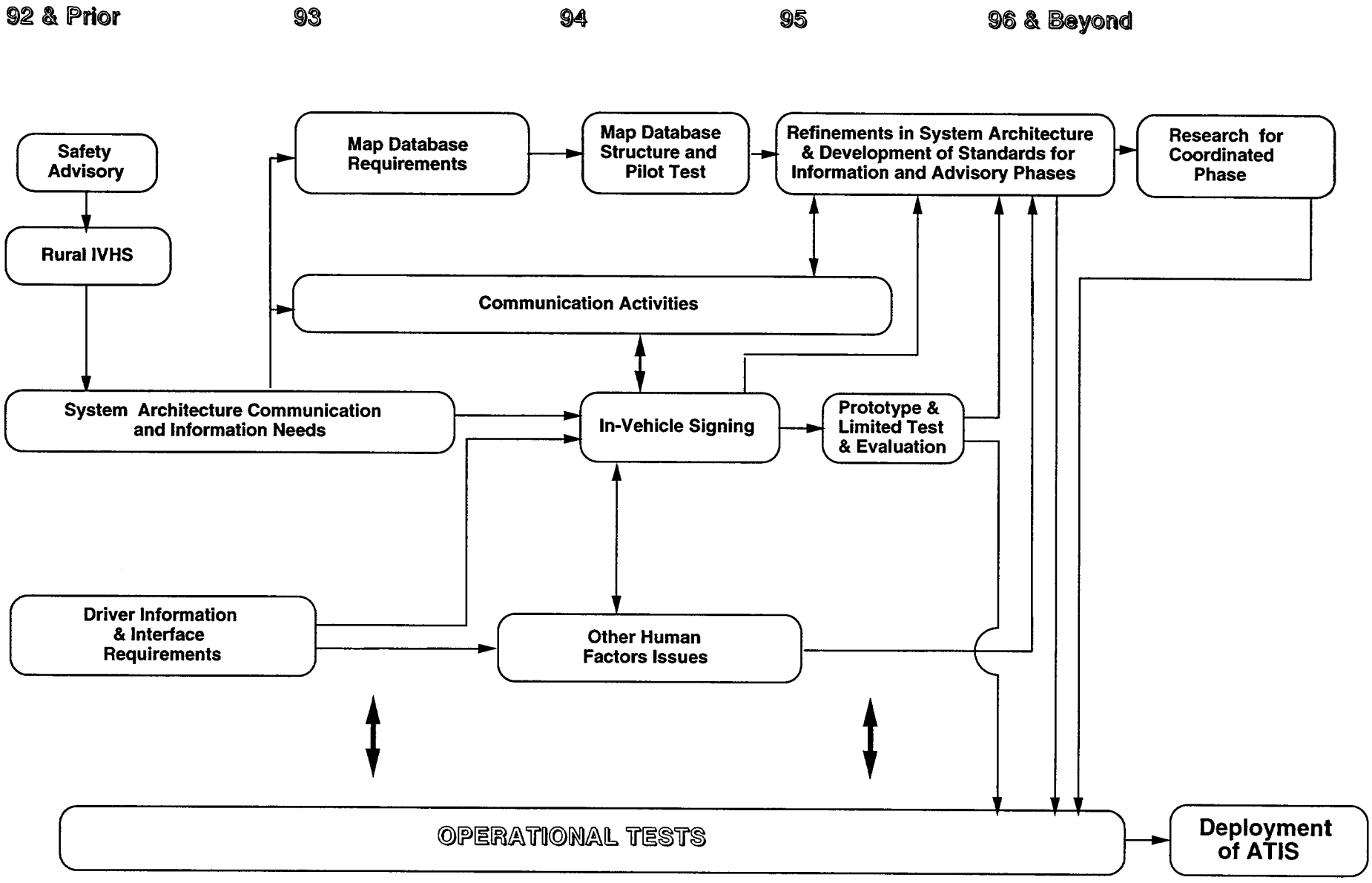

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Figure 3.

