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EXECUTIVE SUMMARY

In the summer of 1993, the Federal Highway Administration (FHWA) awarded a series of contracts under their Automated Highway Systems (AHS) program. The purpose of these efforts, called the Precursor Systems Analyses (PSA), was to identify and analyze the major issues and risks associated with automated vehicle control on our Nation's highways. The program of work was structured to address 16 different activity areas. Fifteen separate teams of researchers were competitively selected to conduct the studies for a total of $14.1 million. All of the research efforts were completed by late 1994.

This report provides a comprehensive summary and evaluation of the PSA analyses. The findings are organized in the following major categories: system-related, transition-oriented, vehicle-related, roadway-related, institutional and societal, and benefits and costs. Two of the PSA teams--Calspan and Delco--were tasked to address all 16 study areas, and to provide an overview of their efforts; summaries are provided as appendices. Additionally, in April, 1994, all of the PSA researchers met in Chantilly, Virginia for a three day Interim Results Workshop. A summary of the proceedings from that workshop are included as an appendix to this report.

The 90 final reports (over 5,000 pages) are being made available through the National Technical Information Service (NTIS). In order to make the findings widely and readily accessible, the U.S. Department of Transportation (US DOT) is transferring the reports onto CD-ROM, which will be available through the National AHS Consortium (NAHSC) or the US DOT. Both the NAHSC and the US DOT plan to make these reports available through a home page service as well. Finally, each researcher was asked to enter its major findings onto a PSA Results Database, which was developed and maintained by Calspan and is being used by the NAHSC participants. Directions for using the database are provided in an appendix.

AUTOMATED HIGHWAY SYSTEMS PROGRAM OVERVIEW

The AHS program was initiated in 1992 as part of US DOT's Intelligent Transportation Systems (ITS) program. Within ITS, the AHS is a user service that applies modem electronics to provide fully automated (hands off and feet off) vehicle control; that is, the vehicle's throttle, braking and steering are controlled by the system. The AHS will be developed from and be compatible with the present highway system.

The promise of AHS is unique in that it offers major improvements in both the safety of highway travel and in the efficient operation of highways, in many cases using existing highway right-of-ways. The drivers will choose to use--or not use--the AHS lane. When a vehicle is accepted, the AHS will move the vehicle from the highway lane onto the AHS lane where the vehicle will be moved safely and efficiently to the driver's desired exit.

The objective of the AHS program is to assess AHS feasibility and to develop an affordable, safe, efficient system that enhances the quality of highway travel.

The Federal government will not be the eventual owner, operator or supplier of the AHS; these will be the roles of the major AHS stakeholders--state and local governments; vehicle, highway and electronics industries; and the system users. For this reason, in October, 1994 the US DOT teamed with the NAHSC, a broad public/private partnership composed of major stakeholder organizations. It is this consortium that will implement the AHS program.

PSA PROGRAM DESCRIPTION

The PSA contracts were focused upon the 16 activity areas described in table ES-1. Table 2-3 in the main body of the report lists the individual contractors and the activity areas they addressed. That table shows that all of the activity areas were addressed by at least three contractors. This overlap added value to the overall body of research since each discrete effort brought a different perspective and emphasis to bear on the analysis of issues and risks.

MAJOR PSA FINDINGS

The PSA studies identified a number of significant challenges to be faced, but found no major "show stoppers" to the implementation of AHS. The major findings addressed in this report are summarized below.

System Related Findings

Vision

The broad vision for AHS is to move people and goods--not just vehicles--more safely and more efficiently; support transit vehicles, commercial vehicles, passenger vehicles, including high occupancy vehicle (HOV) operations; and support urban and rural operations.

Operating Parameters

The safety and operating parameters of AHS are those variables that may be determined by each locale as it installs an AHS. They may include spacing between vehicles, speed, strategy for dealing with varying vehicle types, and entry and exit rules. These parameters will vary from one community to the next to reflect each community's needs and transportation policies; from one highway to the next because of the highway design constraints; from one time period to another to reflect the community's demand management and congestion management policies; and from one minute to the next to reflect environmental factors such as weather conditions (e.g., slow down for rain) and/or traffic conditions (e.g., exit 17 closed because of a collision on the connecting roadway). A community's operating and safety policies will significantly effect the level of safety and efficiency achieved on its AHS.

Safety

The public's perception of AHS safety is critical. Even though AHS operation is expected to be significantly safer than travel on non-AHS roadways, if the public perceives that AHS travel is less safe, then AHS will be avoided. An example is air travel; even though statistics show that air travel is safer than driving, many drivers are afraid of air travel. An AHS can be designed and operated so that statistically it can be shown to be very safe; but if there are rare, catastrophic crashes (multiple vehicles and deaths), the public perception may be that AHS is unsafe. The safety-critical functions of AHS have been identified; the AHS design will need to provide high reliability in those safety-critical areas. A high level of safety also will involve dealing with outside intrusions through the use of obstacle detection, barriers and fences.

System Robustness

The system must be robust--it cannot have frequent traffic blockages. A basic design issue is whether to design for highly robust vehicles and occasional breakdown lanes or less robust vehicles and continuous breakdown lanes. Double or triple redundancy on vehicles may be costly; but continuous breakdown lanes will also be costly, and may not be possible in some urban areas. Another option is very rapid response in removing disabled vehicles in critical areas. A balance will need to be reached. A balance will also need to be identified between (1) on-the-fly (rapid) check-in and periodic off-premise inspections; and (2) thorough, slow-or-stop inspection on every entry with little, if any, off-premise inspections.

Traffic Operations

A concept of traffic operations will need to be determined by each community to handle the various vehicle types. Options could include mixed heavy and light vehicles in same lane with occasional passing lanes; one lane for light and one lane for heavy/light vehicles (light lane narrower?); or one for buses only and one "general purpose" lane. A general purpose lane--as a second lane--could be used for light and/or HOV vehicles in peak hours, and for truck-only in off-hours; it could be used for the breakdown lane when needed and for maintenance in off-hours; during inclement weather, it could be used for snow storage.

National Compatibility

The US DOT visualizes the AHS as evolving to a nation-wide network so that a driver can cross the country using AHS and feel that the AHS in Los Angeles is as familiar as in New York. On the other hand, the AHS is envisioned as a tool to be used by an MPO and/or a state DOT to be tailored to help meet its local needs; an AHS in one city may be for transit and HOV vehicles only, while in another locale, the system use is unrestricted.

