NATIONAL AUTOMATED HIGHWAY SYSTEM CONSORTIUM (NAHSC)

WORKSHOP #3 BREAKOUT SESSION SUMMARY REPORT

SEPTEMBER 19-20, 1996

National Automated Highway System Consortium
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Document Summary:

This workshop was designed to support the process of refining the definition of the AHS concept(s) to be brought forward from Task C2 (Downselect System Configurations) to Task C3 (Develop Candidate System Designs). As such, the emphasis was on analyses that seek to discriminate among the alternative concept attributes, to try to ascertain stakeholder priorities for AHS.

The points of view that were expressed in the workshop's breakout sessions were very diverse, and very analogous to the discussions that have been held internally among the NAHSC Core Participants. This means that the large majority of the issues that were brought up by the workshop participants had already been discussed in one form or another within the NAHSC. It remained very important to hear these issues expressed directly by the stakeholder participants in the Workshop.

<u>Several general trends were evident from the discussions:</u>
(a) The stakeholders were generally more interested in understanding the differences between AHS and more conventional alternatives to AHS, and were seeking absolute comparisons between AHS and non-AHS, rather than comparisons among different kinds of AHS. These issues are extremely important, but in many cases will not be possible to explain authoritatively until substantially later in the NAHSC work program.

(b) In general, participants were more interested in discussing the partial automation associated with near-term driver warning and assistance systems than the fully-automated AHS. The NAHSC work has not yet progressed to the stage that the benefits of full automation and the limitations of partial automation could be explained convincingly enough. This led to an emphasis on "incrementalism" in the discussions of AHS development and deployment, since the larger picture was not so readily discernible. The primary concern was that each step in the deployment sequence be of manageable size and scope.

(c) The participants did not expect the AHS development and deployment to follow any single sequence, but rather to proceed in different ways for different kinds of locations, applications and user categories. This does not make it easy to narrow down the alternatives at this early stage of AHS definition, but is a very important consideration to keep in mind from the start.

A limited number of specific conclusions came forward from the workshop breakout discussions, and these tended to be narrow in scope, but there was a wide range of recommendations about the further analyses and studies that are needed.

Conclusions:

Technical issues:
(a) Explore the non-uniform-spacing cooperative vehicle following approach in depth;
(b) Humans perform poorly when they only have monitoring functions and malfunctions are rare events, and this is of prime importance for partial automation concepts;
(c) Study innovative highway construction materials and techniques and the potential for AHS-unique infrastructure designs.

Deployment issues:
(a) Start seeking deployment champions early (DOTs, transit and commercial vehicle operators), and look for special deployment opportunities (CVO or HOV corridors);
(b) Expect very diverse attitudes and approaches to deployment of new systems such as AHS because of the diversity of the potential deployers;
(c) Consider AHS implications for separating light and heavy vehicle traffic (propounded by advocates of both truck-only and auto-only AHS);
(d) Provide "building block" options for deployment of AHS to meet the expected diversity of preferences;
(e) Emphasize market forces leading toward AHS deployment, and use policy initiatives to catalyze and supplement them when necessary;
(f) Apply a "decision tree" model for local consideration of deployment options and timing;
(g) Consideration of human factors issues must be coupled very closely to deployment sequencing decisions;
(h) Emphasize standards needed for vehicle/vehicle and vehicle/roadside interoperability, consistent human/machine interfaces, and safety-critical systems;
(i) Timing of standardization is crucial;
(j) Consider separate rights-of-way for AHS (completely separate from existing highways) only in non-urban environments;
(k) Liability is a major concern for deployment of fully automated systems, especially in mixed traffic.

Issues to address in further AHS studies:

Throughput and travel time studies:
(a) Compare AHS performance to the best current freeway operations, not average
(b) Analyze multiple-lane AHS, not only single lane
(c) Study bad weather conditions as well as good weather
(d) Study effects of incidents (including, but not only, crashes) on throughput
(e) Study total trip time effects, not only travel time on AHS part of trip
(f) Do case studies with real data, not hypothetical
(g) Study traffic effects at first local signalized intersection by each AHS entry or exit
(h) Quantify benefits of AHS relative to non-AHS alternatives
(i) Study the regional effects of AHS, not just the local effects

Safety analyses:
(a) Consider more crash types than we have so far
(b) Study lateral dynamics effects and multiple-vehicle crashes, not just first crash
(c) Consider total safety for comparison with conventional system, including failure rates
(d) Include property damage effects of crashes
(e) Derive component specs from system safety specs.

Infrastructure cost analyses:
(a) Harmonize assumptions across all analyses (such as ramp lengths)
(b) Use real case study data, not just hypothetical cases
(c) Include issues of construction staging and financing
(d) Concentrate on costs peculiar to AHS, not generic construction costs for HOV-like facilities.

Societal, institutional, energy and environmental studies:
(a) Revisit land use issue
(b) Consider who benefits and who loses from AHS
(c) Broaden environmental analyses to include effects on ramps, local streets, VMT and cold starts
(d) Pay serious attention to the region-wide impacts of AHS, in all its implications
(e) Pay attention to liability concerns for both vehicle and infrastructure providers.

Mixed traffic operations:
(a) Define the hazards that the vehicles must be able to cope with
(b) Define the human interface for activation and deactivation of the automated system, particularly to ensure the driver's mode awareness
(c) Define how much safer than today's travel it should be
(d) Determine how safe automated operations could be in mixed traffic
(e) Collect more data on incidents and crashes to better understand the driving environment.

