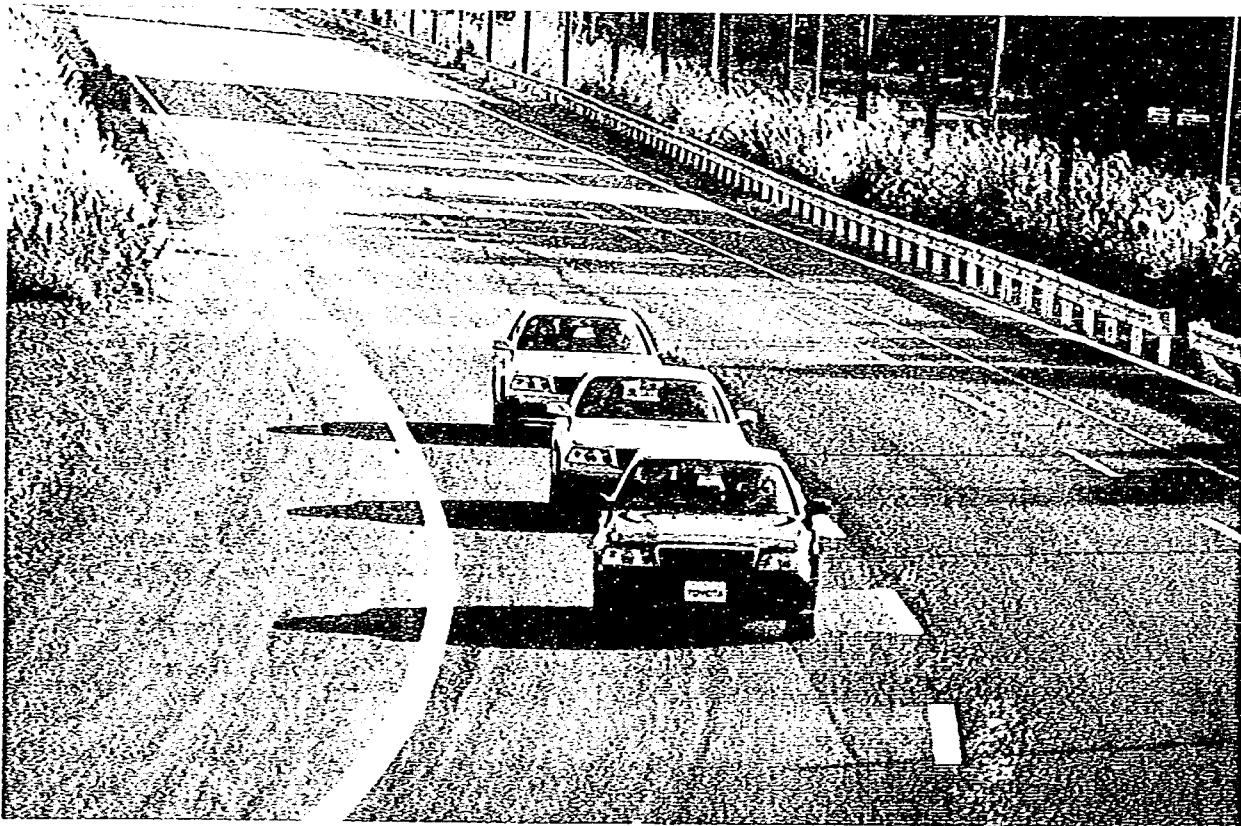


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Technical Memorandum
of PWRI No.3423

PROCEEDINGS OF THE 3RD U.S.-JAPAN ITS GROUP MEETING OF THE U.S.-JAPAN COOPERATION ON HIGHWAY SCIENCE & TECHNOLOGY

6th-8th November, 1995
Tsukuba



JANUARY 1996

**PUBLIC WORKS RESEARCH INSTITUTE
MINISTRY OF CONSTRUCTION
FEDERAL HIGHWAY ADMINISTRATION**

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**PROCEEDINGS OF THE 3RD U.S.-JAPAN
ITS GROUP MEETING
OF
THE U.S.-JAPAN COOPERATION
ON HIGHWAY SCIENCE & TECHNOLOGY**

Synopsis :

The Memorandum includes the Records of Presentations, Discussions on U.S.-Japan ITS Cooperative Effort and Study Tours on the Traffic Control System at the 3rd U.S.-Japan ITS Group Meeting held in November, 1995

Key Words : The 3rd U.S.-Japan ITS Group Meeting
Intelligent Transport System (ITS)
Automated Highway System (AHS)

CONTENTS

	Page
1. Preface	1
2. Program.....	2
3. Picture.....	4
4. Records of Presentations	5
4.1 ITS (Policy & Promotion Establishments)	5
4.1.1 "ITS in Japan"	5
by Yasuhiko Iwasaki (Deputy Director, Planning Division, Road Bureau, MOC)	
4.1.2 "U.S. ITS UPDATE"	23
by C. John MacGowan (Chief, IVHS Research Division, TFHRC, FHWA)	
4.2 AHS (Research Promotion Methods)	35
4.2.1 "AHS in Japan"	35
by Satoshi Ueda (Head, Traffic Engineering Division, Road Department, PWRI)	

4.2.2 "Automated Highway System Cooperative Program — an overview —"	48
by Kurt A. Goddard	
(National Automated Highway System Consortium)	
4.3 AHS (Research & Development)	68
4.3.1 "Automated Vehicle System for AHS"	68
by Keiji Aoki	
(Toyota Motor Corporation)	
4.3.2 "Communication System for Lateral and Longitudinal Control System"	78
by Yutaka Yamada	
(Oki Electric Industry Co., Ltd.)	
4.3.3 "AHS Vehicles"	88
by Steven E. Shladover	
(National Automated Highway System Consortium)	
4.3.4 "NAHSC Communications"	99
by Ron Colgin	
(National Automated Highway System Consortium)	
5. Discussion on U.S.—Japan ITS Cooperative Effort	109
6. Study Tours	112
7. Participants List	116

1. Preface

The 3rd U.S.–Japan ITS (Intelligent Transport System) Group Meeting was held in Public Works Research Institute (PWRI) , November 6–8, 1995 pursuant to the Implementing Arrangement between the Ministry of Construction (MOC) of Japan and the Federal Highway Administration (FHWA) of United States of America on Highway Science and Technology.

The arrangement, signed in May 1992, aimed to enhance public safety and community welfare through research, development and improvement of highway structures and surfaces, and to promote a system of safer, more economical, efficient and environmentally sound highway transportation through research, development and cooperation.

The 1st group meeting was held in PWRI, April 20–23, 1992, and the 2nd group meeting was held in the Turner–Fairbank Highway Research Center (TFHRC) of FHWA, November 14–15, 1994. In each group meeting, representatives from the U.S. and Japan made presentations and discussed present status of ITS and the study of advanced technologies. In the 3rd U.S.–Japan group meeting, representatives from the U.S. and Japan made presentation and discussed ITS, especially AHS (Automated Highway System). It is expected that this group meeting will foster better understanding with each other and contribute to the development of ITS technologies.

A total of about 70 persons participated in the 3rd U.S.–Japan ITS Group Meeting. It was great pleasure that we could get a great deal of accomplishment from the viewpoint of not only information exchange about status of ITS activities and results of research & development but also friendship between the U.S. and Japan through the group meeting.

2. Program

November 6 (Mon)

- 9:00 ~ 9:30 Introduction and Welcome
- 9:30 ~ 10:00 Opening Ceremony
Tadahiko Sakamoto
(Director-General, PWRI)
C. John MacGowan
(Chief, IVHS Research Division, TFHRC, FHWA)
- 10:00 ~ 10:30 Photo
- 10:30 ~ 12:00 Technical Visit of AHS & ETC Field Test Sites
- 12:00 ~ 13:30 ** Lunch **
- 13:30 ~ 14:15 ITS in Japan (Policy & Promotion Establishments)
Yasuhiko Iwasaki
(Planning Division, Road Bureau, MOC)
- 14:15 ~ 15:00 ITS in U.S. (Policy & Promotion Establishments)
"U.S. ITS Update"
C. John MacGowan
(IVHS Research Division, TFHRC, FHWA)
- 15:00 ~ 15:30 ** Refreshments **
- 15:30 ~ 16:00 AHS in Japan (Research Promotion Methods)
Satoshi Ueda
(Traffic Engineering Division, Road Department, PWRI)
- 16:00 ~ 16:30 AHS in U.S. (Research Promotion Methods)
"Automated Highway System Cooperative Program -- an overview -- "
Kurt A. Goddard
(National Automated Highway System Consortium)
- 16:30 ~ 17:00 Discussion

November 7 (Tue)

9:00 ~ 10:00 AHS in Japan (Research & Development)

"Automated Vehicle System for AHS"

Keiji Aoki

(Toyota Motor Corporation)

"Communication System for Lateral and Longitudinal Control System"

Yutaka Yamada

(Oki Electric Industry Co., Ltd.)

10:00 ~ 11:00 AHS in U.S. (Research & Development)

"AHS Vehicles"

Steven E. Shladover

(National Automated Highway System Consortium)

"NAHSC Communications"

Ron Colgin

(National Automated Highway System Consortium)

11:00 ~ 11:30 ** Refreshments **

11:30 ~ 12:30 Discussion (Research & Development)

12:30 ~ 14:00 ** Lunch **

14:00 ~ 16:00 Concluding Remarks & Future Cooperation Plan

16:00 ~ 16:30 ** Refreshments **

16:30 ~ 17:00 Closing Ceremony

Mitsuhiro Nakagaki

(Director, Road Department, PWRD)

C. John MacGowan

(Chief, IVHS Research Division, TFHRC, FHWA)

November 8 (Wed)

Tokyo study tours

- Air Control Systems (Haneda airport)
- Shinkansen General Control Center (Tokyo station)
- Metropolitan Expressway Traffic Control System (Kiba-cho, Koto-ku, Tokyo)

3. Picture



4. Records of Presentations

4.1 ITS (Policy & Promotion Establishments)

4.1.1 "ITS in Japan"

by Yasuhiko Iwasaki

(Deputy Director, Planning Division, Road Bureau, MOC)

In Japan currently 90% of physical distribution and 60% of human mobility is done by vehicles. And the number of people who have drivers' licenses has reached approximately 60million. With this advancement of motorization, there are 3 serious problems now. First is traffic accidents. During the past 7 consecutive years, the number of deaths due to traffic accidents is over 10,000. The next problem is congestion. As for the traffic congestion, it comes to 55 hours per person per year, and in term of yen, it amounts to 12 trillion yen. The third issue is environmental problems such as air pollution and noise.

Now, in order to resolve these issues, the Ministry of Construction has been working on 3 counter measures. Firstly, the construction of new roads and highways. As for the highways, I'm afraid that the highways in Japan have not reached the standards of those in Europe and the U.S. As for the expressways, although the plan calls for 14,000km, what we have constructed so far is about 6,000km. The second counter measure is TDM (Traffic Demand Management) . And the third counter measure is ITS. TDM and ITS are integrated into the fiscal road improvement plan that started in 1992.

(A-1)

First I would like to touch on the government measures. At the government level we have the Advanced Information and Telecommunications Society promotion headquarters and this headquarters is the organization promoting ITS at the government side.

Promotion headquarters consists of the Prime Minister as the Chairman, and all the 21 ministers are executive members. The Board of Advisors consists of 12 advisors and they are from the public sector, private sectors, and academic sectors.

(A-2)

This advanced information and telecommunications society promotion headquarters was

established, actually at the end of last year. In February 1994, the basic guidelines on the promotion of an advanced information and telecommunications society was issued, and this is the overall guidelines that includes not only vehicles but roads.

(B-1)

These are basic guidelines that can be broadly classified into three areas: basic outlook, issues related to measures for the realizations, and international contributions.

I would like to particularly touch on the second area, which is issues related to measures for the realizations. The government has specified 6 areas where information will be promoted in the public sector. And the fifth area assesses roads, traffic and vehicles.

(C-0-1)

Based on these basic guidelines, the guideline for imposing intelligence on public transport which was issued in August of this year was formulated.

The guideline states the basic significance of ITS and also specifies 11 action items. The guideline clarifies 9 fields or areas where the development should be promoted.

(D-1-2)

For the significance of ITS, we are considering 3 areas of significance. The first significance or purpose is to resolve the various road traffic issues.

Although this is the largest objective, there is another objective of creating a new market. For example, in Japan we already have 700,000 units of navigation systems in the market which amounts 140 billion yen.

I'll ask for VICS which will start or which will be implemented next spring. It is estimated that it will generate 2 trillion yen for the next 20 years. The expected market size of the total ITS is 50 trillion yen.

(D-1-3)

A third objective is the multi-media implications for the ITS. This graph shows the results of the surveys run by a private research organization which was conducted in April of this year, regarding the possible multi-media related industries. Approximately 80% of the listed companies in Japan said that the ITS is the prominent for potential multi-media industries.

The reason why they answered this way is because we assume that they expected that with the ITS infrastructure equipment in the future, we can provide information other than traffic related information. And also we can send traffic information to other non-ITS networks. So I

think the companies see large potential and outlook for the future.

(C-1-4)

I would like to touch on the promotion measures of ITS in Japan. At the government levels, 5 ministries are involved in ITS. I would like to start from the Ministry of Construction, the Ministry of Transport, the National Police Agency, the Ministry of International Trade and Industry, and the Ministry of Posts and Telecommunications.

I would like to briefly go over the role played by each Ministry. As for the Ministry of Posts and Telecommunications, its major role is the managing and control of electronic communications waves. MITI's role is to foster industries. And since the automobile industry will play a significant role in ITS, MITI is involved in ITS projects in terms of industrial policies. The National Police Agency's role is the traffic management and signal controls. Ministry of Transport is in charge of establishing standards for vehicle safety control. Whereas the Ministry of Construction is in charge of constructing roads, constructing infrastructures, and promoting advanced information systems. We think it very important that the five ministries will cooperate in promoting the ITS project.

(C-2-1)

Next is industry. At the moment there is an organization called Vertis. In comparison to the U.S. measures, we do not think that the promotion mechanism or structures have not really been clearly established yet.

The overall promotion scheme is that this is the project promoted by the government, academia, and industry. Our goal or objective is to form a basis of ITS at the beginning of the 21st century.

(C-2-2)

In order to realize this goal, we think that we need to implement these 11 policies. I would like to highlight some of the important policies.

First is 1), development of system architecture. Generally speaking, Japan is not very good at formulating this sort of system architecture. Because looking back at what we have been doing, we seem to have a commercialized or implemented system first. That has been the trend.

I understand that the U.S. has spent 2 billion yen to establish the system architecture, and we are very impressed with it. As for the future task to be done, we think that the organizing concerned agencies for the promotion of ITS is important.

I would like to touch on the 7th policy, which is the consideration of legislative institutions. In order for ITS to be well accepted in society, we think that we need to consider what kind of legislative impact ITS will pose. The International standardization and international cooperation are important policies as well.

(C-3-0)

I would like to go on to the topic of the 9 fields of ITS development areas:

(C-3-1)

I would like to use some illustrations to explain these 9 fields one by one. First is the upgrade in navigation systems. In addition to the conventional navigation information that have been provided, what we are aiming for is to provide traffic congestion information, and information regarding the traffic restrictions in real time.

This service will begin its operation next year in the Metropolitan Expressway, Tomei and Meishin Expressway, and this project has been promoted by the Ministry of Construction, the Ministry of Posts and Telecommunications, and the National Police Agency.

(C-3-2)

The second development item is the electronic toll collection system. I understand that the ETC has already been commercialized in the U.S. and in the European countries. In Japan there are various authorities that manage expressways and tollways. What we are developing now is the electronic toll collection system that is standardized and can be used by different authorities.

At the moment, 10 teams that consist of the private sectors and the public sectors, and the public highway corporations, are jointly conducting the development and we are planning to hold the trial operations at the end of next year.

(C-3-3)

The third development item is safety driving assistance. This is research work towards the realization of the AHS, and what we are aiming for is to provide accurate information from road side to vehicles, such as the traffic accident information, or information regarding the road ahead of the cars.

As a background for promoting the research on the safety driving assistance, the Japanese society is rapidly moving towards the aging society. At the moment, the number of senior drivers in Japan is 5 million. However, the number is expected to reach 50 million in 10 to 15

years from now.

Therefore, before realizing AHS, what is urgently needed is how to provide accurate information that will assist drivers for safety driving. Another development is how to control the vehicles after receiving the information from the road side. The research on this area has been mainly conducted by the private sector. As for the advanced functions of the vehicles, there is a project conducted jointly by the Ministry of Transport and MITI.

We think that when the advanced information and the advanced function of the roads and advanced functions of the vehicles are realized in harmony, we think that they will be in line with the realization of AHS.

(C-3-4)

The fourth research topic is improved traffic management. In July of this year, the judge gave a rather strict verdict for the trial regarding the complaint of noise. We might need to separate the heavy duty vehicles as one measure in areas where the pollution or the environmental issues are serious. So, one of the ideas or experiments that we are considering is this item.

(C-3-5)

The fifth research topic is enhancing efficiency of road management. The road management has a wide scope, but this illustration gives one of the most characteristic ones. In Japan now, we see some old bridges passing through the roads. Therefore, with this experiment, or with this project, we will be employing a rule. Before the heavy duty vehicles will actually drive through the roads, heavy duty vehicles will not go through the roads where the old bridges are being passed.

At the moment we cannot confirm where these large size or heavy duty vehicles are driving. This system will expedite granting approvals, and at the same time it can monitor to see if the vehicle is in compliance with the approvals, and if it is following the route according to the approval that this vehicle obtained.

(C-3-6)

The sixth topic is the assistance of public transportation. This system has already been implemented in several cities for bus location systems. Therefore, this system will expand the existing systems and will apply not only to buses but to all public transportation systems. And this system will support this ultimate goal from the viewpoint of providing appropriate information.

(C-3-7)

The next one is improving efficiency of commercial vehicle operation. Some of the private companies are using their own systems to commercialize this system. The concept of this system is to link shippers, freight information, forwarder and trucks, by providing traffic information.

(C-3-8)

The next topic is assisting pedestrians. There are two objectives for this topic. The first objective is to assist the senior pedestrians and the disabled pedestrians. And another objective is to relate to the large earthquake as we had in January of this year. In the case of such a natural disaster, this system will provide the evacuation place for the citizens, and also the necessary information in the vicinity to the citizens.

At the moment, the pedestrian assistance systems, and also the systems for the disabled pedestrians operated by the magnetic systems, have been introduced in about 100 cities.

(C-3-9)

The last topic is support and emergency vehicle operation. At the great Hanshin earthquake that we experienced last January, there was great confusion because the ordinary cars and emergency vehicles had to drive on the same roads. So the objective of this system is to control the ordinary vehicles in the case of emergency situations and provide necessary information to the emergency vehicle operations.

I have gone through nine development areas. From the first one to the fourth one, the work has been quite advanced. As for the fifth item through the ninth one, we are planning to promote the R&D from now. We need to review the status of these projects from time to time, and then we need to see if there is a validity for introducing these research projects.

(D-2-1)

These are the various research projects that we have been working on. As for the budget that is appropriated for these projects, it is approximately 1 billion yen a year.

As for the next fiscal year, the Ministry of Construction, is currently making a budget request. To be more specific, we are requesting 10 billion yen for establishing R&D facilities and equipment. We know that this is still only half of the money that the U.S. is spending, but this shows that the government is going to actively promote ITS.

(D-5-0)

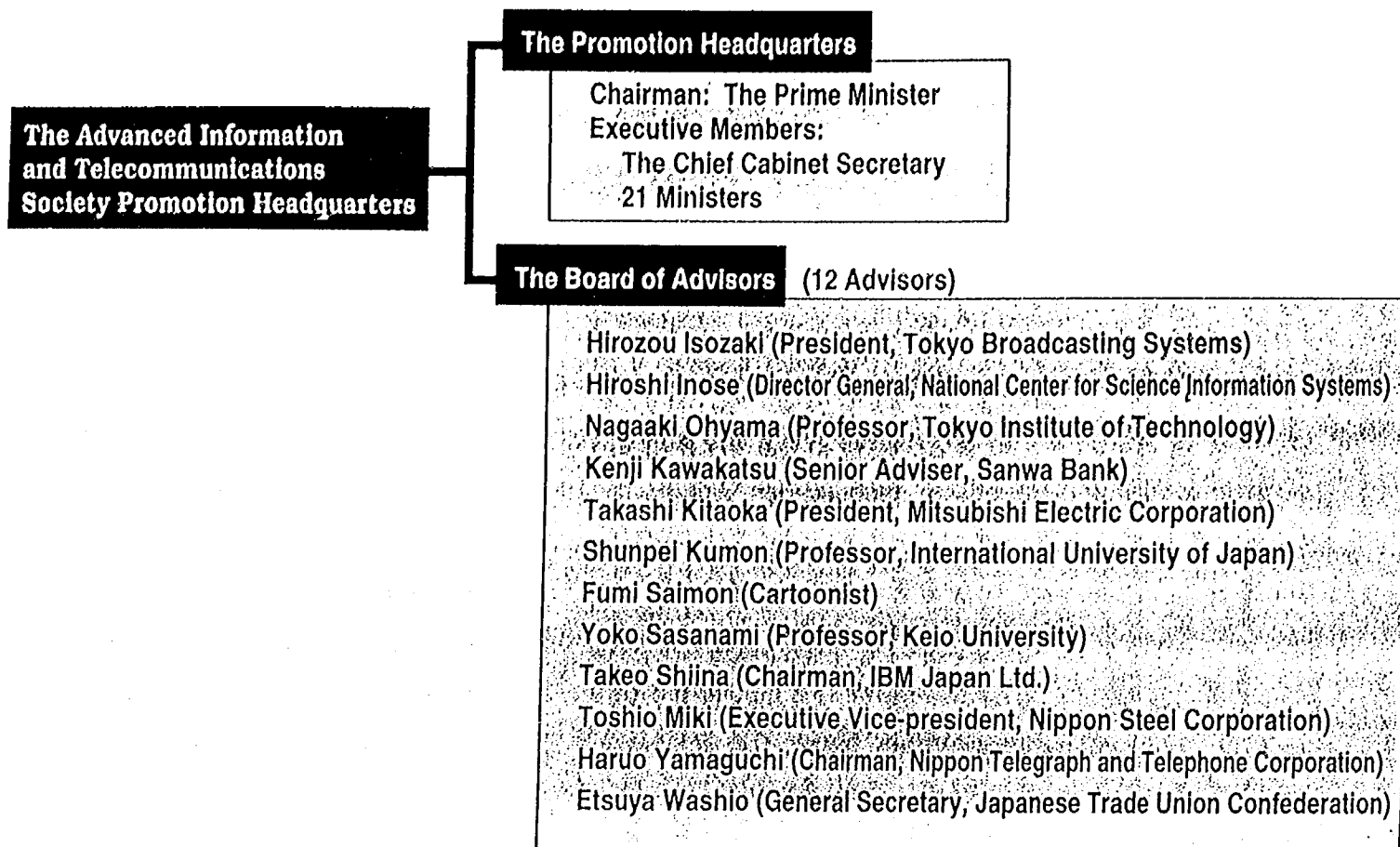
And VICS (Vehicle Information and Communications Systems) will start its operations from next spring. So, the advanced road traffic infrastructure development deployment to support VICS will be necessary and in this area, we are requesting a budget of approximately 35 billion yen.

(D-5-1-1)

This slide shows our deployment target. As for VICS, it will start its service in some highways, or in some expressways in the spring of next year. Ultimately, we would like to expand this system to all the expressways and highways, and in order to expedite this target, we need to promote the beacon installations. And so far 1800 beacons have been installed.

I have been talking about the overview of the counter measures and the measures that the Japanese have been working on for ITS, but at any rate, this is the new system that we will be establishing now. In order to realize the innovative traffic systems toward the 21st century, we need not only cooperation within Japan, but also cooperation among various countries in the world in order to develop better systems.

ORGANIZATION OF THE ADVANCED INFORMATION A-1 AND TELECOMMUNICATIONS SOCIETY PROMOTION HEADQUARTERS



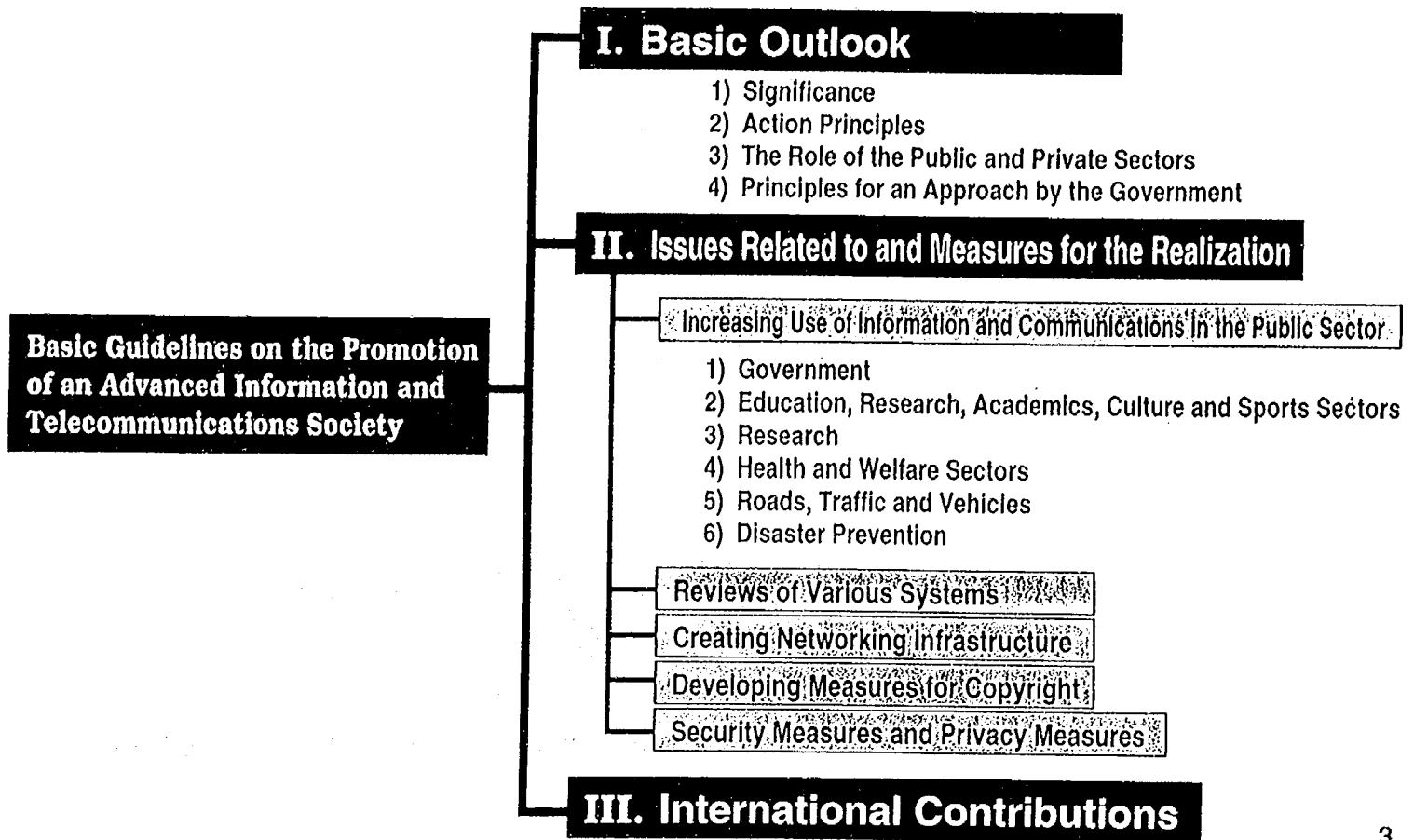
1

PROGRESS OF THE ADVANCED INFORMATION A-2 AND TELECOMMUNICATIONS SOCIETY PROMOTION HEADQUARTERS



<Progress of the Advanced Information and Telecommunications Society Promotion Headquarters>

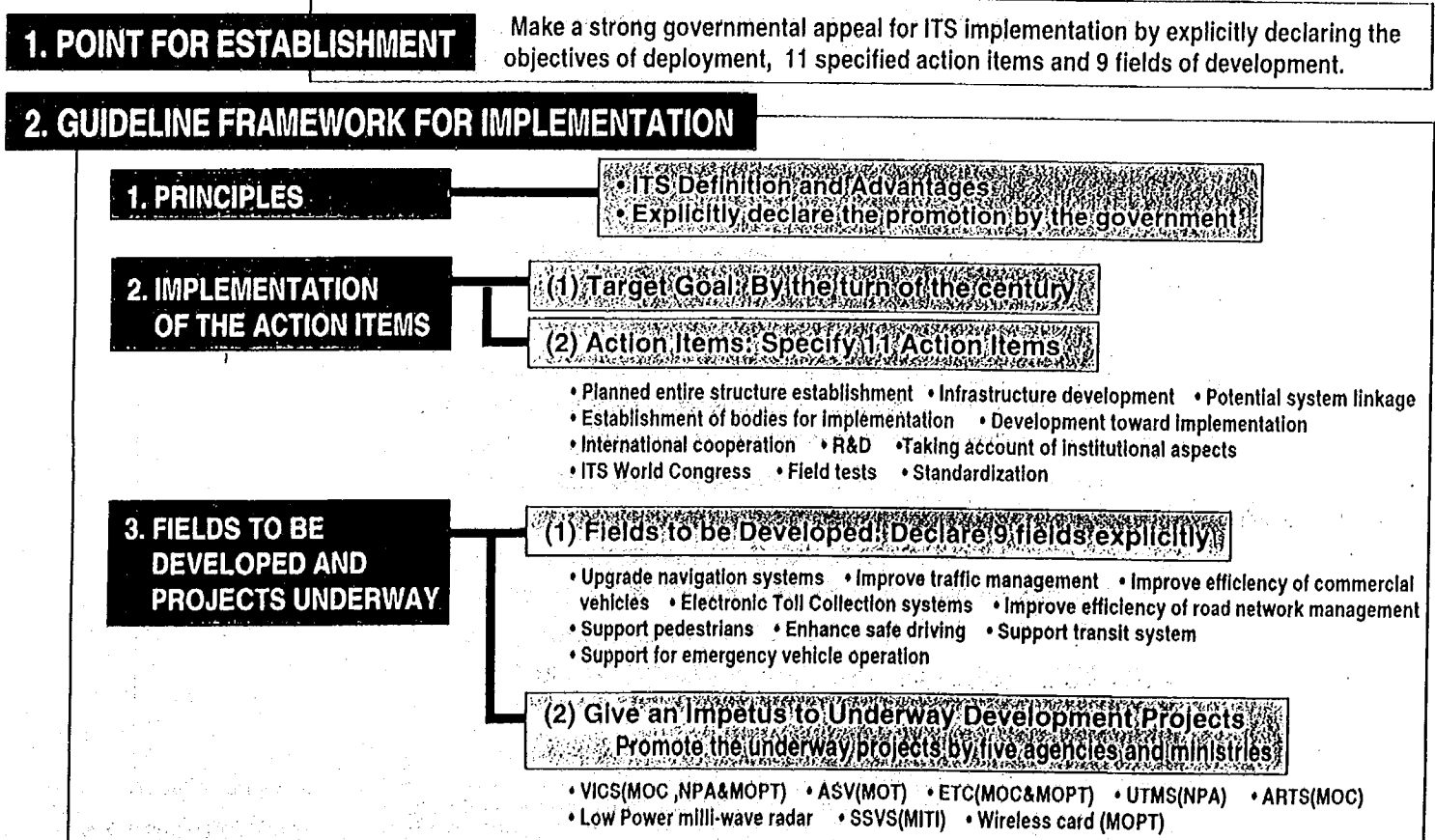
1994 August	The Cabinet resolved to establish the Advanced Information and Telecommunications Society Promotion Headquarters.
February	The Promotion Headquarters issued Basic Guidelines on the Promotion of an Advanced Information and Telecommunications Society.
1995 June	The Cabinet resolved to issue Guidelines on Increasing Use of Information and Communications in the Public Sector earlier (in July) than the original schedule; these guidelines are expected to be a part of immediate measures against the current severe economic trends such as a strong yen.
End of July	The Ministry of Construction prepared Guidelines on Increasing Use of Information and Communications in the Fields of Roads, Traffic and Vehicles in cooperation with the National Police Agency, the Ministry of International Trade and Industry, the Ministry of Transport, and the Ministry of Posts and Telecommunications.
August 28	The latter guidelines were published after approval was granted by the Board of Advisors.



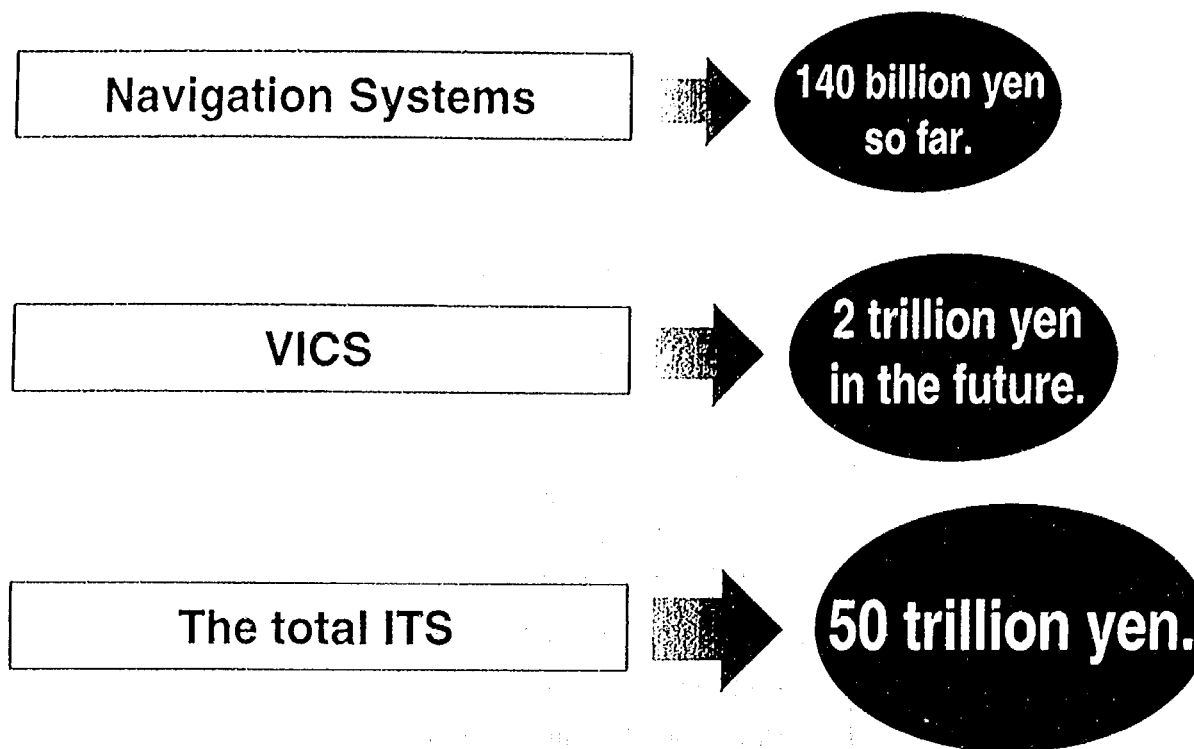
3

GUIDELINE FRAMEWORK FOR IMPOSING "INTELLIGENCE" ON C-O-1 ROADS • TRAFFIC • VEHICLES

<Guideline for Imposing "Intelligence" on Public transport>



4



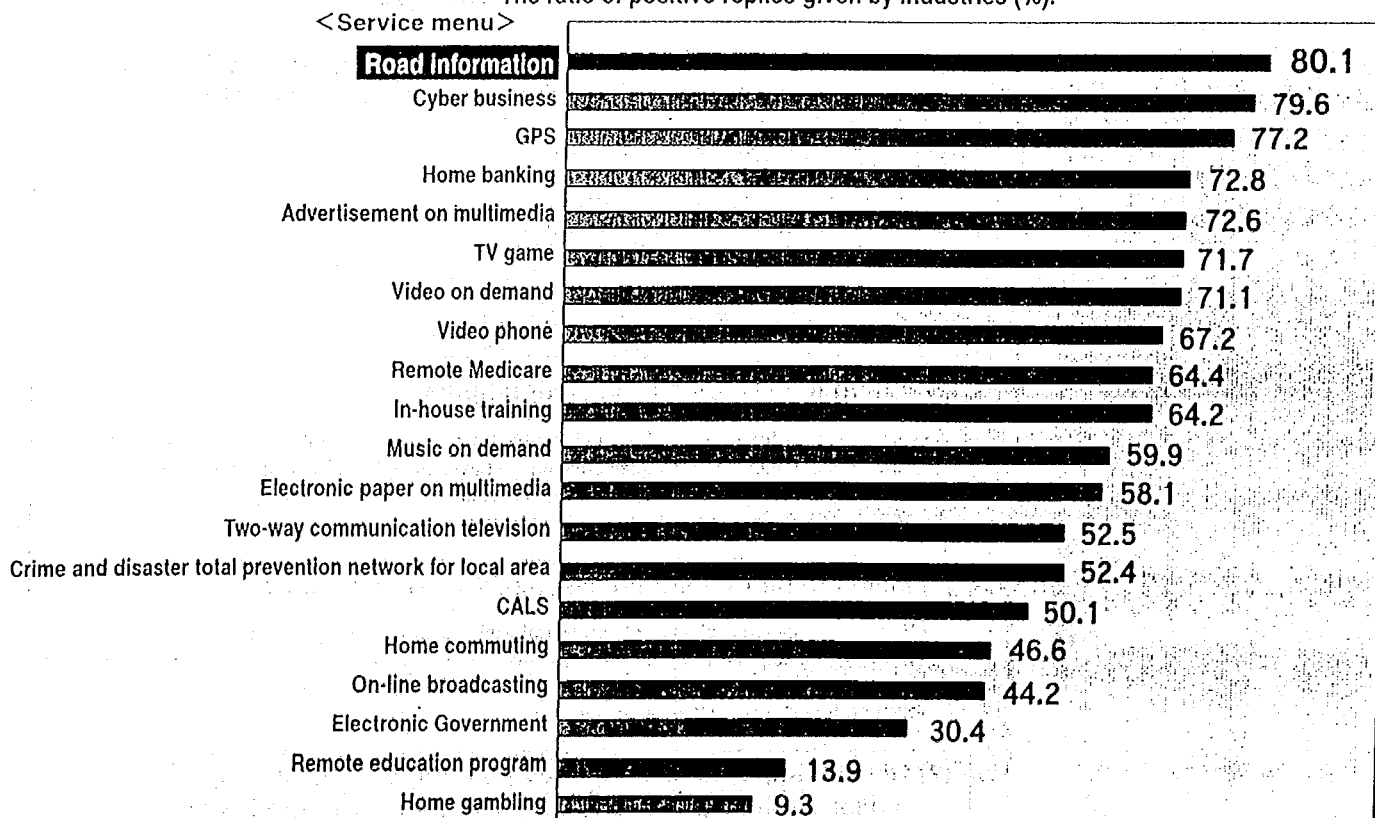
(Effect evaluation of the total ITS development is estimated by VERTIS)

23

D-1-3 EXPECTATIONS BY INDUSTRY

<Evaluation of the potential for possible multimedia related industries>

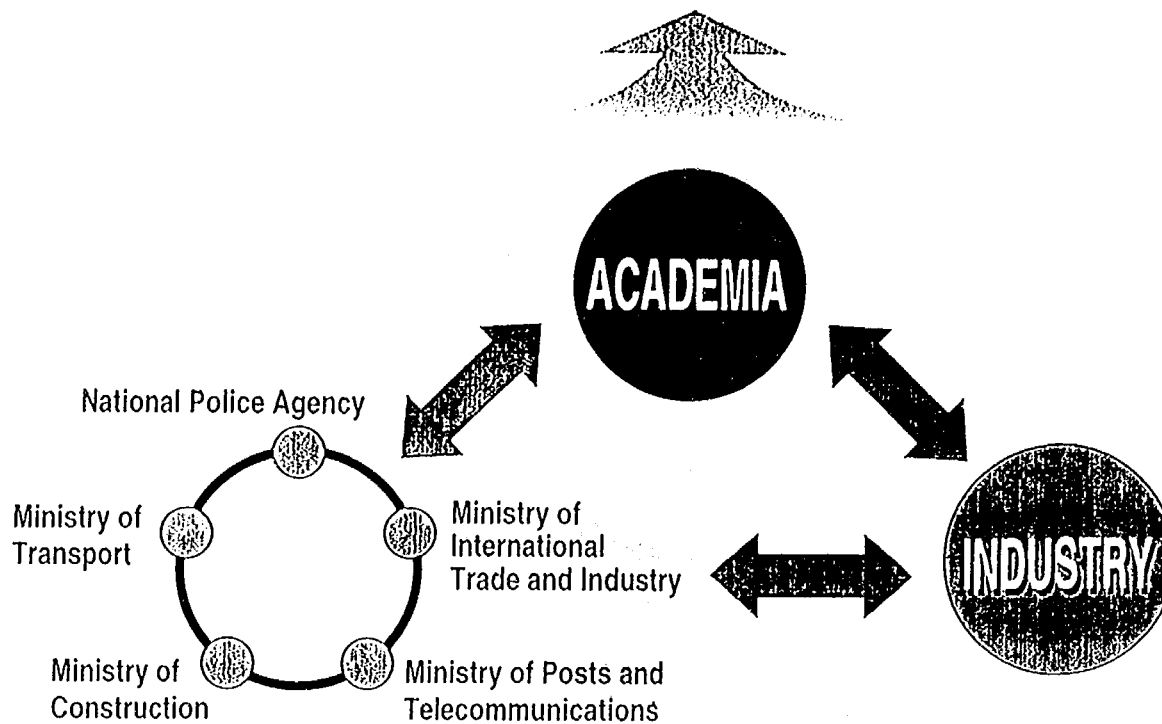
The ratio of positive replies given by industries (%)



Reference: The diagram is created on the basis of questionnaires conducted for "The research of multimedia usage by Japanese industries" (April, 1995) by Nomura Research Institute, Ltd.
Industry participating in the questionnaire: 2137 stock listed industries. Response: 668 (Ratio of response 31%)

24

R&D. Infrastructure Development International Cooperation etc.