Table ES-1. Precursor Systems Analyses Activity Areas

- Urban and Rural AHS Comparison - an analysis that defines and contrasts the urban and rural operational environments relative to AHS deployment.
- Automated Check-In - issues related to certifying that vehicle equipment is functioning properly for AHS operation, in a manner enabling smooth flow onto the system.
- Automated Check-Out - issues related to transition control to the human driver and certifying that vehicle equipment is functioning properly for manual operation.
- Lateral and Longitudinal Control Analysis - technical analyses related to automated vehicle control.
- Malfunction Management and Analysis - analyses related to design approaches for an AHS that is highly reliable and tolerant of faults.
- Commercial and Transit AHS Analysis - issues related to the unique needs of commercial and transit vehicles operating within the AHS.
- Comparable Systems Analysis - an effort to derive "lessons learned" from other system development and deployment efforts with similarities to AHS.
- AHS Roadway Deployment Analysis - issues related to the deployability of possible AHS configurations within existing freeway networks.
- Impact of AHS on Surrounding Non-AHS Roadways - analysis of the overall network impact of AHS deployment and development of mitigation strategies.
- AHS Entry/Exit Implementation - analysis of highway design issues related to the efficient flow of vehicles on and off of the AHS facility.
- AHS Roadway Operational Analysis - issues related to the ongoing operation of an AHS.
- Vehicle Operational Analysis - issues related to the operation of an AHS vehicle, including the retrofitting of vehicles for AHS operation.
- Alternative Propulsion Systems Impact - analysis of possible impacts that alternately propelled vehicles may have on AHS deployment and operation.
- AHS Safety Issues - broad analysis of safety issues pertaining to AHS.
- Institutional and Societal Aspects - broad analysis of the many non-technical issues that are critical to successful deployment of AHS.
- Preliminary Cost/Benefit Factors Analysis - an early assessment of the factors that comprise the costs and benefits of AHS.

Transition-Related Findings

The researchers mostly indicated that an "evolutionary transition" into AHS would be desirable; that is, the evolution should be planned, not occur by chance. A general vision of this evolution was that other partial automated vehicle control (AVC) services would precede the AHS to the marketplace; these services would allow the drivers to become more accustomed to AVC and would give designers more experience in designing AVC products. It was also noted that some of the components needed for these partial AVC services could possibly be used for an AHS; these vehicles would provide a certain level of "market penetration" of vehicles capable of traveling on the AHS lanes. Specific ITS services mentioned for evolution included adaptive cruise control, collision avoidance, and lane keeping. Several researchers, however, cautioned that tying AHS to these services might be risky. These services may not have as broad of an appeal as AHS because they cannot offer the same level of safety, throughput and user comfort. Also, it was noted that designing systems that will work on a roadway with manual drivers may be much more complicated (and expensive) than designing a system that will operate on a roadway dedicated to automated vehicles.

Researchers offered several possible approaches for establishing enough automated vehicles in an area to justify a dedicated AHS lane such as incentives for initial users, fleet conversions, free conversion of buses and HOV vehicles. They believed that once an AHS service began operation, other drivers would see the benefits, and the numbers of potential AHS users would rapidly increase. Once AHS becomes popular, a network of AHS lanes can be established and expanded levels of service can be offered in response to user demands.

Vehicle-Related Findings

Vehicle Design

The performance and reliability of an AHS will be directly influenced by the vehicles that operate on it. The AHS components will be installed on vehicles either at the factory or by retrofit in the field. The vehicles chosen to be equipped for AHS will need to meet certain criteria: they will need electronically actuated steering, braking and engine control; automatic transimissions; and "reasonable" performance. There could conceivably be other safety and performance related criteria as well such as tire type, bumper performance, suspension performance, and cabin-lock control. There will be specifications for both heavy and light vehicles. Initially, it would be expected that AHS-equipped vehicles will be newer models.

Check-In to AHS

Several researchers proposed that vehicles should have on-board self-checking systems that determine if all of the necessary vehicle systems are operative on a continuous basis. As the vehicle attempts to enter the AHS lanes, the roadside check-in processor will communicate with the vehicle to identify it and to verify its operating status (e.g., adequate fuel, sensors and processors operative, communications links open, etc.). Presumably the driver will have been given some indication if the system was not in a "Go" condition before he/she got to the AHS entry point. If the vehicle passes the roadside inspection, then control of the vehicle will be assumed by the AHS system, and the vehicle will be moved onto the AHS lanes. Vehicles that fail the check-in test will be denied entry, and the drivers will be directed to take an exit lane (they may be barred electronically or physically from entering the AHS). These checks will help increase overall AHS reliability, but they cannot detect all conditions such as structural integrity of the exhaust system. Required periodic off-site inspections can help catch some percentage of potential problems, and some researchers suggested that manual visual inspections of vehicles at check-in locations might help. It was suggested that the driver should be responsible for his/her vehicle--responsibilities could be agreed to when the driver is issued an "AHS drivers license".

Lateral Control

Several approaches were analyzed for automatically keeping a vehicle safely in its lane of travel--or lane keeping. The use of magnetic reference points along, or embedded in, the AHS lane appeared to be practical and the most economical; although the actual cost of reliable lane sensing and control will need to be established. Automated lane changing was identified as a potentially difficult maneuver.

Longitudinal Control

It was felt that many approaches exist for controlling a vehicle's throttle and brakes to maintain a safe following distance from the vehicle in front. Again, the ability to provide very high reliability at an economical cost will need to be determined. Safely controlling vehicles at close spacing to increase throughput adds additional design requirements for longitudinal control including more accurate and responsive sensing, faster processing and inter-vehicle communications. One issue is who should pay for components that provide a community with this greater throughput on a single lane?

Obstacle Detection

Detection of obstacles in the AHS roadway appears to be one of the more difficult problems to solve because of the wide variety of obstacles that could be disruptive to traffic flow. Many suggestions were given ranging from vehicle and roadway mounted sensors, to severe fines for drivers who carry items that fall in the roadway, to installation of fences and area detectors to detect animals and other intruders. This area requires further research to define the kinds of potential obstacles and the best way of dealing with them.

Reliability and Maintainability

Vehicle components that contribute to the control of a vehicle's lateral and longitudinal movement--sensors, processors, actuators--must have very reliable operation, and/or must be designed with adequate backup systems. For example, if a vehicle's sensors become inoperative, the system must be able to detect that and be able to switch to backup sensors that can operate until the vehicle is removed from the roadway. Ease of cleaning and repairing AHS components will help increase system attractiveness.