Infrastructure development:
(a) Gather more complete information about importance of shoulders for operations
(b) Define check-in and check-out requirements before designing infrastructure
(c) Study both "building up" and "building out" alternatives for AHS interchanges

Human Factors:
(a) Explicitly address human factors assumptions and requirements in system definition
(b) Study driver roles in each of the partial automation steps that might lead toward full automation.

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AHS WORKSHOP 3 - BREAKOUT SESSION 1A - THROUGHPUT AND TRAVEL TIME ANALYSES	
Date:	19 September 1996
Domain Experts	Mark Miller, PATH
Moderator:	Carol Jacoby, Hughes
Recorder:	Tom McKendree, Hughes

SESSION

This session presented stakeholders with a C2 analysis that measured throughput and travel time.

KEY FEEDBACK

Stakeholders felt that the Consortium should better distinguish between "capacity" and "throughput." Many felt the usage of the two words was confusing, and that the analysis shown was adequate for "capacity" comparisons between approaches for AHS, but not sufficient to make comparisons between AHS and real manual lanes. Stakeholders commented, “If comparisons to ‘manual’ lanes are done, those manual lanes should be to the AHS alternative well-managed, metered lanes with 2200 to 2500 vplvh.

For operations on U.S. highways without modification, the operating speed of interest was 40-70 mph. This was followed by general opposition to having the trade-off space extend above 90 mph or as low as 20 mph.

Some felt that automated "tailgating" would make manual operators nervous, and thus no throughput gain can be expected from AHS on mixed-with-manual lanes.

Based on the data shown, autonomous vehicles without communications on dedicated lanes should be eliminated as an option. Non-Uniform Cooperative appeared to be the approach attendees favor the NAHSC to pursue.

ADDITIONAL FEEDBACK

One person uses "capacity" to mean the maximum number of vehicles (per hour) a road can carry, and "throughput" to mean the actual number of vehicles (per hour) that travel on the roadway. One person uses "throughput" to mean total vehicle miles traveled. Results that say maximum capacity occurs at 20-30 mph do not accord with experience, and were not considered plausible. That throughput for autonomous could, at any regime, be less than the throughput actually achieved by manual vehicles, was counter-intuitive and taken by some individuals to mean that the analysis had some hidden flaw.

According to different audience members, throughputs of well-managed, metered freeways might be:

- 2200 vplph
- 2400-2500 vplph at 50 mph.
- 2300-2400 vplph (would be greater if you slowly add vehicles from zero, but that number would be inappropriate)
- 2200-2300 passenger cars per lane per hour

Vehicles on such a highway may, however, be driving at unsafe (i.e., too close) spacing. Indeed drivers today may drive at unsafe close spacings. Some felt that degradation due to incidents could be the dominant factor in assessing AHS capacity. One person thought this would particularly degrade platooning capacity. Others felt that the meaningful throughput benefits of AHS could be that AHS has fewer incidents, and thus fewer incident-induced delays.

Throughput has to be considered on a 24 hour-a-day, 365 day-a-year basis, not just peak times. There is no sufficiently detailed analysis to claim that we have determined what the throughput would actually be in a deployed AHS.

The merging analysis does not model an upstream exit. That exit should create gaps, which should help with merging. A 1-mile merge lane is unacceptably long.

Many participants distrusted the platooning throughput analysis, because the intra-platoon spacings were independent of the braking distribution.

If taken to excess, sorting light-duty vehicles into different kinds of platoons with vehicles of similar capabilities could result in a "Porsche" platoon, which could be so rare that some vehicles would wait for hours.

Since the Houston case study is the furthest along, it might be the best for looking at total trip time benefit of AHS and the impact of AHS output on immediate surface streets. An autonomous-mixed-with manual system has a requirement, for customer acceptability, that it achieve individual performance (e.g., individual trip times) equivalent to that achieved by aggressive manual drivers.

The sudden stop vignette may be too academic a scenario to base requirements on, and not significant in the real world.

Autonomous mixed-with-manual looks like the first incremental step. An important consideration is that in the mixed traffic analysis we need more understanding of what is going on today.

A single lane AHS may not have adequate benefits, due to the problem of one slow vehicle backing up traffic. This is one reason why it is important to perform multi-lane throughput analysis.

STAKEHOLDER QUESTIONS

On chart 5-26, did the derivation of the curves for the 10 & 2 vehicle platoons include the distribution of braking capabilities?

Yes. [Later Datta added that intra-platoon spacing was designed without guaranteeing that no hard braking failure could cause a collision.]

For throughput, was the design for ideal performance or worst case?

Worst case.

What are you going to use these [throughput analyses] for?

Comparison of AHS concepts.

Please add a comparison case to chart 5-18?

The results in 5-18 are ideal, and data on actual roads is not a valid comparison.

Why is the best capacity [for AHS lanes] at 20-30 mph? Capacity is based on safe spacing—how close can you pack the vehicles?

It is quadratic. For higher speeds, the increased spacings more than offset the speed advantage for throughput.

Are the merging vehicles traveling at the same speed?

No, there is a speed differential between the mainline and the merge lane.

You have non-uniform spacing. Do you have any analysis of how much it would cost to measure braking capabilities of vehicles?

We are actively researching this in the technology task.

The worst case safety analysis looks only pair-wise. In platooning, everyone also knows the platoon leader's data. In these analyses, are any acceleration characteristics considered?

Yes.

Maneuver coordination sounds like a high level of cooperation. What is the difference between Low Cooperation and High Cooperation?