COMMERCIAL VEHICLE OPERATIONS

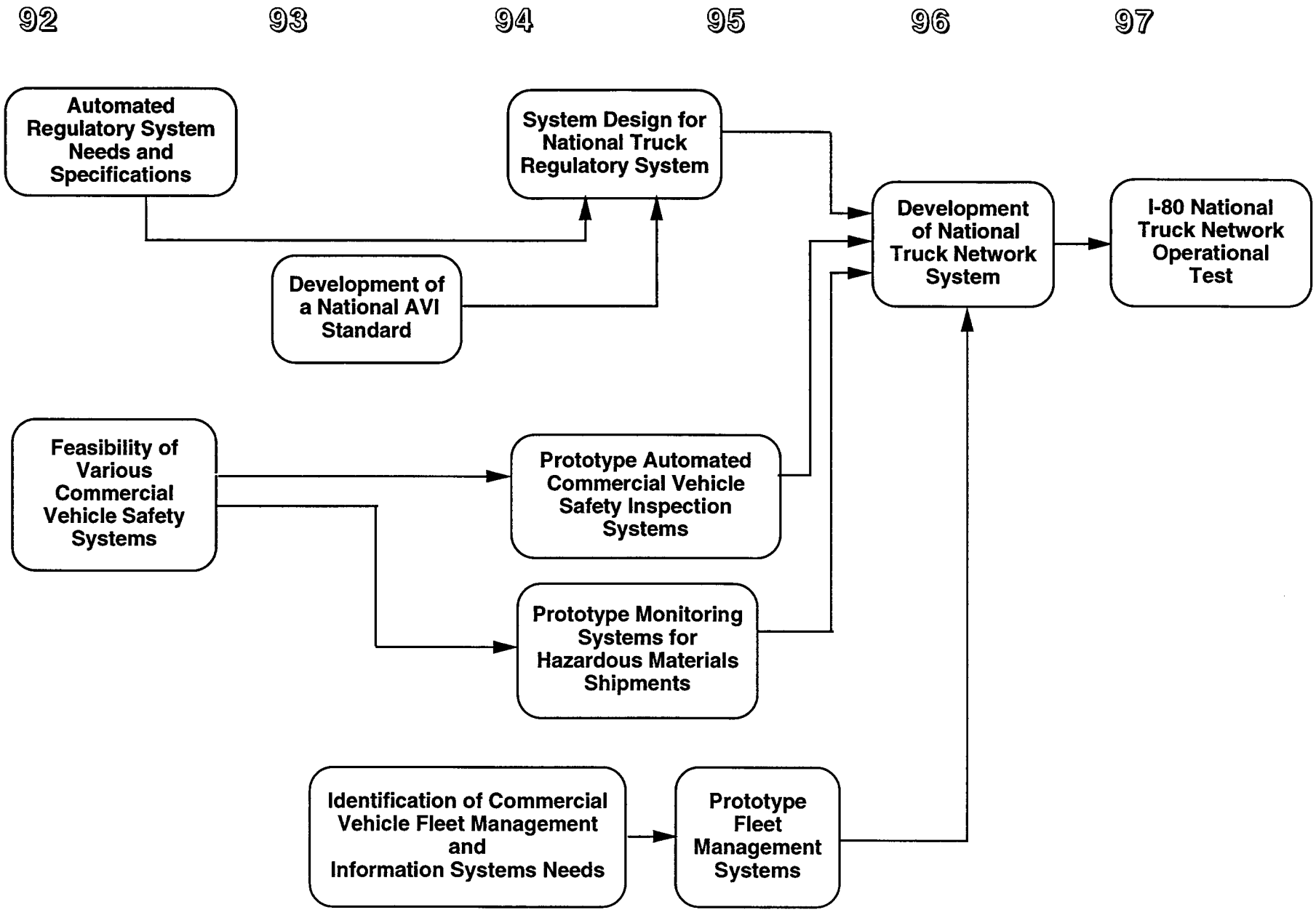

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