Roadway-Related Findings

Functions

The AHS roadway must be instrumented to some extent. At the least, it must have lane markers, communications beacons, and barriers to minimize the impact of adjacent manual traffic. It may also have processors to coordinate vehicle entry, vehicle exit, and merging and lane change maneuvers; and sensors to detect changing weather conditions, obstacles and incidents.

Roadway Design

An AHS could operate on one of today's highway lanes and, in fact, it is believed that many of the AHS lanes will be existing highway lanes that are converted to AHS. Entry and exit ramps for AHS will require additional construction on most roadways. Transition lanes that are located between the AHS and non-AHS lanes were found to have many safety and throughput disadvantages. There is a large variety of roadway configurations that could be used for an AHS; these are very similar to configurations used for today's highways.

New AHS lane construction could vary substantially from today's roadways, however. Because of the highly accurate lateral control, AHS lanes could be narrower than today's lanes. This accurate control also means that vehicle wheels will always track accurately in the same paths; this means that special construction might be needed to help avoid "grooving". It also means that since the areas between the two tire tracks will not need to support heavy traffic, then fly-overs and below-grade AHS lanes could be constructed as guideways with two narrow concrete strips providing the vehicle support.

Barriers and Breakdown Lanes

Barriers between the AHS lanes and the manual lanes were strongly encouraged to protect the AHS from manual traffic. The barriers would be of particular value in keeping crashes in the manual lanes from impinging into the AHS lanes. Instrumented shoulders or breakdown lanes will be needed either occasionally or continuously, depending on the particulars of the highway. One issue is how to deal with the occupants of vehicles that break down on AHS. If they leave their vehicle, they might create a very dangerous situation unless the system is forewarned and is able to slow, divert or halt traffic flow. But if a vehicle is on fire, the occupants must be able to get out.

Impact on Non-AHS Roadways

The interaction of AHS lanes with the manual streets is a major concern that must be addressed locally; each interchange will have different characteristics. The concern is the volume of entering and exiting AHS traffic and the capacity of the existing surface street network to handle it. An example would be an AHS exit to a central business district that is congested every morning. Researchers demonstrated that the impact of the AHS volume can be mitigated through innovative entry and exit design, possible reconfiguration of the surface streets, and active demand management. The cost of manual roadway modifications will need to be addressed by each locality.

Deployment

The deployment process, other than the construction technique, for a new AHS lane will not differ substantially from deployment of a new manual roadway lane; conversion of an existing lane to AHS should be substantially easier. Support and opposition to the AHS may be similar to what would be experienced with a manual roadway.

Operation and Maintenance

AHS operation and maintenance crews will need to be expanded to encompass the new AHS technologies. The AHS is a sophisticated system that will require frequent and sometimes immediate repair of problems that range from potholes (that the vehicles may not detect and avoid) to communications beacons that become inoperative. In some cases those problems will mean that new skills will need to be added to the departments of transportation. This will also be true for the Traffic Management Centers where AHS monitoring will need to take on added urgency and rapid reaction to occurrences such as obstacles falling off vehicles to intruders that attempt to disrupt the system..

Societal and Institutional Findings

There were several areas of concern that surfaced during the PSA studies in which the opinions of a wide range of interested parties were sought and recognized. Many feel that societal and institutional concerns will be more difficult to resolve than technical issues, and that the outcome of their resolution will have more influence on the overall success of AHS.

AHS must be recognized for what it can contribute to the total spectrum of regional surface transportation needs in traditional transit, commercial, rural and urban, private and evolving public para-transit environments; it should be viewed as a flexible tool available to transportation planners and decision makers when they address the complexities of doing more with what they have. Below, some of the leading societal concerns identified by the researchers are described.

Environmental Impacts

There is a need to continue efforts to understand how AHS can play a positive role regarding air and water quality, and noise. The concern remains that an AHS might encourage/induce more vehicle miles traveled (VMT). If so, then overall emissions and fuel consumption may increase even though emissions are reduced on a per-vehicle-mile basis. ISTEA has provided the framework for addressing these conflicting requirements in the expanded planning role given to MPOs. MPOs should be able to take advantage of special AHS characteristics as they incorporate AHS into their transportation plans. In non-attainment areas, AHS could be used to enhance transit, HOV traffic, congestion management and the introduction of alternative propulsion (low and zero mobile source emission) vehicles.

Equity

Should the system be available to the entire public or just for those who can afford the tolls and/or the AHS-equipped vehicles? A limiting (restrictive) deployment could be subject to criticism even though AHS is expected to reduce congestion on both AHS and non-AHS roads. Each region will need to consider the demographic and economic impacts of its AHS installations.

Land Use and Development.

There are concerns for direct and indirect impacts of AHS on land use. The direct impacts have to do with entry and exit facilities and general infrastructure improvements that will probably be undertaken when an AHS is deployed. Beyond the concerns for the environment and equity described above, there are practical issues for surface street operations, local traffic management, signaling, and maintenance. The researchers concluded that AHS deployment in relatively restricted right-of-ways could be achieved using current highway design practices, although their studies were highly site specific as any actual deployment will also be.

The indirect impacts on regional development are a larger question that the PSA efforts did not address. Planning analyses to identify the effects on land use that an AHS deployment may precipitate will be a necessary part of MPO level deliberations within the ISTEA planning framework. One need is to determine the different impacts (if any) that deploying AHS will bring compared to deploying regular highways and/or light rail. These will be very area-specific as are the predicted benefits such as trip-time value patterns and flexibility in regional development concepts.

Role of the Driver

Concerns identified by the PSA research include:

- To what extent will additional skills be required to use an AHS?
- Will the AHS be a significant aid for senior citizens and the physically impaired who sometimes avoid today's highways and their congestion and stress?
- Will the driver be checked in to AHS as well as the vehicle?
- What sort of responsibility will the driver and passenger have, if any, during regular and emergency conditions?

Who Pays for AHS?

There are numerous and varied options for financing an AHS, as with conventional transportation projects. Below are some of the significant findings:

- While there are many ways in which AHS costs can be covered, it is the structuring and division (this relates to the potential exclusivity of AHS) of these costs that will or will not give the perception of whether it is "worth it."
- To some extent, the AHS infrastructure could be paid for with fuel taxes.
- The financing and building of the AHS infrastructure could be handled by an entity that has the rights and privileges of a public utility.
- The Federal Government could provide support to States for operations and maintenance costs because of the increased level of funds required for these types of activities. The ISTEA of 1991 drew attention to the concept of funding for operations and maintenance.
- The question of who pays also impacts the issue of social equity; for example, would congestion pricing be punitive? Should AHS operation be free? Should only high-occupancy vehicles travel free in rush hours? Should the system offer discounts for use during non-peak periods?