High cooperative allows acceleration data (i.e., real-time, on-board acceleration measurements) to be passed between vehicles.

On slide 34, why is there a dip in the 45 mph curve?

An automated vehicle follows a manual vehicle at a greater range than a manual vehicle follows a manual vehicle (due to the 1/2 second headway of buffer space added to the automated following automated headway when automated follows manual, added to account for possible erratic manual driver behavior). At low-market penetrations, an automated vehicle is probably following a manual vehicle.

STAKEHOLDER REQUESTS

- Show the analysis results in a space-time distribution ("the old car following diagram"). Derive how the performance of Cooperative Non-Uniform braking varies as the braking distribution is restricted.

- Determine the cost of estimating and passing braking capability information between vehicles

- Examine the costs and benefits of sorting light-duty vehicles into different kinds of platoons with vehicles of similar capabilities.

- Examine the benefits of mixed-with-manual operations.

- Examine the effect of incidents on AHS capacity. Consider the effects of bad weather on throughput and travel times.
- Determine the distribution of acceleration characteristics of the vehicles on the highway (similar to the work already done to assess the distribution of braking characteristics) and assess its impact.

- Determine in a case study:

  1) What is the total trip time benefit (parked origin to parked destination, not AHS entry to AHS exit) of AHS?
  2) What is the impact at the first signalized intersection of releasing the output of AHS onto the surface streets?

AHS WORKSHOP 3 - BREAKOUT SESSION 1B - SAFETY ANALYSES	
Date:	19 September 1996
Domain Experts	Raja Sengupta, PATH
Moderator:	Jim Lewis, Hughes
Recorder:	Asfand Siddiqui, Caltrans

SESSION

This session focused on vehicle-to-vehicle collisions. Every type of accident was not considered within the analysis due to the focus of the session.

KEY FEEDBACK

The perception of many people is that AHS will have a much lower probability of accidents occurring, but at a higher severity rate, much like airline accidents. For others, it appeared difficult to believe that a closely spaced platoon could be safer than today's transportation.

In addition, stakeholders feel that the news media might project AHS as a system in which a large number of low-severity incidents are created, and unless this perception or possible problem is confronted, people may not support AHS. However, stakeholders feel if AHS vehicles were designed with features like larger bumpers in order to absorb minor bumps and incidents, and if people are aware that vehicles might bump one another, users might accept it without making a lot of noise.

ADDITIONAL FEEDBACK

The Demonstration Team should consider demonstrating some of the results and/or validate results using simulators rather than analysis. Analysis have a very narrow set of assumptions. Virginia Tech's vehicle simulator concluded that people adapt to 90 MPH travel at 1.5 meter spacing rather quickly.

STAKEHOLDER QUESTIONS

Once they adapt to closer headways and higher speeds what happens when they go back to normal streets?

A study performed by Honeywell on the Iowa Driving Simulator did indicate that there might be a carry-over effect when transitioning from automatic to manual driving. In addition, this study showed there may be more carry-over of short spacings. Simple mitigation techniques, such as warning the driver when this behavior manifests itself, may be sufficient to assess problem.

If the safety team comes up with 50 cm headway then will the tech team be able to do it?

If a safety study determined there was a significant benefit, then the Consortium will definitely try to provide the required technology and control algorithms.

How can you make people believe that a close intra-platoon distance is safe?

The safety of this and all other aspects of an AHS must be verified through analysis, test, and controlled operation.

If an AHS operates with three meter intra-platoon spacing and people do not feel comfortable, how will component suppliers be able to sell their products?

Again, the safety of the system will have to be demonstrated sufficiently before people will accept it, and buy it. In the case of spacing, perhaps the system will begin operations with much greater spacing. Then as people become accustomed to and trusting of the computers operating the vehicle, they will allow the spacing to be reduced so that throughput can be increased.

Where do you get data about vehicle dynamic model and braking rates?

This data is derived from industry information, including information from the vehicle manufacturers and from testing organizations.

Has there been any work on a mixed class model? If so, what were the results?

Analysis of throughput with different classes of vehicle on the road have been performed by the Consortium and are available. However, the Consortium has always considered mixing of classes of vehicles within a platoon too dangerous.

Consumer reports does all its tests on a test track. Real world pavement conditions are very different. In your analysis, did you consider this fact?

There are many pavement factors which will degrade braking rates, including weather related factors. The AHS must adapt to all of these factors to maintain safe operations.

What if the car in front brakes for a short while which might cause the following car to jam its brakes resulting in trouble. Have you considered nuisance braking?

Nuisance braking, by manually driven cars, is of major concern in mixed traffic conditions. This is, of course, just one of the nuisance behaviors that manual drivers can and will exhibit. The sum total of these dangerous behavior patterns is one reason why automation in mixed traffic such a difficult proposition. If manual drivers are excluded (by the use of lanes dedicated to automated vehicles) then these types of behaviors will only result from system failures. The system must be built so these failures are extremely rare, or it will not succeed.

Have you thought about driver override?

This is a serious problem which is high on our list. However, the answer is not necessarily simple and the trick will be to provide a safe driver override capability.

Have you worked on a one lane-scenario?

Yes, any AHS will contain one lane portions, even though it may only be on the on and off ramps. It is likely that the first deployment of AHS will be in a largely one lane system.

What will happen when a boulder rolls on that lane?

