Intelligent Vehicle/Highway Systems, 1990 - An EDS White Paper

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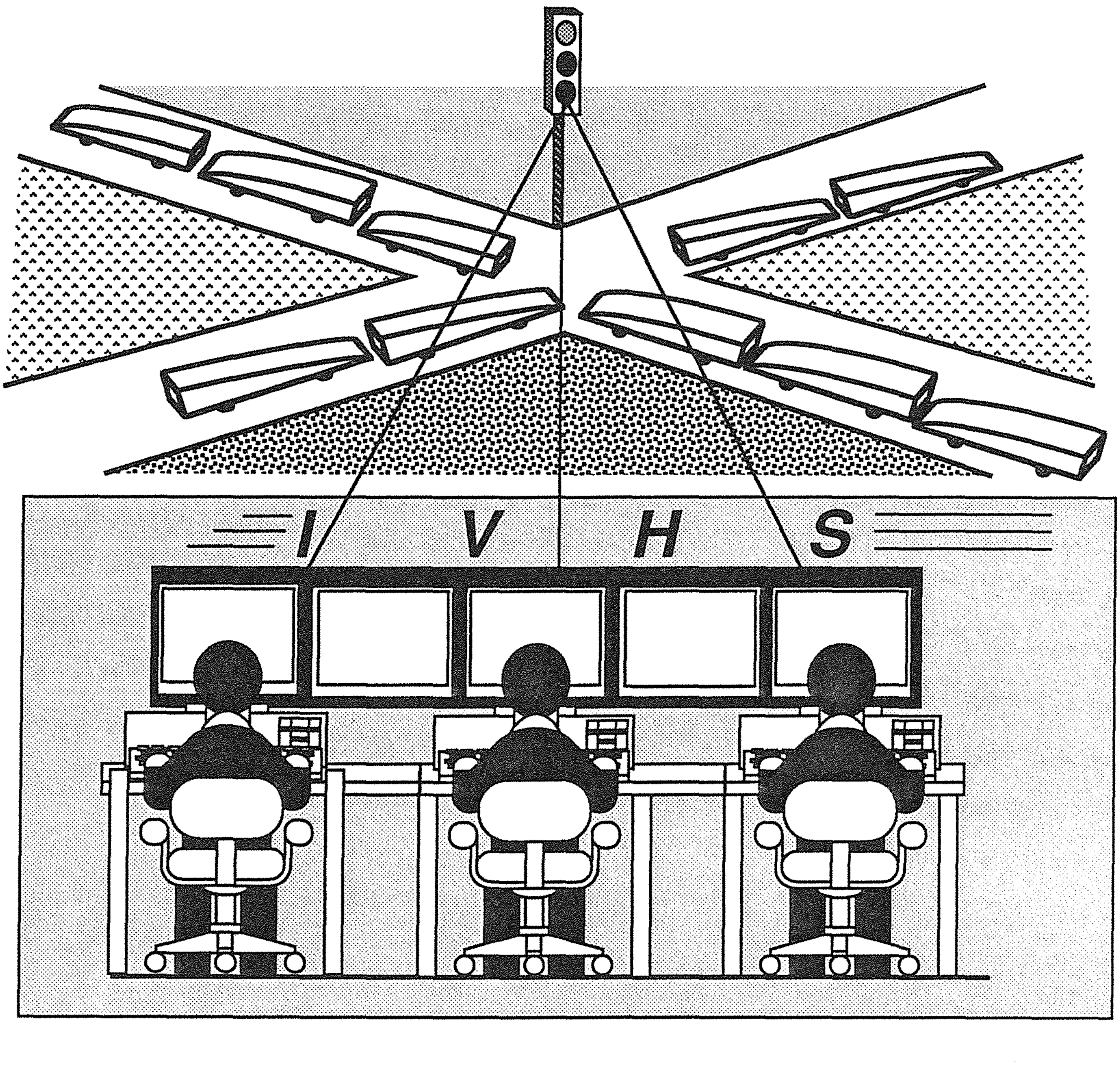
Intelligent Vehicle/Highway Systems



Technical Systems Development
Troy Michigan

EDS

INTELLIGENT VEHICLE/HIGHWAY SYSTEMS (IVHS)

EDS
ROLE AND STRATEGY

WHITE PAPER

FIRST EDITION
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Study Conducted

by

EDS/TSD

C4 Development/CAE Division

INTELLIGENT VEHICLE/HIGHWAY SYSTEMS
IVHS
EDS Role & Strategy

PREFACE

Intelligent Vehicle/Highway Systems (IVHS) are regarded as a key element for improving the efficiency and safety of ground transportation. The benefits to society afforded by the application of this technology and the critical strategic importance of its success to our parent corporation and major customer have prompted EDS to initiate this effort which will provide a foundation for further activities in this field. The entire field of IVHS is one with a wide scope in which many business opportunities will be provided and we believe that EDS can contribute effectively and profitably in many of these areas.

The efforts associated with the EDS/TSD/C4 Development/CAE have roots in several different projects all of which have come together in support of this activity. Focus for IVHS technologies has come from a number of sources, however, several key events contributed toward making this white paper activity a reality. One such activity has been an active effort in support of Timing and Scoring of Indy Car racing where the technologies of tracking vehicles has been defined and matured. Another event was when Keith Miller attended the 22nd International Symposium on Automotive Technology & Automation (ISATA) Conference in Florence, Italy, May 14-18, 1990. At that conference, a number of European companies described their efforts on Intelligent Traffic Management issues. The ISATA conference devoted more than a day of papers on this subject. The third catalytic event stemmed from discussions between Norm Pelot and Laird Johnston regarding the technology transfer applications which surround the IVHS issues.