Responsibility for Property Loss, Injury, or Death

When an AHS assumes control of the vehicles, "the system" must also assume some level of liability for the consequences of any malfunction. An AHS will include the instrumented AHS lane and the instrumented vehicles that travel on the AHS lanes. When a failure of the AHS lane occurs and there are losses, the owner and/or operator of the AHS lane may be responsible (i.e., government, utility, toll road operator, etc.). If a failure occurs on a vehicle, determining the responsible party may not be a simple process. The liability could be deemed to lie with the vehicle assembler, the component manufacturer, the vehicle owner (who is responsible for maintaining the equipment), the state and/or Federal government who establishes guidelines and procedures to ensure each vehicle's safe operation, or some, or all of the above. The preliminary reviews of the product liability costs for an AHS have indicated that it can be controlled through careful design, legislation, and cost transfer. Tort liability is also not seen as a 'show stopper' if costs are controlled and safety is secure. The ongoing ITS program will provide some basis for predetermining the conditions for AHS.

Some additional issues include:

- Should Federal legislative protection be sought to limit liability per transaction and the amount of punitive damages that can be awarded?
- Should the user be expected to accept limited liability through a "user agreement" format? Are there driver and vehicle performance indicators that would serve as probable cause for police intervention?
- Can or should a mediation process be established to avoid non-productive lawsuits?

State and Regional Institutional Concerns

The AHS will introduce a new, high-technology level of complexity to those organizations that are responsible for highway functions and services. The AHS lane instrumentation could include advanced electronic sensors, on-line computers and software, and multi-element integrated communications systems. Installation and maintenance of these systems may present a significant challenge to the operators. For example, maintenance of roadside electronics may involve relatively frequent circuit and/or software testing, component replacement, and system integration testing, as the replacement components are brought on-line. An advanced AHS will employ traffic management functions which may involve real time system monitoring; the operators for such a system may need special training. Planning organizations that recommend AHS must realize that the funds for the systems' operations and maintenance must be adequate and must be included in the State's operating budget as a non-negotiable item.

State transportation organizations are evolving. As planning for AHS begins, funds to build up and evolve the State's transportation departments will need to be made available so that technical staff can be hired and trained. Career paths will need to be established, job descriptions created, etc. This front-end cost will increase State DOT costs long before the AHS becomes operational. Facilities management firms could be hired to provide full service management of the AHS infrastructure; however, this could introduce questions regarding the liability of these firms when incidents occur.

Another option raised by the researchers is that of private ownership of AHS roads such as a private toll road. Also, a separate public utility type of organization could be established to fund, build, and maintain AHS, even the part installed in vehicles.

Insurance companies and insurance regulators will need to assess the impact of AHS operation on rates, and programs for inspection of AHS vehicles will need to be established.

National Certification and/or Regulation

National standards for AHS will need to be established to ensure (1) national compatibility among AHS systems that develop regionally; and (2) that minimum levels of safety and performance are met.

It will be necessary to certify that the vehicle manufacturers' products meet the applicable standards. Similarly, as companies design roadside components, those will also need to be certified to ensure that they operate with the vehicles. A national organization or perhaps the US DOT, will need to be designated as the certification agent.

Standards for operation and maintenance of AHS systems will also be needed. This could include standards for periodic vehicle inspection, AHS check-in and AHS maintenance and traffic management and control. PSA findings referenced an appropriate model for regulations arising from a cooperative arrangement between FHWA, NHTSA, the auto manufacturers, and States.

Public Pressures Versus Engineering Realities

A major new system that will directly interact with the general public faces significant pressures from two sides. The engineering of such a system in the general public eye increases the need for very thorough testing to ensure safety, robustness and operability; virtually every possible way of breaking the system must be identified and designed around. The safety of the system must be demonstrated. Such systems are expensive and some may get impatient with its cost and development schedule.

SECTION 1

INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide an overview and assessment of the findings of the Precursor Systems Analyses (PSA) of Automated Highway Systems (AHS). These analyses consist of 15 research contracts that were funded for a total of $14.1 million to investigate the issues and risks related to the design, development and implementation of AHS. The contracts were awarded during the period of July through September 1993 by the AHS Program within the United States Department of Transportation (US DOT). All of the contracts were completed by December, 1994. The complete list of PSA reports is given in table 1; each of these is accessible through the National Technical Information Service (NTIS). These reports, which total over 3,000 pages, provide an unusual variety and breadth of analysis on virtually every aspect of automated vehicle control and its use in an AHS.

The AHS program was initiated in 1992 by the Federal Highway Administration (FHWA) as part of the US DOT's Intelligent Transportation Systems (ITS) program. This Program, which is responsive to the guidance contained in the Intelligent Vehicle Highway Systems (IVHS) portion of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, is a major government-industry-academia collaboration aimed at applying advanced vehicle control technology to the US highway system in order to improve mobility and transportation productivity, enhance safety, maximize the use of existing transportation facilities, conserve energy resources, and reduce adverse environmental effects.

The PSA findings provide valuable information with which the FHWA has been able to further focus and define the scope, characteristics and benefits of automated vehicle control on our nation's highways. In 1993, as the studies were beginning, the FHWA had many unanswered questions such as:

- What is an automated highway?
- What are the benefits of such a system; that is, is our vision of increased efficiency and safety correct?
- Are there any major issues that would impact or inhibit its deployment?
- What are the perceived risks associated with the AHS concept, and to whom are they of concern?

The PSA research has provided a great deal of information on these and many other questions. In some cases, preliminary answers have been given, prompting increased confidence in the likely feasibility of AHS as a major supplement to the nation's surface transportation system in the twenty-first century.

The PSA findings also provide a substantial and credible baseline of AHS information from which the AHS program can be continued by the National Automated Highway Systems Consortium (NAHSC).

1.2 APPROACH FOR CATEGORIZING FINDINGS

This document provides synthesis and assessment—synthesis in that it gives an overall executive summary of the research; and assessment in that the report contains additional observations and assessments formed by MITRE and the US DOT as the PSA research proceeded. There are many PSA findings that are not included; however, the report has attempted to describe and elaborate on the *major* findings in the 71 volumes of research results. The reader is referred to the individual reports summarized in Table 1-1 for more specific findings in a particular area.