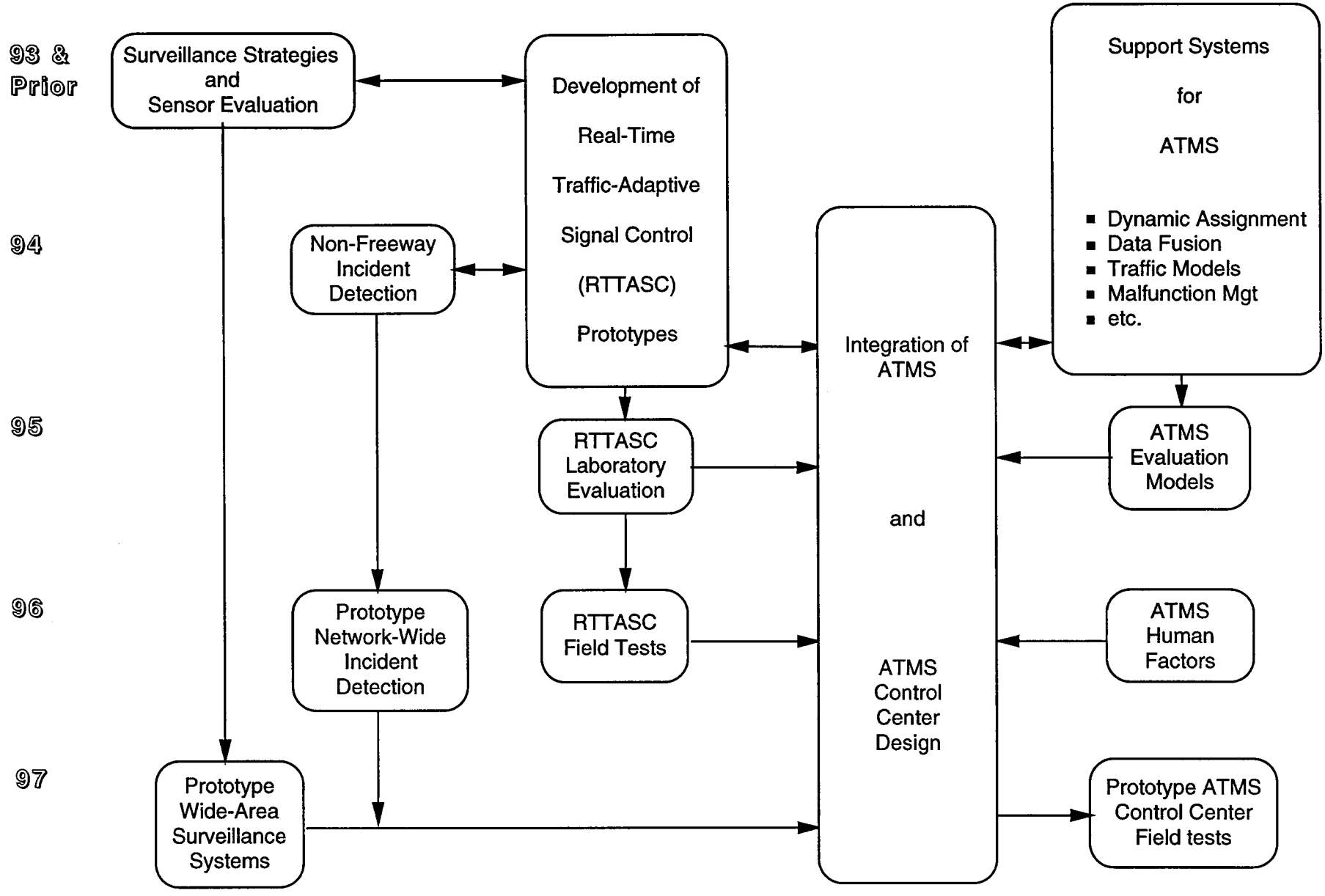
Figure 4.

ADVANCED TRAFFIC MANAGEMENT SYSTEMS



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