For any obstruction, there are two possible approaches to avoiding a collision with it—either stop or maneuver around it. Of course, if there is not sufficient room to maneuver around it (a large boulder on a single lane) then the only option is to stop. Our design must do everything possible to first prevent the boulder, to detect it as early as possible, and to provide for the maximum safe ability of a vehicle to stop or maneuver around it.

The word "severity" is not clearly defined. What assumptions are you making to define it?

At the moment we are relating severity to the square of the difference of velocity between the two colliding vehicles. The square of the velocity is proportional to the energy in the moving vehicles. We have tried other measures of severity, such as fatalities or vehicle damage, but found these unsatisfactory since they are so dependent on the design of the vehicles.

STAKEHOLDER REQUESTS

- The multiple collision scenario should be looked at more closely. Multiple or secondary accidents might be severe. More study is needed in this area since the first collision may not be the most severe. The data collection system at NHTSA may give some insight into secondary collisions.

- Replace the word "collision" with "crash" as collision only means colliding with other vehicles. Crash cover all types of accidents.

- Platoon vehicle should select spacing based on its braking capability.

AHS WORKSHOP 3 - BREAKOUT SESSION 1C - INFRASTRUCTURE COST ANALYSES	
Date:	19 September 1996
Domain Experts:	Ron Hearne, Bechtel
Moderator:	Jerry Sobetski, Lockheed Martin
Recorder:	Jacob Tsao, PATH

SESSION

This session presented a rural, intercity, and four urban hypothetical cases for stakeholder review and feedback. Presentations focused on the addition and/or conversion of one AHS lane, including highway-to-highway and highway-to-street interchanges.

KEY FEEDBACK

Baseline assumptions made by different analysis teams are inconsistent. For example, there is a disconnect between length of the parallel merge ramp assumed by the throughput team and that assumed by the cost team. This is a general comment about the plenary presentations, not peculiar to the cost presentation.

To avoid the "empty-lane" syndrome, sufficient market penetration in mixed traffic operations, possibly with partial automation, is needed prior to dedication of a lane.

ADDITIONAL FEEDBACK

Focus on major infrastructure cost and right-of-way components peculiar to AHS, including:

- the check-in area at a dedicated entrance, including queuing space, rejection lane, and on-ramp
- possible extended parallel merge lane beyond the merge point
- the check-out area at a dedicated exit, including queuing space, facility to accommodate vehicles failing check-out (ramp merging back on to automated lane or holding space), off-ramp
- geometric configuration at and near interface with city streets,
- transition lane configuration
- infrastructure electronics and AHS TMC

Use real and forecast data of real regions, rather than hypothetical data, including:

- regional origin-destination and departure time data, as well as forecasts
- regional surface transportation network, including
  - configuration of highways and interchanges
  - highway-arterial interface
  - arterials

Since adding a lane is expensive, and likely the worst case, the Consortium should study AHS design options that do not require dedicated lanes.

Given the advanced steering technology on AHS, the possibility of narrower lanes needs to be explored.

Also, complications due to construction staging and financing needs to be studied.

STAKEHOLDER QUESTIONS

Given the difficulties, why would the Consortium even consider taking away a conventional lane for conversion to an AHS lane?

Building new lanes at the time of AHS deployment may be difficult too because of lack of right-of-way. If the deployment strategy is to ensure a sufficient amount of vehicles equipped with hands-off and feet-off capability for automated driving on dedicated lanes before the actual conversion of a conventional lane to an AHS lane, then conversion could be a viable approach. Given travel-time and safety advantages (in addition to comfort), the driving public may actually demand such conversion.

STAKEHOLDER REQUESTS

- Identify and estimate only the additional cost of equipping an AHS lane, in addition to the cost of constructing a conventional lane. Refer to the National ITS Architecture for the cost of electronics, communications, and an AHS TMC.

- Clearly define the assumptions of study.

- Study the operational and maintenance costs too.

- Point out future infrastructure cost assessment tasks.

AHS WORKSHOP 3 - BREAKOUT SESSION 1D - SOCIETAL & INSTITUTIONAL VIABILITY AND ENVIRONMENTAL CONSIDERATIONS	
Date:	19 September 1996
Domain Experts:	Steve Weber, Parsons Brinckerhoff
Moderator:	Jim Misener, PATH
Recorder:	Kevin Dopart, Mitretek

SESSION

This session covered the societal and institutional viability of an AHS, with particular emphasis on environmental considerations. Key issues included assignment of ownership, payment, operations, maintenance, and enforcement; liability; investment analysis; and environmental concerns.

KEY FEEDBACK

Cooperative Technology Issues:
In order for the system to function, the equipment of different manufacturers will need to be compatible. GM products would be dependent on the performance of Chrysler products. Core standards that are applied to all systems are necessary in order to make this possible. This is a key issue for differentiating independent vehicle concepts from cooperative concepts.

Liability is another key concern. There was much discussion on who would be liable in the event of an accident, particularly under a cooperative scenario. It was noted that the cooperative concept called for each vehicle to make announcements to the vehicles around it. The other vehicles would react to these announcements, using a predetermined set of protocols. However, one vehicle would not actually order or direct an action by another vehicle. Nevertheless, manufacturers would be concerned that they might be held responsible for an accident that occurred due to the performance of another vehicle.

It was noted that manufacturers are more concerned about liability than any other issue, including user wants and needs. A resolution of the interoperability/liability issue must be developed before they will accept any cooperative system. At the very least a set of core standards will need to be developed and required for all AHS systems.