8

C-2-1 DEPLOYMENT OBJECTIVES

<Deployment Objectives>

- To begin to operate individual systems after their complete development.
- To form a basis of ITS at the beginning of the 21st century.

9

**11 Components
of ITS Policy**

- 1) Development of a system architecture**
- 2) Organizing concerned agencies for the promotion of ITS**
Coordination and cooperation among the government, academia, and the private sector
- 3) R & D**
Diversified measures and distributed responsibilities
- 4) Field tests**
The promotion of field tests and the provision of appropriate test sites
- 5) Provision of Infrastructure**
Systematic promotion
- 6) Deployment of ITS for practical use**
Strategies for practical use and diffusion
- 7) Consideration of legislative institutions**
Product liability, privacy and intellectual property rights
- 8) Standardization**
Coordination with ITU and ISO
- 9) System compatibility**
Compatibility, expandability, and standardized specification of data
- 10) International cooperation**
International standardization, technical cooperation, and technology transfer
- 11) The ITS World Congress**
Continuous participation and positive actions at the congress in Yokohama

10

C-3-0 INTELLIGENT TRANSPORT SYSTEMS (ITS)

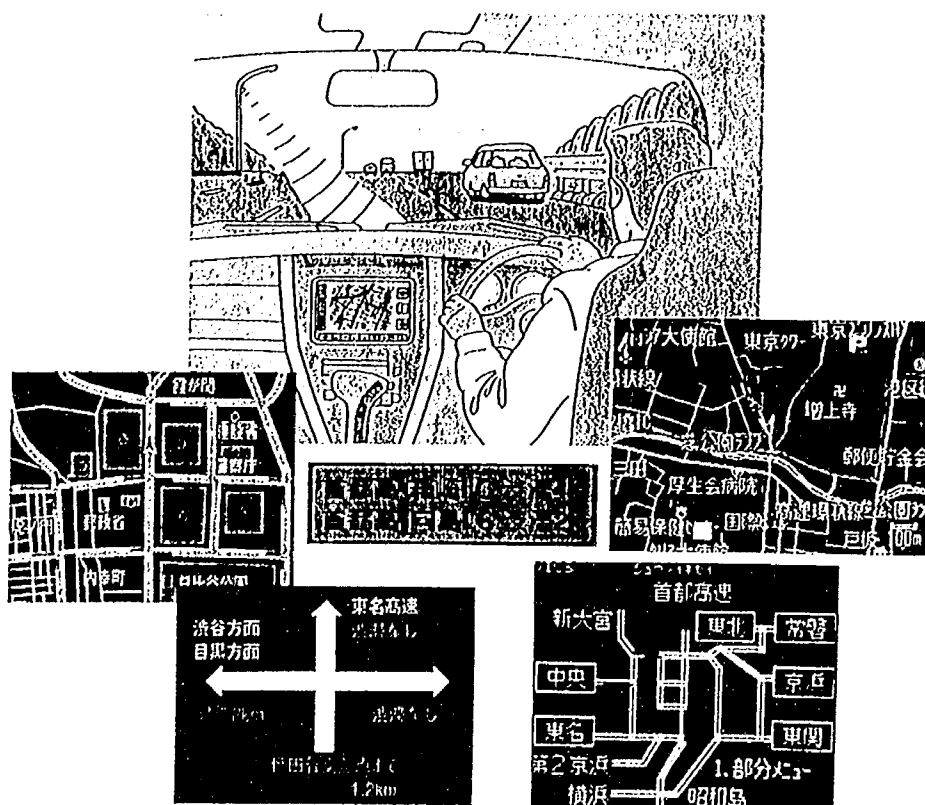
**Intelligent Transport Systems
(ITS)**

- Upgrade Navigation Systems**
 - Gather and provide road traffic information in real time by VICS.
- Electric Toll Collection System**
 - Conduct automatic toll collection at highway gate without requiring a vehicle stop.
- Safety Driving Assistance**
 - Support drivers behavior by giving a warning and performing automated driving by AHS.
- Improve Traffic Management**
 - Improve traffic signal timing for public transportation and give an optimum route guidance.
- Enhance efficiency of Road Management**
 - Control special vehicle operation such as traffic control on the approved routes, planned road work information and its distribution.
- Assist Public Transportation**
 - Schedule headway of public transportation and provide its information.
- Improve Efficiency of Commercial Vehicle Operation**
 - Gather and provide information on truck operation status and provide it. Provide information on pickup and delivery.
- Assist Pedestrians**
 - Guide or lead the disabled to the optimum route. Give evacuation instructions when a natural catastrophe occurs. Provide pedestrians with route guidance and available facilities in the vicinity.
- Control Operation of Emergency Vehicles**
 - Provide reports on conditions of the area subjected to a natural catastrophe.
 - Dispatch restoration vehicles to the affected area

11

C-3-1 ADVANCED NAVIGATION SYSTEM

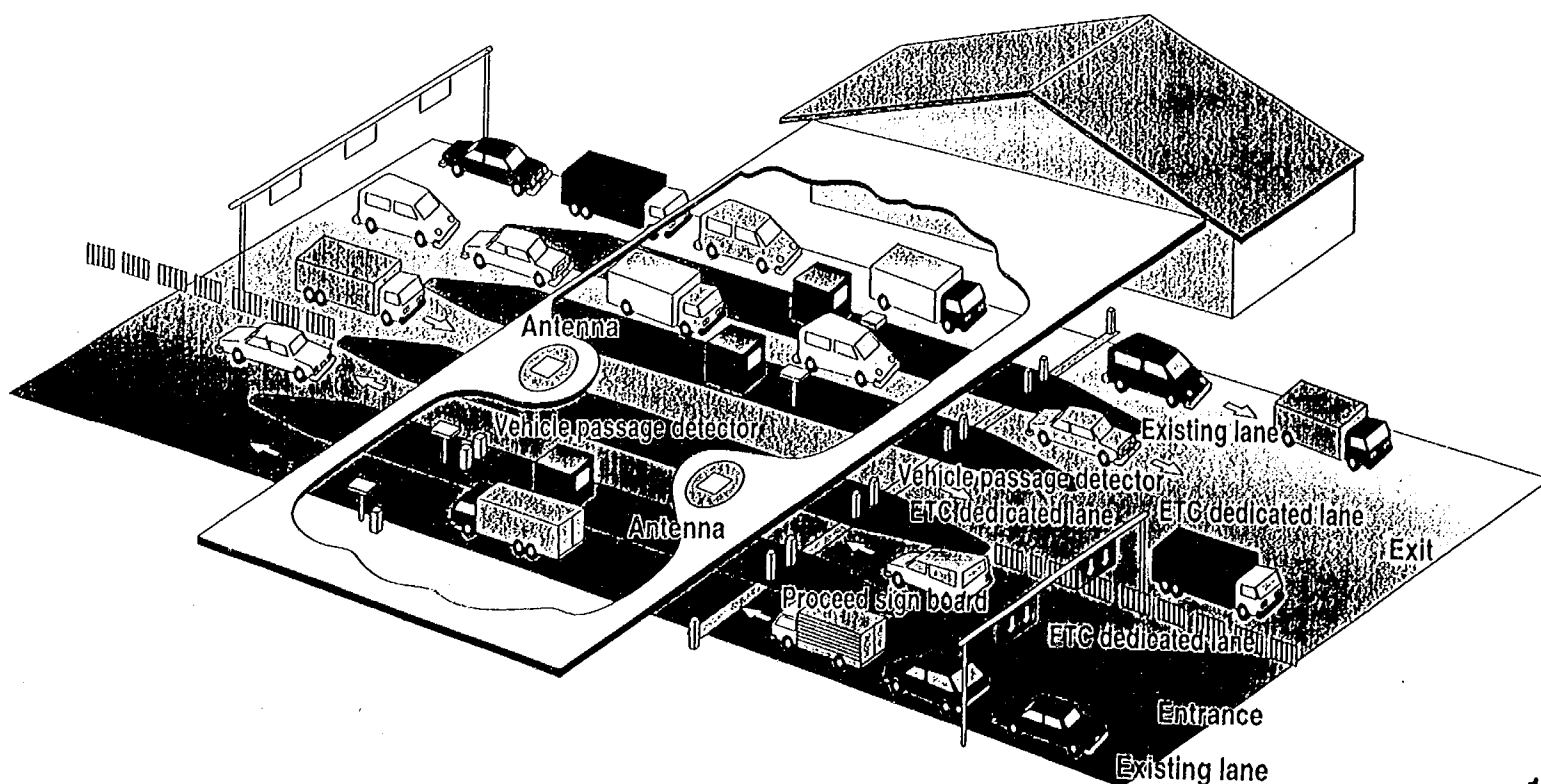
< An example: Information provision through on-board display >



Advances in Navigation Systems

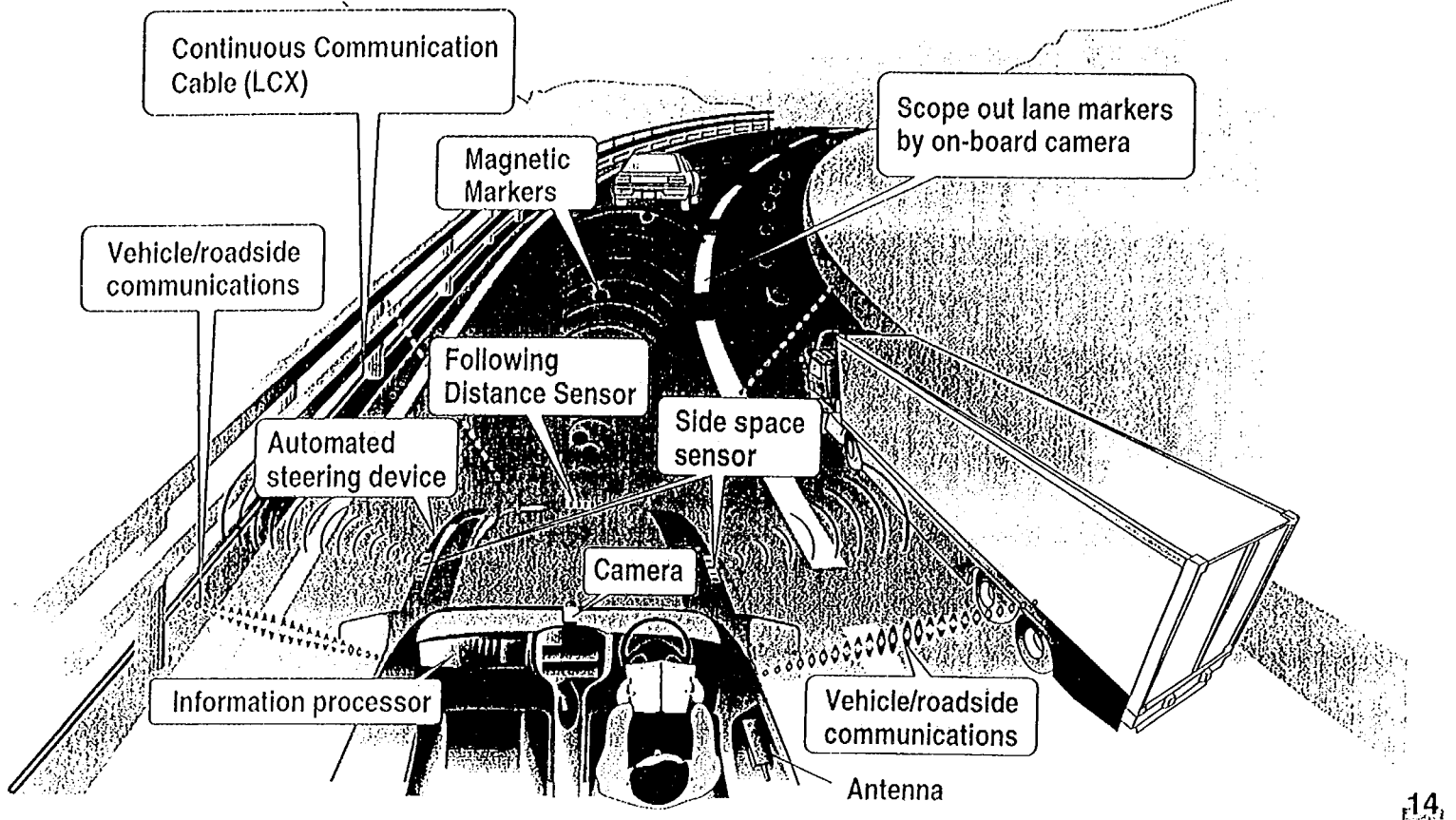
12

C-3-2 ELECTRONIC TOLL COLLECTION SYSTEM



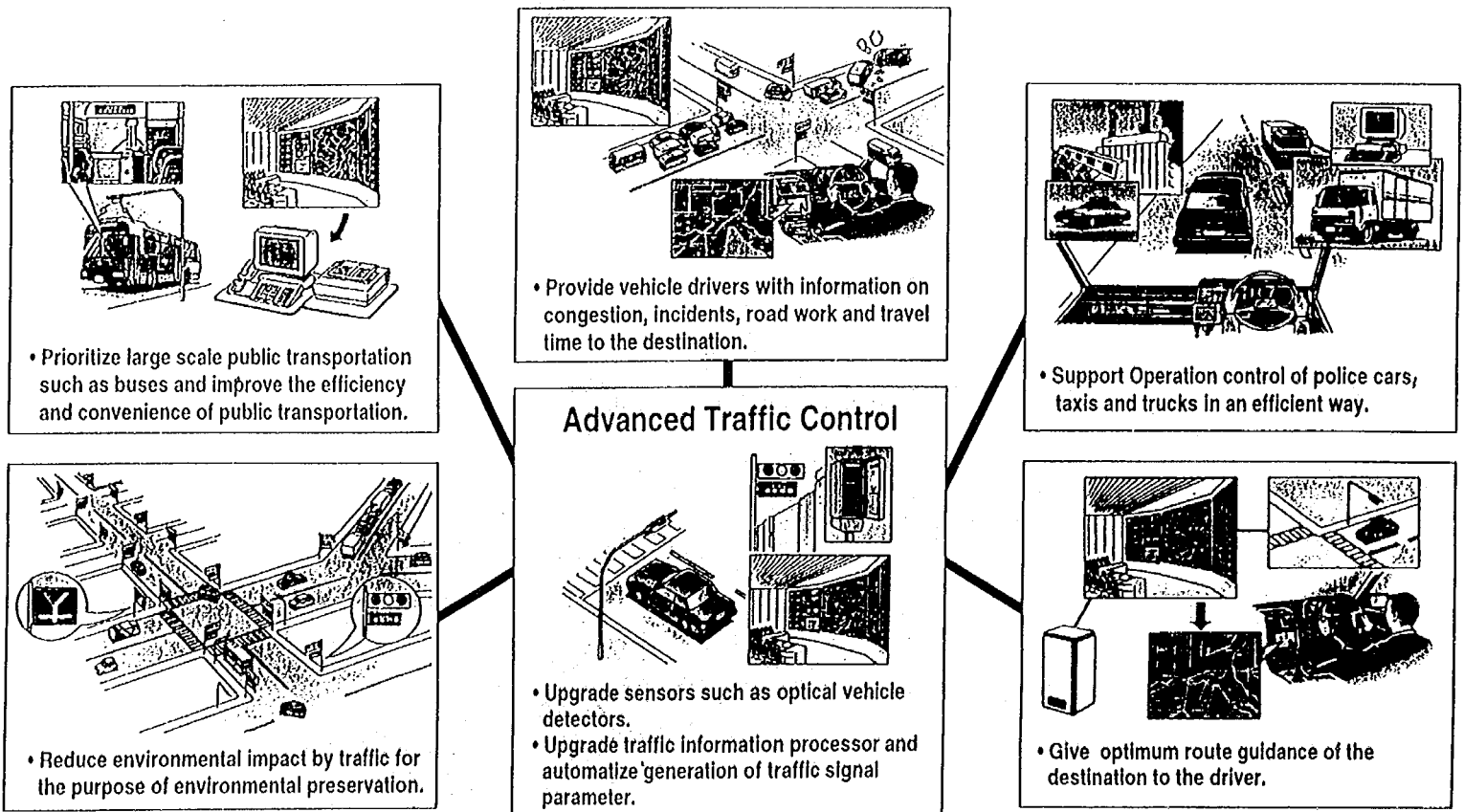
13

C-3-3 SAFETY DRIVING ASSISTANCE



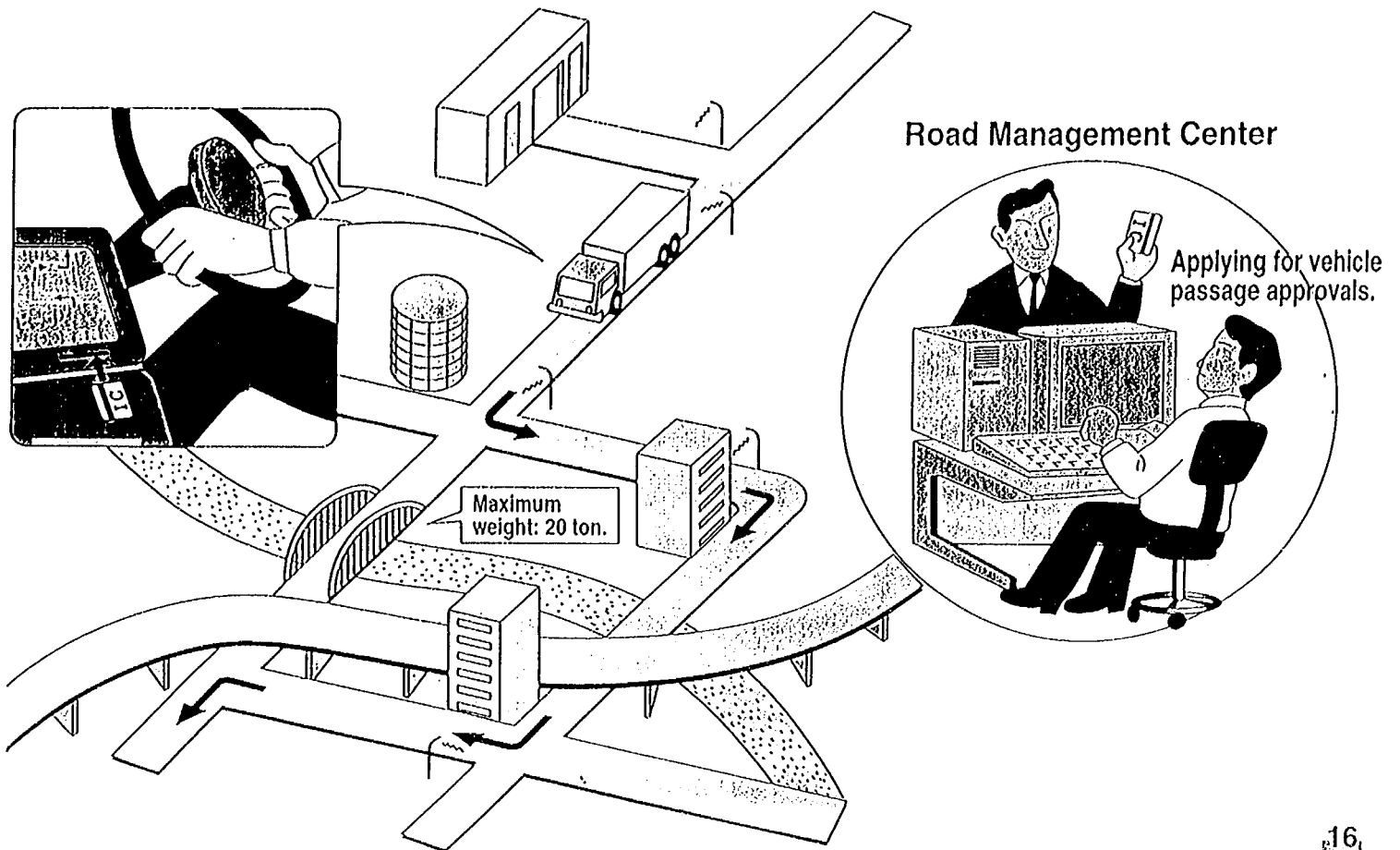
14

C-3-4 IMPROVE TRAFFIC MANAGEMENT



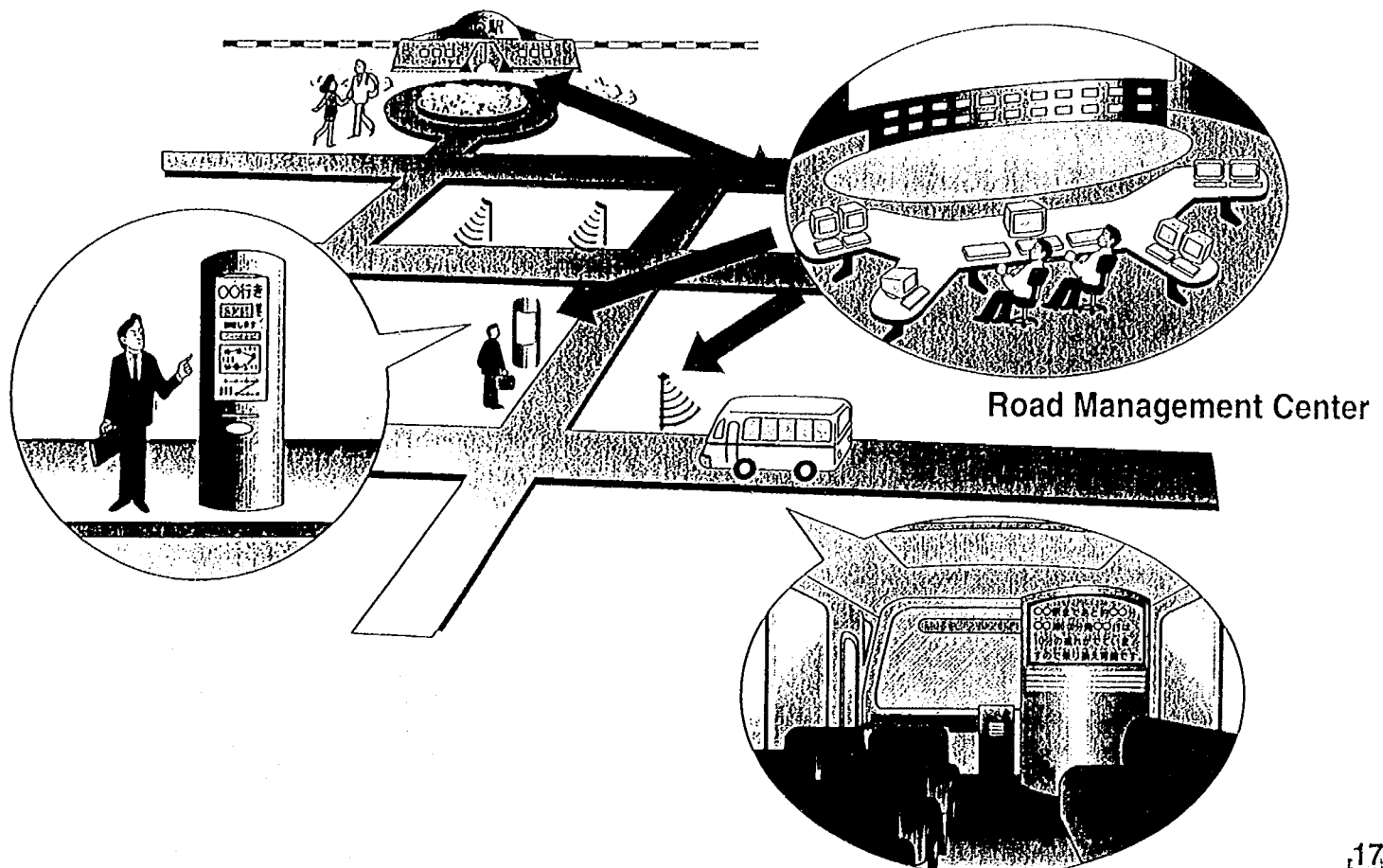
15

C-3-5 ENHANCE EFFICIENCY OF ROAD MANAGEMENT



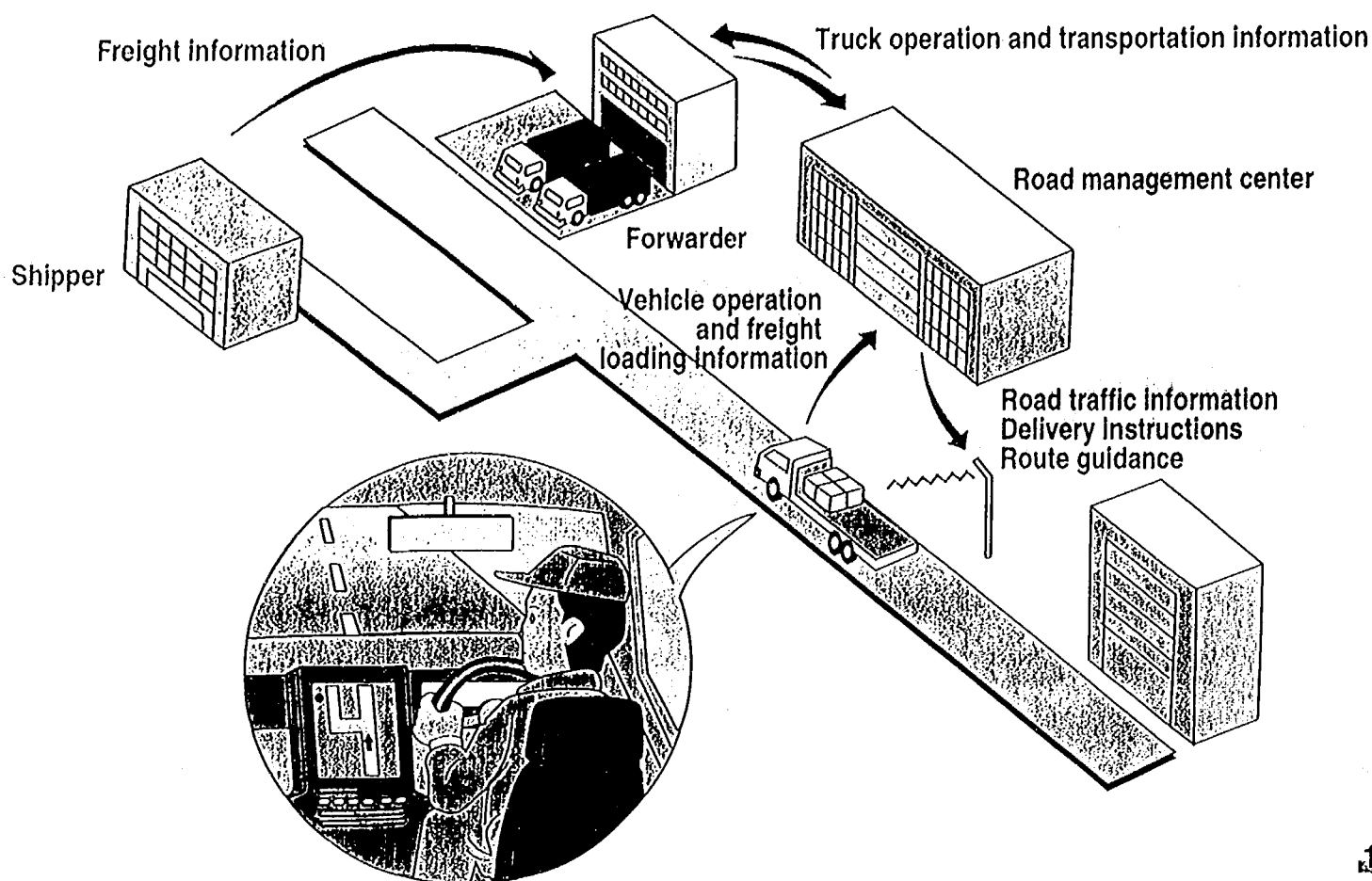
16

C-3-6 ASSIST PUBLIC TRANSPORTATION



17

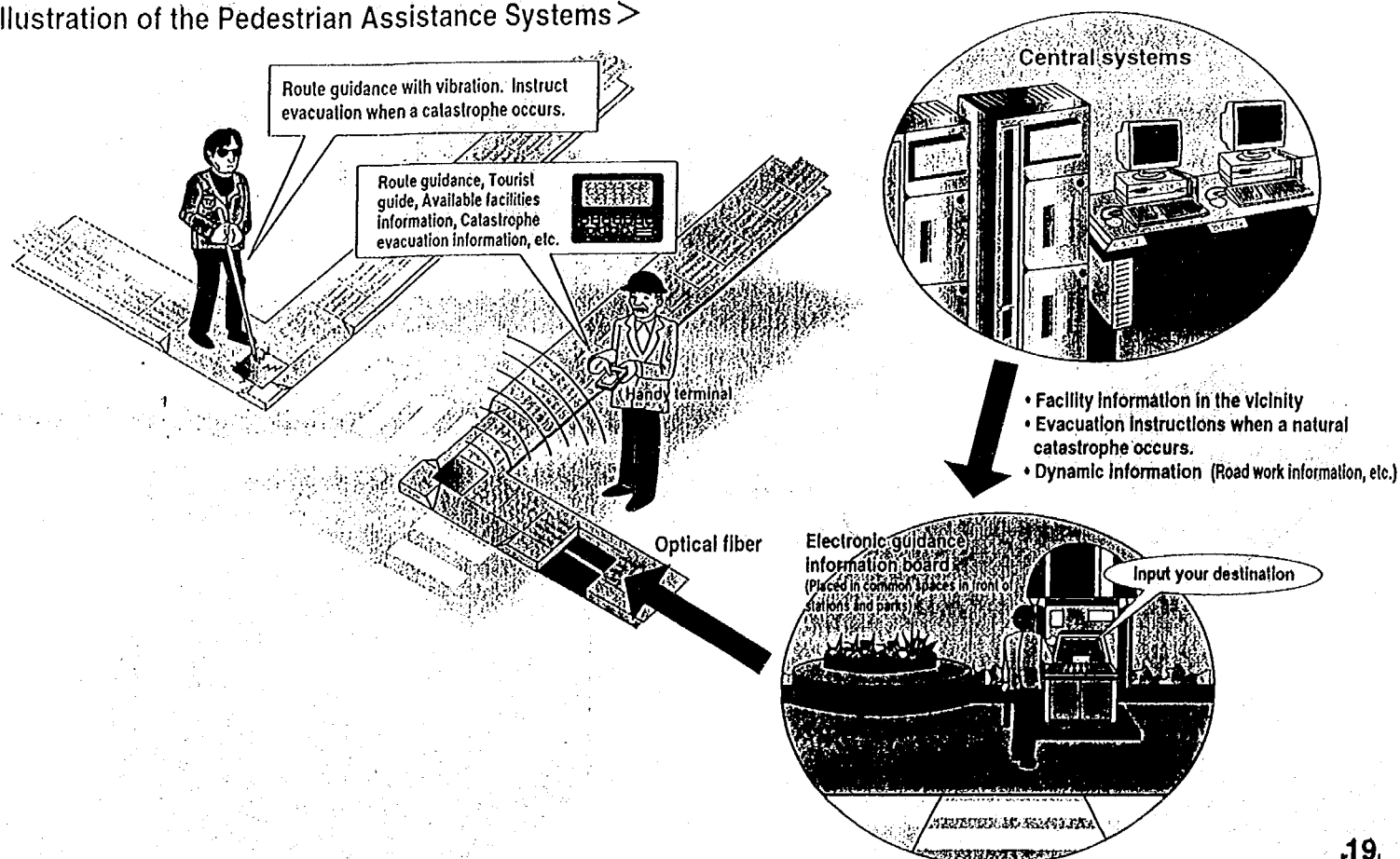
C-3-7 IMPROVE EFFICIENCY OF COMMERCIAL VEHICLE OPERATION