Realizing the business potential it offers to EDS, in June 1990, Laird Johnston recommended that Technical Systems Development management authorize a team to perform a three month study on IVHS technology. After receiving management approval and financial backing from Bob Blake, a team was formed, with Laird Johnston, Keith Miller and Norm Pelot providing advisory functions. The team was charged with the task of:

- o Reviewing the IVHS current situation
- o Identifying business opportunities and risk potential.
- o Analyzing EDS' strengths and weaknesses with regard to IVHS services that can be offered
- o Recommend EDS role and strategy.

The report you are looking at is the result of this study. It has seven chapters. Chapter 1 deals with an introduction and provides background information. Chapter 2 discusses the "Vision of the Future"- where IVHS is heading. Chapter 3 does a situation analysis including EDS expertise in the IVHS related field. Chapter 4 discusses the business opportunities it offers to EDS, including EDS role and strategy. An interim set of recommendations is made in Chapter 5. The list of References used in this report is contained in Chapter 6. Some of the sections in this report are left incomplete or blank. The second edition will contain these information.

(Bill Wachob)

INTELLIGENT VEHICLE/HIGHWAY SYSTEMS
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ACKNOWLEDGMENTS

The IVHS study, on which this report (White Paper) is based, is the result of the cooperative efforts of many people in several organizations, including GMR, Vehicle Systems Research Department, and EDS/GSD and EDS/AES accounts. The request for initiation of an Intelligent Vehicle/Highway Systems (IVHS) Study was made by Dr. Laird Johnston, Divisional Manager EDS, Computer Aided Engineering (CAE) & Test Division. Keith Miller, Manager, EDS/Structures Department provided the basis for conducting this study including the information, brought by him in the form of Conference trip report and the ISATA Proceedings. Bob Blake, Divisional Manager, C4 Development, Technical Systems Development (TSD) provided the required funding.

The major source of information on IVHS, including GMR research publications and Mobility 2000 reports, were provided by Norman D. Pelot, Vice President, Technology Transfer, EDS/AES account. The review of EDS/IVHS Study report (White Paper) was performed by Laird E. Johnston, Norman D. Pelot and Keith Miller.

William D. Wachob, Divisional Consultant at EDS's CAE & Test Division was in charge of the working group that drafted this report. Mr. Wachob and his group led by Biren Prasad, Project Leader met with EDS and FHWA-IVHS team in Washington, D.C. to review Department of Transportation (DOT) initiatives and plans on IVHS. The group also met with GM/Vehicle Systems Research Department in Warren, Michigan to get updates on their current involvements and future plans.

The EDS/AES account staff at Warren, Michigan played an important role in the orientation, and final review of this project. Thanks are also due to the members of the EDS Study Team and Resource Personnel for reviewing this document and providing feedbacks. The joint efforts of all these personnel are greatly appreciated.

Thanks to the whole team.

(Laird E. Johnston)

INTELLIGENT VEHICLE/HIGHWAY SYSTEMS
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EXECUTIVE SUMMARY

(This section will be added in Second Edition)

1. INTRODUCTION

Mobility is becoming an increasingly important part of our life. The nation depends upon the efficient transportation of goods and people to compete effectively with overseas producers [1-10]*. The national interstate highway system covers close to 44,600 miles of concrete construction [9], one of the largest in the world, and the traffic flow and congestion are difficult to control on major roads in cities like Los Angeles and New York. This is because in the last 15 years (1970 to 1985) the vehicle population has increased by 63 percent, while the highway/road construction during the same period grew only by 5 percent [9]. Since 1956, U.S. road travel has more than tripled. The number of miles driven continues to increase by 5 percent per year. These trends are likely to continue well into the next century. Growth in the nation's population, which is projected at 267 million by the year 2000, will occur mostly in metropolitan areas, where congestion problems are already beginning to exist [3].

In a single year (1987), U.S. population lost 2 billion vehicle hours of personal driving time due to congestion alone [4, p.5]. This amounts to a $41 billion cost per year to the nation according to a nation-wide Texas Transport Institute (TTI) study of 39 cities [2,9]. In addition, the fuel wasted for this congestion amounts to a $16 billion cost [4, p.5]. By 2005, the Mobility 2000 study estimates that the lost time due to congestion will be on the order of 11 billion vehicle-hours per year, meaning a five-fold increase in costs. This does not include the increase in basic costs that may result from additional motor-vehicle usage, highway construction and maintenance, land development, and operation. Personal loss associated with increased frustration, reduced traffic safety, increased accidents, and poor driving conditions will result in increased vehicle insurance and associated costs. Economic losses from accidents alone could exceed $100 billion per year by the year 2000 [10].

Open areas and easements for constructing new roads and highways are scarce. The Federal Interstate Highway Program is expected to end by 1991. The costs of highway maintenance and repairs are skyrocketing. These factors have forced the policy makers and automobile manufacturers to seek improvements in traffic conditions and safety [10].

Three alternatives are being considered. The first is to construct new roadways. The second is to manage the growth in travel demand by implementing policies that provide incentives to reduce traffic on the roadways during peak hours. The third is to increase the efficiency of our existing highway system by adding "smart" features. In recent years, increased usage of advanced information processing and communication technologies are being sought to improve traffic conditions. New highway construction is inevitable and we cannot eliminate it completely. Similarly, we cannot instantly change the current situation. The basic idea is to make efficient use of existing highways while minimizing the need for further construction.

These issues have led to the development of what is now referred to as IVHS. The idea is very simple: Employ enabling technologies and systems engineering approach to create an Intelligent Vehicle/Highway Systems (IVHS).

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* The number in the square bracket indicates the references listed in Chapter 6.

1.1 Intelligent Vehicle/Highway Systems

The phrase "Intelligent Vehicle/Highway System" is now commonly used to describe an advanced transportation system having some built-in intelligence. The system works in concert with an implanted infrastructure (sensors, communication devices, strategies, alternatives). The infrastructure helps to manage highway traffic and aids the motorist in many aspects of driving. Some IVHS elements can control vehicles in a way to achieve the desired improvements in driving conditions, efficiency and safety. Others operate with a high degree of autonomy, residing either in the vehicle or in the roadside infrastructure. Most elements are, however, vitally dependent on the communication link to transmit information.