Communication Issues:
Most of the discussion centered on the issue of radio frequency ownership. As demand for frequency spectrum increases, the FCC is expected to refarm private land mobile radio (PLMR) channels from 25 kHz to 6.25 kHz. They will also auction those

frequencies, creating competition in a market that includes existing ITS applications, CB, and other private and business-related uses. It was suggested that the infrastructure provider might be the best potential distributor of spectrum that would be purchased for transportation (including AHS) uses. It was also suggested that the use of channels could be shared by transportation and non-transportation users.

It was noted that if an AHS placed most of the improvements on vehicles, and if the vehicle owners would need to pay for this equipment, then the societal benefits would be short-changed. If throughput is the primary goal, it is not realistic to expect consumers to pay for the improvements (their focus would be on travel time).

ISTEA Reauthorization:
One participant asked what effect the reauthorization of ISTEA would have on the deployability of an AHS system. It was noted that greater flexibility was one of the driving themes for the reauthorization. APTA supports increases in STP and CMAQ, while AASHTO is seeking to remove all restrictions and establish block grants for use by the states.

It was noted that each AHS deployment would probably be decided upon at the local level, although a core set of infrastructure standards would be needed to ensure interoperability.

MIS:
MIS would be the decision-making mechanism that would lead to the deployment of an AHS, should it be found to be the best solution to a corridor's transportation problems.

Major investment studies are undertaken to solve identified transportation problems for a transportation corridor. Accordingly, they must consider all potential modes and require early and meaningful public involvement. Also, they must be financially constrained, meaning that funding sources for proposed improvements must be identified, and they must meet CAAA conformity requirements.

Liability/Insurance:
It is assumed that as driver control is reduced, liability exposure will be increased for manufacturers and system owner/operators. This greater exposure could be acceptable, provided that overall risk is substantially reduced. However, unless there is a reduction in risk that offsets each incremental increase in exposure, these institutions probably will not undertake these improvements.

It was suggested that liability could be a key rationale for establishing dedicated lanes, since this would reduce the chance that non-AHS vehicles would cause an accident for which the highway owner/operator would be liable. However, some participants felt that dedicated lanes could not be deployed in a situation where the highway agency was exposed (at least in California). Some states, including California, Arizona, and Hawaii, use strict liability doctrine.

Strict liability leaves the state liable for damages in accidents where the cause can be attributed, at least in part, to roadway design and/or conditions. Other states apply sovereign immunity doctrine, which leaves the state immune from liability arising from planning or design.

Cases involving a DBOM contractor or other private participation in operations are also a gray area. Most DBOM contracts include a clause that indemnifies the contractor, provided that they meet the state's highway design and operation standards. However, some states, including Minnesota, are not able to offer such protection. This would seem to preclude such contracting arrangements.

Environmental Considerations:
It was argued that an AHS system would be subject to the same criteria that are already applied to other transportation projects. However, an AHS could be expected to affect several criteria in different ways from conventional highway projects. These criteria include: traffic, air quality, and noise. Members of the group also suggested that water quality, parking requirements, and land use and sprawl are also important issues. However, they are not unique to or uniquely affected by an AHS system.

Emissions Models for AHS:
The modal emissions predictions model uses empirical data as a primary source, but then applies simulations to predict platoon emissions. The total air quality picture must also consider ramp effects, cold starts, and changes to VMT.

It was noted that emissions in the future will be reduced per VMT, but that the correlation to VMT will be much stronger than it is today. The more important factors today are cold starts, and acceleration/deceleration.

Land Use/Sprawl:
There was general disagreement with the land use panel's conclusions that AHS would have little effect on sprawl. Since the reports had not been made available yet, there was no opportunity to examine the issues in detail. It was, nonetheless, noted that the conclusions of the panel did not represent an at-large consensus.

Transit:
Several participants expressed skepticism about AHS's potential benefits to transit. They felt that ITS improvements and HOV would combine to provide most of the same benefits, at a lower cost. However, the representative from Houston Metro (transit authority) noted that his area was approaching congestion on existing HOV facilities and his agency was very interested in the potential throughput benefits that could come from automation.

Institutional - Technical Analyses:
The group agreed that it was necessary to continue to reconcile institutional issues as concept development proceeded. In the case of brakes, which are crucial components of

an AHS, the development of standards and regulations should parallel technical development. Institutional stakeholders should continue to be consulted through focus groups to ensure that they buy into the MOE's being developed.

Similar issues relate to societal or market issues, such as driver acceptance of automation. Initial surveys indicate that older people are more accepting than younger people.

Five Who's:
Some suggestions were received to add to the list of stakeholder categories, known as the five who's. "Who benefits?" and "who loses?" were suggested, since they would include larger societal benefits that extend beyond system users and operators. "Whose budget does this go through?" was suggested because some agencies might not have the institutional capability to fund AHS deployment. It was suggested that public agencies would be slower to provide funds than the private sector. This would seem to indicate that vehicle-based systems would find more support.

STAKEHOLDER QUESTIONS AND FEEDBACK

What are the transportation needs/problems that you face, and how can AHS address them?

People want more transportation products and services than they are willing to pay for. Congestion management and pricing was suggested as a lower cost way to provide these services.

Is there political/institutional support for investment in new highway infrastructure?

It was suggested that AHS be installed in the toolbox of transportation improvement options for use where it made sense from a performance and financial perspective.