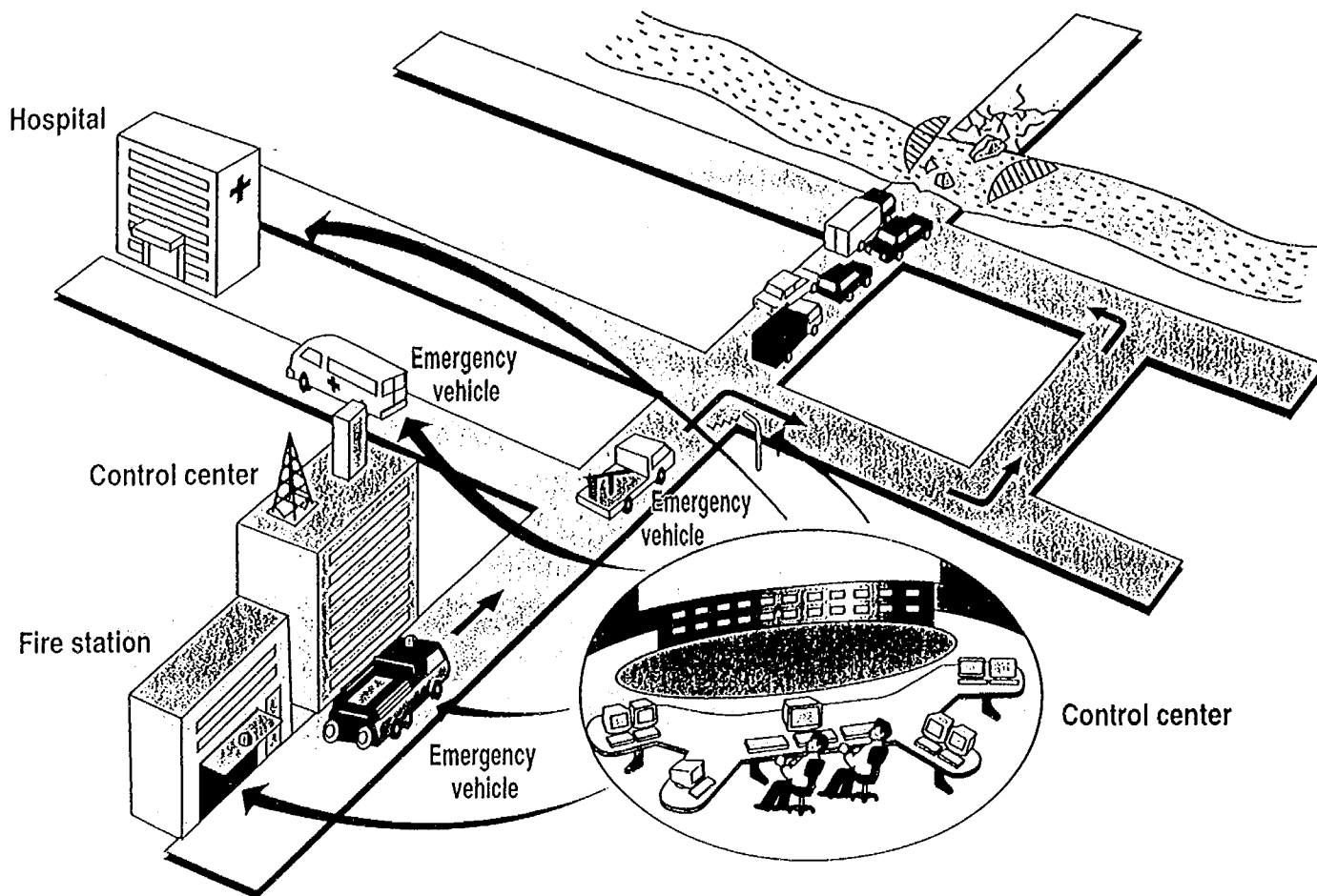
18

C-3-8 ASSIST PEDESTRIANS

< Illustration of the Pedestrian Assistance Systems >

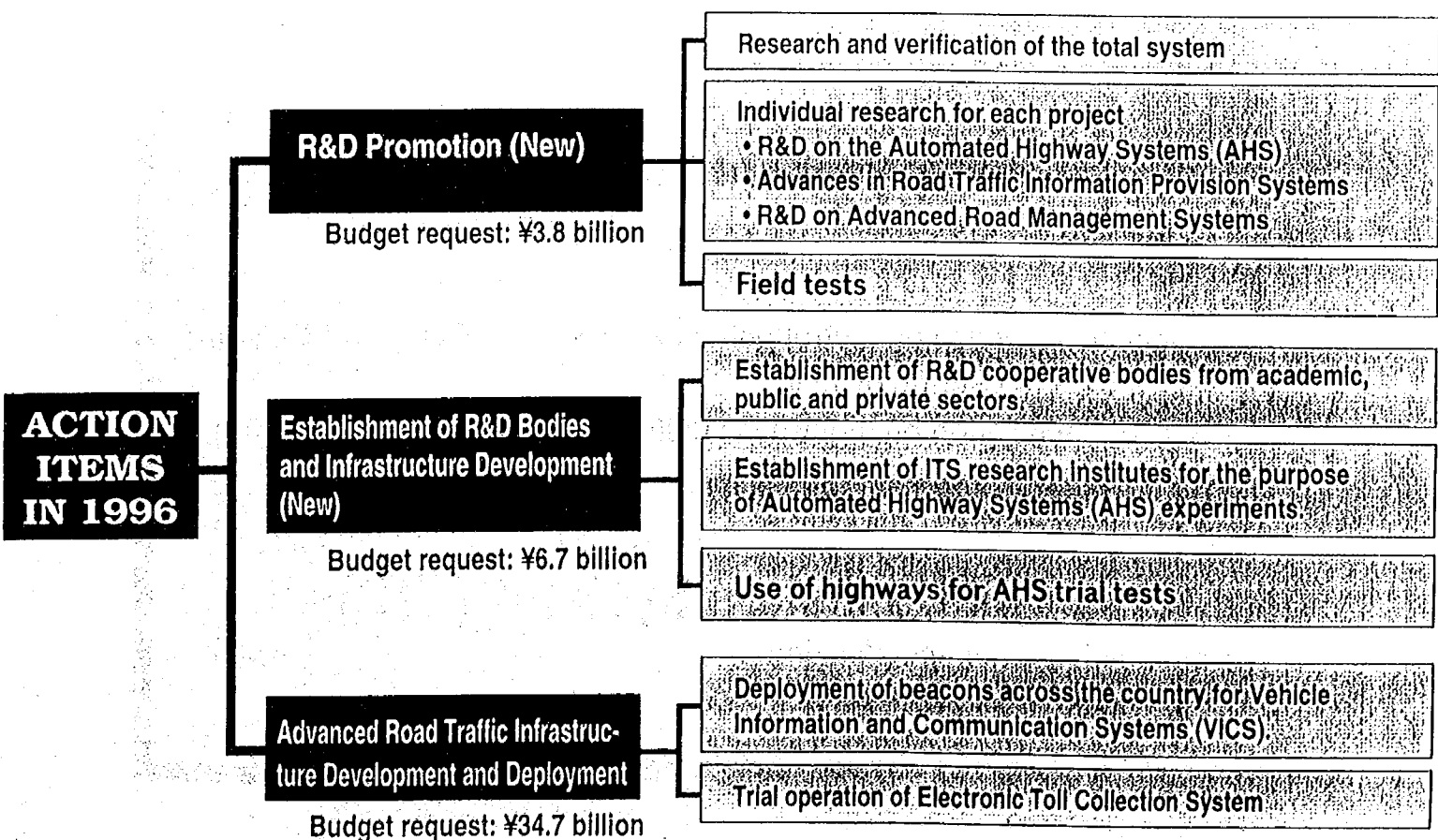


19

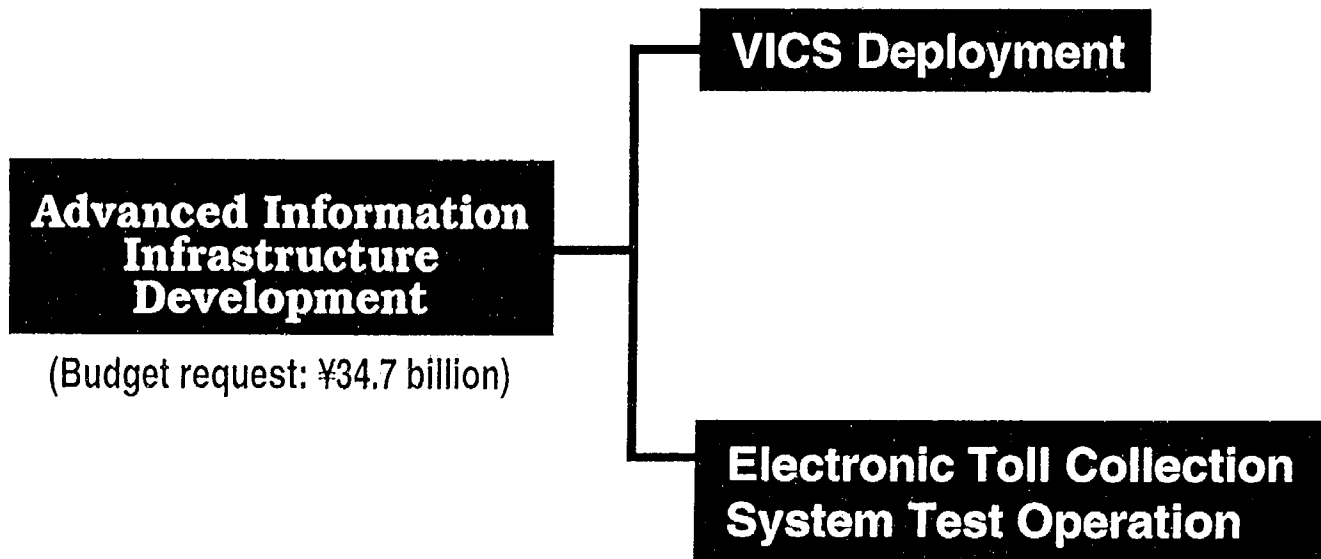


20

D-2-1 FRAMEWORK FOR BUDGET



29



53

D-5-1-1 INFRASTRUCTURE DEPLOYMENT TARGETS (VICS, ETC)

<Deployment Targets>

VICS

- Commence service on metropolitan expressways, Tomei and Meishin highways from Spring of 1996.
- Beacon installation on highways (1800 beacons have been installed).
- Deployment of information centers.

Electronic Toll Collection Systems (ETC)

- Establishment of specifications.
- Test operation start.

54

4.1.2 "U.S. ITS UPDATE"

by C. John MacGowan

(Chief, IVHS Research Division, TFHRC, FHWA)

Although there were early beginnings of the U.S. ITS program, it really didn't begin until the national legislation of 1991 was enacted. This legislation is known as ISTEA, which is short for International Surface Transportation Efficiency Act. That legislation defined the ITS program in the U.S. as one that is principally a research and development program aimed at reducing congestion and improving safety. Another way of defining the U.S. ITS program is by where it has been.

Through FY — or fiscal year 1995, we at the US—DOT have spent over \$787 million. This includes \$132 million on R&D, \$99 million on technology transfer, deployment planning and support activities, \$33 million on AHS and precursor studies, \$27 million on system architecture, \$24 million on commercial vehicle operations, and \$468 million on operational tests.

This includes \$102 million that has been devoted to 77 specific tests that have been launched to give us much needed practical information. Practical information has been needed on the ability of numerous technologies to reduce congestion, decrease emergency response time, increase transit system productivity and passenger convenience, increase safety and personal security, and reduce the environmental impact of transportation.

Yet a third way of defining the U.S. ITS program is by where it is going. This is the way in which I have chosen to elaborate for you, as I view it as the true, real and concrete definition of the future. So, if you'll allow me to ask each of you leave your important jobs here in Japan at least mentally, and transport yourselves 10–14 time zones from here, I am asking that each of you imagine that you are a U.S. county engineer. As a U.S. county engineer or manager, you are faced with all of the problems of operating and maintaining an infrastructure that is under siege by tens of thousands and even hundreds of thousands of vehicles every day, and you have heard about something called intelligent transportation systems, and it promises to solve all of your problems.

But you, being wise, and battle scared from dealing with your frustrated citizenry, day in and day out, day after day, for years, are skeptical, if not a little cynical.

(ITS is Not ...)

Let me begin by telling you what ITS is not. It is not Star Wars. It is not too far off over the horizon to ever be part of your county. And, it's not going to wait until after you've filled all of your potholes.

(You are Deploying ITS Now)

The fact is, ITS is here today. It's affordable, and it is being deployed in many jurisdictions. The approach taken in the deployment however, can either form a platform for the evolution of powerful new tools to empower the choices of transportation managers and the public or they can build the stumbling blocks and barriers of tomorrow.

As county engineers or managers, you are probably deploying ITS now. So it becomes only a question of how. Do you have unintegrated, incompatible stove pipes? Or do you have systems and products that will allow you to grow with technology?

ITS is currently being applied in some of today's thorniest transportation problems — safety, capacity and environmental impact. Some examples of technology deployments are integrated traffic patrol systems with bus priority systems; freeway managing systems, including ramp metering and traffic monitoring; transit fleet management systems, using automatic vehicle location and in-vehicle monitoring; incident response systems; electronic toll and fare collection; high speed commercial vehicle identification and weigh in motion; and travel information systems.

Now, each of these systems rely on core communications, computer and sensing technologies that form the heart of intelligent transportation systems of tomorrow. These technologies are being deployed today, not as components of ITS, but often as stand alone solutions to current transportation problems. And they are yielding the desired results — improved freeway speeds and greater arterial throughput, faster accident response, greater security and productivity for transit fleets, and streamlining safety regulatory functions.

Each component has withstood cost benefit analyses in numerous cities, counties and states, such as where you work, across the U.S., and empirical results have verified initial investments. So now let us look a little more closely at what this core infrastructure really is for you.

(Core Infrastructure 1 ~ 5)

One part of core infrastructure is traffic signal control systems such as those deployed in California with the results of reduced travel time by 15%, and reduced vehicle stops by 35%. Another component of core infrastructure is freeway and incident management systems. In

Minneapolis, a 35% increase in freeway speed and 22% increase in freeway capacity, using ramp metering, has been obtained, which is a form of freeway management systems. Similarly, an incident management system also deployed in Minneapolis, was able to get a 20 minute reduction in response time to accidents.

Transit management systems is yet another kind of core infrastructure. In Baltimore a 23% increase in transit productivity was obtained through such systems.

Two other examples: Electronic fare payment systems and electronic toll collection systems have received benefits in Oklahoma of reduced annual costs of toll lane operation by 91% by using automatic toll collection.

In the face of shrinking budgets, some view ITS as an unaffordable luxury. No one expects that an entire ITS will be purchased all at once as a brand new system. However, most of it will be built over time from system upgrades, expansions and replacements. It is as much a philosophy for investment as it is a development and deployment of technology.

Taking all of these parts together with traveler information and integrated transportation management, behold the core infrastructure. Many of the systems components described involved developing communications infrastructure and information databases. These systems can be deployed so that each contributes to the development of a larger, more robust communications infrastructure and information databases.

Such foresight will yield two beneficial results: first, the performance of each of the stand alone systems is substantially enhanced today. And secondly, the ITS electronic communications and information platform enables a number of new public and private services including a cable TV traveler channel, in-vehicle messaging, traveler information delivered via kiosks, personal digital assistance, cellular phones, interactive television, and other distribution media.

Based on these observation, the US-DOT has defined this core set of first level ITS components, which if deployed as an integrated system, maybe, perhaps one component at a time, can form the platform for launching numerous public and private services and products, some envisioned, and many unimagined today.

We are encouraging the deployment of the appropriate set of each of these components in an integrated system in each of our metropolitan areas. An appropriate set of components means that each metropolitan area will design its own system, tailored to its specific needs. For example, only areas with toll roads will deploy automatic toll collection. The U.S. interstate system applied one design to the entire country, but an intelligent transportation system will be designed to fit the metropolitan area it serves. Decisions will be made locally, to address

specific local needs.

(So What Should I Do Right Now ? 1 ~ 6)

Let me propose that you ask some basic questions. The first question is, "what kind of equipment is in your budget now? Can it link to other systems?"

The second question you could ask is to look at the communications options that are available to you. Are there economic benefits in sharing an investment with a cable or telephone company? Do you have, or are you forming a master communications backbone? In other words, are you ready for the information highway?

You can ask if your database can be read by other agencies electronically. Do you have common references such as geographic references?

You can be a catalyst for getting other players together. ITS is an intermodal partnership. You can make sure your workforce is well trained and share your vision of an appropriate and integrated system. Then consider an evolutionary path as I have described of the core infrastructure.

That is what you as county engineers or managers can do, but what can the US-DOT do to help you? As we begin the construction of the next generation of transportation in the U.S., the federal government is prepared to assume a leadership role. We are no longer linking a nation. We are now underpinning an existing infrastructure with an electronic infrastructure to expand efficiency and service to the communities that have grown up around us.

As I said before, a one-size fits all design was appropriate for the U.S. interstate highway system, but not for the Intelligent Transportation system. The technological underpinning must be designed by you, the county engineers and managers who will use it, and based on the needs of your particular region, but within the framework that provides for the interconnectivity and the free flow of information and national interoperability.

We at the US-DOT have targeted five areas to focus our core infrastructure activities, while research continues to spawn new and innovative technologies for tomorrow.

The first of these is funding. The ISTEA now allows for most core infrastructure components to be paid for with regular federal aid funding. And ISTEA permits federal aid funds to support operating and maintenance expenses of traffic management systems. However, while ISTEA greatly expanded the flexibility with which funds could be spent, overall transportation needs still exceed the available resources. How these funds are used, whether they are used for investment in ITS technologies, or simply to pay for restoring deteriorating pavements, remains the decision of the county engineers and managers such as

yourselves.

The second area is architecture. Just as the federal government drew the broad outlines of the interstate highway system to ensure interconnectivity, we have also invested in developing a national architecture to define minimum requirements for information exchange and to allow for standards development.

The third area is standards. The US–DOT will also facilitate consensus among industry and public investors of key standards to ensure interoperability of certain components and functions. Perhaps more importantly, standards will allow component interchangeability, promote developer confidence that the various components will fit, and ensure competition in the marketplace.

The fourth area is training. The planning, design, implementation, operation and maintenance of ITS requires a cadre of well trained professionals at federal, state, and local levels. However, sufficient numbers of these professionals do not currently exist to enable effective delivery of these ITS systems. A strategic plan for meeting the ITS training needs has been developed. In the coming months, we will be working with our state and local partners such as you, the professional societies like the Institute of Transportation Engineers, ITS America, and American Association of State Highway and Transportation officials, colleges and universities, and the ITS industry, to find and implement the strategic plan.

The fifth area is model deployment. Within each region, the ITS platform will be created from hundreds of independent decisions in dozens of public and private agencies. The federal government has proposed funding two or three model deployments of the core infrastructure to provide local decision makers with real examples of the value of integration and how it can be done without losing institutional autonomy.

So Phase 1 of the ITS revolution is upon us, and ITS components are in the budgets of hundreds of local agencies now like yours. In our changing society, the issues at hand is recognizing the local potential for ITS procurements, and insuring that decisions made today will serve tomorrow. I ask you now all to shed that weighty cloak of a county engineer or manager, and mentally journey back across the Pacific, back here to beautiful Japan. Rejoin us now as we continue our deliberations in the contemplation of still other ITS elements – the automated highway system, which remains in the conceptual developmental stages, but offers the promise of enormously increasing throughput while decreasing access.

U.S. ITS UPDATE

*3RD U.S.-Japan ITS Group Meeting
of the
U.S.-Japan Cooperation
on
Highway Science and Technology*



Tsukuba, Japan

November 6, 1995

ITS is NOT ...

- STAR WARS.
- Too far off on the horizon to ever be part of your county.
- Going to wait until you've filled all your potholes.



That will never be in my county during my lifetime

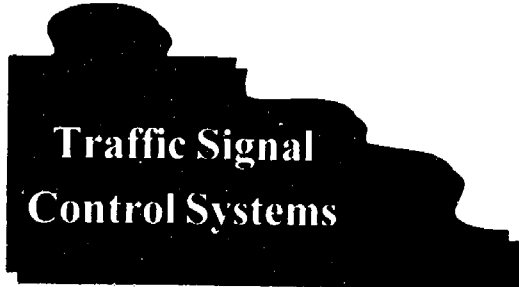
You Are Deploying **ITS** Now

It's a Question of How:

- Unintegrated, incompatible stove pipes
or
- System and products that will allow you
to grow with technology

CORE INFRASTRUCTURE

You can build your own **ITS** system structure
at your own pace using building blocks

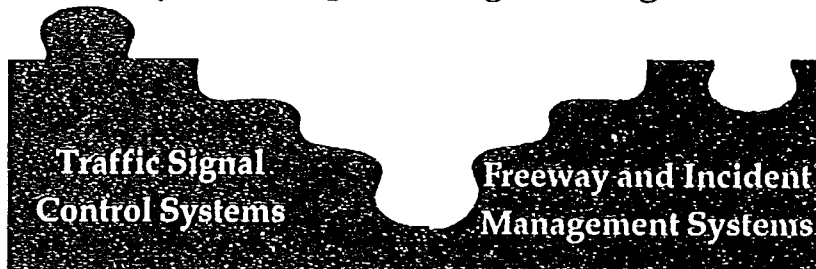


Traffic Signal
Control Systems

BENEFITS:
California reduced travel time by 15% and vehicle stops by 35%

CORE INFRASTRUCTURE

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at your own pace using building blocks

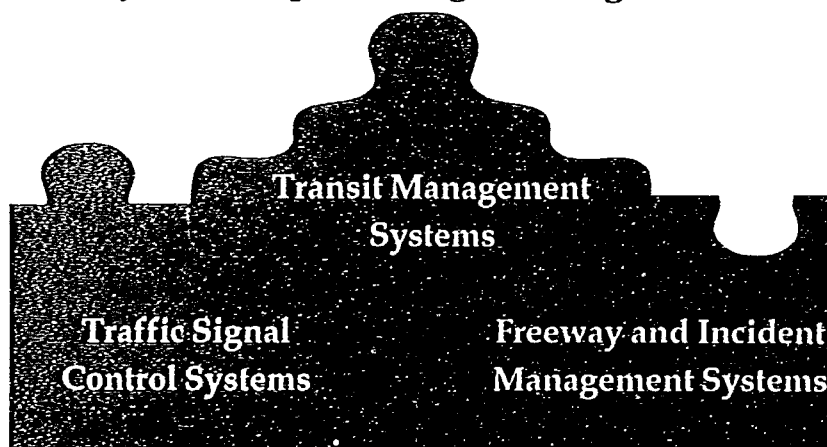


BENEFIT

- Minneapolis : 35% increase in freeway speed, and 22% increase in freeway capacity using ramp metering
- Minneapolis : 20-minute reduction in response time to incidents

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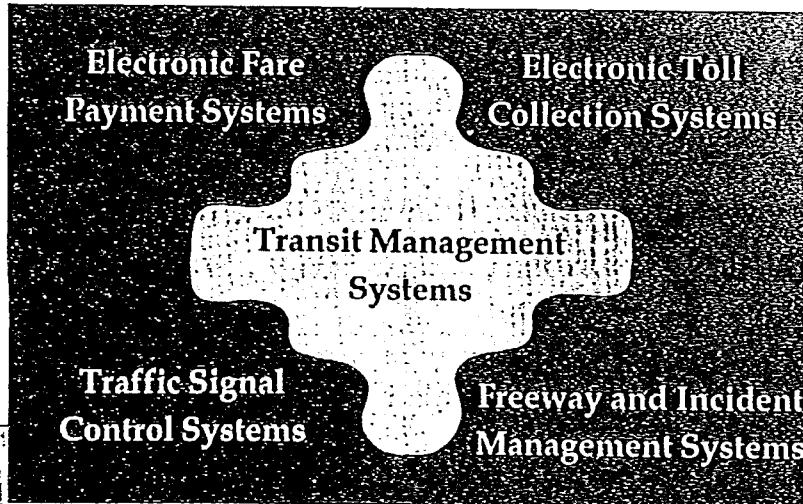


BENEFIT

- Baltimore : 23% increase in transit productivity

CORE INFRASTRUCTURE

You can build your own ITS system structure
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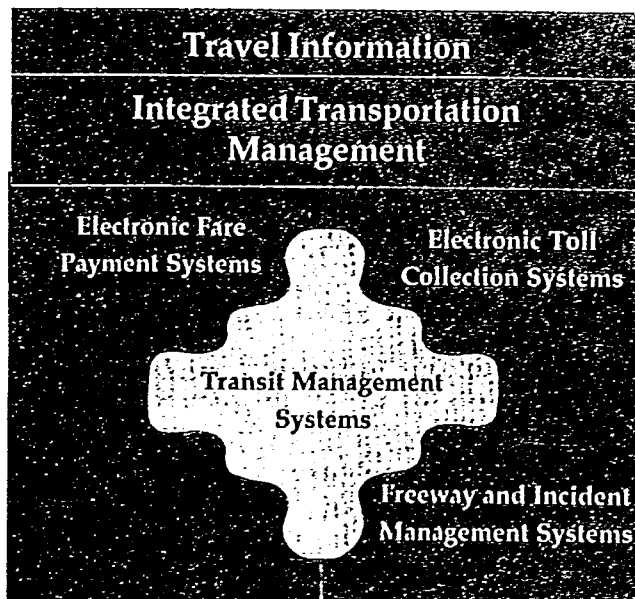


BENEFIT

- Oklahoma: reduced annual cost of toll lane operation by 91% using automated toll collection

CORE INFRASTRUCTURE

You can build your own ITS system structure
at your own pace using building blocks



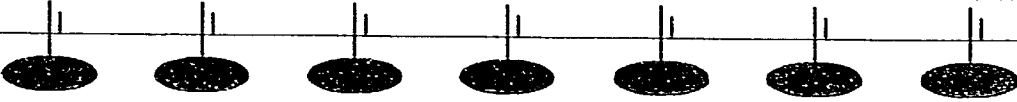
So What Should I Do Right Now ?

- ✓ What kind of equipment is in your budget now ?
 - Will it "talk" to other systems?

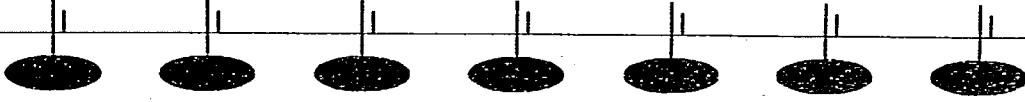
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- ✓ What kind of equipment is in your budget now ?
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- ✓ Look at Communications Options NOW
 - Shared investment with Cable or Telcos
 - Master Communications Backbone

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 - ✓ Be a catalyst for getting players together

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- ✓ Train your workforce

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 - Master Communications Backbone
- ✓ Can my database be read by other agencies ?
- ✓ Be a catalyst for getting players together
- ✓ Train your workforce
- ✓ Then consider an evolutionary path

4.2 AHS (Research Promotion Methods)

4.2.1 "AHS in Japan"

by Satoshi Ueda

(Head, Traffic Engineering Division, Road Department, PWRI)

How do you think about our AHS, and our ETC demonstration this morning? You are the first foreign delegation which enjoyed our system. From now, I'd like to explain about the AHS experiments in Japan using the facilities installed in our test course.

AHS in Japan, which now we are studying, executes consecutive communication between vehicles and road side units, exchanging the dynamic information for traffic conditions in real time. This system helps drivers perceive and recognize a driving environment by providing information in a timely fashion. And it enables drivers to make more informative decisions.

In the future, the system is aiming towards full fledged automated driving operations. And, now also I'd like to explain the system development and the experimental system components which now have been since 1994. And this is also the cooperative research and development of PWRI and some private companies.

(Image of Automated Highway Systems)

We would like to see the overview of the AHS in Japan. This shows the entire system image of the AHS. This is LCX cable – leakage coaxial cable, which is laid out without intermission along roadways. The system provides vehicles with information continuously at the initial stage of operation, and phases toward the AHS by eventually providing various vehicle control functions. So, AHS, at the experimental stage, consists of LCX and sub-control devices. It is installed along the road side, and which processes gleaned information in corresponding LCX sections. And the main control device which controls several sub-control devices and also the magnetic markers to control vehicle positioning in the lateral direction, and the test vehicle equipped with various information displays and control devices.

(Layout Plan of AHS)

This is a layout plan of AHS. You've already seen this project this morning, in our test course, 3 km of LCX was already installed along the test course, this LCX is divided into six sections. And each section is 500 meters in length. So each LCX has a sub-control device and

this main control device operates these sub-control devices.

(Photoes - LCX)

This is also a picture of the LCX, about 5 meters in height. And we use also the magnetic marker. Maybe this is the same as the PATH system in the U.S.— California?

(Photo - sensor)

And other elements are necessary for AHS but speaking from the side of the infrastructure, we need a technology of sensor for information collection and information processor for communication.

(Elementary Technology for AHS)

And, this is the elementary technology just from the side of the vehicle. In detail, Mr. Aoki of Toyota will explain. So, we need the two-way radio link unit technology, magnetic sensor, image sensor.

(Information Flow in AHS)

What kind of information is communicating between the infrastructure and the vehicles? I would like to say that the communication using LCX cable is two-way communication. This is from the infrastructure to the vehicle. So we call it a down link — or long term cycle data for 0.5sec. This long term cycle communication gives kilopost position, LCX numbers 1, 2, 3, 4, 5, 6; road alignment, recommended speeds and μ level — μ level means speed resistance between tire and pavement. This is the information from the vehicle to the infrastructure. We call this up link information. So, short time cycle data. This interval is 0.1sec. The vehicle ID, position, accident, speed, are also communicated.

(AHS Development Plan)

So anyway, we are considering our AHS is developed by some steps, step by step. You already have the pamphlet. This is the Japanese version. Maybe November 10th, the English version will be prepared. So, I prepared the translation only.

We are thinking of three steps. The first step is warning and information level; and the second step is driving assistance level; and the third level is automatic drive level. This is the final goal for AHS. This morning, already you have experienced a prototype of automatic driving level. In detail, please read the translation.

(RIDIS System Structure)

At the initial stage of AHS, I'd like to explain about the road incident detection information system (RIDIS). Road incident detection information system: This involves the detection of dangerous incidents, for example traffic accidents, traffic jams, icing, or the fallen rocks. And warning to the driver to prevent serious accidents, in inclement conditions — snow or fog. This system automatically detects halted vehicles due to accidents or due to congestion, and notifies drivers by providing real-time information using vehicle-roadside communication.

So, as a method of incident detection and processing, we have been concerned studying on the various ways, such as video imaging with all sorts of cameras on the road ways. Incident transmission from on-board May Day equipment to the road side, counting the number of passing vehicles, velocity detection equipment, and extraordinary speed change and crash sound detection.

This is the CCD camera — I mean, the image sensor to catch the information of the, for example, the halted vehicles. This is also installed in our test truck.

Because spot communication is not sufficient to provide real time emergency information to the driver, it is necessary to develop the continuous two-way vehicle-roadside communication. We have been researching the usage of LCX as a continuous communication medium. This LCX has already been implemented for AM radio broadcasts in tunnels, and bullet train communication. PWRI has planned to use LCX for two-way communication between vehicles and roadways in the system, and is now conducting research with an experimental probe for the use in the range of 2.5GHz, and satisfactory results have been achieved.

(Image of RIDIS)

This is an image of this system. This is in the blind curve. The vehicle gets the information by the LCX cable. This image sensor catches this accident, and the information is running through the LCX cable and it is transmitted to the vehicles. And this is an example of the information on the CRT in the vehicle: Drive on the right. Accident 5 km ahead. Stop — accident 300 meters ahead. And, the voice is also used to inform of this accident.

So anyway, we have been engaged in this prototype test with the construction of a 3km course to study various functions such as incidence detection, road side processing, LCX communication capabilities etc. And in-vehicle processing and transfer methods to drivers.

So next I would like to explain about AHS systems. The final goal of AHS still requires long term research and development for its realization. In addition to the RIDIS facilities and the equipment mentioned before, we have developed a test device with vehicle control

functions for AHS. We are now at the stage for prototype structuring of the AHS system, and we will continue to study the various communication and control methods.

(Elementary Technology for AHS)

Now we'll explain about the basic technology of AHS in Japan. First, control methods: the important issues of AHS are longitudinal control and lateral control. The AHS places great importance on these control methods. Longitudinal control is to employ the LCX cable; LCX provides vehicles with speed information as related to road structure, road surface conditions, traffic accident occurrence, passing location etc. This information is processed by in-vehicle equipment of the controller actuator to implement brake and accelerator operations. Clearance distance or headway is controlled by in-vehicle equipment such as infrared ray beams, or laser beams.

Next I'd like to explain the method of lateral control. AHS may have three levels: I mean, there are macro level, medium level, and micro level control for lateral control. So, advance road alignment information by LCX or a digital map for navigation is to be saved for macro level control information. White line detection by image processing using CCD camera as a medium level of control information. And magnetic field detection indicated by the induced current and magnetic markers buried in the road as micro level information.

So, in our test course, these magnetic markers buried at intervals of one meter now. Among the various methods mentioned now, we have selected the equipment for the AHS prototype to perform the platoon running tests at 1sec clearance distance, with a few vehicles. So I mean that we installed the LCX, the magnetic markers and the white lines. The vehicle can use three types of information from the LCX, the white lines, and the magnetic markers.

LCX receivers, magnetic sensors, CCD camera, special controller and actuator on the vehicle side are also needed. The reason for setting 1sec clearance distance is to twice volume of the current traffic capacity per lane, 1800 vehicles per hour per lane. If we reduce the headway clearance time by 1sec, we can make the volume twice.

We are also planning to make some tests concerned with diverging, merging, accident response and human factors using these facilities. Only about one year has past since the beginning of this AHS study, so the test equipment used in this study was developed to experiment with automated driving. And we need to further discuss and examine the research and development and direction of AHS.

In addition to improving AHS control methods, there still remains various problems to be solved, such as response methods to incidents, such as traffic processing in diverging and merging situations, traffic accidents, flat tires and the communication failures. The relationship

between vehicle interval control, which clearance distance is set at 1sec, and human factor, for example. And AHS construction methods in the existing road network in Japan.

So we also need to progress step by step with the public, academic and private sectors to solve the problems regarding acceptance of the AHS in the future.