1.2.1 Precursor Systems Analysis Database Reference

A database of the major PSA findings has also been created; it is called the *PSA Database* and is described in Appendix D. This database is available to researchers in electronic form. In building the database, a goal was to allow any given finding to be accessed from a variety of perspectives or views. These perspectives define the ways in which a finding can be categorized as follows:

- Program phase or aspect (e.g., deployment, 1997 demonstration)
- System perspective (e.g., safety, efficiency, human interface, user acceptance)
- System function (e.g., lateral control, check-in, flow control, operational mode)
- System component (e.g., infrastructure-surface, vehicle sensors)
- Concept boundary (e.g., location of control logic, type of lateral control, vehicle type)

A PSA finding is classified in the database as an *issue*, a *concern*, a *conclusion*, or a *risk*, where:

- **Issues** result from analyses, but are questions or differences of professional opinion that arise from the analyses. Issues are addressed and resolved through further investigation.

Table 1-1. List of AHS Reports

BATTELLE

- Contract Overview
  - A Urban and Rural AHS Analysis
  - E Malfunction Management and Analysis
  - H AHS Roadway Deployment
  - I Impact of AHS on Surrounding Non AHS Roadways
  - J AHS Entry/Exit Implementation
  - K AHS Roadway Operational Analysis
  - N AHS Safety Issues
  - O Institutional and Societal Aspects

BDM

- Contract Overview
  - F Commercial and Transit Aspects
  - O Institutional and Societal Issues

CALSPAN

Volume I	Overview Report
Volume II	AHS Comparable Systems Analyses
Volume III	AHS Roadway Analysis
Volume IV	AHS Systems Analysis
Volume V	AHS Malfunction Management and Safety Analyses
Volume VI	AHS Alternative Propulsion System Impact
Volume VII	Commercial and Transit AHS Analysis
Volume VIII	AHS Institutional, Societal and Cost Benefit Analysis

DELCO

- A Urban and Rural AHS Comparison
- B Automated Check-In
- C Automated Check-Out
- D Lateral and Longitudinal Control Analysis
- E Malfunction Management and Analysis
- I Impact of AHS on Surrounding Non-AHS Roadways
- J AHS Entry/Exit Implementation
- K AHS Roadway Operational Analysis
- L Vehicle Operational Analysis
- M Alternative Propulsion Systems Impact
- N AHS Safety Issues
- O Institutional and Societal Aspects
- P Preliminary Cost/Benefit Factors Analysis

Table 1-1. Continued

HONEYWELL

- Malfunction Management Activity Area Report for AHS Health Management Precursor Studies Analysis

MARTIN MARIETTA

Volume I Executive Summary
Volume II Maneuver Definition and Functional Requirements
Volume III AHS System Concept Definition
Volume IV AHS System Concept Evaluation
(Note: all in one report binder)

NORTHROP-GRUMMAN

- AHS Check-In Activity

PATH

- Overview
  - A Urban and Rural AHS Comparisons
  - H Roadway Deployment Analysis
  - J Entry/Exit Implementation
  - P Preliminary Cost/Benefit Factors Analyses:
    - Volume I Cost/Benefit Analysis of Automated Highway Systems
    - Volume II System Configurations: Evolutionary Deployment Considerations
    - Volume III Electronics Cost Analysis
    - Volume IV Roadway Costs
    - Volume V Analysis of Automated Highway System Risks and Uncertainties
    - Volume VI Review of Studies on AHS Benefits and Impacts
  - F Commercial and Transit AHS Analysis
  - G Comparable Systems Analysis
  - H AHS Roadway Deployment Analysis

RAYTHEON

Volume I Executive Summary
Volume II Automated Check-In
Volume III Automated Check-Out
Volume IV Lateral and Longitudinal Control
Volume V Malfunction Management and Analysis
Volume VI Commercial Vehicle and Transit AHS Analyses
Volume VII Entry/Exit Implementation
Volume VIII Vehicle Operational Analysis
Volume IX AHS Safety Issues
Volume X Knowledge Based Systems and Learning Methods for AHS

Table 1-1. Concluded

ROCKWELL • Overview • Vehicle Operations Analysis • Malfunction Management and Analysis • Lateral and Longitudinal Control Analysis
SAIC • Legal, Institutional and Societal Issues Related to the Deployment and Operation of an Automated Highway System
SRI • Use of Global Positioning Satellite (GPS) Carrier-Phase Integration for AHS Vehicle Control
TASC • HiVal: A Simulation and Decision Support System for AHS Concepts Analysis
TRW • Alternative Propulsion Systems Impact
U.C.-DAVIS • Automated Construction, Maintenance and Operational Requirements for AHS

- **Concerns** differ from issues in that not enough detail is credibly known for robust opinions to be debated and, given common intent, for a way to proceed to be negotiated. Concerns may be expressed by directly or indirectly interested parties. They may simply express the sense that similar, but not identical, conditions exist for AHS to some which caused difficulty in another project. A concern requires further study to resolve as a conclusion or issue.

- **Conclusions** are findings that are supported by analysis and provide guidance and direction to follow-on activities. They are findings which are complete enough to support a milestone or a certification. Conclusions may close out the line of research that they addressed.

- **Risks** are conclusions that identify potentially negative situations that, if they should happen, could result in system failure or major problems. Risks are managed.

1.2.2 Categorizing Approach in This Document

The category approach in this document views the system as two physical entities—*vehicle* and *infrastructure*. In addition, many findings apply to the system as a whole, not just the vehicle or infrastructure; these findings can, in turn, be categorized as *systems design, transition, institutional and societal,* and *cost and benefit.* There is a separate section for each of these categories.

1.3 REPRESENTATIVE SYSTEM CONFIGURATIONS

For the PSA to have maximum benefit to the US DOT, some assumptions were made regarding the design of the eventual AHS system configuration. Since the purpose of the PSA was to identify issues, concerns, conclusions and risks, more than one design approach was assumed so that issues and risks of a variety of potential solutions could be examined.

There are many characteristics that distinguish one design approach from another; however, the scope of the PSA did not allow an examination of the full set of variations (this is the task of the NAHSC). Each of the contractor teams conducted their analyses under the influence of a few pre-defined sets of potential AHS system configurations, termed "representative system configurations" (RSCs). The RSCs were designed as boundaries of the major design characteristic categories defined above: for example, one design set could be a system in which there is minimum impact on the infrastructure since existing roadways are used; platoons with close headway are used; most instrumentation is in the vehicle; and most AHS lanes operate at normal speed, but selected lanes are operated at high speeds.

Since the use of the RSCs was only for the PSA, they are defined only to the level of detail needed to perform the analyses.