For this investigation, IVHS is divided into four basic categories:

1. **"Smart" vehicle:** is equipped with on-board traffic probes, navigation equipment, etc., that provide the driver with information relevant to driving tasks, warning of impending dangerous situations, assistance with driving, etc.

2. **"Smart" highway**: is equipped with signs, electronic message display and television or video equipments mounted above the roadway to monitor traffic flow and provide a local communication link to passing drivers.

3. **"Smart" roadside infrastructure**: is equipped with sensors, inductive loops, signal lights, controller etc. to monitor the traffic flow, adverse conditions and provide a local communication link to passing drivers.

4. **"Smart" traffic management system (TMS)**: consists of a Traffic Management Center (TMC), an IPC type setup that controls the communication and coordinates all necessary traffic management functions to and from highway, roadside infrastructure and the passing vehicles (drivers).

These categories are not mutually exclusive. A complete implementation of an IVHS will require careful review of the capabilities proposed for each of its categories. First, any new highway facility constructed should have "smart" signs and sensors built as integral elements. Second, roadside infrastructure should be equipped with "smarts" to sense the traffic flow, and to detect obstacles and congestion. It should also readily communicate to traffic management systems. The latter in turn could control highway signs, detours, etc., and could alert drivers of suitably equipped vehicles to any possible obstacles.

1.2 Background

In recent years, many automotive companies have demonstrated a series of communication products aimed at improving highway efficiency and increasing traffic safety using an IVHS system. GM is currently in the forefront of IVHS technology and has three major involvements.

The first is a cooperative demonstration program called PATHFINDER [3], initially conceived in October 1986 during a special CALTRANS planning conference. A demonstration operation is scheduled to begin by late 1990. It has four participants: Etak, Inc., the California State Department of Transportation (CALTRANS), the FHWA, and GM. The program is being conducted in the Los Angeles-Santa Monica corridor (referred to as "smart-corridor"; it runs roughly 12 miles from the Pacific Ocean at Santa Monica to downtown Los Angeles) with 25 Oldsmobile Delta 88 vehicles specially-equipped with Etak navigators. Two-way communications between traffic management sensors, traffic data centers, and telecommunication capability are being utilized to advise the drivers of any travel impediment and to suggest possible alternate routes.

The second one is a more comprehensive experiment and field demonstration of a motorist information and communication system in Orlando, Florida, called TRAVTEK [3]. The five participants include: the American Automobile Association, the FHWA, the Florida Department of Transportation, the City of Orlando, and GM. The field demonstration involves 100 rental cars provided to visitors in the Orlando area. The core elements of TRAVTEK include on-board navigation and communications equipment. The navigation equipment gets the required information on current road status and services through a data center and road-installed sensors. The objectives of the field test are to demonstrate the system and technology and to learn about human factors, customer requirements, and marketing aspects of the system. The TRAVTEK system can provide suitably equipped vehicles with trip-planning capabilities and real-time route guidance. It can also provide tourist information (such as accommodations, restaurants, weather, and special events), and special services (such as reservations and emergency service).

The third major project is NAVICAR [3]. GM/Delco Electronics is developing a dead-reckoning, map-matching navigation system called NAVICAR as a future car option. The navigation technology is based upon ETAK, Inc. equipment. NAVICAR will allow a vehicle driver, as he registers his intended destination, to watch the progress of his vehicle on an electronic map as he moves forward (or away from) the destination. The system also can include "yellow pages" services and route planning/guiding information.

1.3 GM Developmental Programs

Currently, technology development for IVHS is under way in several places within GM and its subsidiaries. Reference 3 includes the information contained herein.

- **Hughes Aircraft** has a number of traffic management systems under consideration. Working cooperatively with GM staffs and divisions, Hughes also is pursuing a variety of advanced technology applications in obstacle detection, vehicle spacing, lane control, and vision enhancement [3].

- **Delco Electronics**, working with Hughes Aircraft and other GM divisions, has programs in heads up displays (HUD) and near obstacles detection systems (NODS). The Heads Up Display is presently available as a production option in the Oldsmobile Cutlass Supreme and the Pontiac Grand Prix. HUD permits the driver to monitor the car speed, headlight beam status, turn-signal operation, and other information without diverting his eyes from the road. The Near Obstacle Detection System (NODS) is based on microwave radar and continuous wave doppler technology [2]. The device, which is located in the rear bumper of the vehicle, detects the presence of moving objects in that vicinity. When an object is detected, the driver is alerted the potential obstruction.

- **GMR Computer Science Department** is pursuing research in automotive computing systems, autonomous mobility, artificial intelligence, and real-time sensors for intelligent vehicles.

- **GMR Vehicle Systems Research Department** is pursuing the Highway Driver's Assistant Project, which would provide not only advice and computerized-assistance to drivers but, possibly, automatic chauffeuring. GMR has initiated several evaluations of human factors' issues associated with navigation and route guidance systems. Three of the projects, two completed by outside contract and one by the GMR Operating Sciences Department and the Systems Engineering Center, investigated the effects of the ETAK navigator on driver performance. Another project compared four different route guidance systems that employed audio "display" exclusively.

- Self-contained and satellite-based vehicle navigation systems are under study at Delco Electronics, Advanced Engineering Staff (AES), and GMR.

1.4 U.S. Development Programs (Outside GM)

(This section will be added in Second Edition)

2.0 VISION OF THE FUTURE

(This section will be added in Second Edition)

3.0 SITUATION ANALYSIS

3.1 Current Situation

IVHS activities are occurring in a number of groups within and outside GM. Within GM, Hughes Aircraft, Delco Electronics, GMR, AES, CPC/AVE, and Flint Automotive Division are the most active groups. They are unofficially linked through ongoing projects such as PATHFINDER, TRAVTEK, and NAVICAR. The individuals from the major operating groups also came together informally in summer of 1989 when GM convened the IVHS Tiger Team to develop the Corporation's viewpoint on strategic IVHS issues [3]. EDS was one of the participants. Such informal ties have been very useful for generating common interests and creating momentum for IVHS within GM.