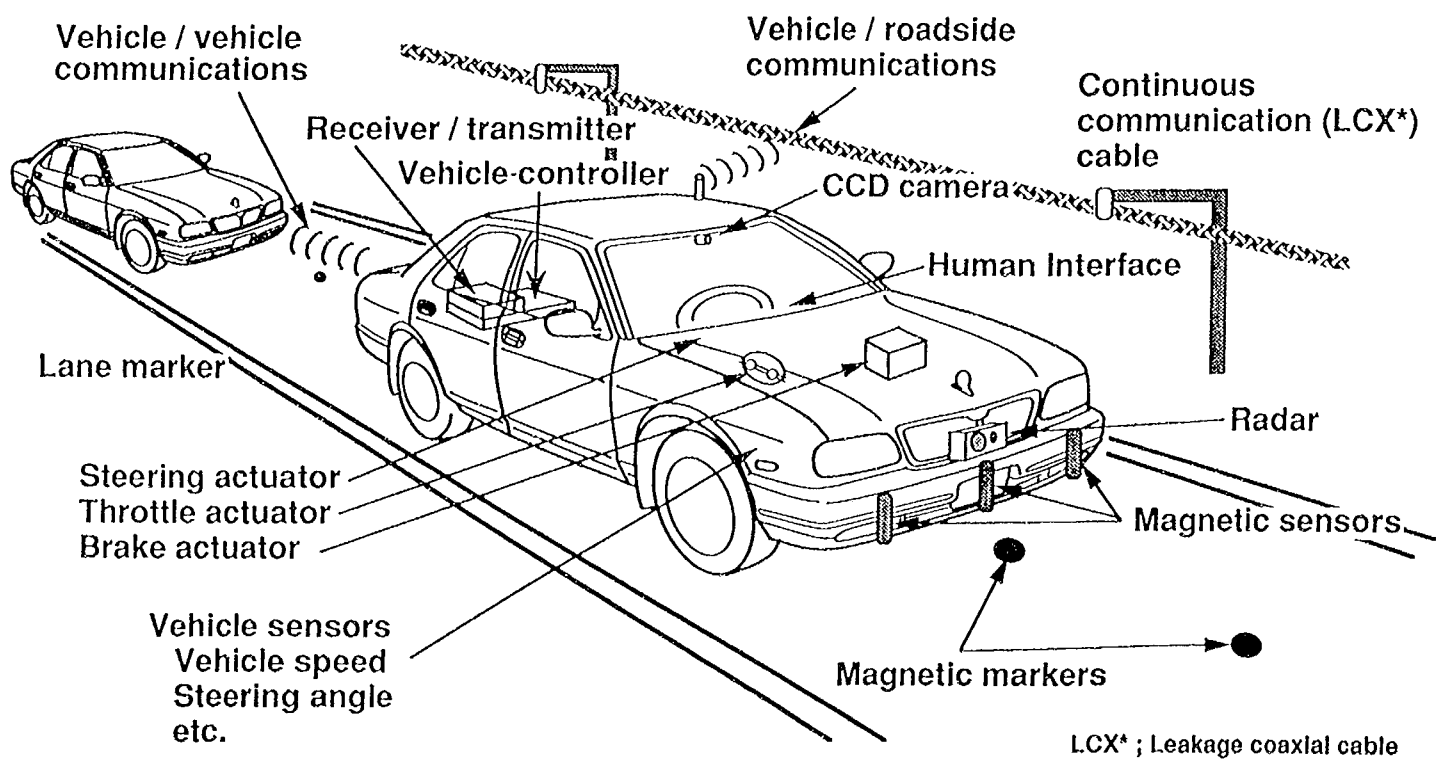
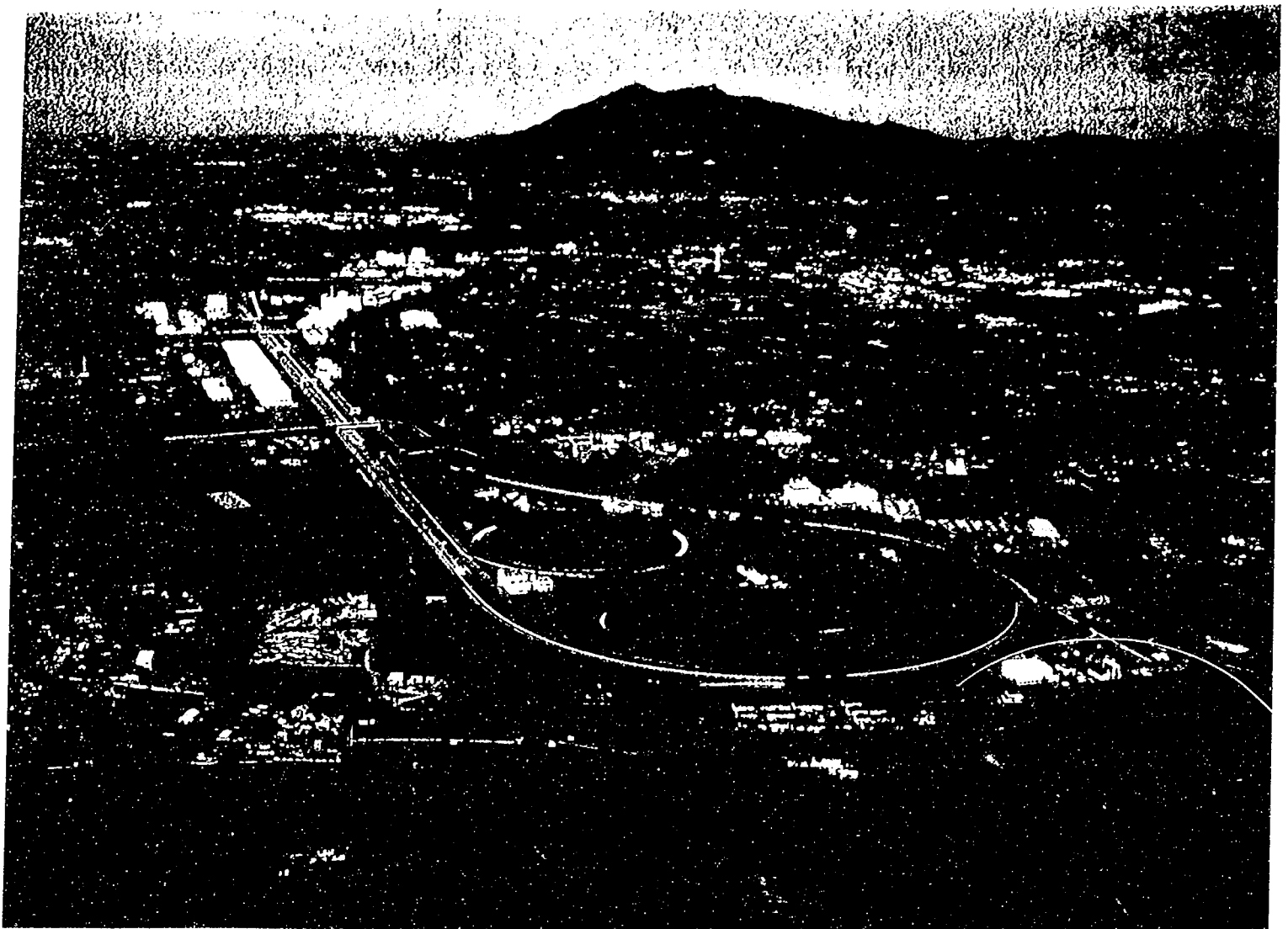
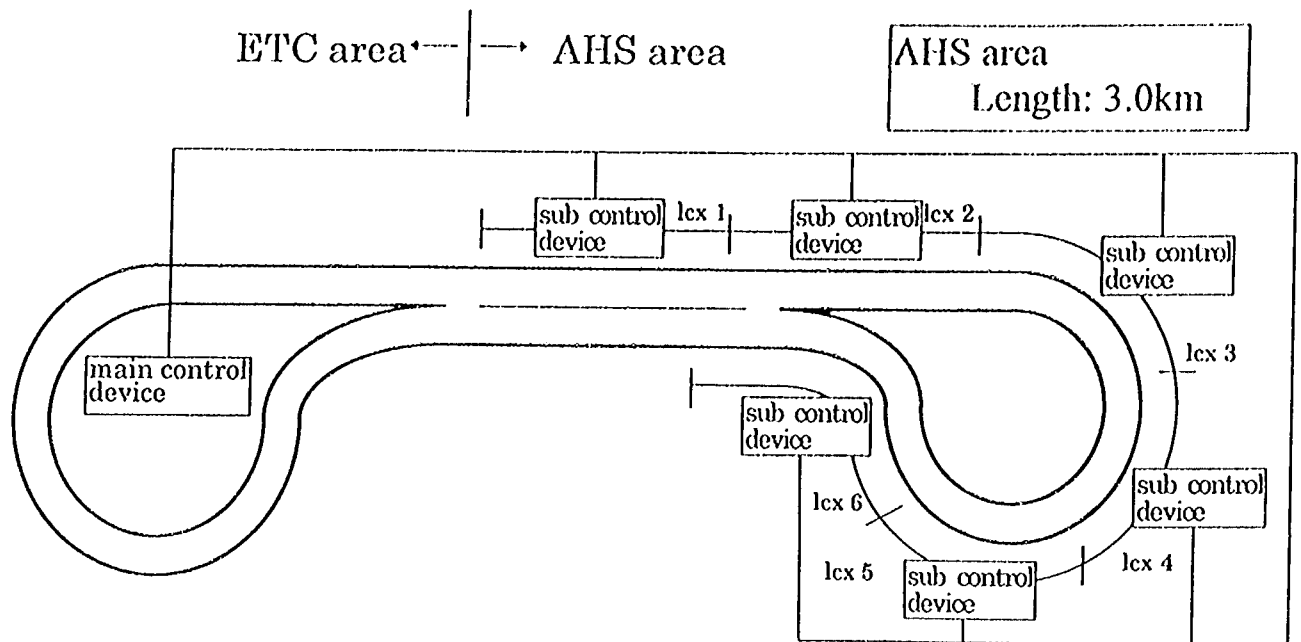
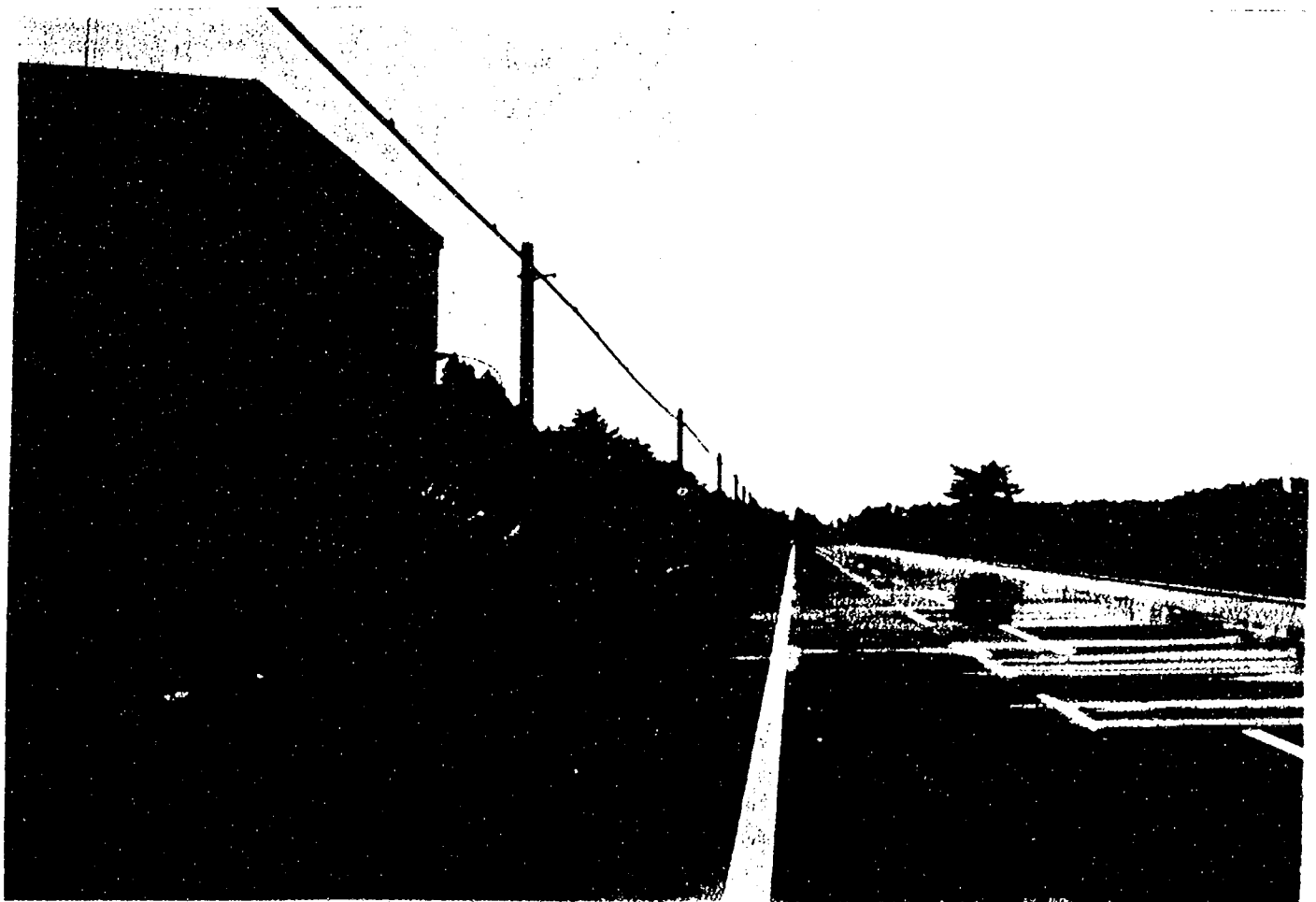
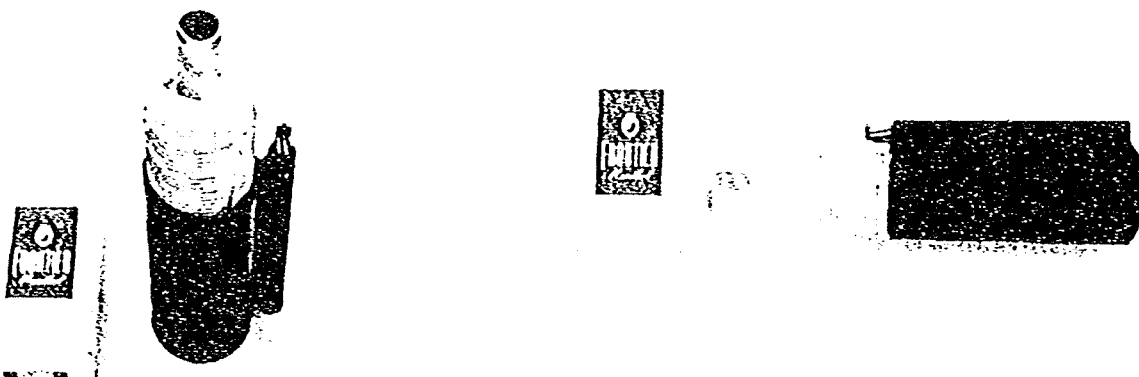


Image of Automated Highway Systems

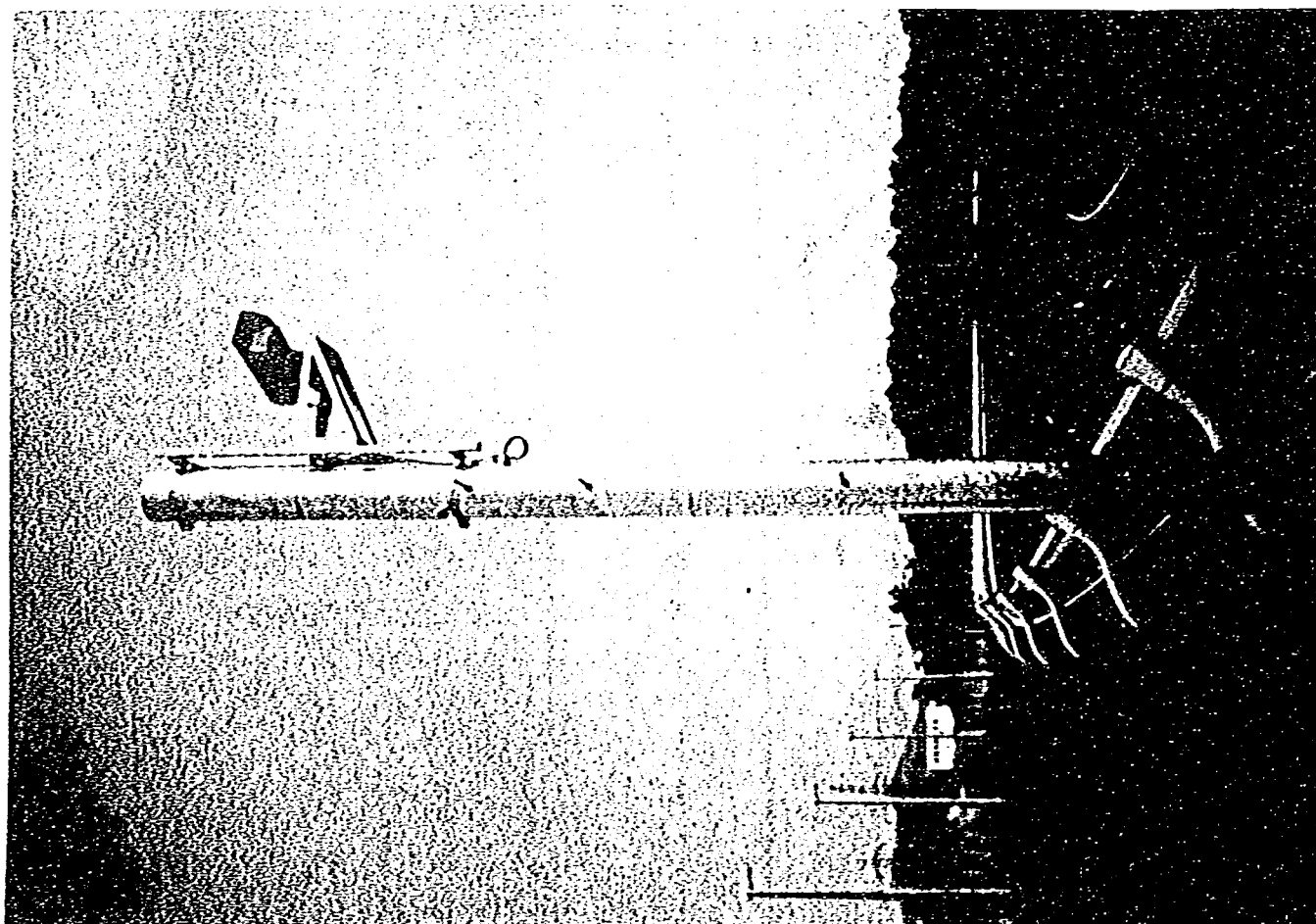


Layout Plan of AHS



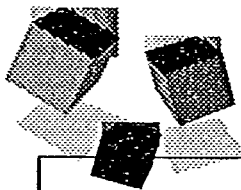


LCX



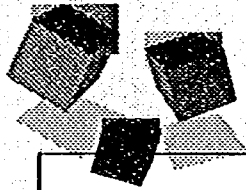


Magnetic Marker



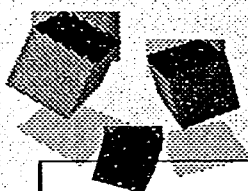
Elemental Technology for AHS

- Infrastructure
 - Sensor for information collection
 - Information processor, communication unit
 - Leakage coaxial cable (LCX)
 - Magnetic nail
 - Lane marker



Elemental Technology for AHS

- On-vehicle
 - Two-way radio link unit
 - Magnetic sensor
 - Image sensor
 - Vehicle information processor
 - Vehicle control unit



Information Flow in AHS

- Infrastructure → Vehicle (Down Link)
 - Long-term cycle data (0.5 ~ several sec.)
 - Kilo post (Start position of LCX)
 - LCX number
 - Road geometric alignment
(Curvature, beginning of curve etc.)
 - Recommended speed in the section of LCX
 - Emergency message (Clash etc.)
 - μ level

AHS deployment plan is broadly structured in three phases:

The following phases shall be edged through to achieve the goal of AHS program. These systems shall accommodate instruction of equipment on the infrastructure and vehicles when achieving the level which can satisfy practical conditions.

1. (The First phase)

Warning and information provision level

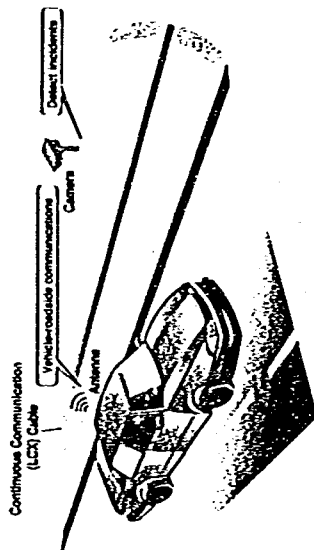
(1) Incidents on road ahead warning function
Incidents which occurs on the roads ahead are detected instantly by the embedded sensor of roadways and the system informs following vehicles of the incidents via LCX. This system helps prevent or minimize the severity of multi-car collisions.

(2) Emergency notification function

Various types of incidents (accidents, congestion, etc.) and anomalies with vehicle operation (a vehicle or a driver) are informed to the road manager via LCX. Thereby, a road manager can identify and analyze the conditions of the incident at an early stage, allowing him to take an appropriate action immediately.

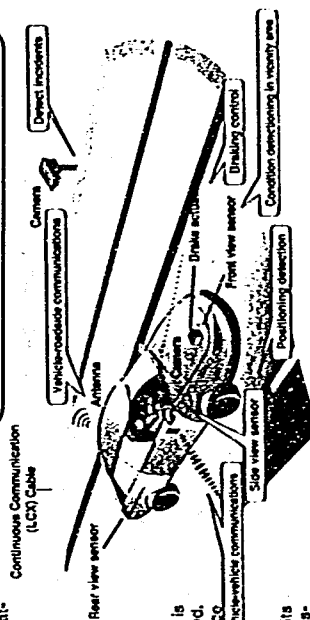
(3) Peripheral vehicle positioning display warning function

Information on other vehicle operation in the vicinity is provided to the driver. This system assists a driver's tasks in merging and diverging. A warning is generated when a vehicle does not keep a safe distance.



The Second Step

(Driving support with automated control system)



2. (The second step)

Driver support level

(1) Collision prevention function

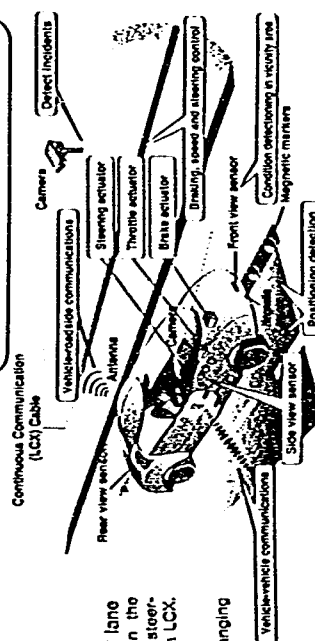
When a safe distance becomes too close, a warning is generated. Automatic braking is actuated if required. A warning and braking respond to the road surface conditions which are transmitted via LCX.

(2) Lane deviation prevention function

This function allows the running vehicle to discern its appropriate positioning in respect to the lateral distances from a vehicle in the next lane and the roadside sideways. When lane change has a potential risk or lane deviation, an avoidance-oriented warning is generated, if needed, automated steering control takes place.

The Third Step

(Automated driving and high density traffic operation)



3. (The third step)

Automated vehicle operation level

(1) Automated vehicle operation in the dedicated lane
Automatic Platoons operation is conducted in the dedicated lane. Automated vehicle control and steering control are conducted by the instructions via LCX.

(2) Full automated vehicle operation

Full automated vehicle operation including changing lanes and passing.

Information Flow in AHS

• Vehicle → Infrastructure (UP Link)

• Short-term Cycle Data (0.1 sec.)

- Vehicle specification data (ID, length, wide etc.)
- Vehicle position
- Vehicle accident (clash, stop etc.)
- Vehicle speed
- μ level

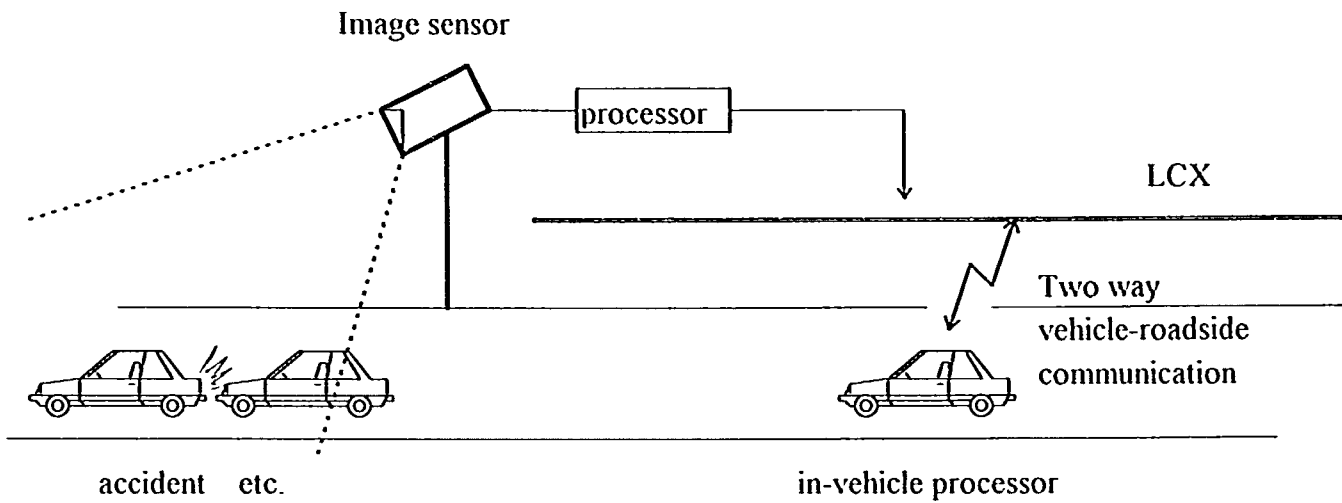


Figure RIDIS System Structure

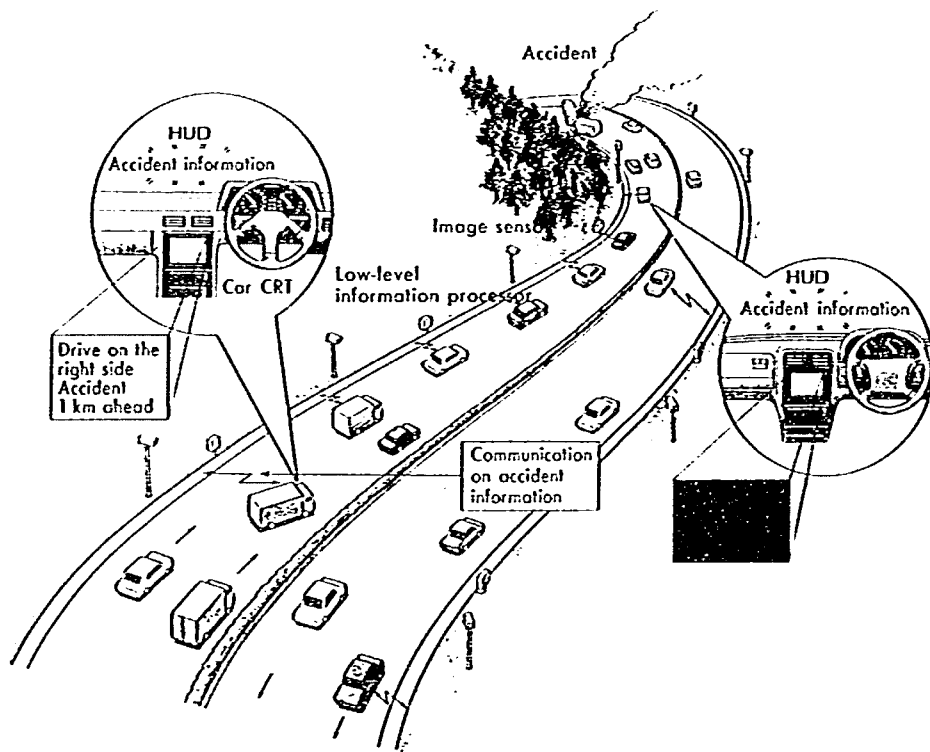
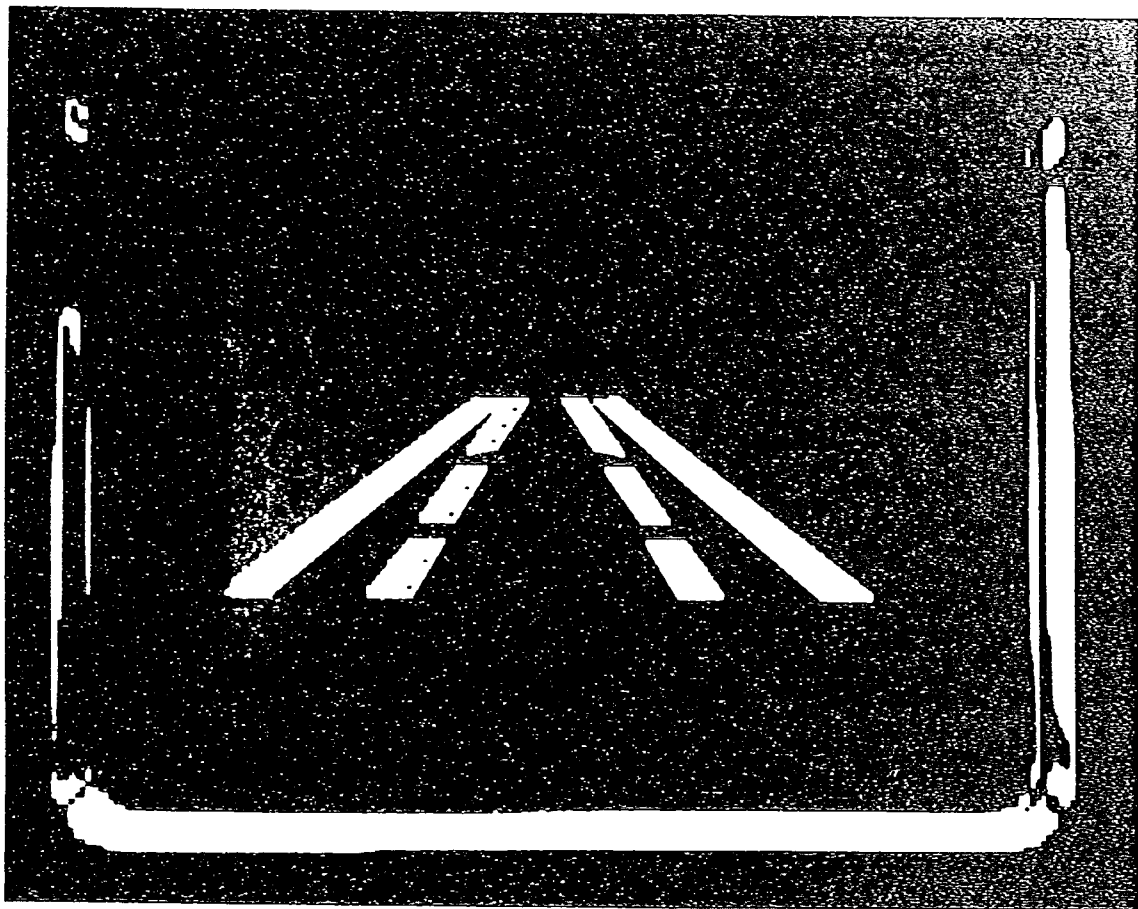


Fig. Image of Road Incident Detection and Warning System



4.2.2 "Automated Highway System Cooperative Program — an overview —"

by Kurt A. Goddard

(National Automated Highway System Consortium)

(Current Program)

The current program was mandated in the 1991 ISTEA legislation, and the legislation says that the Secretary of the Department of Transportation has developed an automated highway and vehicle prototype from which future automated intelligent vehicle-highway systems can be developed. The goal is to have this program on the road in a test track by 1997, and that will be our 1997 feasibility demonstration.

(NAHSC Core Participants)

The core participants in the consortium — core participants meaning the actual organizations that signed the agreement with the U.S. Department of Transportation are Bechtel, California Department of Transportation, Carnegie Mellon University, Delco Electronics, General Motors, Hughes Aircraft, Lockheed Martin, Parsons Brinkerhoff Company and the University of California, the Path Program.

We are all equal partners in the consortium. There is no one particular lead organization. And the role of each organization: Bechtel is doing infrastructure work and environmental analysis; California Department of Transportation is doing infrastructure development; Carnegie Mellon University is technology development; Delco Electronics, vehicle development; and of course General Motors, vehicle development; Hughes Aircraft is performing communications systems and is development and systems engineering; Lockheed Martin is doing overall system integration; Parsons Brinkerhoff is performing traffic engineering and social and institutional analysis; and UC the Path Program is doing technology development. And all the organizations are doing outreach to other organizations to encompass a larger group of people in the consortium.

(NAHSC Mission)

The mission of the consortium is to specify, develop and demonstrate a prototype Automated Highway System. That's to deliver a set of specifications and a working prototype that can be further developed for an implementable system.

(NAHSC Mission, cont'd)

The specifications will provide for an evolutionary deployment that can be tailored to meet regional and local transportation needs. What this means is that the AHS in the United States will not be a revolutionary deployment. In other words, one day we just won't roll it out. But it will be evolutionary deployment that will build on all of the ITS work that's going on now and over the next 5 or 10 years.

(NAHSC Mission, cont'd)

The consortium will seek opportunities for early introduction of vehicle and highway automation technologies to achieve early benefits for all surface transportation users. What this means is that, as technologies are developed, we'll try to get them out on the roads, rather than wait for the complete system to be implemented.

(NAHSC Mission, cont'd)

The NAHSC will incorporate public and private stakeholder views to ensure that the AHS is economically, technically and socially viable. What this means is that we are reaching out to states and local groups, Department of Transportations, other companies that are not core participants in the consortium, to incorporate their views on highway automation, so that as it's rolled out, there won't be any impediments technologically or socially to the implementation of highway automation.

(48+ Associations Participants)

As a function of that outreach, we currently have 48 associate participants, and it's growing every day – various stake holder categories: vehicle industries, we have 6, for example both Toyota and Honda are associate participants in the consortium, and we have 10 vehicle electronics; 7 highway design and construction organizations; one trucking firm, 2 transit operators, 2 organizations representing environmental interests, 5 transportation user groups, 15 government agencies.

We're working very hard to find an insurance company or companies that will join as an associate, because as you know, nobody's going to use this without insurance. And we have 14 outreach participants. And outreach are organizations that are just interested in following the program.

(NAHSC Purpose)

The purpose of the consortium is to be the focal point for the U.S. AHS program, and to provide national coordination for AHS in the U.S. And our other purposes are to manage the AHS program and provide a balance to the decision making. And to participate in resource contribution and resource management. The consortium is putting up 20% of the cost for this program.

(Major Goals)

The major goals of the program are to improve highway safety; every year in the U.S. We lose about 40,000 people in traffic fatalities and injure close to 2 million. We want to increase highway throughout to double or triple today's capacity. We want to enhance mobility and reduce the environmental impact.

(AHS is Part of ITS)

The automated highway system is a part of the overall ITS umbrella, and it is being developed underneath the ITS framework.

(NAHSC and ITS Architecture Team)

The NAHSC is working with the ITS architecture team to ensure that the AHS that we develop is compatible with the overall U.S. ITS architecture.

(AHS Concept Requirement)

The only technical requirement that was levied on the consortium was that our design had to be a non-contact electronic based design.

(AHS Development Strategy)

The overall AHS development strategy put forth by US-DOT is actually a 3 phase strategy which I know it doesn't show up very well. I hope you can read this on your handout.

First there was the analysis phase. This phase ended in October 1994 and included work on human factors and collision avoidance. The more common name for this particular phase is a precursor systems analysis.

The second phase is the system definition phase, which is the phase we're currently in, and we have six milestones which I'll get into in a moment. And the last phase is the operational evaluation phase which is where the system concept will be further refined into a system that can be implemented.

I've provided our milestone summary schedule in your handout: so you can get a sense for how we've put together the program.

- Milestone 1 is the preliminary system requirements and objectives which is due this Friday.

- Milestone 2 is the final systems requirements and objectives which is due more towards the end of this year.

- Milestone 3: the feasible AHS concepts is due in the middle of 1996.

- Milestone 2: the proof of feasibility demonstration will begin in august of 1997, and that will take place in San Diego, California. We hope all of you can attend our demonstration, and participate in it, too.

- Milestone 4 is where we select the preferred AHS configuration. That occurs in early 1999.

- Milestone 5 is where we complete the AHS prototype testing in late 2001.

- Milestone 6, where we finish the complete system documentation finishes in early 2002.

I'm going to show you just how the Consortium is organized:

The bottom 2 blocks are really where all the work takes place. We have the program manager, who of course is responsible for all of the AHS program activities, and he sits on top of the AHS program office, and what's called the Program Managers' Council. the Program Manager's Council is a representative from each organization in the consortium – the lead technical person – and they help, or actually lead all the technical work in their home office.

And we also, along with the program manager's council, in conjunction with the program office, work together to plan and execute the program. And then we have the Program Management Oversight Committee. They're responsible for helping to outreach to associate participants and stakeholders.

And then, for senior policy oversight of the program, we have the Policy Steering Board that's made up of very senior corporate officers from each organization. And an important thing to know about this organizational structure is that US–DOT participates in all of these groups in a day–to–day working activity. This is a function of the fact that this is a cooperative agreement between the consortium and US–DOT, rather than the typical contractor where you have a contractor and the client relationship.

(1997 Demonstration)

Just a word on our 1997 demonstration, the objective is to approve the technical feasibility of highway automation.

The sight will be on I-15 in San Diego. We will use the high occupancy vehicle lanes which will be used only for AHS during the test. We will have operational demonstrations and an automated highway exposition, we plan to demonstrate up to 20 vehicles with passenger cars and light trucks, heavy trucks and buses, and potentially construction & automated maintenance vehicles.

We'll demonstrate check in and check out, lateral and longitudinal control, traffic management and construction maintenance.

Automated Highway System Cooperative Program

an overview



**Third Japan-U.S. Intelligent Transportation
Systems Group Meeting**
November 6-7, 1995

Kurt A. Goddard
Business Manager

Current Program



- **AHS Program is mandated in the 1991 ISTEA Legislation:**

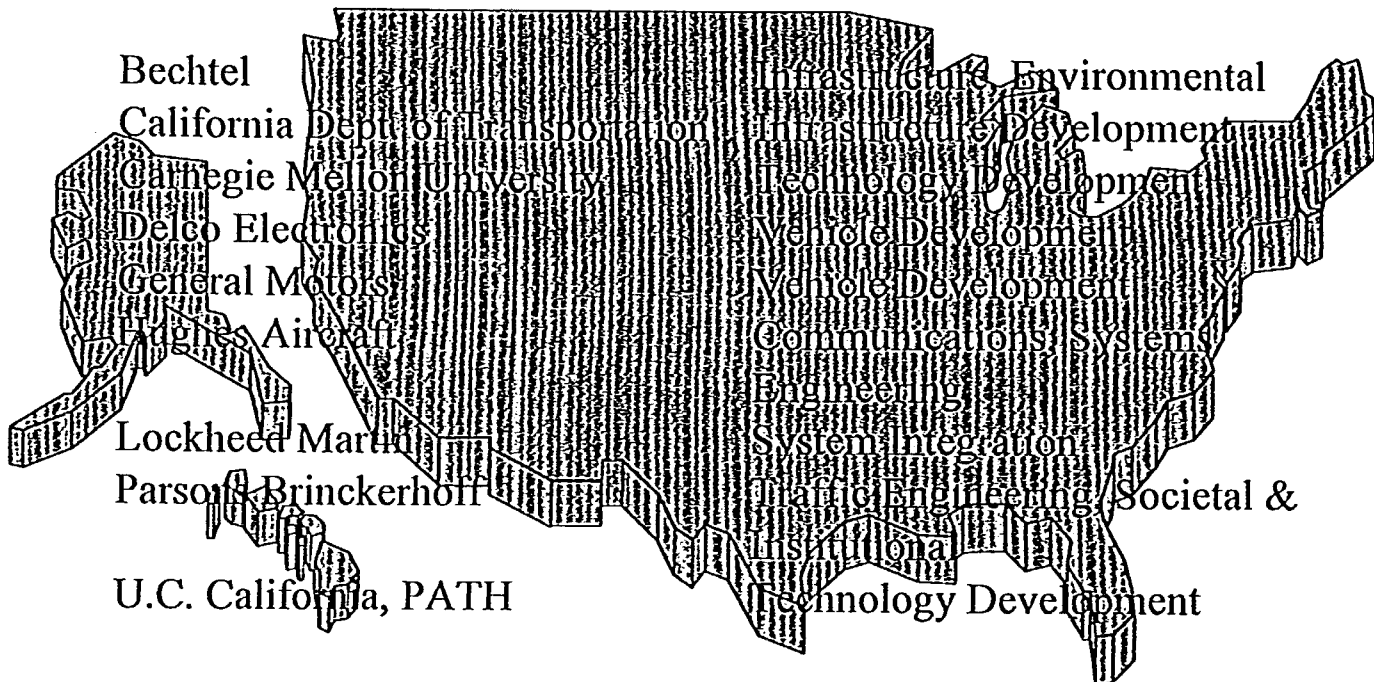
"The Secretary shall develop an automated highway and vehicle prototype from which future fully automated intelligent vehicle-highway systems can be developed....the goal of this program is to have the first fully automated roadway or an automated test track in operation by 1997"

National AHS Consortium Core Participants



Organization

Task*



*all are involved in Outreach

48+ Associate Participants



Stakeholder Category

Number of Associates

- Vehicle Industry 6
- Vehicle Electronics 10
- Highway Design & Construction 7
- Trucking 1
- Transit Operators 2
- Environmental Interests 2
- Transportation Users 5
- Government Agencies 15
- Insurance 0

14 Outreach Participants

NAHSC Mission

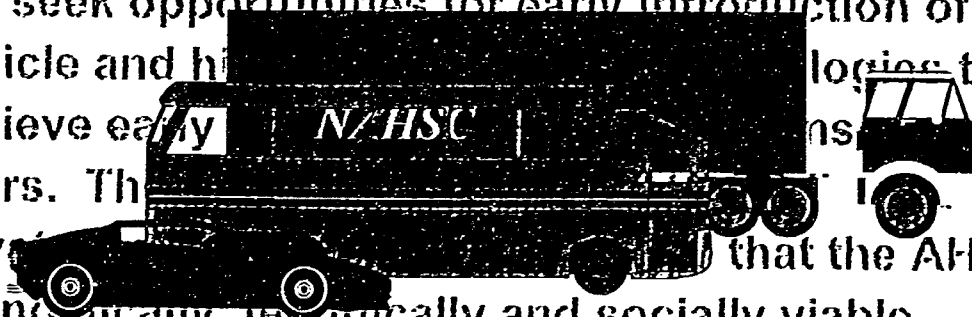


The NAHSC will specify, develop and demonstrate a prototype Automated Highway System. The specifications will provide for evolutionary deployment that can be tailored to meet regional and local transportation needs. The Consortium will seek opportunities for early introduction of vehicle and highway technologies to achieve early benefits for surface transportation users. The NAHSC will incorporate public and private stakeholders to ensure that the AHS is economically, technically and socially viable.

NAHSC Mission (cont'd)



The NAHSC will specify, develop and demonstrate a prototype Automated Highway System. The specifications will provide for evolutionary deployment that can be tailored to meet regional and local transportation needs. The Consortium will seek opportunities for early introduction of vehicle and highway technologies to achieve early benefits for surface transportation users. The NAHSC will incorporate public and private stakeholders to ensure that the AHS is economically, technically and socially viable.



NAHSC Mission (cont'd)



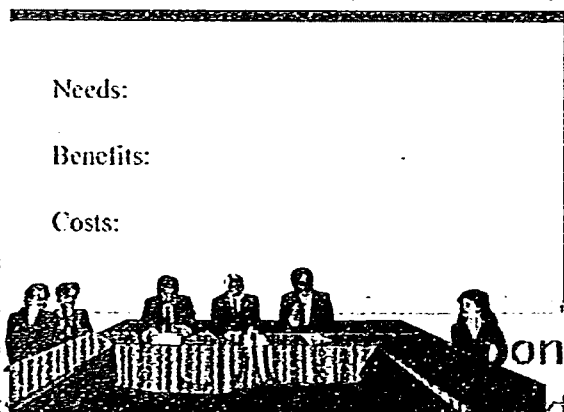
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NAHSC Mission (cont'd)



The NAHSC will specify, develop and demonstrate a prototype Automated Highway System. The specifications will provide for evolutionary deployment that can be tailored to meet regional and local transportation needs. The Consortium will seek opportunities for early introduction of vehicle and highway automation technologies to achieve early benefits for all surface transportation users. The NAHSC will incorporate public and private stakeholder views to ensure that the AHS is economically, technically and socially viable.