Throughout the individual activity area studies, the contractor teams applied their research within the framework of RSCs developed by their team or one of the other contractor teams. These RSCs gave the individual activity areas and the overall studies a broad framework from which to investigate issues and risks.

The RSCs used in the PSA are defined in table 1-2. Distinguishing characteristics of each RSC and the contractor team that developed and/or used them is highlighted in the table. The characteristics and the descriptors used in describing them all are defined below:

- **Infrastructure Impact** Includes the sub-categories of *Passive Infrastructure* and *Active Infrastructure*. - Describes the amount of construction required to implement the AHS. This includes factors such as modification of existing roadways, construction of new roadways and lanes, entry and exit point construction, and land

- **Traffic Synchronization** - Includes the sub-categories of *Highly Synchronized, Asynchronous Operation*, and *Mixed.* Describes the degree of synchronization of AHS traffic. Highly synchronized systems would encompass concepts such as platooning with short headway, or the assignment of space/time slots on the roadway by a supervisory system. Asynchronous operation would rely on each vehicle to negotiate with adjacent vehicles on an ad hoc basis to perform lateral and longitudinal control.

- **Instrumentation Distribution** - Includes the sub-categories of *Smart Vehicle, Smart Roadway*, and *Mixed.* Describes the degree of distribution of the AHS instrumentation between the vehicle and the roadway. This distribution can range between a system in which virtually all instrumentation is part of the AHS roadway, to a system in which the instrumentation is virtually all on the vehicles and the roadway has little if any instrumentation.

- **Operating Speed** Includes the sub-categories of *Low, High*, and *Variable by Conditions.* - This refers to the maximum system operating speed up to which the AHS can safely perform.

- **Vehicle Classes** - Includes the sub-categories of *Light* and *Heavy.* Light vehicles include light trucks and vans. Heavy vehicles include heavy trucks and buses.

- **Power** - Includes the sub-categories of *On-Board* and *Roadway Provided Electric. On-Board* implies that the power requirements of the vehicle are supplied by power systems on-board the vehicle. *Roadway Provided Electric* implies that the roadway provides the power necessary for the vehicle to operate on the automated roadway.

- **Headway Strategy** - Includes the sub-categories of *Single Vehicles Only* and *Platoons Possible. Single Vehicles Only* implies that vehicles are not allowed to form into groups to travel along the automated highways. *Platoons Possible* implies that vehicles are allowed (or commanded) to form groups of two or more vehicles in which to travel along the automated highway.

- **Lateral Control Strategy** - Includes the sub-categories of *Passive Infrastructure* and *Active Infrastructure. Passive Infrastructure* means that lateral control of the vehicle is accomplished through detection of an infrastructure feature that is not electrically activated, such as a barrier, painted stripes or magnetic nails. *Active Infrastructure* means that lateral control is accomplished through interaction with an element of the infrastructure that is activated such as embedded wire or roadside beacons.

- **Longitudinal Control Strategy** - Includes the sub-categories of *Rubber Tire* and *Pallet. Rubber Tire* implies conventional vehicle/road interaction where each vehicle travels on its own rubber tires. *Pallet* implies that individual vehicles are transported on some type of pallet.

- **Control Location** - Includes the sub-categories of *Mostly Vehicle, Mostly Infrastructure*, and *Combined. Mostly Vehicle* implies that the overall control of the AHS system is accomplished mainly through functions performed within the individual vehicles traveling in the system. *Mostly Infrastructure* implies that the overall control of the AHS system is accomplished mainly through functions performed within the infrastructure. *Combined* implies that the overall control of the AHS system is shared between functions performed within the vehicles and functions performed within the infrastructure.

- **AHS Lanes and Access** - Includes the sub-categories of *Transition Lane to Parallel AHS, Ramp to Dedicated AHS*, and *Mixed Partial, and Automated. Transition Lane to Parallel AHS* implies that vehicles transition from manual to automated mode and from automated to manual mode through the use of a transition lane parallel and adjacent to an AHS lane. *Ramp to Dedicated AHS* implies that vehicles enter and exit from the AHS through the use of dedicated AHS ramps. *Mixed Partial and Automated* implies that vehicles freely transition between automated and partially automated or non-automated operation on the AHS. This includes the concept of individual automated vehicles operating on a non-dedicated AHS together with manually controlled vehicles.

Shaded cells in Table 1-2 indicate characteristics that distinguish the RSC identified by the column heading. Some of the AHS characteristic categories listed above are unshaded for certain RSCs. This indicates that the particular category was not specified in the RSC description.

1.4 ORGANIZATION OF THE REPORT

Section 2 provides an overview of the AHS program and how the PSA efforts fit into it. Section 3 synthesizes the findings that relate to the overall system design and operation; this includes the overall AHS vision, safety, malfunction management, and operations. Section 4 focuses on transition-related findings; these address the evolutionary aspects of controlling vehicles and vehicle types, and the introduction of levels and regional applications of services. Sections 5 and 6 synthesize the major findings that are specifically related to vehicle and infrastructure design and operation, respectively.
The balance of the report deals with specific institutional and societal aspects of AHS such as AHS management, emissions and user acceptance (section 7); and some early thoughts on benefits and costs (section 8).

Appendices contain the specific synthesis reports from the two largest PSA contractor teams, Delco and Calspan, as delivered to the PSA Results Conference in November 1994. And for completeness, the summary of the Interim Results Workshop Discussion and Findings from April 1994. Finally, Appendix D contains a description of the PSA Database.

1.5 REFERENCES

References are given throughout the text. These references provide pointers to work done by specific PSA researchers that relate to the subject issue, conclusion, or concern. The references , while not exhaustive, do point to key research that relates to the material. When the material shown is a researcher statement, the material is shown in quotes.