A list of the major companies engaged in IVHS activities either through government initiatives or through voluntary assignments is given in Appendix A. The two outside organizations, which have been active are:

Highway Users Federation (HUF) and
Mobility 2000.

The HUF is a national coalition of 400 businesses and associations working for better highways and improved traffic safety. Mobility 2000 is a self-appointed informal assembly of interested individuals from the public and private sectors, who send their representatives to formulate new programs and strategy for IVHS developments in North America.

In the US, the largest project so far is $32 Million "Smart Corridor" project in Southern California, scheduled to begin in 1991 [10]. The project will monitor the traffic flow over a 12-mile segment of the Santa Monica Freeway. The project is expected to touch all aspects of IVHS. Smart highway features will be accomplished by technology such as variable electronic message signs and "smart infrastructure" will be provided by ramp metering, sensors, etc.

Europe and Japan are much more aggressive in IVHS technology and are spending a lot of resources. A single program called "Prometheus" (Program for European Traffic with Highest Efficiency and Unprecedented Safety) has a budget of $ 800 million over 8-year period [3]. Although Prometheus is the largest program in the world today, several European governments have also subsidized national or multinational projects (see Appendix C).

3.2 EDS Strengths and Weaknesses

Up to now, EDS has not been very active in IVHS. However, EDS has many strong points that permit the corporation to enter successfully into the U.S. and foreign markets. EDS strengths that can be drawn upon to assure success in IVHS markets include:

- o EDS experiences in OEM installation of telecommunication technology.
- o EDS capabilities in network management.
- o EDS leadership in managing data processing centers (IPC).
- o EDS ability as a systems integrator.
- o EDS corporate mechanism for pooling experts from several SBU's.
- o EDS Government Systems Group link with DOT and its familiarity with government RFQ/RFP process.
- o EDS personnel's ability to learn quickly and leverage the technical know-how and research done with our customers.
- o EDS potential to capitalize on GM's technology transfer initiative. This will be worthwhile in overcoming the basic hurdles often encountered in starting up a new area of business.
- o EDS favorable position to form domestic alliances.

Nevertheless, EDS has some weaknesses, too, including:

- o EDS is considered to be a newcomer in IVHS because of its lack of significant prior involvement.
- o Traditional reluctance to set aside seed money.
- o Reluctance to assign people for voluntary jobs as is the case with PATHFINDER and TRAVTEK projects.
- o Minimal working level expertise of IVHS within EDS.
- o Minimal knowledge of IVHS players in the field.
- o Competitors' head-start in working with IVHS customers.

If EDS forms an alliance with a renowned Traffic Engineering Company, most of these weaknesses can be void or lessened.

3.3 Areas of Interest

The Traffic Management System (TMS) appears to be a prime area of interest for EDS. The smart TMS in this context includes the following four separate types of services:

- *Traffic Management Centers (TMC's)*
- *Traffic Network Infrastructure*
- *Communication Services*
- *Commercial Services*

The main goal of TMS is the fusing of inputs from the previously defined areas of IVHS; namely, smart cars, smart highways and roadside infrastructure into a smart/efficient system which optimizes the flow of traffic and enhances safety. Traffic flow is aided by proper timing of traffic signal lights, rapid identification of traffic incidents, and quick deployment of emergency resources (e.g., police, tow trucks). Both traffic flow and safety are enhanced by disseminating real-time traffic information to motorists so they can avoid traffic congestion. The creation of this real-time traffic information requires the processing of inputs from network infrastructure (e.g., vehicle detectors in the roadway), police reports, and other sources. The traffic network infrastructure also provides a conduit for routing requests for emergency service and reports of vehicle theft. An efficient traffic management system requires that all the above four types of services be performed accurately.

3.3.1 Traffic Management Centers (TMC's)

Traffic Management Centers (TMC's) are the command, control, and communications hub of the system (TMS) that monitor and coordinate traffic flow through a highway/street network infrastructure.

Currently, there are two distinct types of TMC's (city-run arterial-road, and state-run freeway), and there is little communication between the two. However, the magnitude of the traffic congestion problem is causing city and state traffic management organizations to begin talking. The cooperation is increasing, and traditional jurisdictional walls are beginning to crumble. The Federal Highway Administration (FHWA) is leading the charge with the funding of projects like PATHFINDER and TRAVTEK. However, the pickup of IVHS in United States is slow.

3.3.1.1 PRINCIPAL FUNCTIONS OF TMC

Three principal functions of TMC are command, control and communication. These functions work as a group and are expected to perform all necessary traffic management (TMS) tasks.

- <u>Command Function of TMC</u>: The command function of the TMC is to dispatch crisis teams, including police, fire, ambulance, and traffic engineers to the site of traffic incidents. Radio is used to maintain communication with the teams in the field. In the future, video will also be used.

- <u>Control Function of TMC</u>: This involves real time control of traffic signal lights. In the city TMC, there are lights at the intersections; for the state TMC, there are lights at the limited-access highway on and off ramps. Their timing patterns are often fixed according to time of day or week. TMC can be used to speed traffic flow by controlling signals in a coordinated, interactive way.

- <u>Communication Function of TMC</u>: The communication function will involve receiving traffic surveillance data and transmitting to road signs and highway lane management systems in real-time. The communication infrastructure (both aerial and roadside) will be required to collect and analyze real-time traffic data, and to provide for the movement of information to support decision making processes both at the TMCs and in "smart" cars.