NAHSC Purpose



- Be the Focal Point for the US AHS Program
 - Provide national coordination
- Manage the AHS Program
 - Provide balanced, technically correct decision making
- Participate in Resource Contribution and Management
 - Share in the Program's cost
 - Manage all Program resources

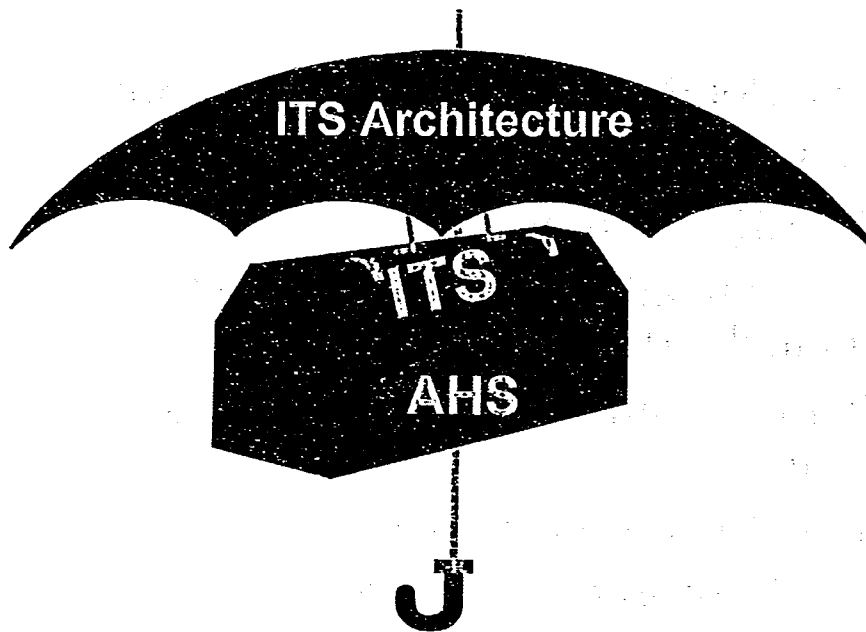
Major Goals



- ✓ Improved Highway Safety
 - No Collisions In the Absence of System Malfunctions
 - Fail-Safe and Fail-Soft System Design
- ✓ Increased Highway Throughput
 - Double to Triple Today's Capacity per Lane
 - Less Capacity Reduction Due to Incidents
 - Increased Speeds Possible at Local Option
- ✓ Enhanced Mobility
 - Shorter, More Predictable Trip Times for People and Freight
 - Easier, More Reliable Travel in Inclement Weather
- ✓ Reduced Environmental Impact
 - Less Need for Additional Lane-Kilometers
 - Reduced Fuel Consumption and Exhaust Emissions per Vehicle-Kilometer Traveled



AHS is Part of ITS



The AHS Program fits under the overall US ITS Program umbrella

NAHSC and ITS Architecture Team

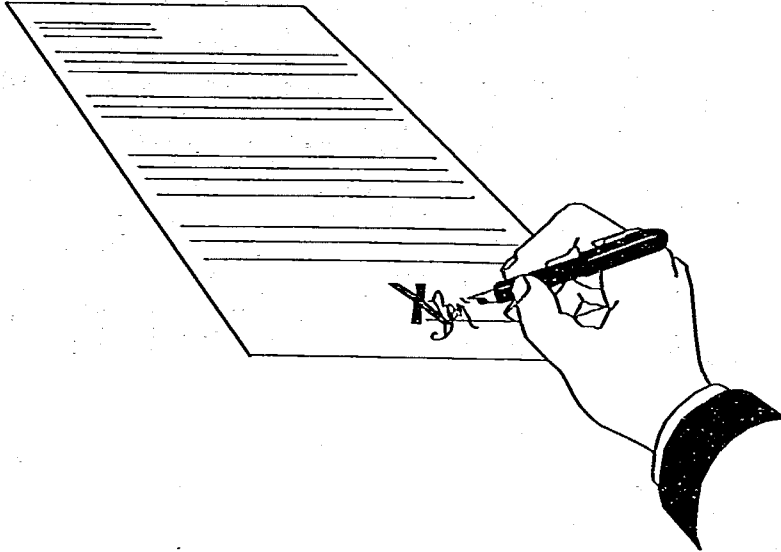


- The NAHSC has signed a memorandum of understanding to work with the ITS Architecture team
- This MOU ensures that AHS is compatible with the overall ITS Architecture

Program Background



- Request for Applications issued 12/15/93
- Awarded to the NAHSC 10/7/94
- Agreement executed 12/7/94



AHS Concept Requirement



- A non-contact electronics based design

AHS Development Strategy



**ANALYSIS
PHASE**

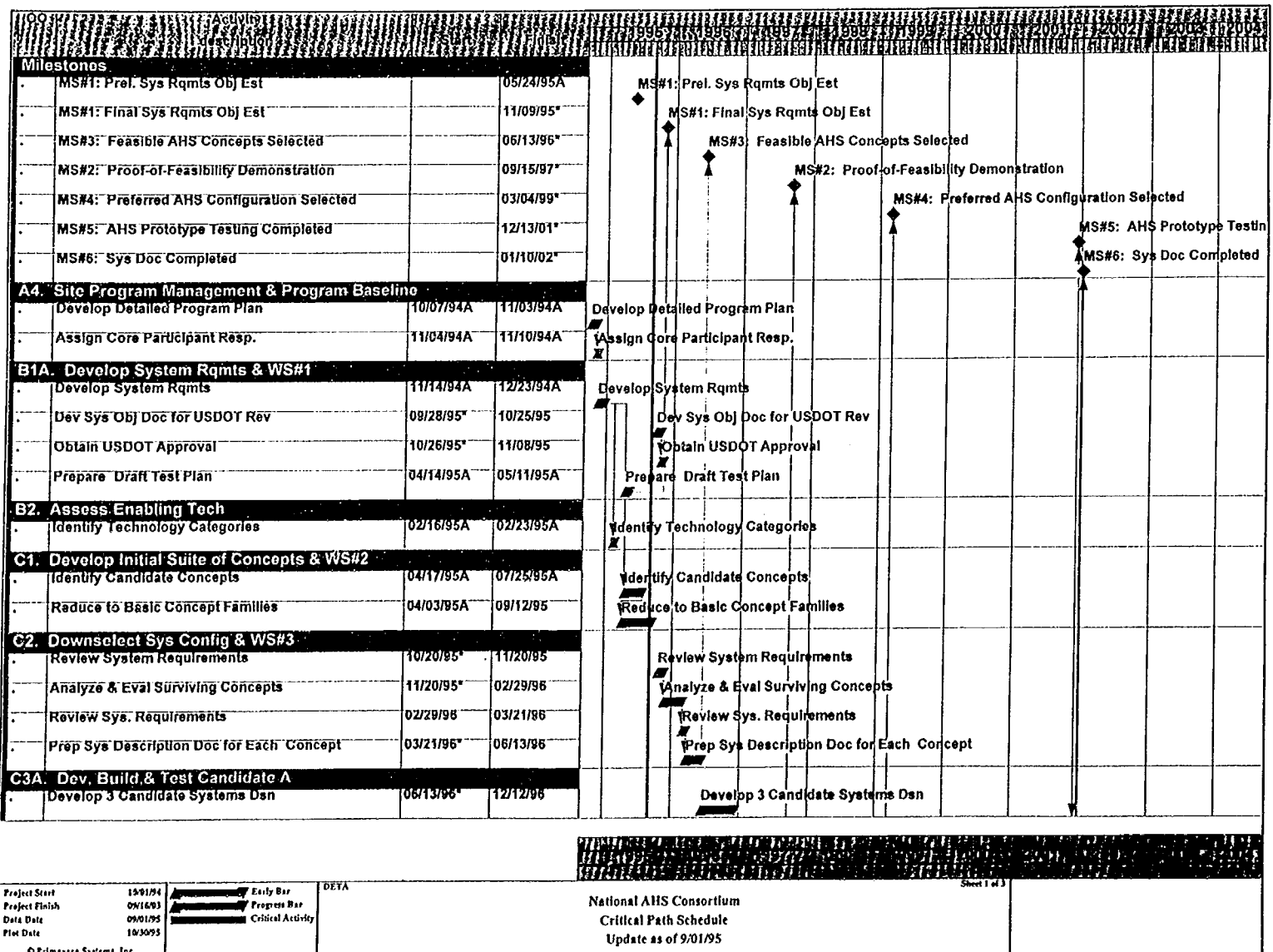
**SYSTEM DEFINITION
PHASE**

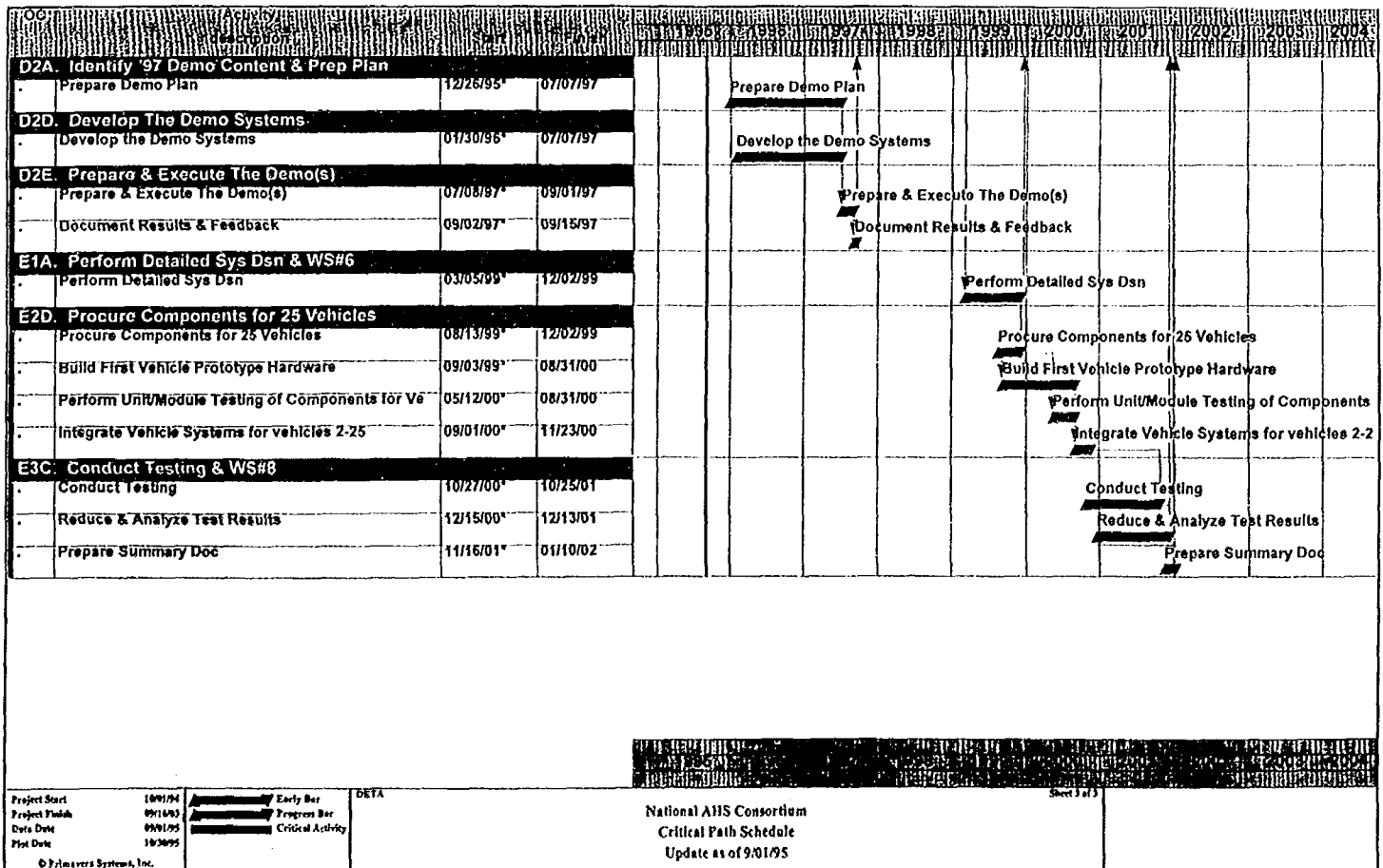
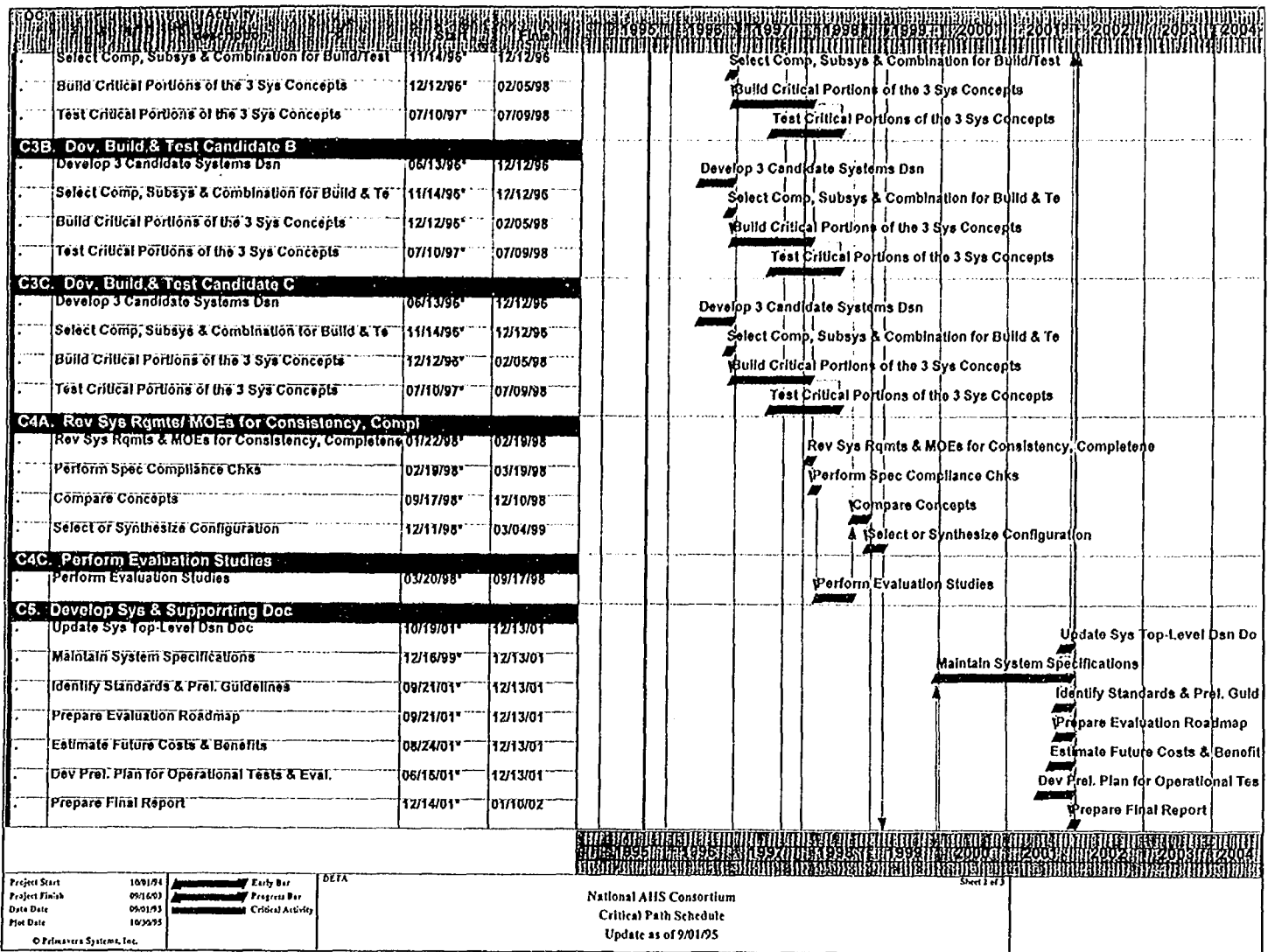
**OPERATIONAL
EVALUATION PHASE**

- AHS Human Factors Analysis
- Collision Avoidance Studies
- Precursor Systems Analysis

Milestones

1. Performance & Design Objectives Established
2. Proof of Feasibility Demonstrated
3. Feasible AHS Concepts Selected
4. Preferred AHS Configuration Selected
5. AHS Prototype Testing Completed
6. System Documentation Completed

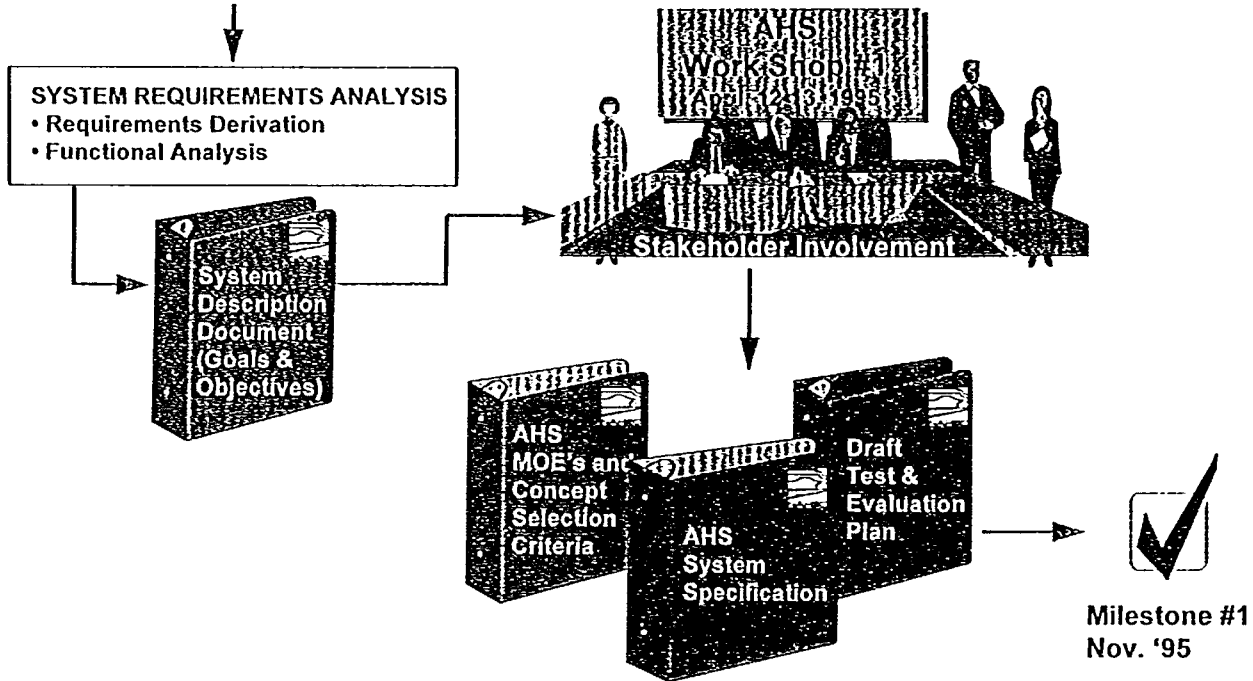




Milestone #1 : Performance & Design Objectives Established



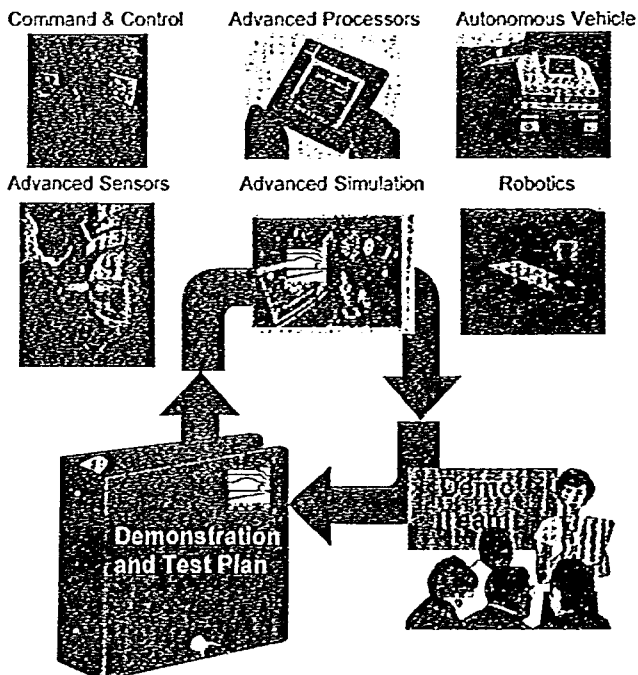
- AHS Precursor System Analysis
- USDOT RFA



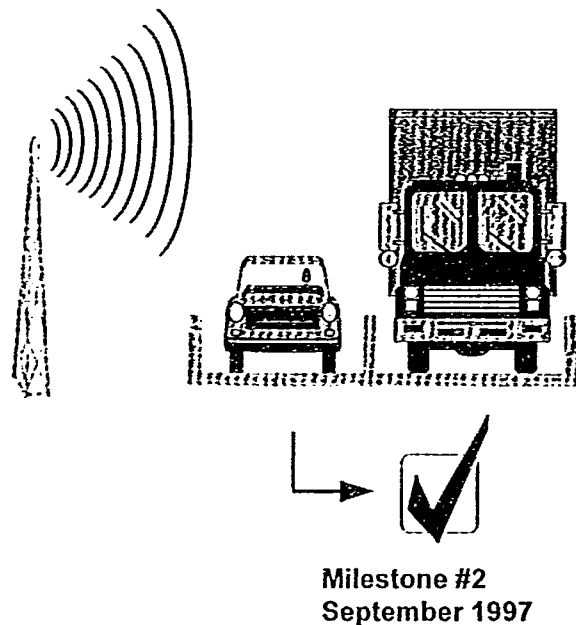
Milestone #2 :



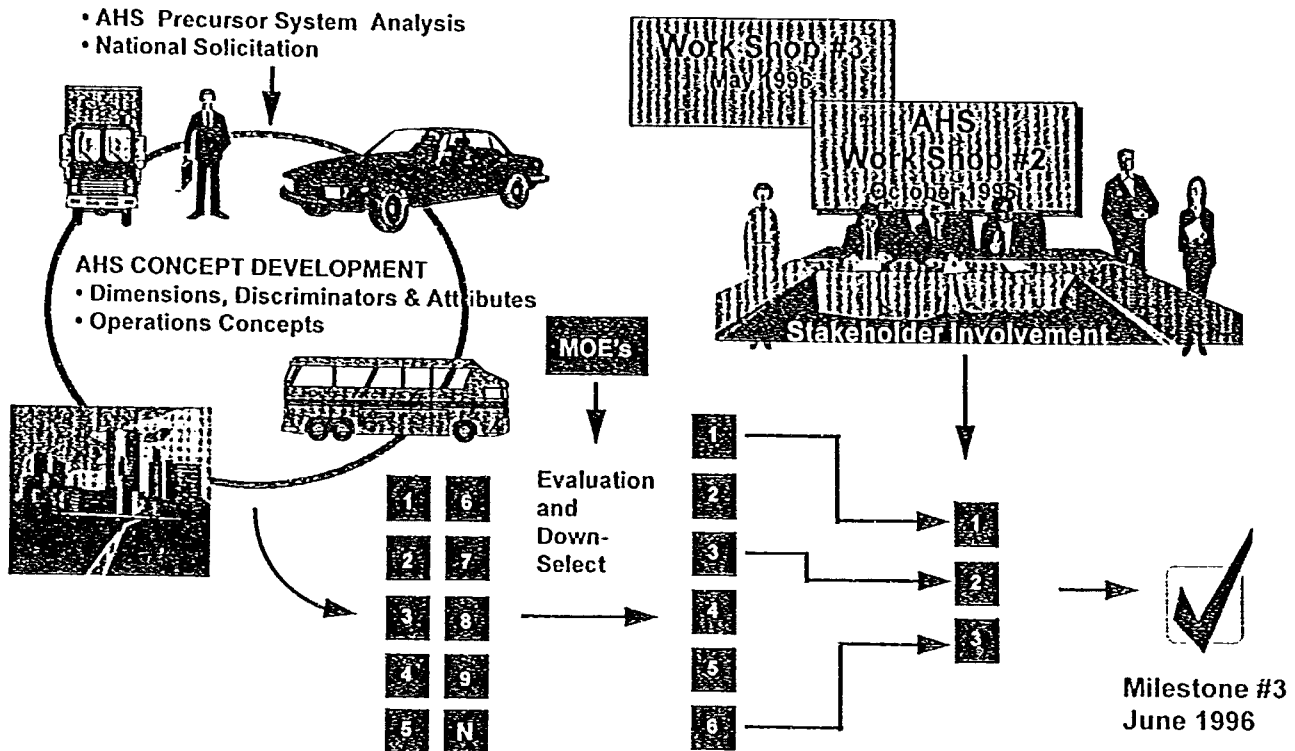
EXISTING ADVANCED TECHNOLOGIES



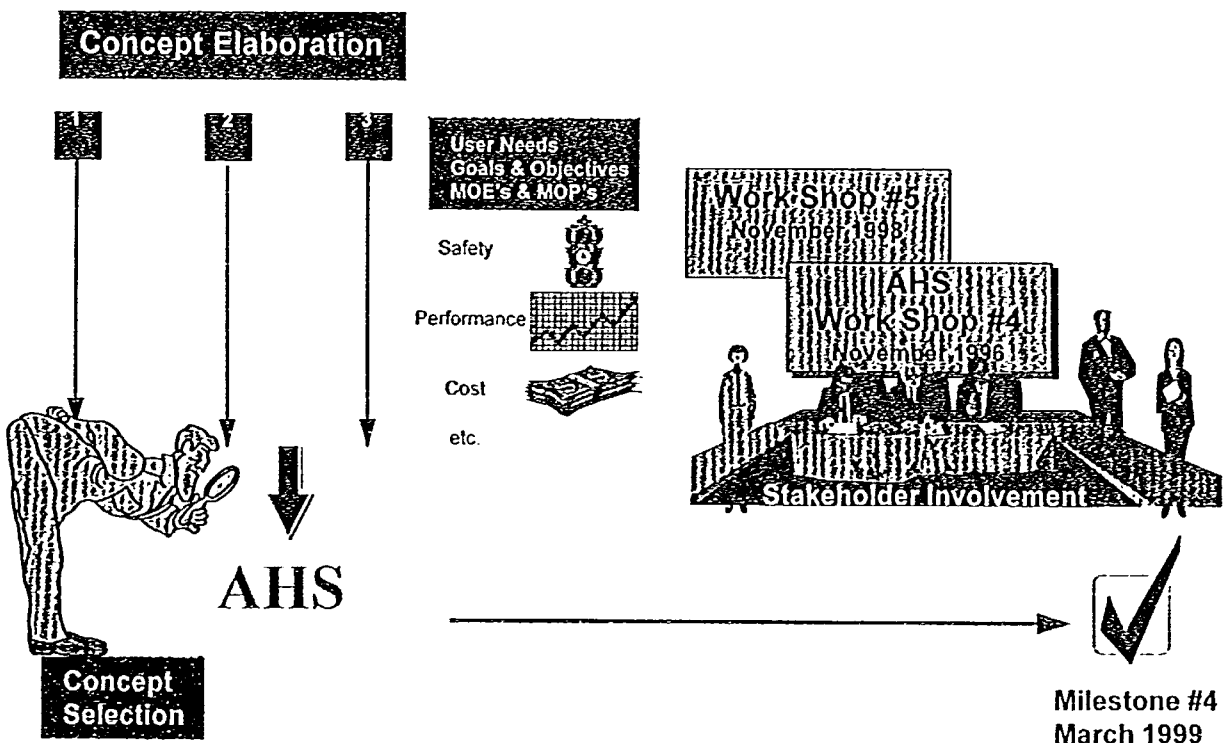
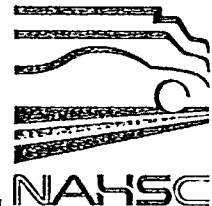
1996 World Congress Exhibits
1997 Feasibility Demo



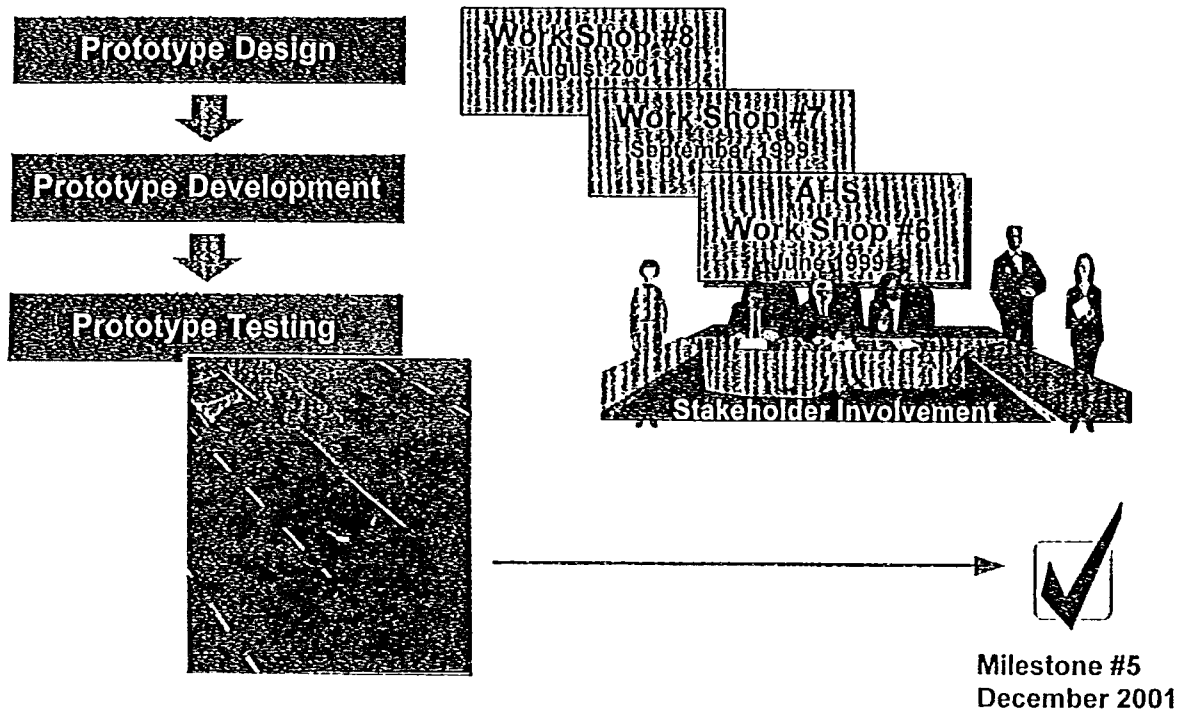
Milestone #3 : Feasible AHS Concepts Selected



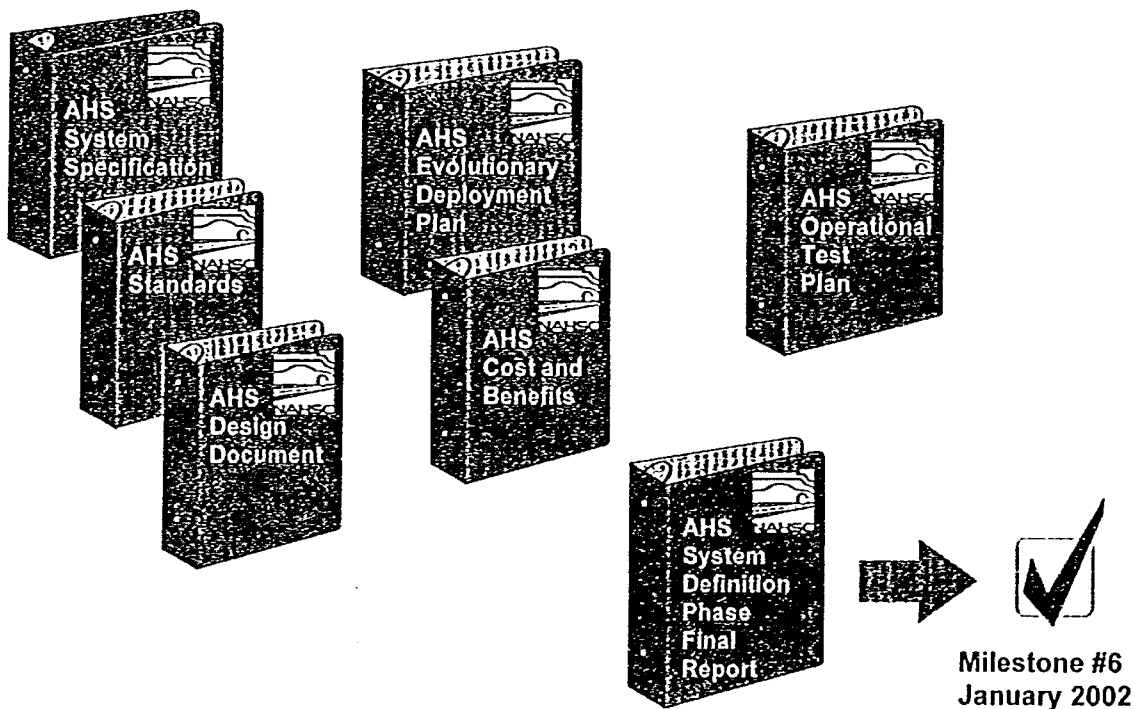
Milestone #4 : Preferred AHS Configuration Selected

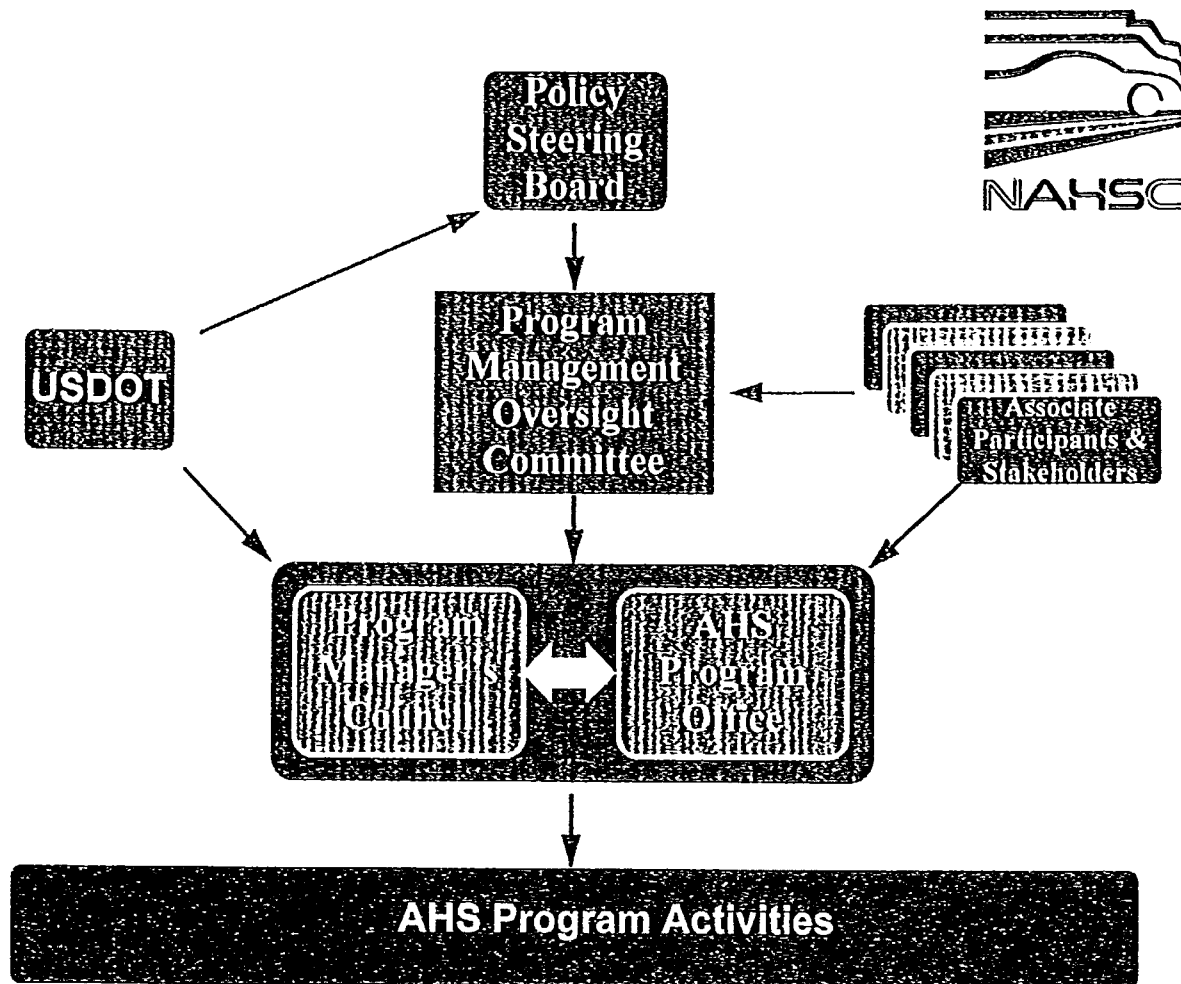


Milestone #5 : AHS Prototype Testing Completed



Milestone #6 : System Documentation Completed

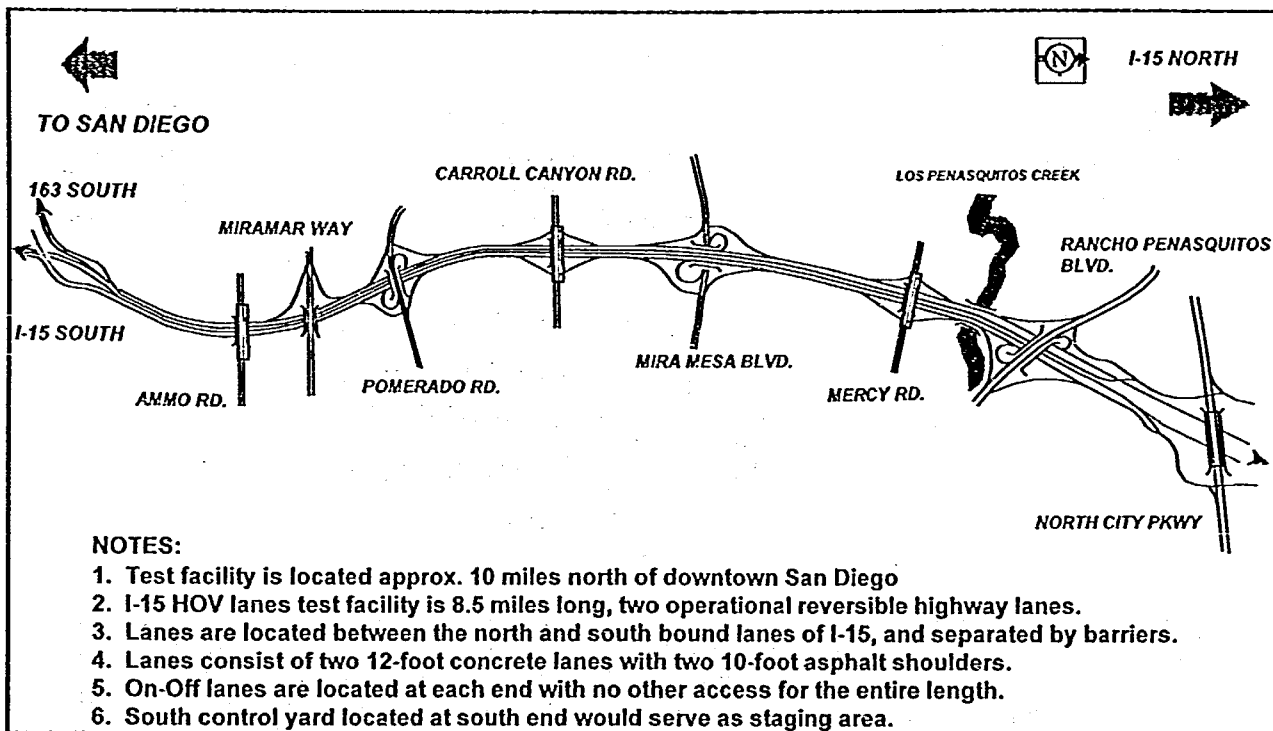




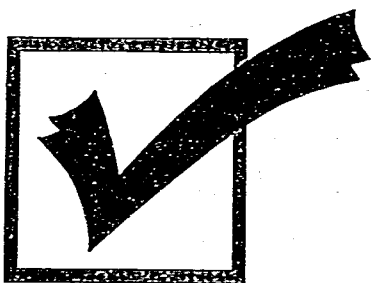
1997 Demonstration

- **Objective: Proof of Technical Feasibility**
 - Will Demonstrate Alternative Approaches
 - Will Show Technologies are Available and Practical
 - Will Show Social, Economic and Environmental Benefits
 - Will Not Necessarily Reflect Final Prototype AHS
- **Site: I-15 HOV Lanes in San Diego - August 1997**
- **Operational Demonstrations and AHS Exposition**
- **Plan for 20 Vehicles to Take Part in Operational Demos**
 - Passenger Cars & Light Trucks
 - Heavy Trucks & Buses
 - Construction and/or Maintenance Vehicles
- **Will Demonstrate**
 - Check-in/Check-out, Entry/Exit, Lateral & Longitudinal Control, Traffic Management, Construction & Maintenance

I-15 HOV Lanes - San Diego, Ca. 1997 Demonstration Site



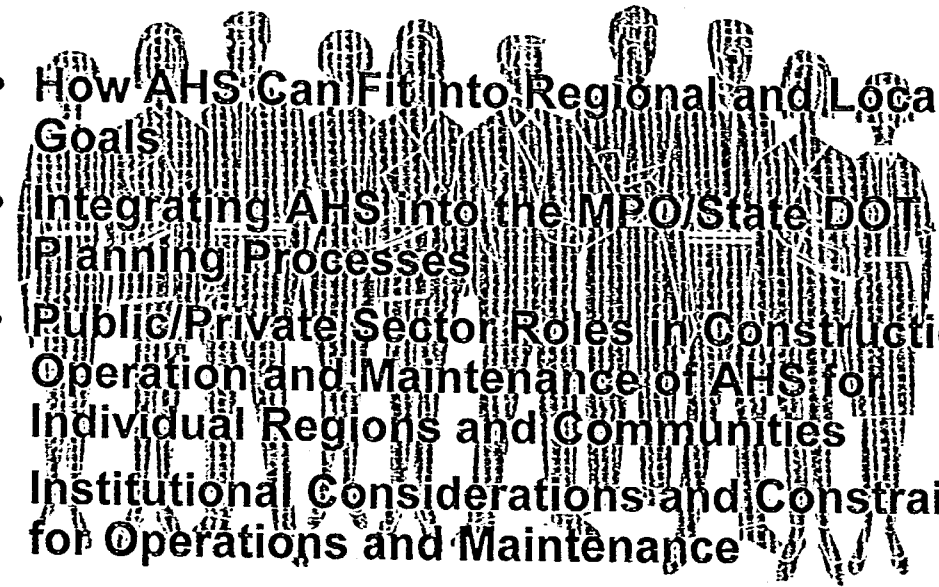
Major Societal and Institutional Issues



- Environmental
- Societal and Institutional
- Land Use
- Urban Planning

Sampling of Societal and Institutional Issues Being Addressed



- 
- A background image showing a group of approximately 15 people standing in a line, facing forward. They are dressed in business attire, and the image is somewhat faded and serves as a backdrop for the list of issues.
- **How AHS Can Fit into Regional and Local Goals**
 - **Integrating AHS into the MPO/State DOT Planning Processes**
 - **Public/Private Sector Roles in Construction, Operation and Maintenance of AHS for Individual Regions and Communities**
 - **Institutional Considerations and Constraints for Operations and Maintenance**
 - **Is Liability a Constraint or only a Cost?**

4.3 AHS (Research & Development)

4.3.1 "Automated Vehicle System for AHS"

by Keiji Aoki

(Toyota Motor Corporation)

(Operational Summary of AHS)

Here is the operational summary of the AHS. The AHS has three operating models. They are: check in, AHS run operation and check out. The vehicle identification and the control system errors are checked by the control centers. If the system operation is available, the entries are admitted. The automated vehicle has operational function of the free agent operation and the platoon operations.