Table 1-2. Summary of Representative System Configurations

AHS CHARACTERISTIC	Battelle RSC#1	Battelle RSC#2	Battelle RSC#3	Battelle RSC#4	BDM	Calspan RSC#1 *I1 C1 V1*	Calspan RSC#2 *I1 C1 V3*
Infrastructure Impact					Using		
High	■	■	■	■	Battelle		
Low		■	■	■	RSCs	■	■
Traffic Synchronization							
Highly synchronized	■						
Asynchronous operation		■	■	■		■	■
Mixed							
Instrumentation Distrib.							
Smart Vehicle		■	■	■		■	■
Smart Roadway	■						
Mixed							
Operating Speed							
Low						■	■
High							
Variable by conditions	■	■	■	■			
Vehicle Classes							
Light	■	■	■	■		■	■
Heavy							■
Vehicle/Road Interaction							
Rubber Tire	■	■		■		■	■
Pallet			■				

Table 1-2. (continued)

AHS CHARACTERISTIC	Battelle RSC#1 (con'd)	Battelle RSC#2 (con'd)	Battelle RSC#3 (con'd)	Battelle RSC#4 (con'd)	BDM (con'd)	Calspan RSC#1 (con'd) *I1 C1 V1*	Calspan RSC#2 (con'd) *I1 C1 V3*
Power					**Using**		
On-board	■	■	■	■	**Battelle**	■	■
Roadway provided electric					**RSCs**		
Headway Strategy							
Single vehicles only	■		■	■			
Platoons possible		■		■			
Lat. Control Strategy							
Passive infrastructure	■	■	■	■		■	■
Active infrastructure							
Long. Control Strategy							
Passive infrastructure		■	■	■		■	■
Active infrastructure	■						
Control Location							
Mostly vehicle		■	■	■		■	■
Mostly infrastructure	■						
Combined							
AHS Lanes and Access							
Transition lane to parallel AHS	■	■	■	■			
Ramp to dedicated AHS	■	■	■	■			
Mixed partial and automated	■			■		■	■

Table 1-2. (continued)

AHS CHARACTERISTIC	Calspan RSC#3 *I2 C1 V1*	Calspan RSC#4 *I2 C1 V2*	Calspan RSC#5 *I2 C2 V1*	Calspan RSC#6 *I2 C2 V2*	Calspan RSC#7 *I2 C2 V3*	Calspan RSC#8 *I3 C1 V1*	Calspan RSC#9 *I3 C2 V1*
Infrastructure Impact							
High						■	■
Low	■	■	■	■	■		
Traffic Synchronization							
Highly synchronized							
Asynchronous operation	■	■				■	
Mixed			■	■	■		■
Instrumentation Distrib.							
Smart Vehicle	■	■				■	
Smart Roadway							
Mixed			■	■	■		■
Operating Speed							
Low							
High							
Variable by conditions	■	■	■	■	■	■	■
Vehicle Classes							
Light	■	■	■	■	■	■	■
Heavy		segregated, except transitions		segregated, except transitions	■		
Vehicle/Road Interaction							
Rubber Tire	■	■	■	■	■	■	■
Pallet							

Table 1-2. (continued)

AHS CHARACTERISTIC	Calspan RSC#3 (con'd) *I2 C1 V1*	Calspan RSC#4 (con'd) *I2 C1 V2*	Calspan RSC#5 (con'd) *I2 C2 V1*	Calspan RSC#6 (con'd) *I2 C2 V2*	Calspan RSC#7 (con'd) *I2 C2 V3*	Calspan RSC#8 (con'd) *I3 C1 V1*	Calspan RSC#9 (con'd) *I3 C2 V1*
Power							
On-board	■	■	■	■	■	■	■
Roadway provided electric							
Headway Strategy							
Single vehicles only							
Platoons possible							
Lat. Control Strategy							
Passive infrastructure	■	■	■	■	■	■	■
Active infrastructure							
Long. Control Strategy							
Passive infrastructure	■	■				■	
Active infrastructure			■	■	■		■
Control Location							
Mostly vehicle	■	■				■	
Mostly infrastructure							
Combined			■	■	■		■
AHS Lanes and Access							
Transition lane to parallel AHS	■	■	■	■	■		
Ramp to dedicated AHS						■	■
Mixed partial and automated							

Table 1-2. (continued)

AHS CHARACTERISTIC	Calspan RSC#10 *I3 C2 V2*	Calspan RSC#11 *I3 C2 V3*	Calspan RSC#12 *I3 C3 V1*	Calspan RSC#13 *I3 C3 V4*	Delco RSC#1	Delco RSC#2	Delco RSC#3
Infrastructure Impact							
High	■	■	■	■	■		■
Low						■	
Traffic Synchronization							
Highly synchronized			■	■			■
Asynchronous operation					■	■	
Mixed	■	■					
Instrumentation Distrib.							
Smart Vehicle						■	
Smart Roadway					■		
Mixed	■	■	■	■			■
Operating Speed							
Low							
High						■	
Variable by conditions	■	■	■	■	■		■
Vehicle Classes							
Light	■	■	■	■	■	■	■
Heavy	segregated, except transitions	■					■
Vehicle/Road Interaction							
Rubber Tire	■	■	■	■	■	■	■
Pallet							

Table 1-2. (continued)

AHS CHARACTERISTIC	Calspan RSC#10 (con'd) *I3 C2 V2*	Calspan RSC#11 (con'd) *I3 C2 V3*	Calspan RSC#12 (con'd) *I3 C3 V1*	Calspan RSC#13 (con'd) *I3 C3 V4*	Delco RSC#1 (con'd)	Delco RSC#2 (con'd)	Delco RSC#3 (con'd)
Power							
On-board	■	■	■	electric only	■	■	■
Roadway provided electric				■			
Headway Strategy							
Single vehicles only							■
Platoons possible					■	■	
Lat. Control Strategy							
Passive infrastructure	■	■				■	■
Active infrastructure			■	■	■		
Long. Control Strategy							
Passive infrastructure							
Active infrastructure	■	■	■	■	■		■
Control Location							
Mostly vehicle						■	
Mostly infrastructure			■	■	■		
Combined	■	■					■
AHS Lanes and Access							
Transition lane to parallel AHS							■
Ramp to dedicated AHS	■	■	■	■	■	■	
Mixed partial and automated							

Table 1-2. (continued)

AHS CHARACTERISTIC	Honeywell	Honeywell	Martin Marietta	Northrop	PATH
	RSC#1 *Base Configuration*	RSC#2 *Alternate Configuration*			Will vary the following highlighted characteristics
Infrastructure Impact			Will	Will work	
High			review	within	
Low			RSCs of	other	
			Calspan	RSCs	
Traffic Synchronization			& Delco		
Highly synchronized			and use		
Asynchronous operation			modified		
Mixed			versions		
Instrumentation Distrib.					
Smart Vehicle					
Smart Roadway					
Mixed					
Operating Speed					
Low					
High					
Variable by conditions					
Vehicle Classes					
Light					
Heavy					
Vehicle/Road Interaction					
Rubber Tire					
Pallet					

Table 1-2. (continued)