3.3.2 Network Infrastructure Services

The network infrastructure services include systems such as those deployed for traffic surveillance, traffic flow control, traffic command, driver information and tolling. These may include surveillance devices such as buried magnetic loops and video cameras, and information dissemination systems such as changeable message signs, highway advisory radio, and possibly in the future, smart signs that broadcast messages to passing motorists.

3.3.2.1 TRAFFIC SURVEILLANCE:

The traffic surveillance is one of the important functions of a TMS/Network Infrastructure service. Some means of probing the traffic flow information are often employed to communicate the surveillance information to a TMC for further processing.

Three different ways of providing vehicle surveillance are possible, based upon the three possible means of probing the required information: roadside, aerial and vehicular.

- Roadside Surveillance: The simplest and almost universally used is inductive loops buried in the roadway which sense the presence of a vehicle and transmit a variable-width electrical pulse to a signal light controller. The controller can be programmed to control adjacent traffic signal lights, and can also override the normal light timing to "flush" the heavy congestion. However, Inductive loops are unreliable, and when they fail, the roadway must be torn up to install a replacement. This can be very expensive.

- Highway Surveillance: The second way is to use closed-circuit television cameras [called wide-area detectors (WAD)] mounted above the roadway. In their simplest application, they provide a view of traffic conditions to the TMC operators. A more sophisticated use of the cameras is to process their images, counting vehicles in each lane. The next step is to add logic for detecting traffic incidents. Shadows present WAD with problems in the daytime, and blooming headlights are a problem at night.

- <u>On-board Surveillance</u>: The third way is to use traffic probes. The vehicles are outfitted with navigation systems and two-way radios. The TMC can poll these vehicles to obtain their current locations, their average speeds, and the number of stops made since the last poll. In return, the TMC can broadcast current congestion information for display within the vehicle and for use in generating an optimal route selection for the motorist. The on-board surveillance concept is being demonstrated in the PATHFINDER Project and may have in the TRAVTEK Project. With enough traffic probes on the road, the TMC could receive extremely high-quality surveillance input.

The synergism between driver information systems and traffic management is another important area of interest for EDS. It can be exploited to create market for commercial services.

3.3.2.2 TRAFFIC CONTROL

Traffic surveillance provides the means to sense the traffic flow and condition, including vehicle positions and velocity. A traffic control system in turn processes the surveillance information and optimally predicts the control for the traffic flow and routing data to meet the required condition at that time. It also transmits traffic information to drivers, fleet managers and traffic authorities, if needed.

3.3.2.3 TRAFFIC COMMAND

The traffic command sets position or velocity of individual vehicles, or both (on automatic highways). To support these functions, the traffic command system draws upon sensors, incident reports, traffic models, and world knowledge to transform traffic data into information about current and predicted roadway status.

3.3.2.4 TOLLING

This includes the mechanism to identify vehicles and determine appropriate tolls based upon size, shape and weight. These systems will elliminate manual toll collection activities in the future and provide the necessary ground for a variety of commercial services.

3.3.3 Communication Services

Communication systems provide the "glue" that integrates the IVHS functions. The following are some of the common situations that commonly arise during TMC/IVHS communication:

3.3.3.1 Broadcast from the TMC to vehicles: Two options are available.

- o The simplest is a conventional radio technology. EDS needs to obtain a frequency allocation from the Federal Communications Commission (FCC). Permission for its use across the country will give EDS a large enough market pulls for the required vehicle receiver.

- o The second option is to use RDS (Radio Data System). This is like a European system for radio broadcast of traffic information to motorists. Data is broadcast on the subcarrier of a cooperating FM radio station. A low-cost vehicle radio add-on translates the data into alphanumeric displays.

3.3.3.2 Interagency (e.g., police-to-TMC) communication: This is often handled by conventional radio and leased telephone line communication, as appropriate.

3.3.3.3 Vehicles to network infrastructure communication: These include all types of short distance local communications, such as vehicle-to-toll booths, vehicle-to-weigh-in-motion stations, and smart signs-to-vehicles.

3.3.3.4 Traffic probes to the TMC Communication: Radio technology is well suited to this purpose. However, it may pose a bandwidth problem as the number of probes per vehicle becomes large.

3.3.3.5 Broadcast Highway Messages/Display: This is accomplished by a short-range radio channel (usually AM 500-600 KHz) and using a short-range antenna to broadcast messages to passing motorists on a highway.

3.3.4 Commercial Services

Many types of commercial services are possible using the TMS/TMC concepts. "Commercial Services" are defined to include any services provided to a vehicle driver (passenger or commercial vehicle), or its owners, or third party providers. Commercial vehicles include trucks, buses, taxis, emergency and delivery vehicles.

TMC's providers can profit from providing real-time traffic information to radio stations for inclusion in their newscasts, or to a third party commercial service provider, who could market the packaged information to delivery trucks, taxi, or limousine fleet owners. This real-time information can include one or more of the following services:

- Guide operations of heavy trucks that cannot be operated on all roads.
- Guide operations of vehicles carrying hazardous materials.
- Provide on-board ability to tune in traffic information broadcasts everywhere they travel without having to carry several kinds of radio receivers.
- Automatic-toll-billing (ATB)
- Weigh-in-motion (WIM)
- Automatic-vehicle-identification (AVI)
- Automatic-vehicle-classification (AVC)
- Electronic Placarding/Bill of Lading
- Automatic-vehicle-location (AVL)
- Two-way real time communication (TWC)
- Automatic-clearance-sensing (ACS)
- Emergency/May Day services
- Automated Driver/Vehicle Record Keeping and Reporting
- Fuel tax records
- Invisible border system, which monitors transport of goods across states and between cities, and provides for the record keeping, licensing, taxation and billing of commercial traffic (especially trucking).