The key question is whether the market or state policy should take the lead in deploying the system. It was suggested that no single answer is needed. In some cases, a DOT may wish to advance a system at an early stage to encourage market penetration, give industry an advantage, or just be the first on the block with a new system. In other cases, a state may wait until the technology has become ubiquitous, then implement without risk of seeing empty lanes. A similar approach would be used in the market place. Some manufacturers might wish to get the jump on the rest of the market and be the market leader. Others may wait to see if there is a market, and then get in on a winning game.

There were several recommendations on how the toolbox should be presented. It emphasizes that these are "transportation", not highway improvements. If a system will be cost effective, then it can be built. The deployment path should be presented as a decision tree, rather than as a road map.

How does your institution make decisions to consider new technology?

The auto industry uses consumer and human factors research. Highway agencies use cost benefit analyses, although some are willing to use new technology that is not proven.

Can existing highways be expanded to accommodate additional AHS dedicated lanes and entrance/exit ramps?

It was suggested that the first projects should be demo projects which would not be subjected to the typical cost effectiveness criteria. It was also noted that DOTs are going to traffic management because there is no longer room to expand highways in many areas. Therefore, an AHS that would increase overall throughput could potentially justify taking a lane. In real terms, a dedicated lane must be both cost effective and politically feasible. The experience with HOV has shown that take-a-lane scenarios are generally unpopular. Highway shoulder conversions, while they do not comply with AASHTO guidelines, have nonetheless been popular for HOV lanes.

AHS WORKSHOP 3 - BREAKOUT SESSION 2A - OPERATIONS AND TECHNOLOGY ISSUES FOR MIXED TRAFFIC	
Date:	20 September 1996
Domain Experts:	Carol Jacoby, Hughes
Moderator:	Jim Misener, PATH
Recorder:	Steve Schuster, Hughes

SESSION

This session explored the technical and operational issues related to an AHS system based on a fully automated vehicle designed to operated on the same lanes as ordinary manual vehicles as well as dedicated lanes. There is considerable interest in this capability because of the costs of converting or building dedicated lanes. One of the major concerns is the roe of the driver, since drivers generally will not maintain vigilance if they are not involved in moment-by-moment control of the vehicle. This means that the system must automatically respond to any actions by other vehicles, which can neither be predicted nor controlled, and so the feasibility of such a system is not clear.

KEY FEEDBACK

Driver Attentiveness:

Full automated control may divert a driver's attention to other things so we should add something to maintain a driver's attention. Stakeholders suggested tactile feedback from accelerator or brake pedals and not taking away steering control and the ability to override the system.

Liability:

We must give drivers enough control so liability is not an issue. If control system fails, users will hold manufacturer liable. However, if new components are as reliable as current systems, liability should not be an issue.

Safety:

It has taken between 10 to 15 years to understand the pros and cons of antilock braking systems (ABS). The same may be true for adaptive cruise control.

Many feel that ABS should be accompanied by training because users do not understand what ABS does and does not do. The truth is that ABS makes the average driver safer to others, but not as safe as an expert driver, and is widely accepted as a safety feature.

Deployment Path:
The early systems will need to keep the driver attentive. It will be many years before the technology supports full automation. Dutch DOT studies indicate that many, if not most, drivers will not know what to do if they are not driving—forcing driver involvement is not currently much of a negative.

To get to fully automated control without losing the necessary driver attentiveness, allow driver-automated lateral or longitudinal control, but not both, unless it is implemented on dedicated lanes.
The public will accept incremental improvement in services—each step must prove itself before the next is introduced.

A driver should have the ability to turn an automated system on and off as with cruise control.

Benefits:
— Automated distance control dampens propagation of shock waves through traffic.
— People will buy the system for comfort and convenience, and to reduce stress.
— Public benefit of mixed traffic model is safety. However, if mixed-with-manual decreases throughput, it is providing a negative benefit to the larger public.
— Dedicated lanes are public interest, public benefit. The ability to use time for other things should motivate drivers.
— People will use driving aids where they provide an advantage, e.g., turn them on in rural areas, off in city traffic.
— Mixed traffic benefits include constant flow and lack of disturbances, as well as safety, comfort, and convenience.
— Tolls on dedicated lanes may be based on travel time.

Human Factors:
An AHS vehicle needs to recognize situations it cannot deal with and alert the driver.

Drivers will learn quickly how/when to use the advantages of automated systems.

To prevent drivers from dropping out, the system should maintain the steering task and keep control (ability to override) of the AHS driver's vehicle.

In mixed traffic, a manual driver may not tolerate close-following automated vehicles.

Design:
An average design vs a poor design is an important issue.

Automated vehicles can request a gap between vehicles by using a turn signal similar to today's manual vehicles, i.e., must behave like a manual vehicle (be slightly aggressive)
Automated vehicles could form themselves into clusters or convoys

Accident data is available from NHTSA - National Accident Sampling System, Truck Accident database - UMTRI and others.

Dutch DOT performing focus group studies on what would motivate a vehicle owner to buy a car that can operate automatically in mixed traffic.

ADDITIONAL FEEDBACK

The proposed control systems are just an extension of current control systems. The driver still chooses when to turn it on and off, and is responsible for their vehicle.

Liability in the eyes of a jury is subjective, not objective, and negligent over-reliance on an AHS does not necessarily make someone liable. For example, a collision occurred between two ships, with one ship on auto-pilot and the crew asleep. The sleeping crew members drowned were never viewed as liability candidates. The argument for who was liable was between the crew of the other ship and the manufacturer of the auto-pilot.

If an auto manufacturer claims "brain-off" in mixed traffic, the user will expect zero accidents and blame the manufacturer for any failures. For a driver to operate safely in an automated vehicle "brain off" in mixed traffic, the vehicle must be prepared to deal with six sigma events which have serious consequences.