When the AHS ran, the vehicle is completely controlled by the AHS. Therefore, the system has a driver support functions, such as collision avoidance warning, and lane departure warnings on the non-AHS lanes.

Here is a functional summary of the vehicle control systems: The vehicle has a lane tracking based on the magnetic nail and lane boundaries, and adaptive cruise control and operating control managed by the external command, and the obstacle avoidance function incorporated with the infrastructures.

(Control System Configuration for AHS)

This figure shows the configuration of the AHS. Two kinds of the forward looking sensor are installed. The laser radar is used as a long range distance measure, capable of detecting the vehicle 100m ahead. The vehicle has 3 CCD cameras looking forward. The one is a CCD camera with infra-red band pass filters. It looks optical markers mounted on the rear tray of the preceding vehicles. The others are virtual stereo cameras. They look at the road. Their optical markers are LED array for the inter-vehicle communications. The antenna for the vehicle road communication system is mounted on the rear trunk.

(Block Diagram of Control System)

This is a breakdown of the control system. The CCD camera image is input into the image processing computers. The image processing computer can recognize lane boundary and the vehicles. The customized image processors, capable of recognizing it within 30msec, are

installed in the image processing computers.

The throttle and the steering coil are driven by the stepping motors. The electrical brake system applied the hydraulic brake booster system. The brake oil pressure is controlled by the electro-linear barbs.

(Magnetic Marker Detection)

This figure shows the marker detections. The three magnetic field sensors are installed under the front bumpers. The distance with sensor and the magnetic markers is a height of 15cm. Each sensor can detect the horizontal magnetic field B_y , and vertical magnetic field B_z , emitted from the magnetic nails.

The lateral displacement is calculated best on B_z and B_y . This figure shows the performance of lateral displacement detections. The resolution is about 5cm. The saturable core is used as a sensor for magnetic fields.

(Functional Feature of Automated Vehicle)

I would like to talk about the vehicle control sub-systems. The first is a lane tracking control sub-system. The lane tracking sub-system consists of magnetic nails, magnetic sensor, the machine vision, vehicle speed, LCX receiver and steering actuator.

(Lane Tracking Control Subsystem)

Lane tracking algorithms are based on the lateral displacement, the yaw rate and the lane curvatures. The lane curvature is needed for the improving of the tracking controllability using feed forward control. The lane curvature data with a span of about 500m, is transmitted to the vehicle using LCX. Even if the magnetic field sensor has failed, the lane tracking is continued by the machine vision system.

(Adaptive Cruise Control Subsystem Function)

Next is the adaptive cruise control sub-system. The adaptive cruise control on the AHS lane is completely controlled by the AHS. The cruising vehicle speed is managed by the external command from control centers. The vehicle keeps the commanded vehicle speed. Furthermore, this system has an obstacle avoidance function by stopping when the vehicle is in the path. The command to stop and the information of the vehicle location, obstacle location, are transmitted to the vehicles. The deceleration rate is controlled to stop before the obstacle.

(Block Diagram of ACC)

This figure is a block diagram of ACC. The ACC consists of the LCX receiver, and headway distance measurement sensor such as a radar system, a throttle actuator and a brake actuator. The cruising speed is set by the external command from the control centers.

(Control Processing of ACC Functions)

When the preceding vehicle's speed is slower, the vehicle's speed is adjusted to keep the safe inter-vehicle gaps. The inter-vehicle gaps depend on the vehicle speed, on the real time vehicle speed and the road surface condition. The road surface condition is transmitted to the vehicle from the control center. The transmitted data is dry, wet, or icy conditions.

(Platooning Control Subsystem)

The final is a platoon operation. The vehicle has an optical inter-vehicle communication system and precise short range system based on image processing. The communication system consists of a transmitter mounted on the rear tray and an optical receiver mounted near the dashboard. The inter-vehicle gap within a platoon is controlled to the headway time of 1sec.

(Inter-Vehicle Communication for Platooning)

This figure shows the configuration of the optical inter-vehicle communications systems. The infra-red beams are emitted from the LED array installed in the transmitters. The vehicle speed, acceleration and the deceleration rate and the braking signal are transmitted to the following vehicles at the interval of 20msec. It was proved in the demonstration tests that the inter-vehicle communication enhanced the controllability of the inter-vehicle distance when the preceding vehicle deceleration is quickly.

(Conclusion)

Here is the conclusion. The successful AHS operation can be made by the cooperation with the continuous, the vehicle communications. The platoon with the cross spacing can be made by the inter-vehicle communication. The cooperation with the road vehicle communication and inter-vehicle communication can make the successful platooning systems. A proof demonstration can be made on the test truck.

Automated Vehicle System for AHS

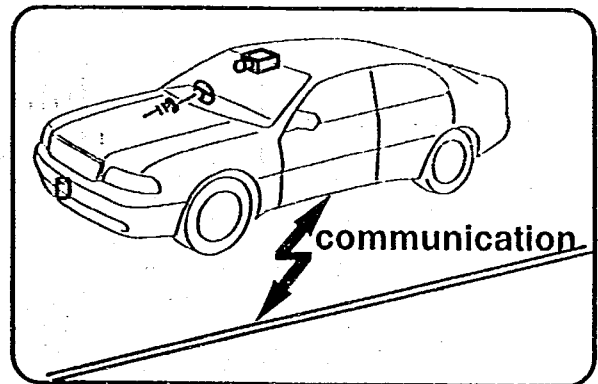
Operation Summary of AHS

■ Check In / Entry

- Checking of control system and admission by control center
- Starting by manual operation

■ AHS Lane Operation

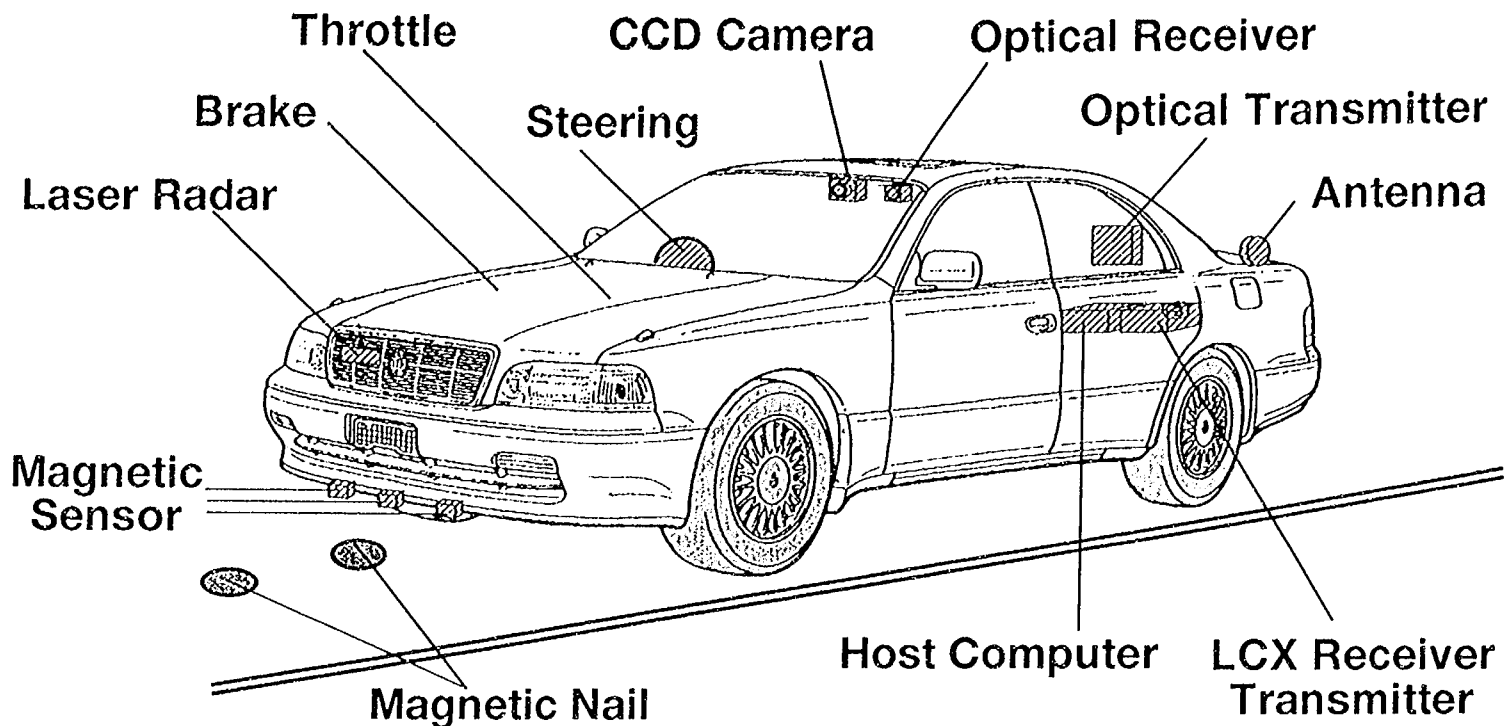
- Autonomous operation
- Platoon operation
- Emergency Response



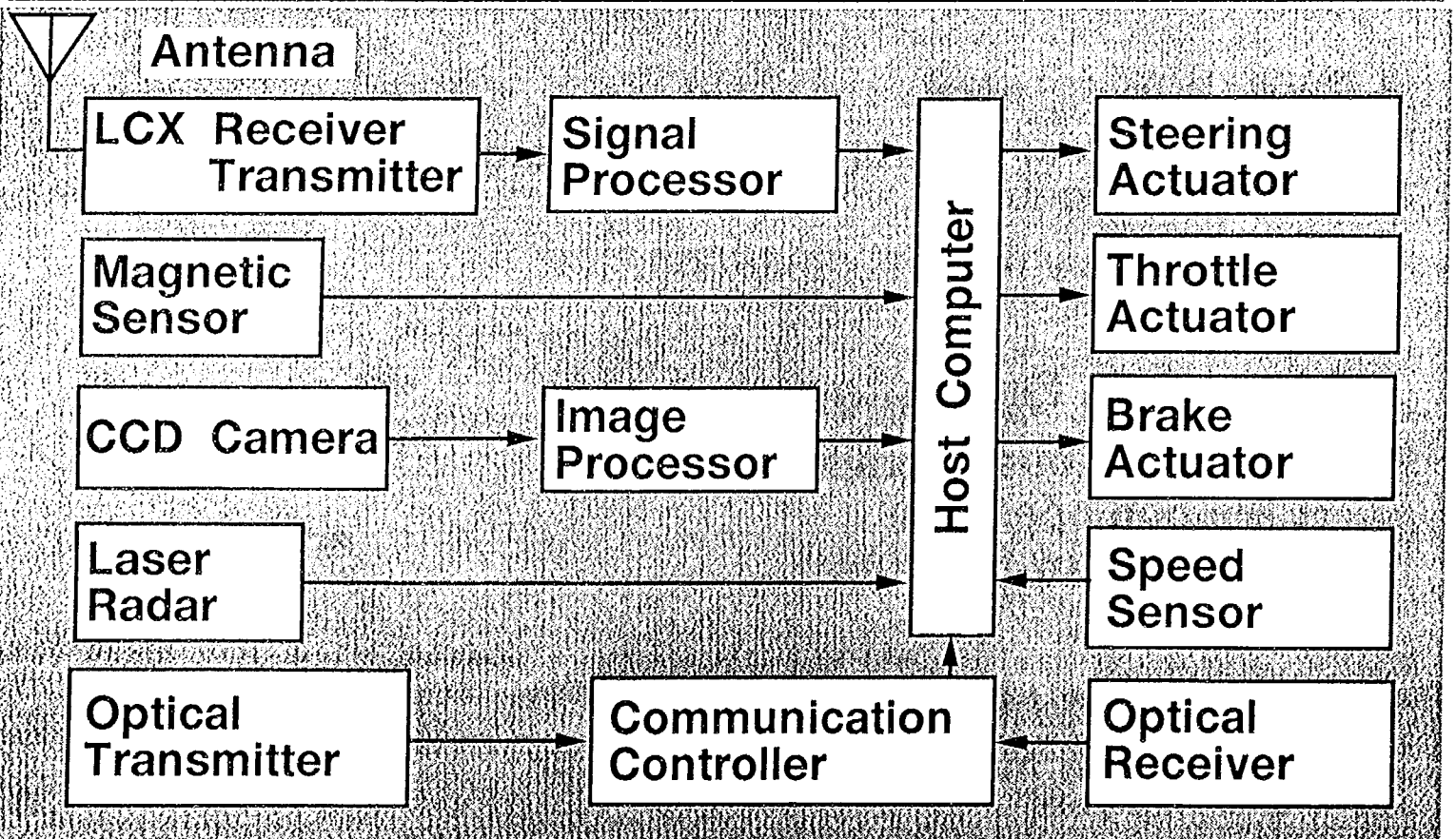
■ Check Out / Exit

- Take over manual vehicle operation

Control system configuration for AHS



Block Diagram of Control system



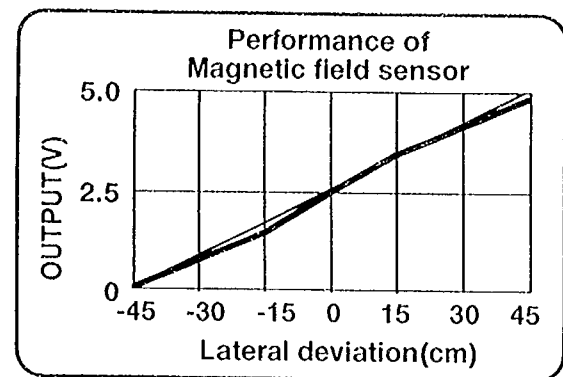
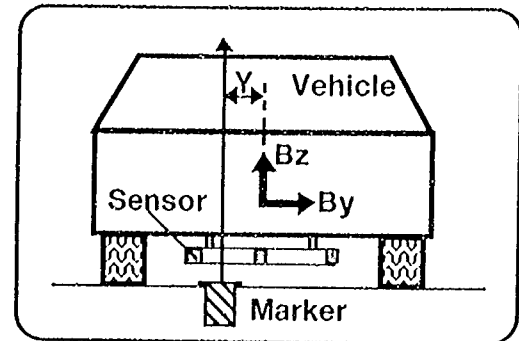
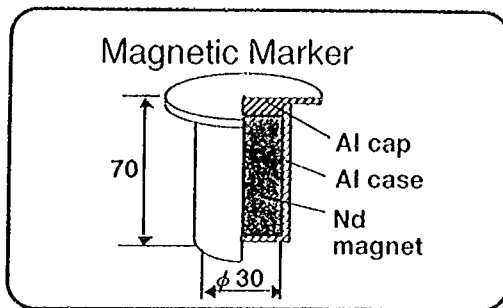
MAGNETIC MARKER DETECTION

Features

- Small size Magnetic Marker using Neodymium
- Highly sensitive Magnetic Sensor within Saturable Core

Detection of Lateral displacement

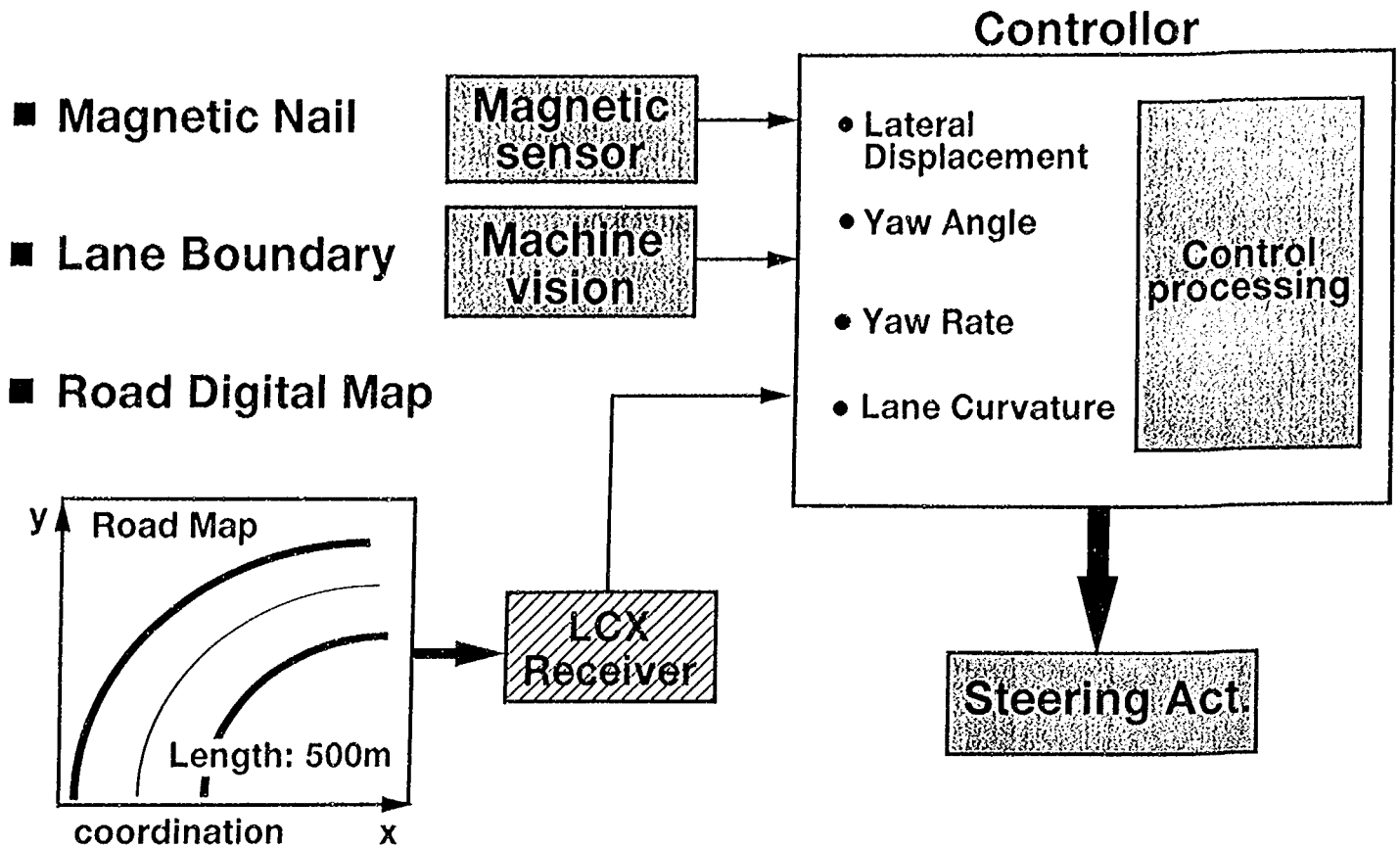
- Detectable range 0.5m
- Accuracy 0.05m



Functional Feature of Automated Vehicle

- Lane Tracking based on Magnetic Nails and Lane Boundary
- Adaptive Cruise Control managed by external command
- Platooning enhanced by Inter Vehicle communication system
- Obstacle avoidance cooperated with infrastructure

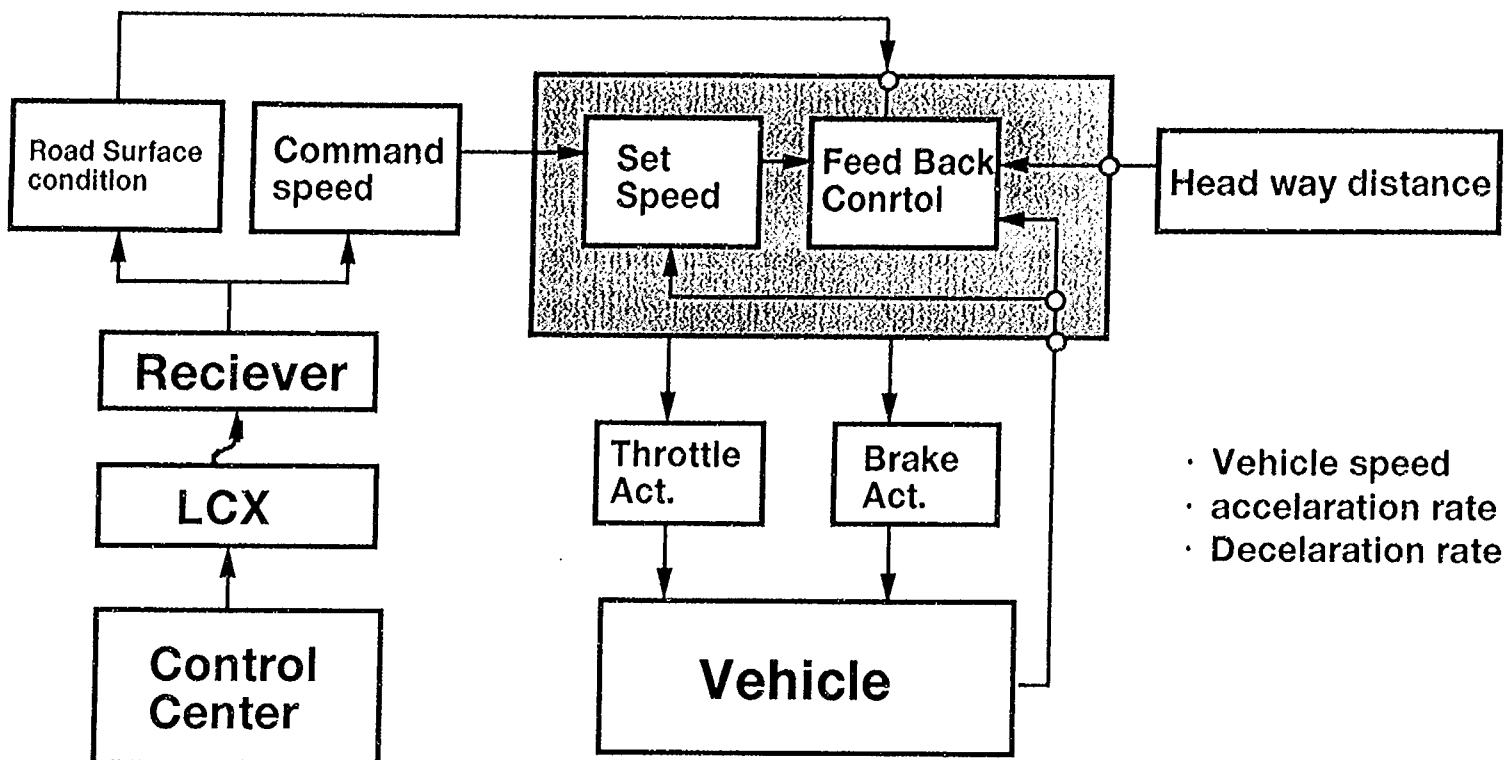
Lane Tracking Control Subsystem



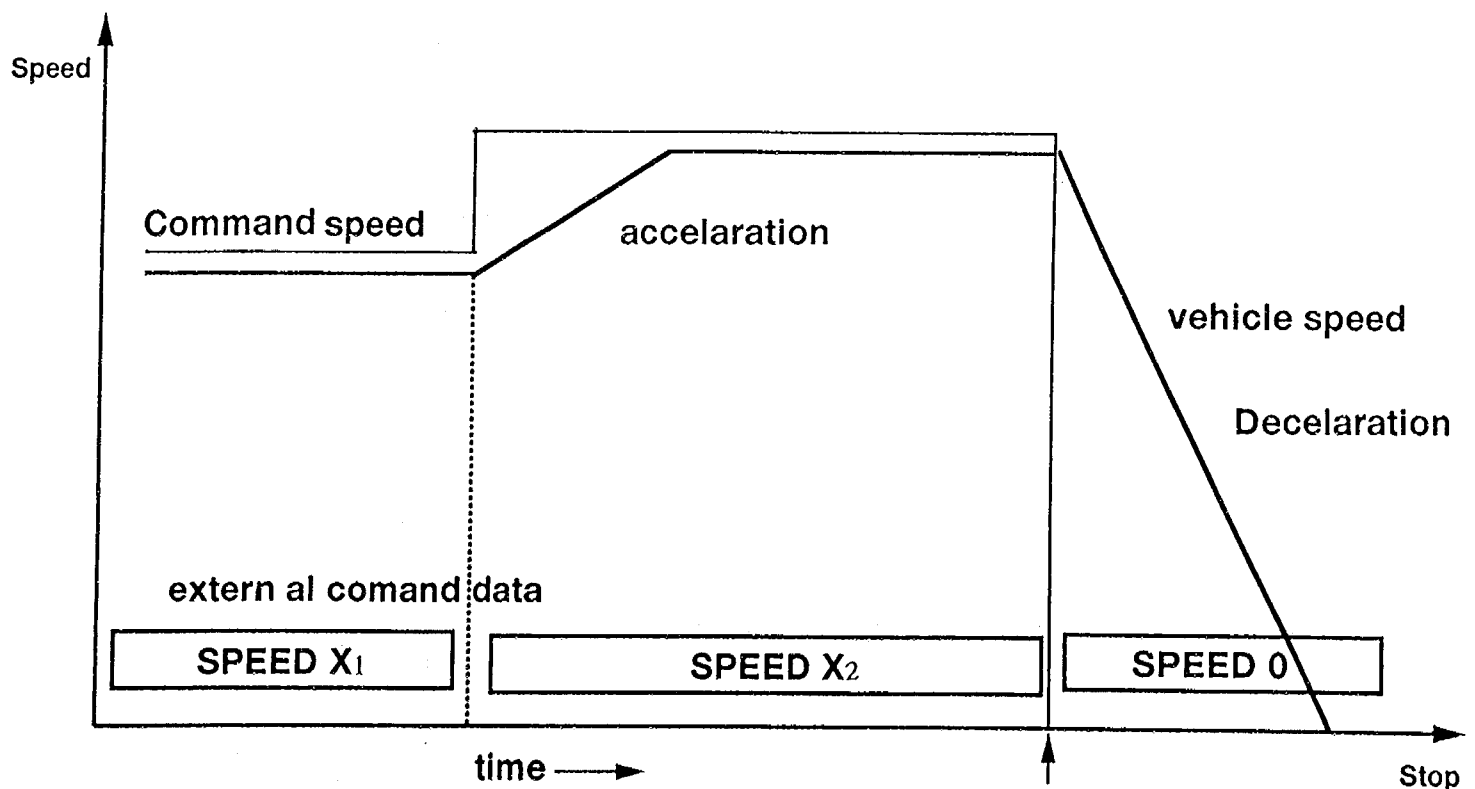
Adaptive Cruise Control Subsystem Function (ACC)

- Cruising vehicle speed intervened by external command
- Headway distance based on a Vehicle speed and road surface condition
- Obstacle avoidance gained by intensive deceleration

Block Diagram of ACC



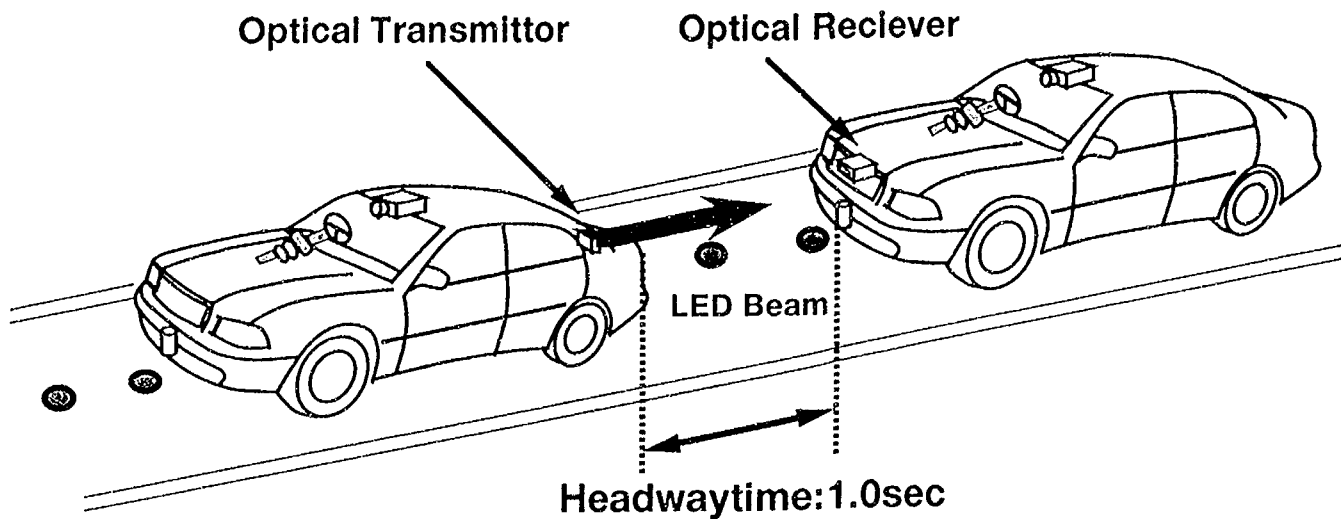
Control Processing of ACC Function



Platooning Control Subsystem

■ System Configuration

- Optical Inter-vehicle communication system
- Precise short range system based on Image Processing



Inter-Vehicle Communication for Platooning

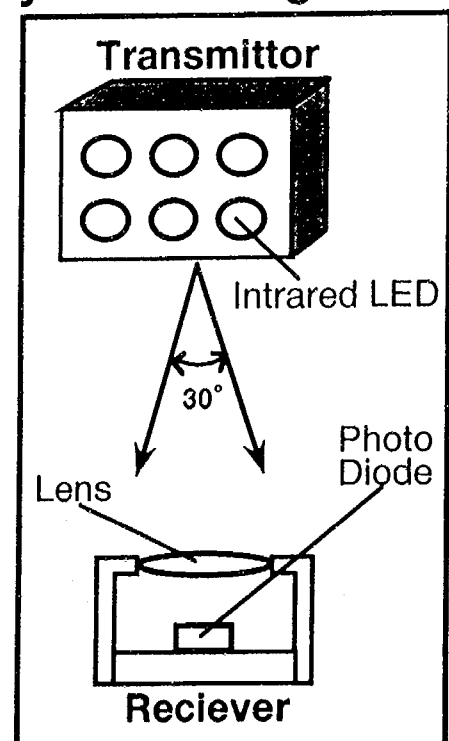
■ Communication data

- Vehicle speed
- accelaration / deceleration rate
- Braking signal
- Vehicle location

■ Communication frequency

- 20msec

system configuration



Conclusion

- ***Successful AHS operation can be made by cooperation with continuous read-vehicle communication.***
- **A platoon with close spacing can be made by inter-vehicle communication.**
- **A proof-demonstration test can be made on the test track.**

4.3.2 "Communication system for Lateral and Longitudinal Control System"

by Yutaka Yamada

(Oki Electric Industry Co., Ltd.)

Communication System for Lateral and Longitudinal Control System

Yutaka Yamada
OKI Electric Ind. co., Ltd.

1. Functions Implemented This Year

Out of the lateral and longitudinal control system, the road incident detection and warning function and emergency notification function have been implemented this year. The road curvature information and vehicle speed information are provided additionally for assisting the automatic driving system.

2. Communication Equipment Configuration

Continuous road-vehicle communication is enabled by laying 3km leakage coaxial cables (LCXes) on the 6.2km test course of the Public Works Research Institute. The experimental system is divided into 6 sections approx. 500m in length each.

A 500m leakage coaxial cable is laid in each section with a radio transmitter-receiver and local processor at an intermediate position, and a central processor is installed in the new traffic experiment building.

A CCTV camera is installed in each of experiment sections 3 and 6 to enable the experiment state to be monitored at the new traffic experiment building while an image processing sensor is installed in section 5 for detecting abnormalities on the course.

LCXes are installed at a height of approx. 5m above the ground. A radio transmitter-receiver and a local processor are installed at an intermediate position in each section. An optical fiber LAN connects the central processor and local processors for signal transmission. The transmission rate in the LAN is 10 M bps conforming to the Ethernet standard. Each of the local processors installed along the test course is housed in a small shelter for improvement and addition of the experimental equipment in the future and to facilitate experimental operation.

3. Function of Each Unit

1) Local processor

Each local processor handles communication with the vehicles traveling in the respective section, information interchange with other local processors and roadside sensors, and communication with the central processor.

2) Central processor

The central processor controls local processors. It performs monitoring and recording of the communication state of each local processor and remote setting of the information to be sent to the vehicles.

3) Radio transmitter-receiver

The radio transmitter-receiver uses two frequencies in the 2.5 GHz band, and the transmission power is 1W on both the vehicle and road sides. A continuous transmission system is adopted for the road side transmitter while a time-division multiplex transmission system is adopted on the vehicle side for transmitting only in the assigned time slots.

4) Leakage coaxial cable

Leakage coaxial cables designed for exclusive use in the 2.5 GHz band are used. The diameter is approx. 50mm, the coupling loss 60dB and the transmission loss is 0.12 dB per meter.

5) Automatic Vehicle Monitoring unit

The AVM unit displays the positions and speeds of the vehicles on the test course.

6) CCTV monitor cameras

Two monitor cameras are installed at different positions on the test course to monitor the state of the experiment in progress on the course at the new traffic experiment building. Optical fiber cables are used for monitor signal transmission.

4. Communication Protocol

The communication protocol is designed for transferring the information on 54 vehicles in total (36 vehicles assumed to coexist in a section, 9 vehicles about to arrive in the section, and 9 vehicles that have entered the next section).

The communication is performed in two types: in short communication cycles (0.1 sec each) and long communication cycles. The types of information requiring urgent transmission are assigned to short communication cycles and those relatively less in urgency are assigned to long communication cycles.