The following commercial services (most related to passenger vehicles) will require close cooperation between vehicle manufacturers and the TMS suppliers:

- Advance Driver Information Systems (ADIS)
- AutoGuide--> An inexpensive in-vehicle system that provides information and routing instructions to driver. Requires an extensive highway infrastructure.
- Automated Chauffeuring-->System provides hands-off driving by integrating several vehicle control systems and coordinating them with smart highway. Assumes responsibility for most of the driving tasks currently managed by the driver.
- Cooperative Headway Control-->System aggregates vehicles into convoys, coordinates their speed, and controls the gaps between vehicles. System requires close communication among vehicles and between vehicle and smart highway.
- Cooperative Vehicle Tuning-->Smart highway coordinates with adaptive vehicle tuning system to provide longer-range capability. Highway either recommends or initiates adjustments to vehicles.
- Hazardous Condition Warnings by Highway-->Highway sensors advise oncoming traffic of road surface and weather conditions.
- Minimum Headway Advisory-->Vehicle and highway based system that indicates to the driver the minimum safe headway distance. Determination of safe headway distance is based on speed, vehicle, and roadway condition.

There is a great potential for third party commercial service (traffic) providers to do business in this sector. They can lease the computer time from TMC's. They can profit from providing timely, real-time traffic information to their subscribers. The subscribers can benefit from avoiding possible traffic congestion, or hazard conditions. The commercial service providers can also utilize the real-time traffic information provided by the TMC for selling services like tourist events, motel reservations and vacancy information.

3.4 Key Areas of EDS Involvement & Participation

In the following sections, we review these TMS elements in greater detail and outline the major technical challenges. Table 1 lists the possible services EDS can provide and estimates the potential impact on safety and congestion, the level of technical sophistication, and the liability/marketing risks.

(This section will be completed in Second Edition)

Table 1: Impact of Selected IVHS/TMS Elements

3.5 EDS Expertise/Experience

(This section will be added in Second Edition)

4.0 BUSINESS OPPORTUNITIES

4.1 Market Opportunities

Section 3.5 contains descriptions of XX potential products. The feasibility of developing and marketing these products ranges from near term to midterm and long range.

TMS requires a good deal of preliminary thought and investigation. These systems have a strong functional similarity to the military command and control systems that Hughes has marketed for many years. Also, there are similarities to systems developed by EDS for federal government customers. However, there appear to be significant differences as well.

The first step which EDS can undertake must begin with activities that produce a realistic evaluation of EDS capabilities and show how it can contribute to this new business area called TMS. Both EDS and Hughes Aircraft are in the systems business, with experience in developing high-performance, customized products and services. By comparison, GM traditionally has built its business on large-quantity, low-priced products, such as on-board equipment.

Historically, traffic management systems have been relatively low-cost, low-technology systems. The traffic engineering companies that have developed these systems are small, low-overhead firms [3]. They have been conditioned by years of experience with local government traffic organizations not to propose advanced technology solutions.

However, it now appears that the nation's burgeoning congestion problems can be solved only by incorporating high technology in traffic management. Thus, there is a potential market for hi-tech companies like EDS.

4.2 Possible Initiatives (Near–term)

IVHS is a new area for EDS. Last year, EDS participated as a representative on the GM/IVHS Tiger team which produced a draft plan and a report [3]. In order for EDS to position itself as a true contender, EDS will have to assume a more visible leadership role and take some bold initiatives. The kinds of things EDS must do are:

I: Test the traffic management marketplace.

This involves identifying the roles EDS, GM and Hughes Aircraft can play independently and as a team. It also involves defining a strategy which might be the best in the overall interest of EDS and GM as a corporation. From the materials we read, it is clear that Hughes Aircraft and EDS technology have some overlapping areas/capabilities, but both are capable of meeting the vision of the future.

II: Find a customer and/or a partner.

A customer who is willing to work with us and participate in profit-sharing. Hughes Aircraft plans to bid on design contracts for the next generation of CALTRANS traffic operations systems [3]. CALTRANS expects bidders to team for these contracts. It may be worthwhile for EDS to identify areas in CALTRANS where EDS can add values and consider submitting a joint proposal with Hughes. This way EDS and Hughes together will surpass the IVHS capabilities that no other bidder can be able to match.

III: Invest time and money in both demonstration projects and marketing.

If EDS intends to be a serious contender, it must invest time and resources to market its capabilities and expertise. The customer does not know EDS and what EDS can offer. The customers must be made aware of the EDS technological advances that are applicable to traffic management. While EDS is educating its customers, EDS must go through its own educational process. EDS must become familiar with the IVHS customers, their needs, and their contracting approaches.

IV: Formulate EDS/IVHS business plan and a long-term strategy.

EDS is not recognized as a traffic engineering company. EDS must evaluate whether it can expand into this business sector. This may require creating or acquiring more expertise in civil engineering, Highway design & construction, transportation engineering, etc. If not, EDS must identify the companies to team up with on potential contracts. Most of the forthcoming contracts (such as FHWA and CALTRANS) would require a traffic engineering functions with elements from major civil engineering and construction fields. Hughes Aircraft also does not possess traffic engineering expertise at this time. It must also bid as a subcontractor to a company that does.

V: Make strategic alliances.

If EDS intends to be a leader and a prime contractor, EDS should become familiar with the popular traffic engineering companies who could be potential competitors, potential strategic partners, or both. EDS must identify companies that are perceived to be the leaders in the field. It may not be cost effective for EDS to hire experienced personnel or build expertise within the company. Instead, EDS may have to acquire a company already experienced in this area, invest equity in such companies, or establish contractual or strategic partnership.

It is also worthwhile to team up with university researchers in soliciting governmental funding, as this provides seed money for new initiatives, establishes a "need to know" about ongoing programs, and provides access to the forefront of IVHS academic research.

VI: Support GM Projects.

EDS must support GM sponsored projects. The TRAVTEK Demonstration Project is a good example. EDS can learn from it while working and gain insight into real-world requirements for TMS. Moreover, EDS will be working with a valued customer, whom we trust to share our concern, as well as our commitment to working toward defining a national or global IVHS network system.