Throughput is too diffuse a benefit to motivate the individual driver. Mixed traffic is low throughput, private interest, market-driven. Public may not buy throughput; we need to sell comfort, convenience, and safety.

Adaptive cruise control vehicles require more headway and take off slowly at green lights; this is likely to cause negative publicity towards automated driving aids. (Counter: No one would use ACC in city traffic, headway can be adjusted.)

An AHS must always maintain the public good, i.e., throughput, safety, efficiency.

Less stressful driving may result in induced demand.

STAKEHOLDER QUESTIONS

It has taken time to gain experience with ABS, how do we allow for this with mixed traffic?

Although we do not yet know all the steps of the progression, it is clear that we will progress incrementally to an automated vehicle in mixed traffic. Adaptive cruise control is being sold on light passenger vehicles in Japan, and will be available in the U.S. within a year or two. After that will probably come lane departure warning, and then perhaps obstacle warning. Each of these important elements of the AHS mixed traffic solution will be tested by tens of thousands of drivers over hundreds of millions of miles long before they become part of a fully automated vehicle. The remaining elements of an automated vehicle designed for mixed traffic will be road tested first with test drivers, and then perhaps with a limited pool of senior professional drivers (bus, truck, etc.) supervising operation similar to the way in which new airplanes are "broken in".

How do we close the gap between statistical and perceived safety?

Human factors studies can give us some guidance as to what sort of interface will make people feel safer, e.g., clear feedback on system status, a panic button to stop the vehicle, etc. Furthermore, the issue of perceived safety dictates that the safety standards for AHS must be set higher than those for a manual system, if the AHS is to be perceived as "safe" by the great majority of its potential users. Finally, it is worth noting that the airlines have never succeeded in entirely solving the problem of perceived versus statistical safety, and this has not stopped air travel from being a commercial success. If we design a system which is convenient, fast, reliable, and has good statistical safety, the airline analogy suggests that people will use it, even if it doesn't "feel" entirely safe to everyone at first. It is likely that not every farmer at the turn of the century felt safe traveling at 20 miles per hour in a horseless carriage at first.

Can we afford to design a vehicle that requires cooperation by manual drivers?

Not entirely, but neither can we afford to design a vehicle which is capable of dealing with every six sigma (extremely unusual) event which occurs in mixed traffic. The answer lies somewhere in between. We will design an automated vehicle for mixed traffic operation which will be as safe as, or safer than, a good human driver today. It will rely to some degree on manual driver cooperation in achieving travel time goals (to change lanes, for example), but it will be capable of guaranteeing safety (under almost all circumstances) even if this cooperation is not forthcoming.

STAKEHOLDER REQUESTS

- Credibility may be improved among drivers with better displays in vehicles.
- The automated vehicle in mixed traffic must be as safe as today's despite increased traffic.
- We need incident as well as accident data. For example, truck accident databases are available (UMTRI and OMC), but are not the only freeway hazards. Therefore, we need a list of hazards manual drivers are likely to respond too.
- Commercial vehicle operators need a quantitative statement of benefits and costs before they will sign on.

WORKSHOP 3 - BREAKOUT SESSION 2B - HIGHWAY CONFIGURATION AND IMPLEMENTATION ISSUES	
Date:	20 September 1996
Domain Experts:	Ron Hearne, Bechtel
Moderator:	Mark Miller, PATH
Recorder:	Asfand Siddiqui, Caltrans

SESSION

This session deals with issues related to the configuration of AHS infrastructure and implementation for the existing environment of developing major highway public works projects.

KEY FEEDBACK

Analyze trip lengths with respect to AHS design. Results will have a major impact on AHS design. Caltrans' existing standards for freeway design may help determine results before continuing to develop an AHS freeway design.

While driving on reversible lanes, with fixed signs posted, the driver will be held responsible for any accidents as if he/she failed to follow the signs. In contrast, if we put up changeable message signs and the sign fails to display the right message and/or fails completely, public agencies will be held responsible. The point is that putting more and more electronics on the freeway makes the agencies more responsible.

We should try to design AHS with current highway operational procedures. Otherwise it will degrade today's highway performance.

AHS may begin with lanes for trucks only. Additional lanes are not possible in urban areas. However, they may be possible for trucks only. Also, longer/heavier trucks on AHS lanes might make it viable.

STAKEHOLDER QUESTIONS

What is the need for a transition lane?

A transition lane is required because there are likely to be speed differences between AHS and non-AHS traffic. Also, transition lanes may provide sheltered areas where the transfer of control between automated and manual driving can take place.

Why should the transition lane be separated by a barrier?

It has not yet been determined that a barrier is a requirement. However, for safety and liability considerations it is probable that either the barrier, or some form of spatial separation will be required.

Is there not an option for testing whether the check in/out electronics are working or not?

At the highway entrance just prior to going onto the on ramp, it may be possible to test whether the electronics is working.

Does the access ramp have a shoulder?

In the transition lane scenario, where the AHS equipped vehicles and manual vehicles use a common ramp, the access ramp does have a shoulder. In the dedicated ramp scenario, it has not been determined that a shoulder is necessary.

If your car is not accepted by AHS, where should your car go?

Your car would be directed back to the manual lanes.

Is it possible to do check in/out without infrastructure interference?

Possibly. It depends on the check-in/check-out requirements which have not been specified.