The transmission rate is made at a rate of 512 Kbps continuously from the road side and as time division multiplex communication using burst signals from the vehicles side.

In one short communication cycle for 0.1 second, communication with each of 54 vehicles is performed always.

First a composite signal consisting of the registration timing signal and a long cycle downstream signal is sent from the road side. The vehicle receiving the composite signal, transmits the registration signal. Then the registered vehicle ID and the assigned transmission time slots are informed to the vehicle. The informed transmission time slots covers both the short and long communication cycles.

Any vehicle failed in registration retries registration in the next 0.1-second period. For vehicles once registered, no new registration is made until it enters the next LCX section.

Each registered vehicle transmits its information in the assigned long cycle upstream signal time slot. Since the long cycle upstream signal involves a large amount of data, transmission from all vehicles can not be assigned within one cycle (0.1second) and the data are assigned to several cycles for transmission from each vehicle. For the short cycle upstream signal, on the other hand, one transmission time slot always assigned in one cycle to make every vehicle send its information in each 0.1-second cycle.

The short cycle downstream signal is given in two modes: individual caution/warning mode for the vehicle judged by the roadside sensor to cause a safety problem and normal mode for relaying the short cycle upstream data from each vehicle.

The long-cycle signal provides vehicles with less urgent information.

Table below shows the types of information contained in each signal.

Short-cycle signal	
Vehicle → Road	Road → Vehicle
* Temporary vehicle	* Not to be used this year
* ID	
* Vehicle length	
* Vehicle width	
* Vehicle position	
* Vehicle abnormality information	

Long-cycle signal	
Vehicle → Road	Road → Vehicle
* Final vehicle ID	* LCX position
* Vehicle attributes	* Emergency vehicle information
* Vehicle abnormality information	* Road information
	* Accident information
	* Calamity information
	* Abnormality information
	* Emergency message
	* Road curvature information
	* Vehicle speed information

5. Subjects of Future study

The study matters that have been found in the system construction work up to the present are as follows:

1) Problems at each section boundary.

(1) Weaken electric field strength considered due to direction of wave radiation from LCX arises at each section boundary.

Countermeasure: Prepare a cable which has the radiating direction of 90 degrees, vertical to the road and test if the fields distribution can be improved. Also test by slightly lapping the cables in both sections.

(2) At each section boundary, a alternate signal reception of both sections in the downstream occurs for a length of about 10 m. Because of the interference between signals of the two sections, receiving failure occurs.

Countermeasure: Try electric field improvement by using the cable suggested for improvement of previous phenomenon. Also devise the signal processing software for the transmitter-receiver for improvement. At present, the software for correction is used.

2) Reception of signals in the opposite lane

(1) The signals in the opposite lane are received in the present system.

Countermeasure: Add processing for discarding received signals from the opposite lane by improving the signal protocol.

(2) The electric field in the local lane is interfered from the opposite lane.

Countermeasure: Improve the vehicle antenna front-back ratio. Modify the LCX installation position to make the interference 4minimum.

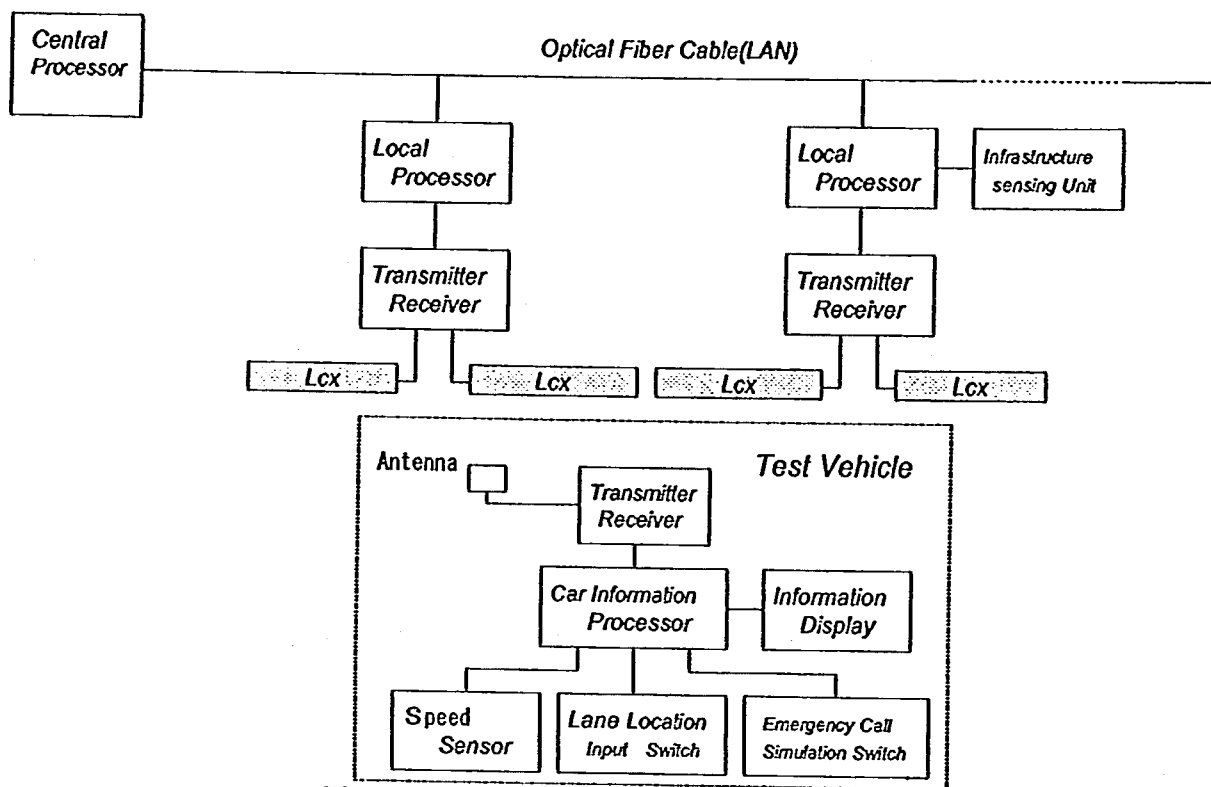


Fig.1 Experimental System Block Chart

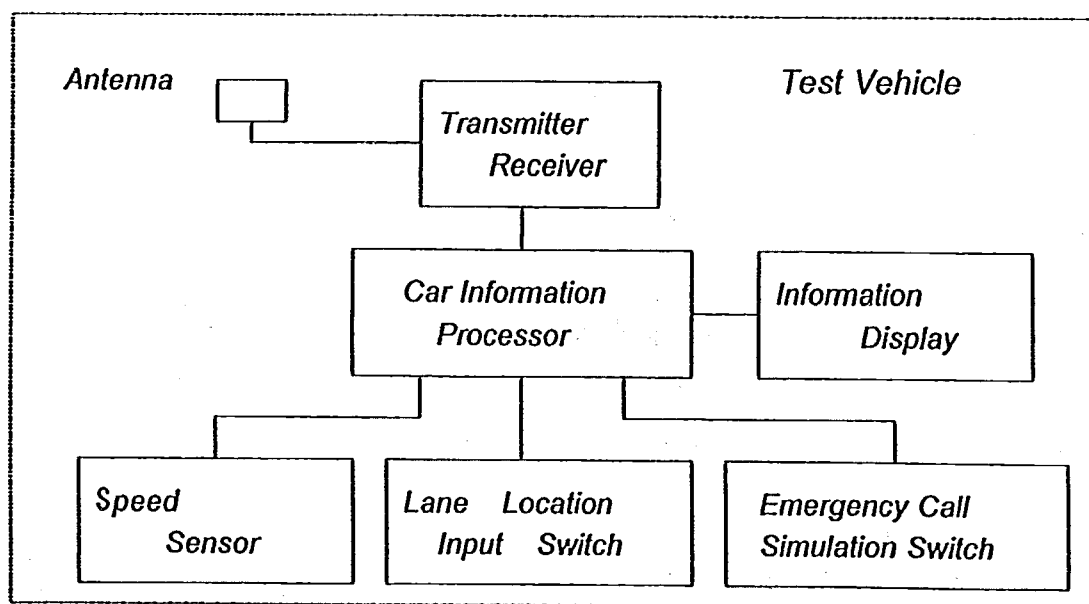


Fig.2 Test vehicle System Block Chart

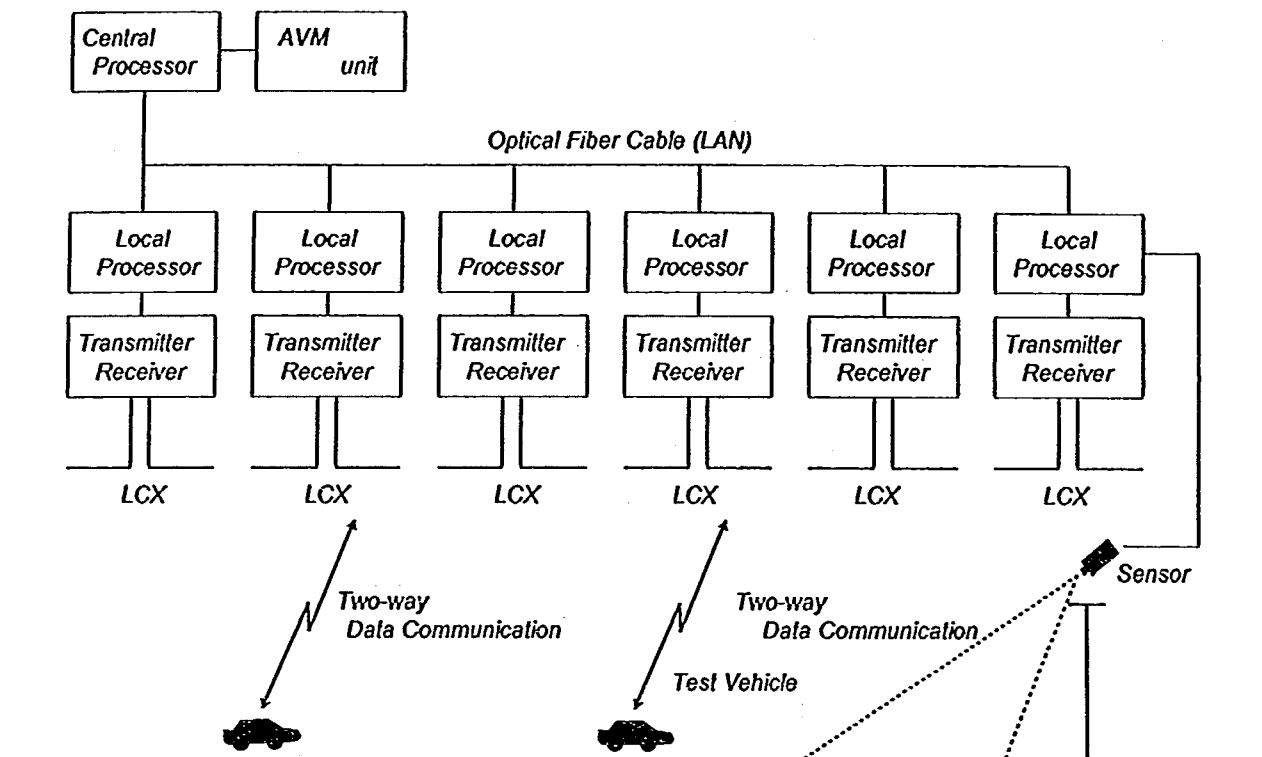


Fig.3 Experimental System

Road Side to The Vehicles

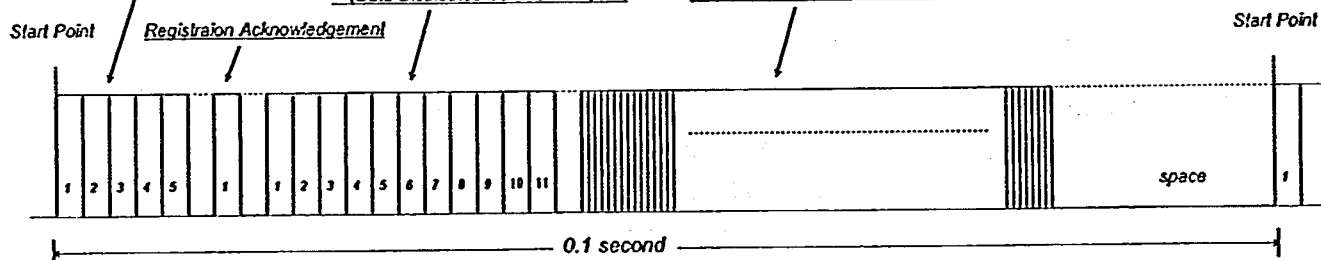
Registration Timing Signal and

Data of Long Communication Cycle

Data of Small Communication Cycle

(Data Distributed To Each Car)

(Relayed Data Received From Each Car)



Vehicles to The Road Side

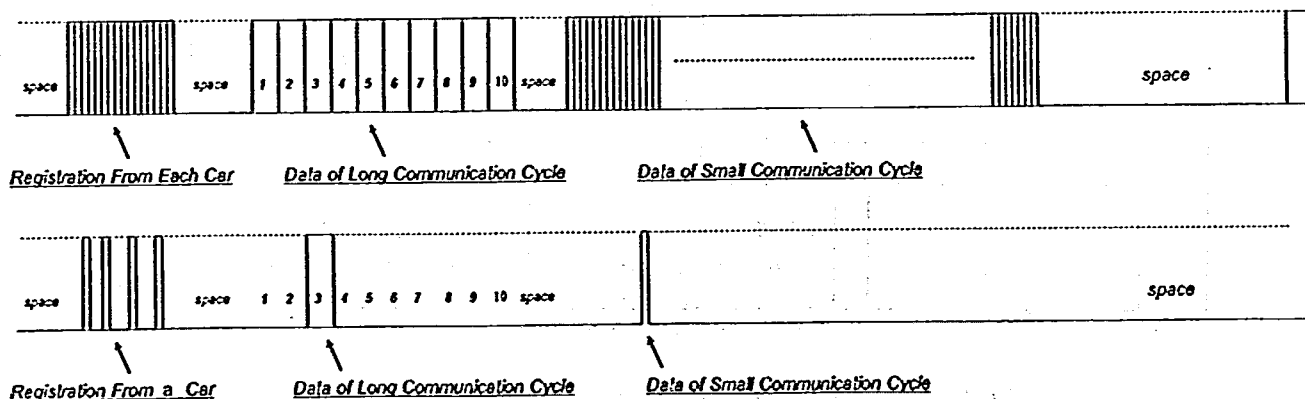


Fig.4 Communication Format

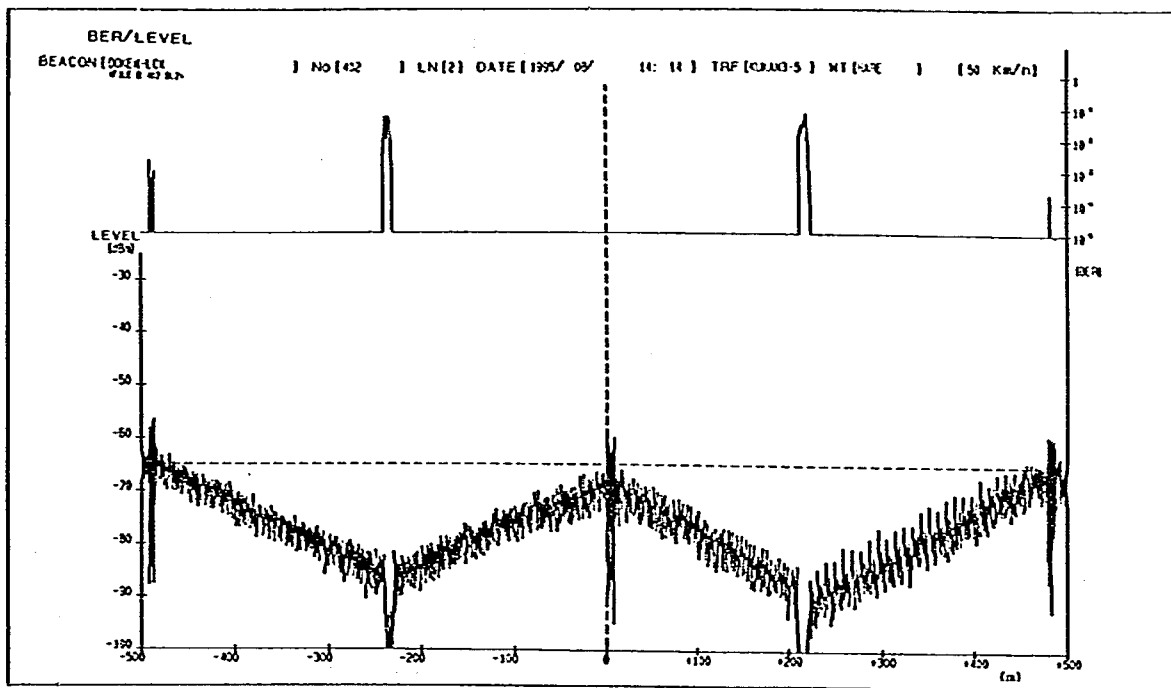


Fig.5 Radio Receiving Level and Error Rate

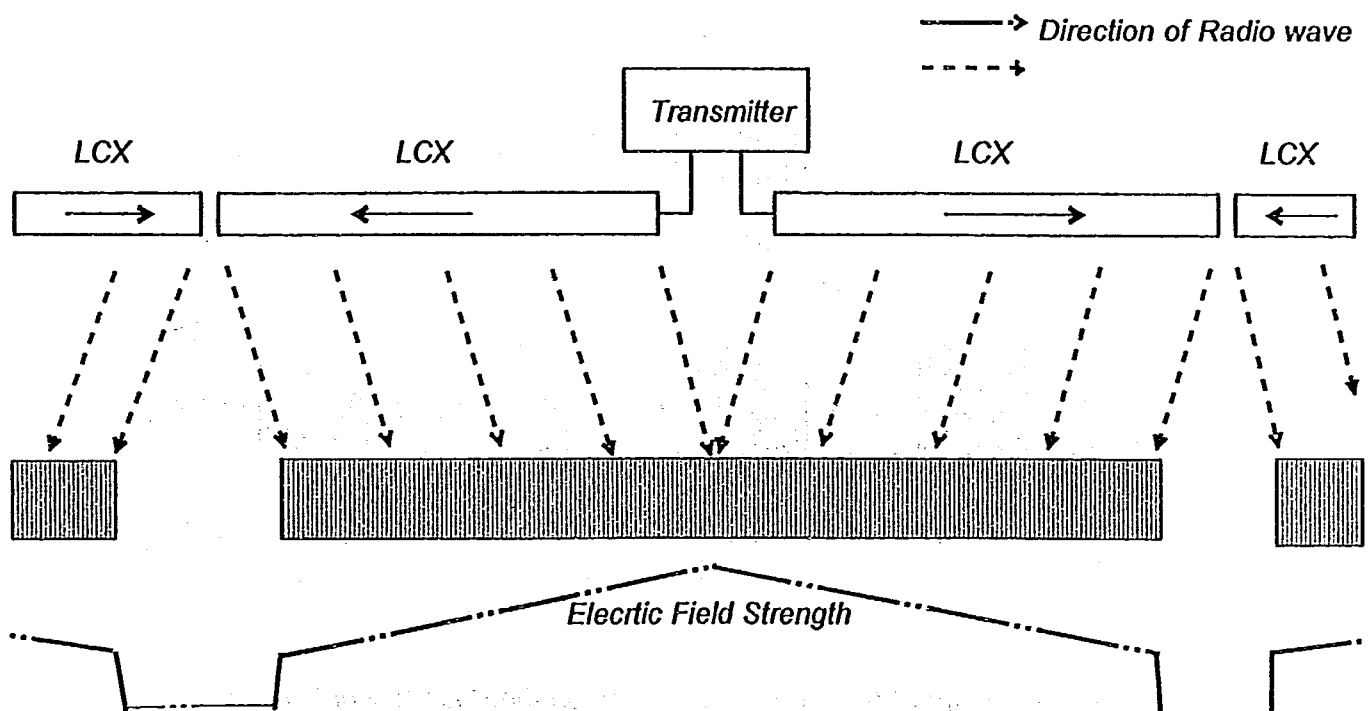


Fig.6 Effect of Radio Radiation Angle (Assumption)

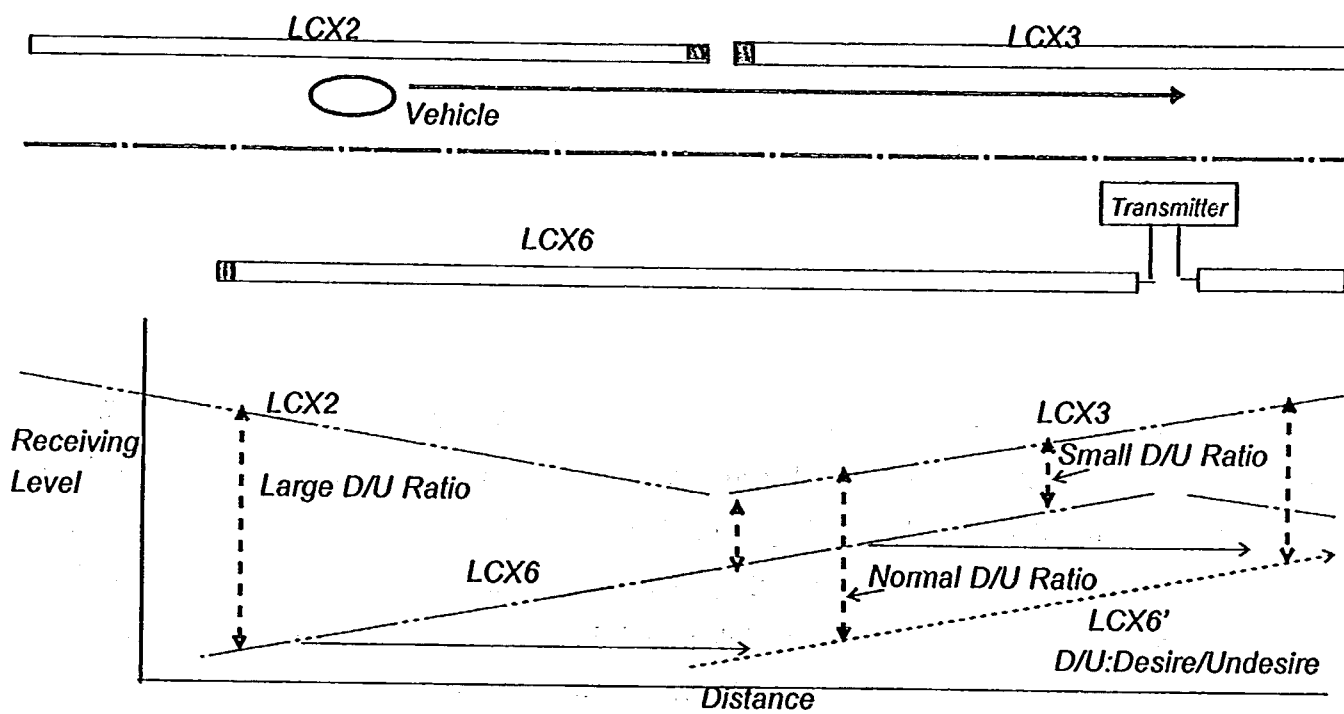


Fig.9 Receiving Level nterference between LCX3 and LCX6

4.3.3 "AHS Vehicles"

by Steven E. Shladover

(National Automated Highway System Consortium)

(AHS Vehicle Classes)

Many of the vehicle issues have not been decided yet. We are considering many different alternatives, and it will take us several years to reach decisions about many of those vehicle issues. We have decided that the AHS system should be able to operate with a wide range of vehicle classes including light duty vehicles, heavy duty vehicles, but not motorcycles. The light duty vehicles include both automobiles and both light trucks and vans, which are becoming an increasingly important part of the vehicle fleet in the U.S.

We believe that the heavy duty vehicles are very important users of the AHS — both buses for use in local transit service and inter-city touring coaches and trucks, which includes both single unit truck and multiple unit tractor trailer trucks. We believe that the AHS needs to be designed so that all of these vehicles can operate on the system, but we could still allow for local options to restrict some classes of vehicles at some times. For example, in some locations, trucks might not be able to operate during the peak traffic periods, and in some locations, there might be restriction for buses and multiple occupancy vehicles only during certain periods of time.

(AHS Concept Dimensions)

We are at the stage of the program where we are considering many different concepts for operation of the AHS so that we can decide which are the most suitable to use for the long term system. The most significant of the issues or the dimensions that we use to distinguish the concepts, is the distribution of intelligence which means how much of the information processing is done on the vehicle, how much is done on the road side.

We are also considering concepts with different roles for the drivers. That could range anywhere from the driver being very much involved in control of the vehicle to the driver being totally uninvolved in control of the vehicle, and perhaps even being asleep while the vehicle is traveling.

We are also considering concepts in which vehicles operate in platoons with close coupling of the movements between them or in which the vehicles operate as free agents with very coupling between the movements of the vehicles. We're also considering concepts with

different amounts of mixing between the manually controlled and the automated vehicles which could range anywhere from having automated and manual vehicles operating together in the same lanes, to systems in which the automated and many vehicles would be completely segregated from each other with barriers to prevent them from mixing.

And a final dimension that we use to distinguish among the different concepts is the range of options that would be available at the same time for a vehicle, for example. We refer to this as the layering of functions.

(AHS Concepts for Evaluation)

We are considering five families of concepts for AHS. We will be studying these five families between now and next June, at which time we expect to reduce to three concepts which will then be studied in further detail.

These concepts are mainly distinguished by the distribution of intelligence, but within each of these we will be studying the other concept dimensions such as the role of the driver, the separation policy between vehicles, the separation between automated and manual traffic. The first of these we refer to as the independent vehicles. These would be vehicles that make maximum use of sensors on board the vehicles and minimum use of communication between vehicles or between the vehicles and the road side.

In the second concept, called cooperative vehicles, we make maximum use of communications between the vehicles, so that vehicles can share information among — with each other — about what's happening on the road way, but we still minimize the amount of the communication between the vehicles and the road side. The infrastructure supported and managed vehicle systems represent two different levels of information provided from the road side to the vehicles.

In the infrastructure supported vehicle type of concept family, we would have a common broadcast of road side information to all of the vehicles that are in the neighborhood, and that could correspond to one section of LCX to be compatible with the type of concept you were describing to us.

In the infrastructure managed concept, we would have more specific customized information transmitted from the road side to individual vehicles to govern their movements. The maximally layered function family of concepts tried to combine as many of the other distributions of intelligence as we can, while maintaining the interoperability among the vehicles, so that vehicles could operate in some regions where the functions might be defined to be independent, or cooperative, or infrastructure supported, but could also operate in other areas where the infrastructure provided the capabilities for infrastructure managed operation.

The maximal layering function family also provides for full back positions in the event of failures, so that if, for example, higher level functions suffer failures, it's possible for the system to operate with lower levels of infrastructure involvement, or lower levels of communication with other vehicles.

And the evaluation of this function family will need to consider those advantages as compared to the probably higher cost associated with providing this capability.

(Context Diagram)

Another important issue that we have been working on is definition of the context of the AHS, which means making sure we understand what's included inside the AHS, and what are the external issues, the external functions that are not part of the AHS.

We show the AHS inside the circle which is moving fully automated vehicles on dedicated highway lanes, and we show a variety of other things that the AHS must exchange information with. The AHS system needs to communicate its operational status to the driver, and the driver will probably need to provide some control inputs to the AHS.

The AHS will need to collect data from many different non AHS systems, which could include non AHS controlled vehicles, road way obstacles, non AHS instrumented roadways, and the ambient environment. That data could be gathered either by sensor systems or by communications systems. The AHS will also need to exchange a lot of data with other transportation operation systems. It's important to remember that the AHS is part of the overall ITS system, and needs to exchange information with many of the other ITS functions as well as non ITS functions such as construction, maintenance, and the rest of the transportation system operations.

(Preliminary AHS Functions)

As part of our work on defining the AHS concepts, we also need to define the functions that the AHS must perform. This is work that is still underway, that is not defined in any final form. Some of the higher level functions within the AHS at the system level, include planning the flow of traffic, which means both monitoring the flow that we have in the system and then optimizing that flow so that we can give suitable commands to the vehicles.

Vehicle movement planning includes planning of the routes that we take from the origin or the entry point to the system, to the destination as well as the more local path planning to get around obstacles or traffic jams. That also includes planning the distribution of gaps between vehicles based on issues such as the level of traffic and the weather and road conditions.

(Preliminary AHS Functions, cont'd)

The more detailed functions within the movement of the vehicle are shown here. The first three functions are associated with starting a trip on an AHS. The check in would be condition checking to make sure that on board systems are working correctly, the manual to automated transfer is the transfer of control from the driver to the automated system, and then the move into the AHS would actually represent the motion of the vehicle into an AHS lane.

During normal traveling within the AHS, we have lane tracking, or automatic steering control to follow the lanes, steering to do lane changing from one lane to another, and longitudinal space regulation, controlling the spacing between the vehicle and the vehicle in front of it.

There is a higher level function of maneuver coordination management, which is coordinating the movements of different vehicles that are near each other to make sure that the vehicles are not trying to occupy the same space at the same time. We show both steering and braking movements for collision avoidance, when something goes wrong.

And then the last three functions here are associated with leaving the AHS. The first of those is driver readiness test, to make sure that the driver is indeed able to resume manual control of the vehicle, then we have the transition from automated to manual control, and moving out of the vehicle from the AHS.

This is the first step in trying to define the entire range of the functions that the AHS might need to perform. As we go through the different concepts, some of the concepts may not need to implement all of these functions, while other concepts may implement all of those functions.

(Technology Categories)

We will also be defining functions in much lower levels of detail than what we have shown here, in order to be able to design the system. Our time is getting very short, so we can probably not get into technologies in great detail, but I will simply show some of the listings of the types of technologies that we expect to need to make an AHS work.

Probably the largest category of technology is the on-vehicle sensing technologies, and we've listed here many different types of sensing that we expect to need for the AHS.

(Technology Categories, cont'd)

The next categories of technology are first of all, the actuators, that cause the vehicles to move the way that we want to, and those actuators would need to be available for cars, trucks, and buses, and in the communication technologies for both vehicle to vehicle and vehicle to roadside communication, which I'm not going to talk about any more.

(Technology Categories, cont'd)

We also have some more computer related technologies: the computer processing technologies for both vehicle and infrastructure, a large set of computer software algorithms and more basic work on software safety engineering, to make sure that we can prove that our software intensive system is indeed safe.

(Technology Categories, cont'd)

There's a final list of technologies associated not so much with the vehicles as with the road way and infrastructure sensing, and then infrastructure and configuration level issues. Again, these are not directly vehicle related, but they are still important parts of the system.



AHS Vehicles

Steven E. Shladover

Page 1

AHS Vehicle Classes



- Light-duty vehicles
 - automobiles
 - light trucks and vans
- Heavy-duty vehicles
 - buses (transit, touring coaches)
 - trucks (single and multiple unit)
- No motorcycles
- Local options to restrict some classes at some times

Page 2

AHS Concept Dimensions



- Distribution of intelligence (vehicles and roadside)
- Role of the driver
- Separation policy (platoons/free agents)
- Mixing of manual and automated vehicles
- Range of options available simultaneously (layering)

Page 3

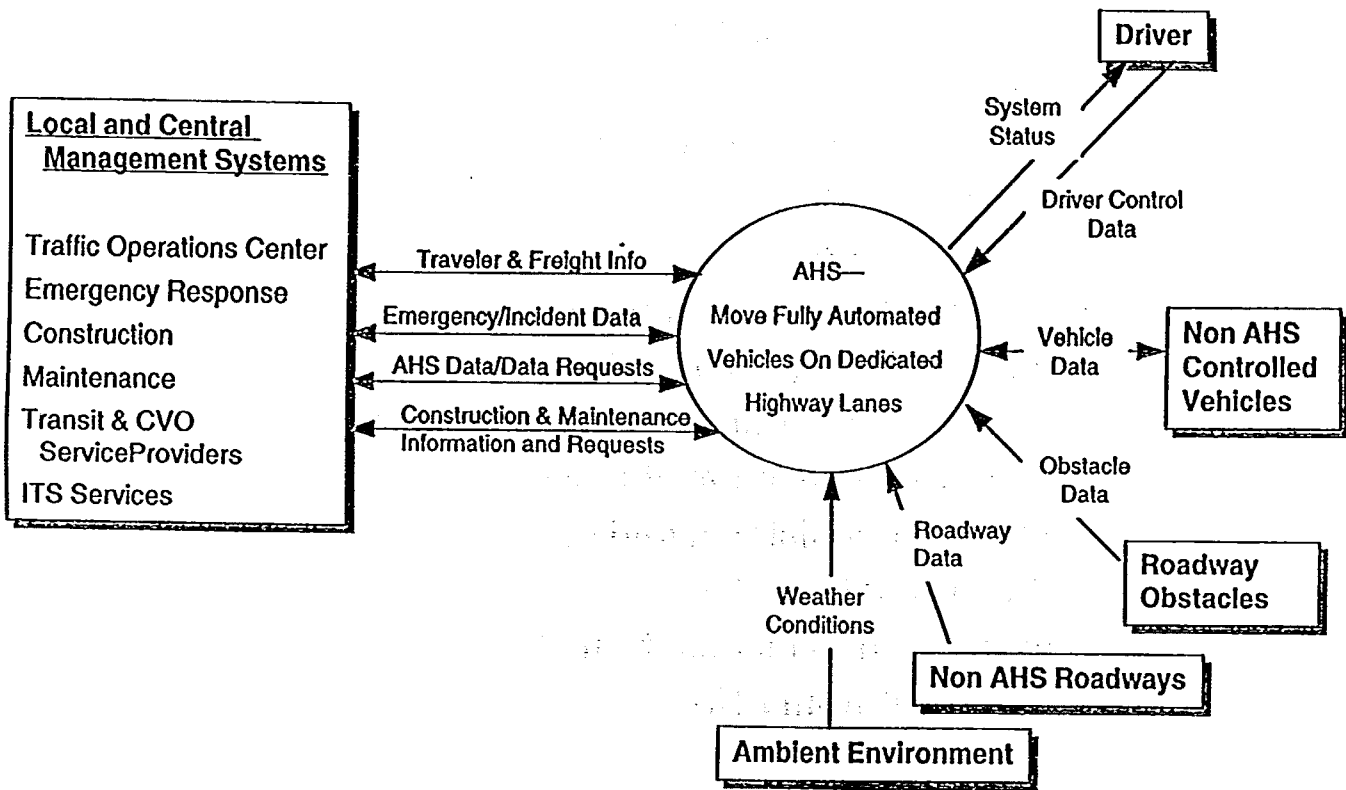
AHS Concepts for Evaluation



- Independent vehicles
- Cooperative vehicles
- Infrastructure-supported vehicles
- Infrastructure-managed vehicles
- "Maximally layered" functions

Page 4

AHS Context Diagram



Preliminary AHS Functions



- System Flow planning
 - flow monitoring
 - flow optimization
- Vehicle movement planning
 - route planning
 - path planning
 - vehicle gap distribution

Preliminary AHS Functions (cont'd)



- Vehicle movement execution
 - check-in
 - manual to automated transfer
 - move-in to AHS
 - lane-tracking
 - steering for lane changing
 - longitudinal space regulation
 - maneuver coordination management
 - steer for collision avoidance
 - brake for collision avoidance
 - driver readiness tests
 - automated to manual transition
 - move-out from AHS

Page 7

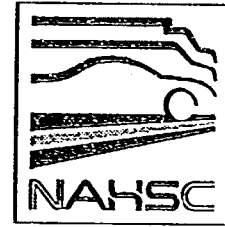
Technology Categories



- On-Vehicle Sensing Technologies:
 - Longitudinal Separation
 - Obstacle Detection
 - Lateral Position
 - Motion
 - Absolute Position
 - Vehicle Systems Status
 - Driver Condition

Page 8

Technology Categories (cont'd)



- **Actuators (for Cars, Trucks and Buses):**
 - Steering
 - Braking
 - Throttle
- **Communications**
 - Vehicle-vehicle
 - Vehicle-roadside

Page 9

Technology Categories (cont'd)



- **Processing:**
 - In-Vehicle Processing and Data Link
 - Infrastructure Command and Control Processing
- **Algorithms:**
 - Lateral and Longitudinal Control Algorithms
 - Check-in
 - Check-out
 - Obstacle Avoidance
 - Roadway Traffic Management
- **Software Safety**

Page 10

Technology Categories (cont'd)



- **Roadway and Infrastructure Sensing:**
 - **Environment**
 - **Macroscopic Traffic Condition**
 - **Roadway Impediments**
 - **Microscopic Traffic Condition**
- **Infrastructure and Configuration:**
 - **Traffic Operation/Management**
 - **Roadway/Lane Barrier Design**
 - **AHS-Specific Construction Technologies**
 - **AHS-Specific Maintenance Technologies**

Page 11

4.3.4 "NAHSC Communications"

by Ron Colgin

(National Automated Highway System Consortium)

(AHS Communications Functions)

The AHS system will have to perform at least four communications functions: the first function is the control loop support, which is for the exchange of velocity and acceleration information within a coordinated unit such as a platoon. The second function is maneuver coordination, which is the transfer of control unit or platoon level maneuvering information between vehicles and between vehicles and the roadside. The next function is route guidance, which provides information for vehicles to aid in the determination of the best route and to guide the vehicles along that route. And finally, network status control, is the dissemination of congestion and incident information throughout the automated highway network.

(Control Loop Support Communications)

For the control loop support communications function, each vehicle in a platoon must send his velocity and acceleration information to the vehicle immediately following every 20–50msec. The lead vehicle must send his vehicle velocity and acceleration information to all other vehicles in the platoon every 20–50msec. Characteristics of control loop support, are short range, reliable, deterministic latency and forward error correction.

For an example of a time slot architecture for platoon control loop communications, you might have time slots for 20 vehicles each with a length of about 1msec and within it, in a time slot would be information on the address or preamble, the data, and a guard space.

(Maneuver Coordination Communications)

For maneuver coordination communications, maneuver messages will occur in bursts, but the overall data rate is low. Normal maneuver control requires a reliable link but can tolerate message latencies greater than the control loop channel and it would be used, for example, for entry and exit maneuver, as well as lane changes.

Emergency maneuver coordination requires much shorter latencies and would be used for such things as obstacle avoidance and malfunction management.

(Route Guidance and Network Control and Status Communications)

Route guidance communication is used for supportive check in and check out, dissemination of origin destination pairs and enroute changes to destination.