4.3 Challenges to Overcome (Risk Potential)

IVHS presents many opportunities, but it has a few challenges, too. Involvements are not risk free. Previous attempts by many U.S. companies for the introduction of IVHS have been hampered due to the following factors:

1. The technology has only been tested on a piecemeal basis. While the entire system eventually is expected to act in an integrated fashion, little systems analysis research has been performed.

2. IVHS requires a multiplicity of parties. To make IVHS a reality, manufacturers of hardware and software, federal and state governmental agencies, and other private, social, and technical associations must all work in harmony. Each possesses its own strengths and weaknesses. It is difficult, however, to agree on a plan to accomplish the tasks somewhat independently and still provide an integrated IVHS solution at the end.

3. IVHS is fairly new. No standards exist. Incompatibility among hardware, software, communications links, information display formats, databases, is likely to continue. Though strategies for updating software and databases can be assured by adoption of a series of standards agreed to by the interested parties, no one is taking real initiative. Presently, there is no market leader and the technical associations are not very proactive. Standards may take some time to put in place.

4. Today, there exists no significant infrastructure of intelligent highway. The early "smart car" means that on-board products will have to be autonomous. Conversely, early "smart highway" products (e.g., traffic management centers) must be compatible with conventionally equipped vehicles. The potential for IVHS business is therefore small, at least initially, until the automobile manufacturers and the highway users both agree to adopt it (IVHS) nationally.

4.4 Strategy for EDS Involvement

EDS opportunities lie mainly in the areas of Traffic Management Systems and in the supporting roadside infrastructure and highway communications. The car manufacturers have more control on the vehicles and the equipment they can design into the vehicles, such as on-board navigation. It will be desirable for EDS to stay away from "Smart Cars" elements of IVHS and concentrate more on TMS side of business. However, TMS would require close cooperation.

Early EDS/IVHS presence can be established through the collaborative participation into current projects (such as PATHFINDER, TRAVTEK, GM/NAVICAR), or through low-cost systems like the Radio Data System (RDS). Particular attention should be given to the use of our IPC as Traffic Data Centers (TDC). Early introduction of a try-out demonstration of TDC concept using existing IPC/EDSNET facility provides a leadership position for EDS while limiting the risk and manpower requirements. By necessity, EDSNET products will be largely independent of the IVHS infrastructure, although incorporation of RDS in such try-out would require the participation of local radio stations. Follow-on contractual agreements with federal, state and local government and research bodies will allow us to develop the customer base needed to support expansion of the communication links to the entire IVHS infrastructure.

Strategies will also need to be implemented to develop and deploy low-cost/hi-tech communication equipment on the highways, roadside and on-board (in vehicles), that lead to the development of an efficient and smart TMS/TDC system.

Another problem is that at this time there is no leadership aimed at providing any form of "industry standards." As a result, the individual IVHS elements are likely to be developed and deployed somewhat independently. A majority of industry and public sector groups will be contributing elements of IVHS according to their own visions of what national IVHS program should be. For this reason, EDS's long-term plan for IVHS services/products must be capable of changing with time to adapt to the evolving national/international standard and must include a focussed effort to shape those standards in a direction which position EDS to take better advantage of its strengths.

5.0 Recommendations

We recommend that:

- O. EDS fund a business development effort for 1990 to continue interest and explore traffic management marketplace. EDS should build enough internal presence to bid on traffic management contracts, write unsolicited proposals, and to obtain R&D contracts from federal (such as FHWA) and state agencies (e.g., CALTRANS).

- O. EDS should consider teaming up with other GM organizations (such as Hughes Aircraft or Delco Electronics) on projects according to their strengths. EDS strengths primarily reside in systems integration, implementation of application-specific data management and telecommunications technology and should be exploited wherever possible.

- O. The search for synergistic activities must be continued throughout the EDS/GM/Hughes/Delco. Membership into the GM/IVHS Tiger Team should be continued. EDS should participate on TRAVTEK, voluntarily in the beginning until a new IVHS project is acquired. TRAVTEK provides an opportunity for EDS to advance its knowledge and learn the basics. It also provides an environment for achieving worldwide leadership in the traffic management marketplace.

- O. EDS should consider making some long-term strategic alliances with leading traffic engineering firms. This will enable EDS to be rapidly recognized as a leader in the IVHS market.

EDS participation and joint IVHS efforts must be weighed against the associated gains on a case-by-case basis. The gains are of two basic types:

a. Return on investments (ROI), and
b. Increased potential for future business.

Both are intangibles. The ROI of joint efforts is comprised of the following: the acquisition of knowledge, improving EDS image as a leader of the national "IVHS team", and the ability to influence the nature of technical standards and regulations.

6.0 References

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7.0 Appendix

7.1 Appendix A: Major U.S. Companies Involved in IVHS

The following are major U.S. companies engaged in IVHS:

- o American Automobile Association (AAA)
  - (John W. Archer, Managing Director)
- o American Association of State Highway and Transportation Officials (AASH-TO)
  - (Francis B. Francois, Executive Director)
- o AT&T ^
  - (Min I. Chung, Director)
- o Bosch^
- o Department of Transportation (DOT)
  - California Department of Transportation (CALTRANS)
  - Federal Highway Administration (FHWA)
    - (Lyle Saxton, Assistant for Advanced Technology Systems)
  - Florida Department of Transportation
  - Michigan Department of Transportation
  - National Highway Traffic Safety Administration (NHTSA)
  - Pennsylvania State DOT
    - (Harvey Haack, Deputy Secretary)
  - Urban Mass Transportation Administration (UMTA)
    - (Brian W. Clymer, Administrator)
  - Washington State DOT
- o Etak Inc.^
  - (George Bremser, Chairman of the Board)
- o Ford Motor Company- Scientific Research Lab.
  - (Edward S. Greene)
- o General Motors
  - General Motors Research Lab
  - Advanced Engineering Staff
  - Delco Electronics
  - Hughes Aircraft Company
- o Highway Users Federation for Safety and Mobility
  - (Lester P. Lamm, President)
- o IBM ^
- o Institute of Transportation Engineers ^
- o JHK and Associates ^
  - (Jack L. Kay, President)
- o Lockheed Information Management Services^
  - (Harry W. Voccola, Senior Vice-President)
- o Mitre Corporation ^
- o Mobility 2000 (self appointed individuals from public & private sectors)
- o Motorola AIEG, Transportation Management systems ^
  - (Randy Dol, Director, IVHS)
- o Ontario Ministry of Transportation, Ontario, Canada
- o Phillips Petroleum Company
- o Transportation Research Board, Washington, DC
  - (Thomas B. Deen, Executive Director)

The names marked with ^ are EDS competitors.