AHS CHARACTERISTIC	Honeywell	Honeywell	Martin Marietta	Northrop	PATH
	RSC#1 (con'd) *Base Configuration*	RSC#2 (con'd) *Alternate Configuration*	(con'd)	(con'd)	(con'd) Will vary the following highlighted characteristics
Power			Will	Will work	
On-board	■	■	review	within	■
Roadway provided electric			RSCs of	other	
			Calspan	RSCs	
Headway Strategy			& Delco		
Single vehicles only		■	and use		
Platoons possible	■		modified		■
			versions		
Lat. Control Strategy					
Passive infrastructure	■	■			■
Active infrastructure					
Long. Control Strategy					
Passive infrastructure					■
Active infrastructure	■	■			
Control Location					
Mostly vehicle					
Mostly infrastructure					
Combined	■	■			■
AHS Lanes and Access					
Transition lane to parallel AHS	■				■
Ramp to dedicated AHS	■	■			■
Mixed partial and automated					

Table 1-2. (continued)

AHS CHARACTERISTIC	Raytheon RSC#1 *1) Designated Entry/Exit -- Low Infrastr.*	Raytheon RSC#2 *2) Continuous Entry/Exit -- Low Infrastr.*	Raytheon RSC#3 *3) Designated Entry/Exit -- High Infrastr.*	Raytheon RSC#4 *2a) Continuous Entry/Exit -- High Infrastr.*	Rockwell RSC#1 *IWSM/BT*	Rockwell RSC#2 *IWSM/DE*
Infrastructure Impact						
High			■	■	■	
Low	■	■				■
Traffic Synchronization						
Highly synchronized			■	■	■	■
Asynchronous operation	■	■				
Mixed						
Instrumentation Distribution						
Smart Vehicle	■	■				
Smart Roadway			■		■	■
Mixed				■		
Operating Speed						
Low						
High						
Variable by conditions	■	■	■	■	■	■
Vehicle Classes						
Light	■	■	■	■	■	■
Heavy	■	■	■	■	■	■
Vehicle/Road Interaction						
Rubber Tire	■	■	■	■	■	■
Pallet			■			

Table 1-2. (continued)

AHS CHARACTERISTIC	Raytheon RSC#1 (con'd) *1) Designated Entry/Exit -- Low Infrastr.*	Raytheon RSC#2 (con'd) *2) Continuous Entry/Exit -- Low Infrastr.*	Raytheon RSC#3 (con'd) *3) Designated Entry/Exit -- High Infrastr.*	Raytheon RSC#4 (con'd) *2a) Continuous Entry/Exit -- High Infrastr.*	Rockwell RSC#1 (con'd) *IWSM/BT*	Rockwell RSC#2 (con'd) *IWSM/DE*
Power						
On-board	■	■	■	■	■	■
Roadway provided electric						
Headway Strategy						
Single vehicles only		■				
Platoons possible	■		■	■	■	■
Lat. Control Strategy						
Passive infrastructure	■	■			■	■
Active infrastructure			■	■		
Long. Control Strategy						
Passive infrastructure	■	■			■	■
Active infrastructure			■	■		
Control Location						
Mostly vehicle	■	■				
Mostly infrastructure			■		■	■
Combined				■		
AHS Lanes and Access						
Transition lane to parallel AHS		■		■	■	■
Ramp to dedicated AHS	■		■		barrier transitions	
Mixed partial and automated						

Table 1-2. (continued)

AHS CHARACTERISTIC	Rockwell RSC#3 *VWAM/BT*	Rockwell RSC#4 *VWAM/DE*	SAIC RSC#1 *Subordinate Control System*	SAIC RSC#2 *Autonomous Control System*	SAIC RSC#3 *Combined Control System*
Infrastructure Impact					
High	■		■	for segregated	for segregated
Low		■		■	■
Traffic Synchronization					
Highly synchronized			■		
Asynchronous operation	■	■		■	
Mixed					■
Instrumentation Distrib.					
Smart Vehicle	■	■		■	
Smart Roadway			■		
Mixed					■
Operating Speed					
Low					
High					
Variable by conditions	■	■	■	■	■
Vehicle Classes					
Light	■	■	■	■	■
Heavy	■	■	■	■	■
Vehicle/Road Interaction					
Rubber Tire	■	■	■	■	■
Pallet					

Table 1-2. (continued)

AHS CHARACTERISTIC	Rockwell RSC#3 (con'd) *VWAM/BT*	Rockwell RSC#4 (con'd) *VWAM/DE*	SAIC RSC#1 (con'd) *Subordinate Control System*	SAIC RSC#2 (con'd) *Autonomous Control System*	SAIC RSC#3 (con'd) *Combined Control System*
Power					
On-board	■	■	■	■	■
Roadway provided electric					
Headway Strategy					
Single vehicles only					
Platoons possible	■	■	■	■	■
Lat. Control Strategy					
Passive infrastructure	■	■		■	
Active infrastructure			■		■
Long. Control Strategy					
Passive infrastructure	■	■		■	
Active infrastructure			■		■
Control Location					
Mostly vehicle	■	■		■	
Mostly infrastructure			■		
Combined					■
AHS Lanes and Access					
Transition lane to parallel AHS	■	■	■	■	■
Ramp to dedicated AHS	barrier transitions		■	■	■
Mixed partial and automated				■	■

Table 1-2. (continued)

AHS CHARACTERISTIC	SRI	TRW	TASC	UC Davis
Infrastructure Impact	Will work	Will work	Will work	Will work
High	within	within	within	within
Low	other	other	other	other
	RSCs	RSCs	RSCs	RSCs
Traffic Synchronization				
Highly synchronized				
Asynchronous operation				
Mixed				
Instrumentation Distrib.				
Smart Vehicle				
Smart Roadway				
Mixed				
Operating Speed				
Low				
High				
Variable by conditions				
Vehicle Classes				
Light				
Heavy				
Vehicle/Road Interaction				
Rubber Tire				
Pallet				

Table 1-2. (concluded)

AHS CHARACTERISTIC	SRI	TRW	TASC	UC Davis
	(con'd)	(con'd)	(con'd)	(con'd)
Power	Will work	Will work	Will work	Will work
On-board	within	within	within	within
Roadway provided electric	other	other	other	other
	RSCs	RSCs	RSCs	RSCs
Headway Strategy				
Single vehicles only				
Platoons possible				
Lat. Control Strategy				
Passive infrastructure				
Active infrastructure				
Long. Control Strategy				
Passive infrastructure				
Active infrastructure				
Control Location				
Mostly vehicle				
Mostly infrastructure				
Combined				
AHS Lanes and Access				
Transition lane to parallel AHS				
Ramp to dedicated AHS				
Mixed partial and automated				