Network status and control communications is used to monitor the status of the automated lanes, dissemination of congestion information, and dissemination of incident information. Characteristics of this function are contention access, non-deterministic latencies, and commercial communication protocols may be allowed.

Individual vehicles will send data to the traffic operations center and the traffic operations center will send data to individual vehicles and broadcast to groups of vehicles by way of zones or local transceivers.

(Communications Technology)

As far as communications technology goes, control loop support could be by digital packet radio, unlicensed spread spectrum, infrared, or beacon tag. For maneuver coordination, we may be able to preempt the control loop communications circuit for emergencies and share capacity on the route guidance network status and control circuit for normal communications.

For route guidance and network status control, we could use cellular digital packet distribution, beacon tag, digital radio, packet radio, and broadcast communications.

(The AHS Communications Problem)

We will consider building an end-to-end communications system in layers. The communications problem is vehicles entering and exiting the system, perhaps entering and joining and splitting from platoons.

(Add Check-in / Check-out Communications)

We'll add check-in / check-out systems, which may be a low power beacon tag system used for vehicle to infrastructure communications.

(Add Vehicle-to-Vehicle Communications)

We add a low power vehicle-to-vehicle communications system such as 900MHz spread spectrum.

(Add Vehicle-to-Infrastructure Communications)

Add to the communications system, vehicle-to-infrastructure communications (roadside communications) equipment provides redundant path to each vehicle, frequency spreading

codes or hopping codes alternate in fixed pattern such as this.

(Add Infrastructure—to—Infrastructure Communications)

We add infrastructure—to—infrastructure communications which could be fiber optic data link between the roadside equipment and the traffic operations center, or leased lines, or wireless point to point communications could also be used.

(AHS Communications can become complex)

AHS communications can become complex. Communications systems include beacon to tag at check—in and check—out stations, low power spread spectrum, vehicle—to—vehicle transceivers, roadside transceivers spaced at to be determined intervals with corresponding vehicle transceivers.

(AHS Communications using single technology)

Some of the tradeoffs: The AHS communications could use a single technology such as digital packet radio for all communications, the radios must be capable of operating in multiple bands. The advantage would be a single piece of hardware in the vehicles, but the disadvantage is that this would require some hardware development that doesn't exist today.

(Hybrid Communications System)

We could use a hybrid communications system which might consist of a beacon tag for infrastructure—to—vehicle communications, spread spectrum, or infrared for vehicle to vehicle communications. The advantages would be inexpensive vehicle hardware, existing technology with modified protocols, unlicensed spread spectrum bands — it's easy for you to say. The disadvantages would be numerous closely spaced beacons, and two communications systems in each vehicle.

These are some of the issues concerning AHS communications. Our job for the next couple of years is to do the studies and analysis and pick the optimal solution for our system.

NAHSC Communications

Ron Colgin

November 1995



AHS Communications Functions



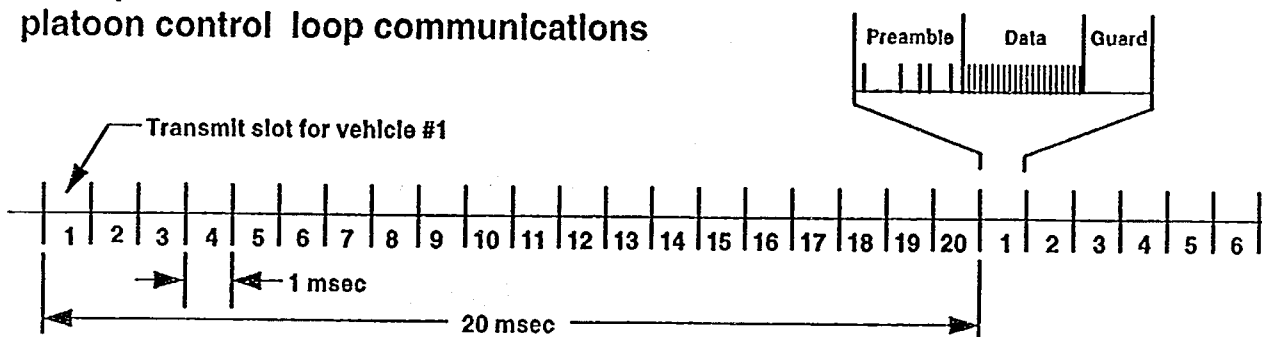
- **Control loop support**
 - Exchange velocity and acceleration information within a coordination unit
- **Maneuver coordination**
 - Transfer control unit or platoon level maneuver information:
 - » between vehicles
 - » between vehicles and the roadside
- **Route Guidance**
 - Provide information to vehicles to aid in the determination of the best route and to guide the vehicle along that route
- **Network Status and Control**
 - Disseminate congestion and incident information throughout the automated highway network

Control Loop Support Communications



- Each vehicle in a platoon must send his velocity and acceleration information to the vehicle immediately following every 20-50 msec
- Lead vehicle must send his velocity and acceleration information to all other vehicles in the platoon every 20-50 msec
- Short range, reliable, deterministic latency, forward error correction

Example of a time slot architecture for platoon control loop communications



Maneuver Coordination Communications



- Maneuver messages will occur in bursts, but overall data rate is low
- Normal maneuver coordination requires a reliable link, but can tolerate message latencies greater than control loop channel
 - entry / exit maneuvers
 - lane changes
- Emergency maneuver coordination requires much shorter latencies
 - obstacle avoidance
 - malfunction management

Route Guidance and Network Control and Status Communications



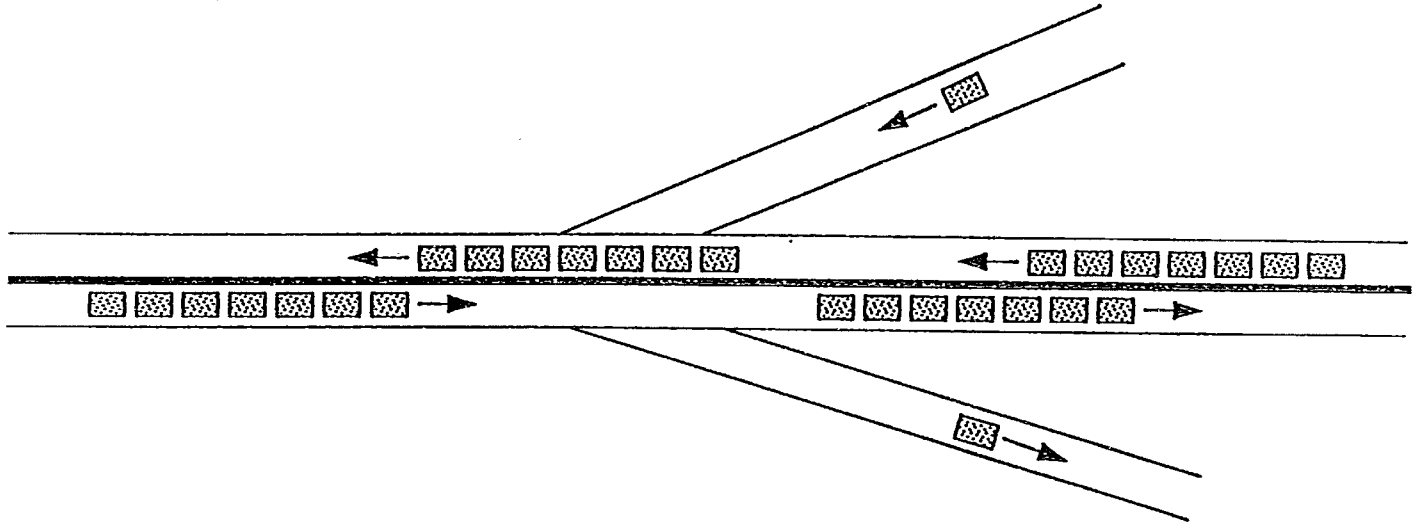
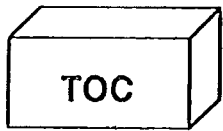
- **Route guidance communications is used for:**
 - Support of check-in and check-out
 - Dissemination of O-D pairs
 - Enroute changes to destination
- **Network Status and Control communications is used for:**
 - Monitor the status of automated lanes
 - Dissemination of congestion information
 - Dissemination of incident information
- **Contention access, non-deterministic latencies, and commercial communications protocols are allowable**
- **Individual vehicles will send data to TOC**
- **TOC will send data to individual vehicles and broadcast to groups of vehicles via zone or local transceivers**

Communications Technology

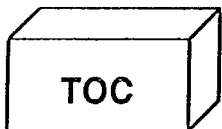


- **Control loop support**
 - Digital packet radio
 - Unlicensed spread spectrum
 - Infrared
 - Beacon/tag
- **Maneuver Coordination**
 - May be able to preempt on control loop communications circuit for emergencies and share capacity on the route guidance/network status and control circuit for normal communications
- **Route Guidance / Network Status and Control**
 - CDPD
 - Beacon/tag
 - Digital packet radio
 - Broadcast communications, such as HAR, RBDS, SCA
 - GPS

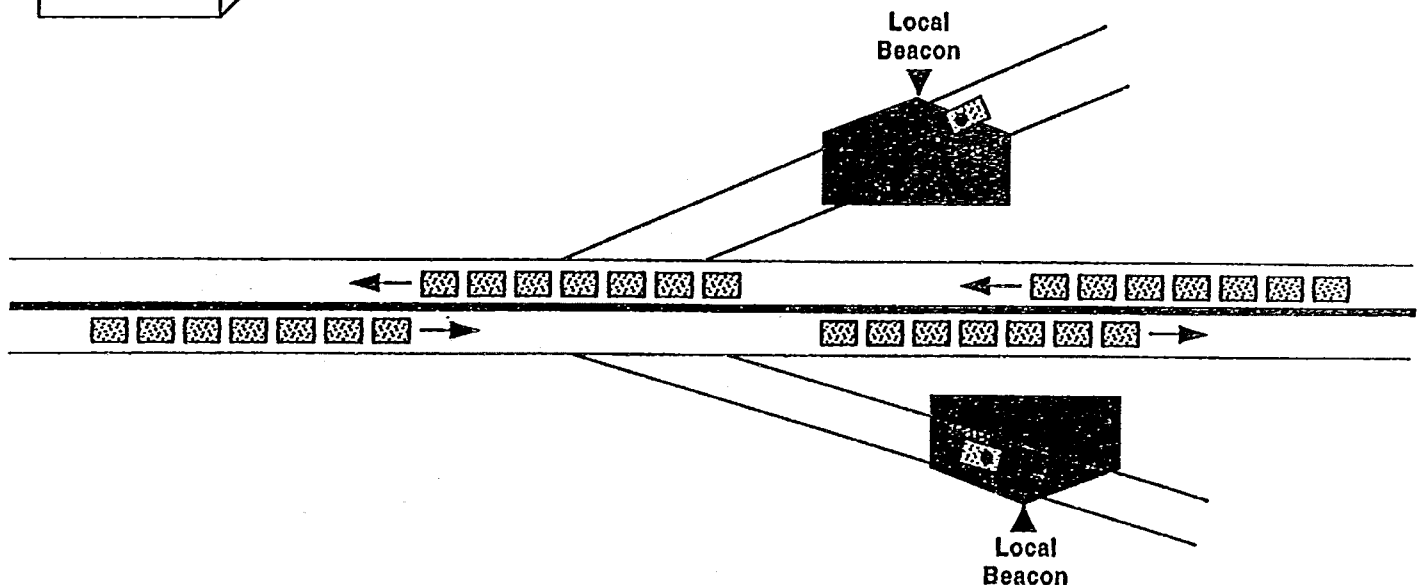
The AHS Communications Problem



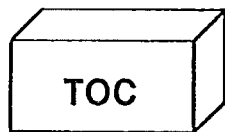
Add Check-in/Check-out Communications



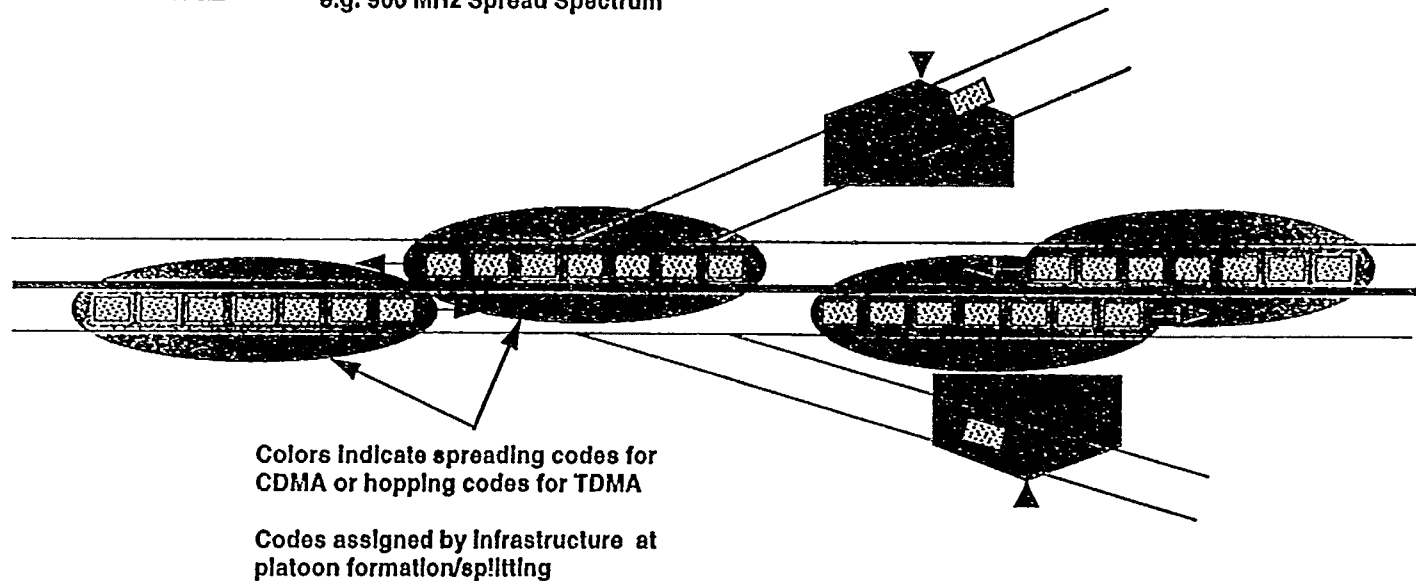
Low power beacon/tag system used for vehicle-to-infrastructure communications system



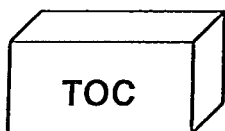
Add Vehicle-to-vehicle Communications



Low power vehicle-to-vehicle communications system
e.g. 900 MHz Spread Spectrum

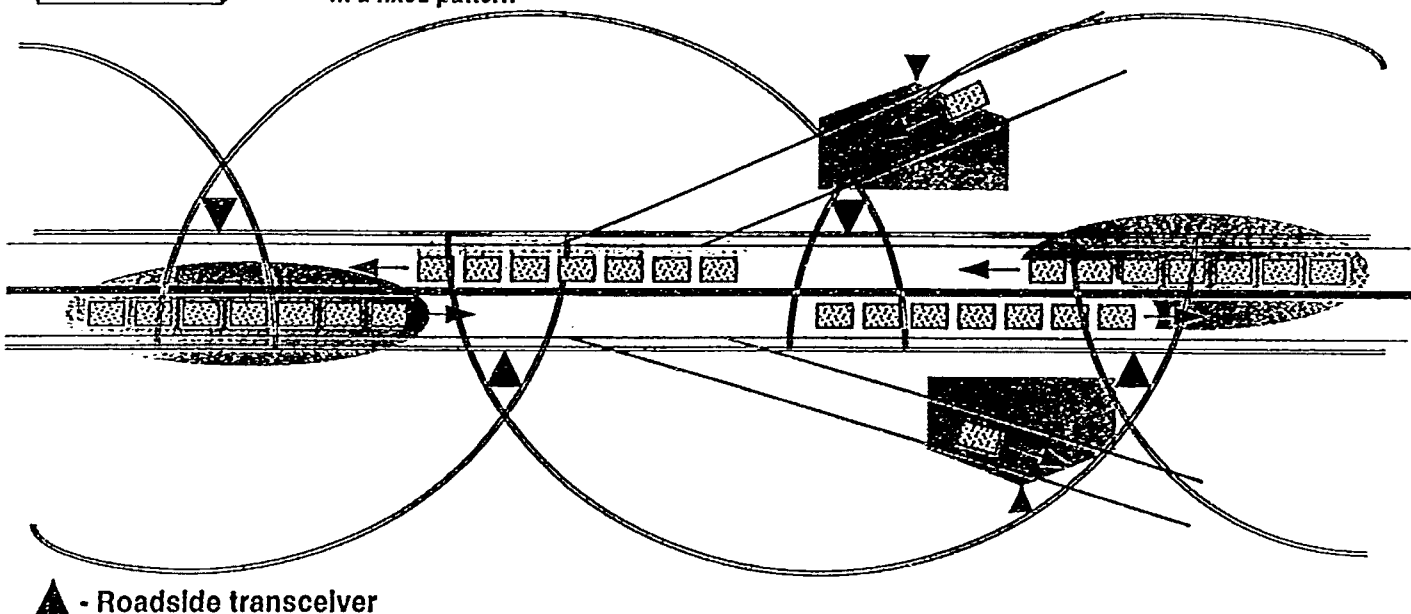


Add Vehicle-to-infrastructure Communications

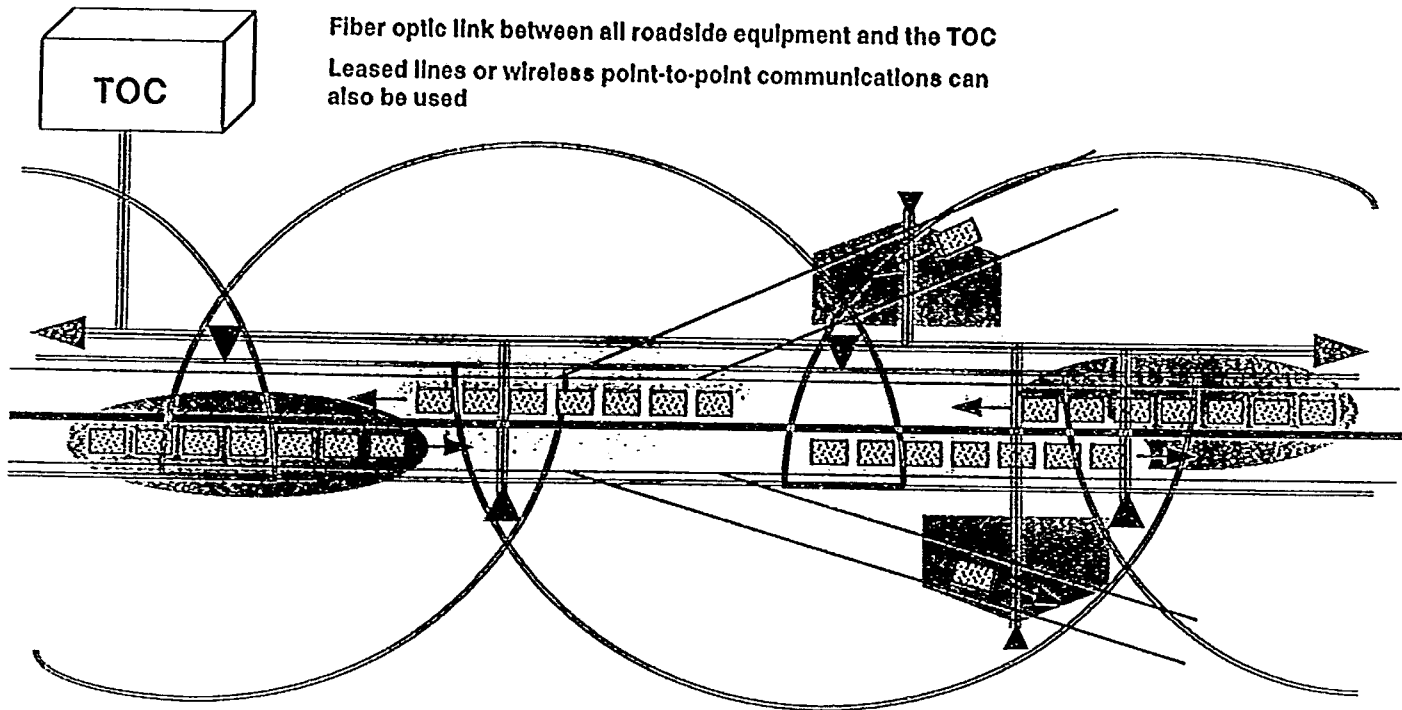


Roadside communications equipment provides redundant path to each vehicle

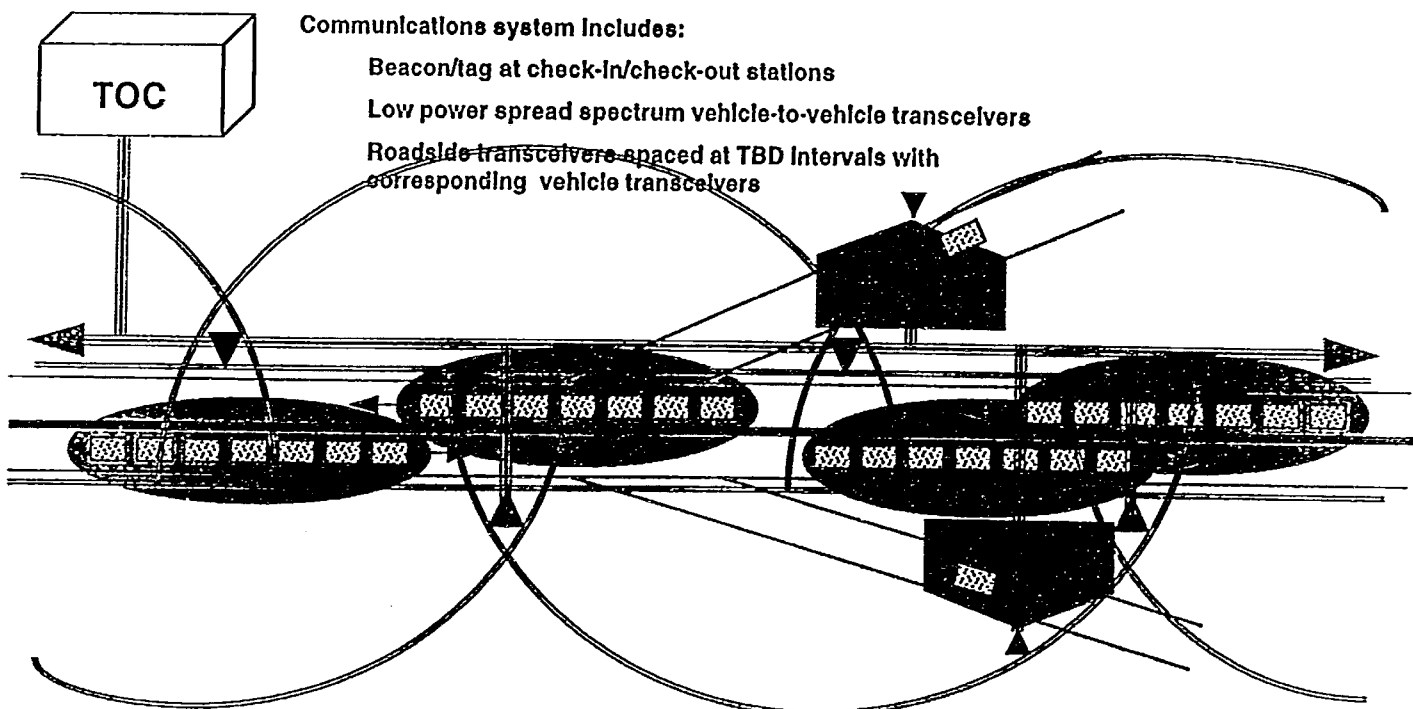
Frequencies, spreading codes, or hopping codes alternate in a fixed pattern



Add Infrastructure-to- infrastructure Communications



AHS Communications can become complex



AHS Communications using single technology



Use digital packet radio for all communications
(radios must be capable of operating in multiple bands)

ADVANTAGES:

- Single piece of hardware in vehicles

DISADVANTAGES:

- Requires some hardware development

Hybrid Communications System



Beacon/tag for Infrastructure-to vehicle communications

Spread spectrum or Infrared for vehicle-to-vehicle communication

ADVANTAGES:

- Inexpensive vehicle hardware
- Existing technology (may use modified protocols)
- Unlicensed spread spectrum band

DISADVANTAGES:

- Numerous, closely spaced beacons
- Two communications in each vehicle

5. Discussion on U.S.–Japan Cooperative Effort

Attendees:

U.S. Side

C. John MacGowan	Chief, IVHS Research Division, TFHRC, FHWA
Toni Wilbur	Program Delivery Team Leader, Office of Traffic Management and ITS Applications, FHWA

Japan Side

Mitsuhiro Nakagaki	Director, Road Department, PWRI
Makoto Nakamura	Research Coordinator for Road Traffic, Road Department, PWRI
Satoshi Ueda	Head, Traffic Engineering Division, Road Department, PWRI

The 9 member U.S. delegation was held by Mr. John MacGowan, Chief, IVHS Research Division, FHWA Turner-Fairbank Highway Research Center.

The approximately 50 member Japanese delegation was led by PWRI Director General Sakamoto.

Director General Sakamoto gave opening remarks welcoming the U.S. delegation. Mr. MacGowan responded on behalf of the U.S. delegation, and expressed their appreciation for the PWRI hospitality and their anticipation of an excellent meeting.

The group visited the PWRI test track for an excellent demonstration and test rides in the AHS vehicles, and a demonstration in the control facility of the incident avoidance capabilities. This was followed by a demonstration and tour of the ETC facility.

After lunch, Mr. Iwasaki of the MOC made a presentation on Japanese ITS deployment plans and future program direction. This was reciprocated by Mr. MacGowan's presentation on the same subjects for the U.S. ITS program. Then Mr. Ueda and Mr. Goddard gave overview presentations on the AHS programs in Japan and the U.S., respectively.

The following day, Mr. Aoki and Mr. Yamada presented technical presentations on the automated vehicle and communications systems for the Japanese AHS. Mr. Shladover and Mr. Colgin described the U.S. National AHS Consortium's vehicle-highway concepts and communications alternatives. There were many good questions following the technical presentations, and a lively and fruitful exchange among the delegations. Topics of particular interest to the group included varying approaches to the development of an AHS system architecture, alternative communication concepts, and differing organizational approaches between the Japanese and U.S. programs.

At the closing ceremony, Mr. Nakagaki acknowledged the value of the 2 day meeting and the importance of technological exchange among the two countries. Mr. Nakagaki expressed the hope that the cooperation between the two countries would continue, and would lead us to cooperative use of new information and communication technologies. Mr. MacGowan

responded with deep gratitude for the hospitality afforded by PWRI, and expressed a similar desire for continued cooperation and information exchange among the two countries.

The following day, the U.S. delegation was provided with a very informative study tour of Metropolitan Expressway Traffic Control Center, Haneda Air Control Center, and the Bullet Express Train Control Center.

Next year's meeting is tentatively planned for a suitable time immediately before or after the 3rd World Congress in Orlando, FL on October 14–18, 1996. Building on the results of this meeting, the priority topics to be discussed at the next meeting will be ETC and AHS. A study tour, possibly focusing on AHS and ETC activities in the U.S., will also be arranged in conjunction with the next meeting.

Conclusion: The 3rd U.S.–Japan ITS Working Group Meeting has continued a very successful tradition of information exchange among the two countries, reinforcing the need to continue this mutually beneficial cooperation.

6. Study Tours

(1) PWRI

The participants went on a study tour to the test sites of ETC (Electronic Toll Collection System) and AHS (Automated Highway System).

The principal functions of ETC are as follows. The first one is that an on-board equipment is set in an appropriate part of the vehicle. The second one is that a roadside equipment is installed at the toll gate canopy and the toll booth island. The last one is that the information of customer vehicle and charged toll is transmitted by radio communication between the on-board equipment and the roadside equipment when the vehicle drives through the toll gate without stopping and thus completes the toll collection process automatically.

AHS realizes various information communication between vehicles using LCX which is laid out without intermission along roadways. The system provides vehicles with information continuously at an initial stage of operation and phases toward AHS by eventually providing various vehicle control functions.

(2) Tokyo

The U.S. members went to Tokyo on November 8. They visited the air control system at the Haneda Airport, the Shinkansen control center and the Traffic Control Center of Metropolitan Expressway.

The air control system is a system to control various air flights and manage air facilities.

The core of the Shinkansen control center is a computer-aided traffic control system. It monitors and supervises train operations by communicating with and collecting information from the centralized traffic control system and controllers on a real-time basis.

The traffic control center is a system to collect, analyse and provide the traffic information by using a computer. This system supports the traffic management works such as managing damaged vehicles and closing the toll gate.

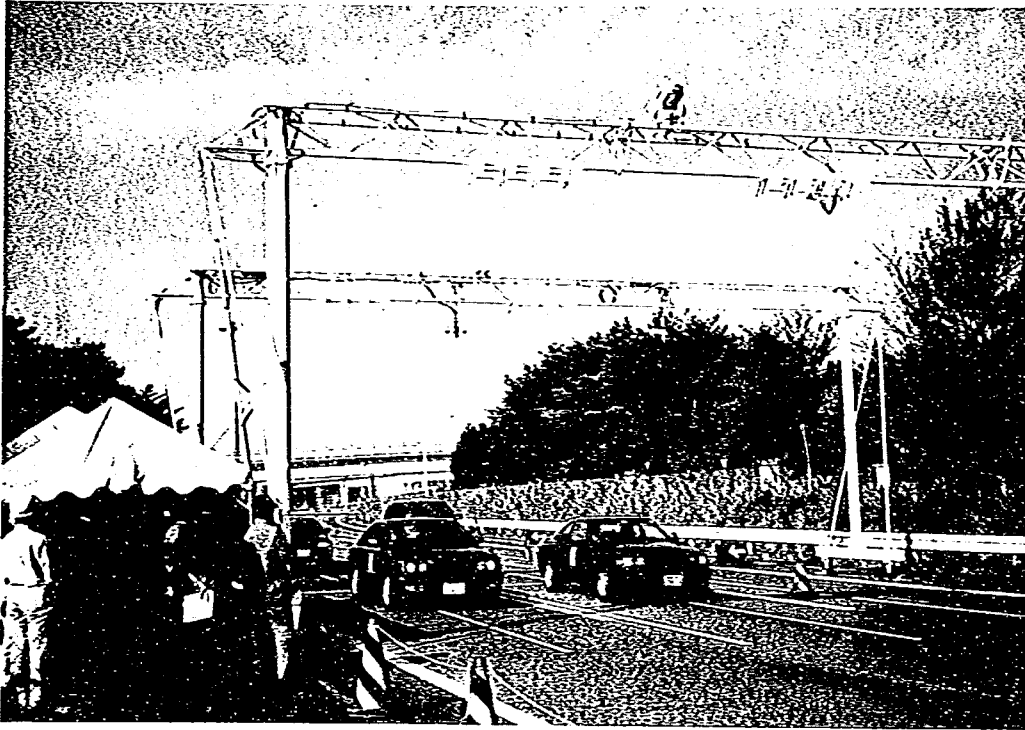


Photo 1 Electronic Toll Collection System (ETC)

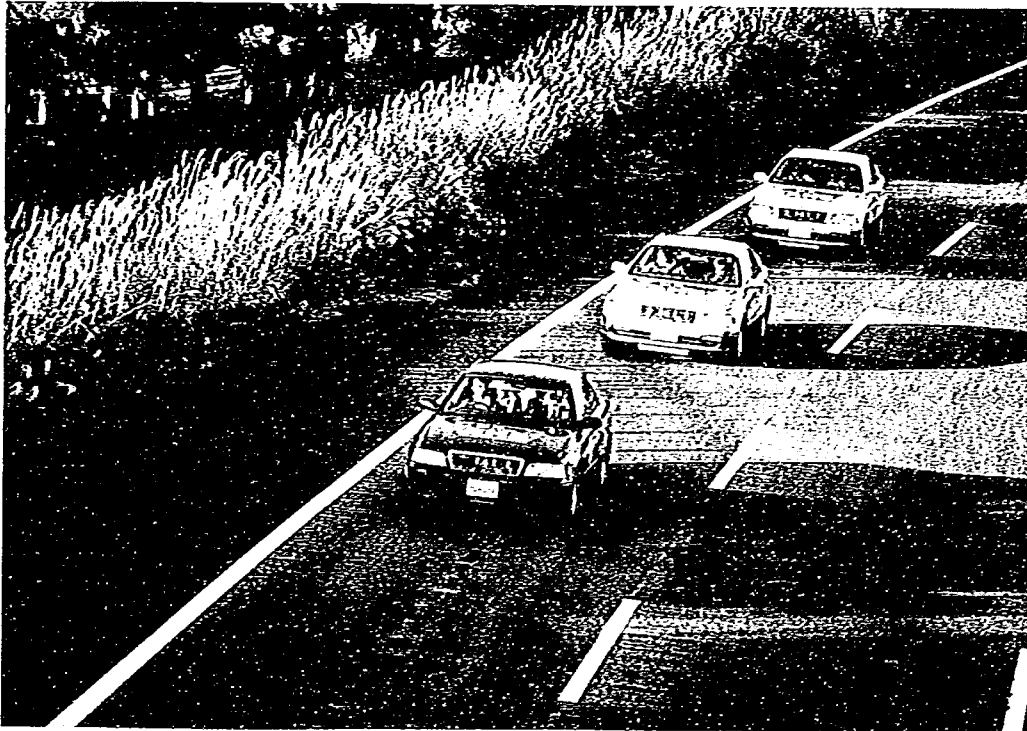


Photo 2 Automated Highway System (AHS)

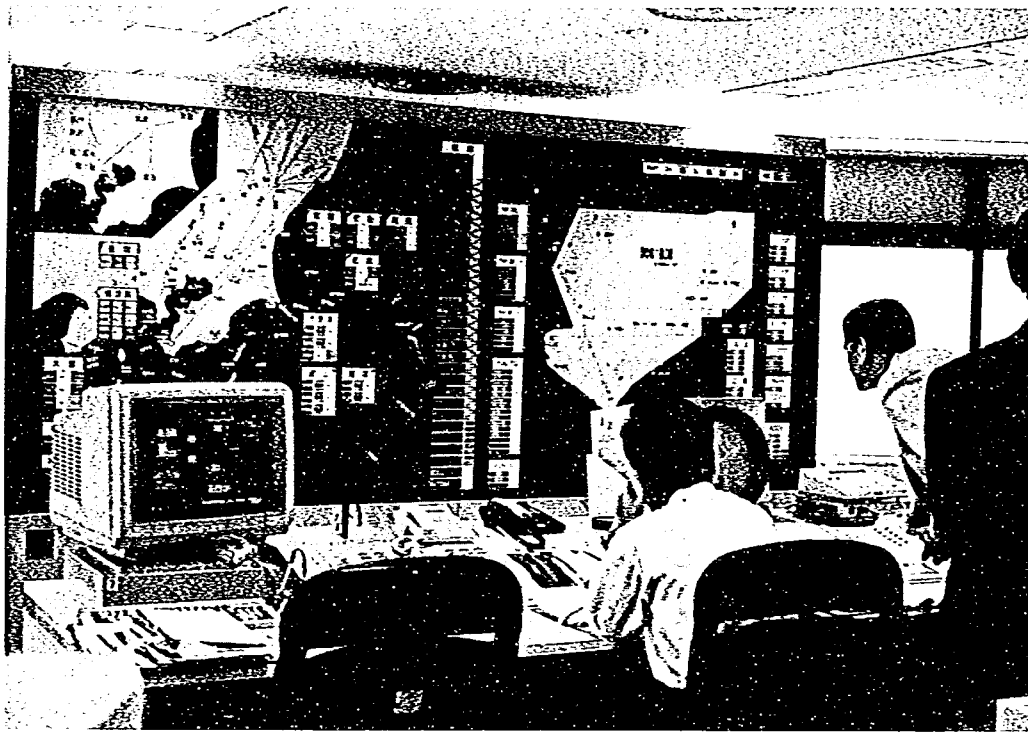


Photo 3 Air Control System



Photo 4 Shinkansen Control Center

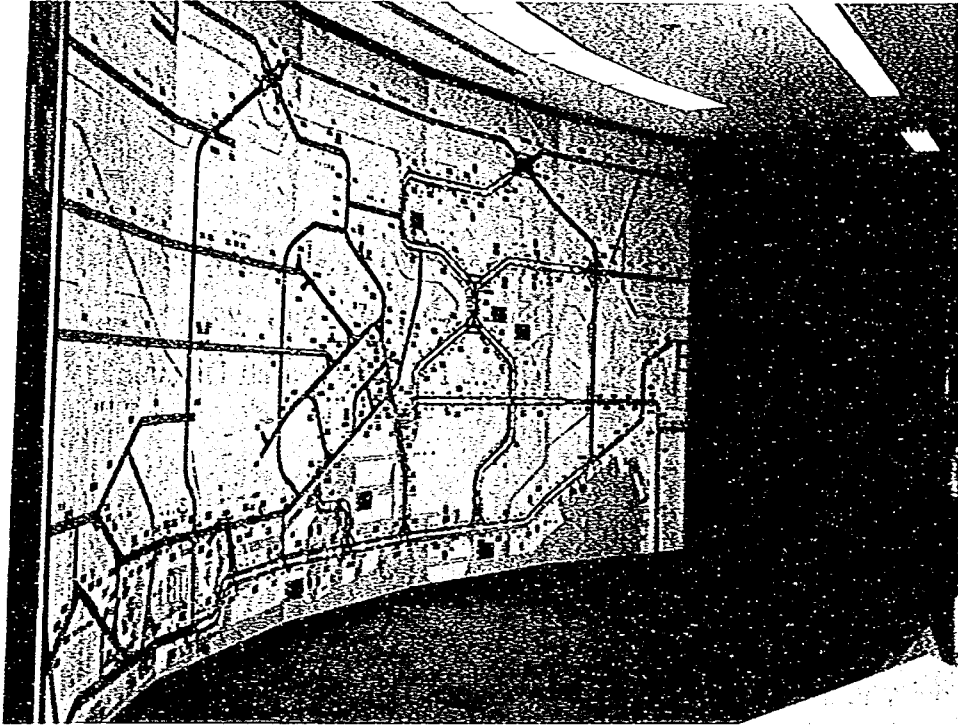


Photo 5 Metropolitan Expressway Traffic Control Center

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