7.0 Appendix

7.2 Appendix B: U.S. University Involved in IVHS

Many major universities are also involved in IVHS. The largest is in the University of California. They are involved in the Program for Advanced Technology for the Highway (called PATH). PATH is supported financially by California Department of Transportation, FHWA and NHTSA. There is a small program underway in Texas A&M university at the Texas Transportation Institute. It has received financial support from Texas Department of Highways and Transportation. Many of the following universities have expressed interests in IVHS by participation but have no major formal programs.

o Transportation Research Institute
-The University of Michigan
(Robert D. Ervin, Head, Engineering Research Div.)
o Texas Transportation Institute
-Texas A&M University
(Wiley D. Cunagin, Program Manager)
o Center for Transportation Studies
-MIT
o Institute of Transportation Studies
-University of California at Berkeley
(Steven E. Shladover, Technical Director, PATH)
o Pennsylvania Transportation Institute -Transportation Operations Programs
-Pennsylvania State University, PA
(John Mason, Director)
o Princeton University

o University of Minnesota, MN
-Center for Transportation Studies
(Richard P. Braun, Director)

7.3 Appendix C: European IVHS Programs

Because congestion and safety problems are perceived to be more acute in Europe, major programs are already under way there. PROMETHEUS (which stands for Program for European Traffic with Highest Efficiency and Unprecedented Safety) is the largest ($800-million R&D program) of the projects sponsored by the European Research Coordination Agency (EUREKA). This is a seven-year program, started in 1986 and involves six European nations, most European vehicle manufacturers, and the European research community.

European IVHS Programs

ATIS: $8.5-million, five-year project aimed at providing pre-trip information on traffic conditions to tourists.

AUTOGUIDE: British route guidance system under development

CARMINAT: A four-year project to develop in-vehicle electronic navigation and communication systems.

DRIVE: A European R&D effort concerned with the transmission of information between vehicles and infrastructure-side control or assistance centers.

EUROPOLIS: $150-million, seven-year project to design automated road systems and develop technologies to automate driver functions.

ERTIS: $2.7-million, three-year project to develop a common road information and communication system for motor carriers.

EUREKA: Pan-European collaborative research program.

PROMETHEUS: $800-million broad-based European R&D effort aimed at developing a uniform European traffic system incorporating IVHS technology.

7.4 Appendix D: Japanese IVHS Programs

Japan has the following three projects, the exact funding is not known. There are strong indications that Japanese manufacturers are considering extending their IVHS to the U.S. market.

AMTICS: Japanese motorist information-traffic advisory system now operating in Tokyo.

IVS: Japanese intelligent vehicle system under development.

RA/CS: Japanese in-vehicle navigation system combined with motorist information services now undergoing field testing.

7.5 Appendix E: Other Foreign Programs

Following are the efforts undergoing in other foreign countries. However, they appear to be small.

ALI-SCOUT: Route guidance system under development by Siemens and Bosch/ Blaupunkt.

LISB: Berlin route guidance pilot study.

TRANSPOLIS: EUREKA project concerned with industrial parks for transport operators.

Combined funding of these programs (combining both European and Japanese) is estimated to be in the range of $1.5 billion to $2 billion [3].

Within the United States, IVHS development programs are on a much smaller scale. Nevertheless, it can be anticipated that competition will be aggressive and that manufacturers offering superior IVHS services will have a winning edge.

7.6 Appendix F: Glossary of IVHS Terminology

The definitions are compiled based on Reference 3.

Automated Chauffeuring-->System provides hands-off driving by integrating several vehicle control systems and coordinating them with smart highway. Assumes responsibility for most of the driving tasks currently managed by the driver.

Cooperative Headway Control-->System aggregates vehicles into convoys, coordinates their speed, and controls the gaps between vehicles. System requires close communication among vehicles and between vehicle and smart highway.

NAVICAR-->Interactive navigational system developed by Delco Electronics and based on Etak, Inc. technology. The system includes a color monitor and a map database; indicates the position of the vehicle on displayed map.

Traffic Management Center-->A command, control, and communications center that monitors and coordinates traffic flow through a highway/street network.

Roadside Infrastructure-->The traffic data gathering and monitoring systems used for traffic coordination. These may include surveillance devices such as buried magnetic loops and video cameras, and information dissemination systems such as changeable message signs, highway advisory radio, and possibly in the future, smart signs that broadcast messages to passing motorists.

Wide-Area Detector (WAD)-->Electronic camera equipped with wide-angle lens; being developed for traffic surveillance. Advances in fabrication methods for infrared sensitive materials may make infrared arrays applicable to WADs in the future.

Highway Advisory Radio-->A short-range information channel (usually AM 530 KHz) using a short-range antenna to broadcast messages to passing motorists on a highway.

Secure Data System-->A short-range on-board radio-frequency transceiver that could be used to "pay" tolls electronically, etc.

Radio Data System-->A European system for radio broadcast of traffic information to motorists. Data is broadcast on the subcarrier of a cooperating FM radio station. A low-cost vehicle radio add-on translates the data into alphanumeric displays.