Is anyone in the Consortium looking into check-in and check-out procedures, and how they will be implemented?

In the next phase of activity, which begins in October '96, this will be looked into by the Consortium.

Have you considered putting AHS lanes on the right side of existing freeways?

Yes, that has been considered. But the AHS lanes would serve as a barrier to the manual traffic. The manual traffic would not be able to penetrate the AHS lanes without severe degradation to the AHS flow.

Since AHS has higher throughput what will happen at weaving intersections?

Where weaving volumes are low, the weaving sections may function within acceptable limits. However, where the weaving volumes are too high and exceed acceptable limits, there may have to be braiding sections, or elevated ramps which cross over the other traffic to accommodate the crossing traffic, but to eliminate the weaving sections.

STAKEHOLDER REQUESTS

- Study must identify which standards are being compared against the AHS configurations shown.

- Highway design is never referenced in the context of risk analysis. In the AHS freeway design, we need to do a risk analysis.

- People driving non-AHS cars, will adapt to drive on a AHS lane. We need to do a case study in this area.

AHS WORKSHOP 3 - BREAKOUT SESSION 2C - HUMAN FACTORS ISSUES: PARTIALLY & FULLY AUTOMATED SYSTEMS	
Date:	20 September 1996
Domain Experts:	Vicki Neale, Virginia Tech
Moderator:	Jim Lewis, Hughes
Recorder:	Bret Michael, PATH

SESSION

The dominant theme of the breakout session discussion was that human factors should be considered in tandem with analyses and deliberations of technical and institutional aspects of an AHS. There was also a common resolve amongst the human factors experts within the breakout session that the Consortium should take a more proactive stance in addressing human factors issues.

KEY FEEDBACK

Many breakout session participants felt that it may not be feasible for the Consortium to address the entire spectrum of human factors in depth. A recommendation was made that the Consortium should prioritize the non-concept-specific human factors issues and assign those resources to human factors studies as high-priority issues. A second recommendation was that the Consortium should not duplicate other human factors analyses within the same time frame (e.g., human factors studies of adaptive cruise control systems). Rather, the Consortium should leverage as much as it can from the ongoing work on collision avoidance and collision warning systems.

During the discussion of prioritization of human factors issues, the stakeholders stated that many of the AHS human factors issues have already been identified. They cited the AHS Precursor Systems Analyses (PSA) and other studies performed by Honeywell. In addition, Tom Dingus of Virginia Tech is in the process of completing a literature review, the purpose of which is to assist the Consortium in understanding the current state of the art technologies and knowledge in terms of driver-vehicle-highway interaction. (The research will include an analysis of the collected data to determine the most critical human factors issues relevant to AHS design.)

Explicit and Consistent Modeling Assumptions:
In response to the earlier presentations of the system safety and throughput/travel time results, the stakeholders recommended that the Consortium explicitly state and consistently use the same set of modeling assumptions across these and other studies. This set of modeling assumptions was recommended to encompass human factors. For

example, the system safety and throughput/travel time studies should incorporate the human factors research findings regarding vehicle closing rates: the speeds corresponding to closing speeds are required inputs to AHS vehicle merging protocol designs and analyses.

Consumer Preference and AHS Acceptance:

Stakeholders asked if drivers should be responsible to remain vigilant at all times. In other words, are there any productivity gains to be realized by the driver if he or she must remain vigilant rather than attend to other, non-driving-related tasks such as conducting business, catching up on sleep, reading the newspaper, etc. This led to yet other questions, such as the following: Should the driver be encouraged to participate in activities which will make it difficult for him or her to retake control of the vehicle in an emergency? Should the driver be responsible for detecting obstacles on the roadway and under what circumstances should the driver be expected to resume control during a failure of the automated system?

In response to these questions someone replied "the market will dictate the degree of automation and human intervention." User acceptance of AHS will be dependent on the adaptability and acceptance of the individual components leading up to a fully automated highway system. These products require driver alertness, and the products will be sold on safety, convenience, and price, not on driver disengagement.

In yet another response to the driver role question, one of the stakeholders posed the following questions: What is the potential for conflicts between the expectations of AHS designers and users with respect to the role of the driver? How do we meet user expectations? After some debate, Jim Lewis noted that the breakout session group would not be able to (and was not expected to) resolve the unanswered questions and open issues. However, he and the other session attendees expressed satisfaction that the issues were being openly discussed and thrashed out.

Evolution of Highway Automation:

The discussion of the evolution of highway automation began with the following example of a deployment sequence:

1. Adaptive cruise control with collision warning
2. Adaptive cruise control with collision warning and lateral warning
3. Adaptive cruise control with collision warning and lateral guidance

The point was made that when the third step in the sequence is reached, the addition of lateral guidance may lull the driver into thinking that monitoring the driving situation and remaining vigilant are optional rather than mandatory tasks.

There was strong sentiment within the group that the market will dictate an evolutionary path for the development and deployment of vehicle-highway automation, with the Consortium and AHS technology providers responding to advances in AHS-enabling technology (e.g., collision avoidance and warning systems) and experiences with operational partial automation systems (e.g., adaptive cruise control).

However, there was disagreement as to whether the "last step," from partial-to-full automation, would require a revolutionary step (i.e., large leap forward). The issue was posed as a list of questions: What are the logical steps after the introduction of collision warning systems into the vehicle-highway system? Can one realize attractive safety, throughput, travel time, and other benefits of AHS travel within a mixed traffic environment?

Many of the session attendees agreed that the most dangerous step in the evolution from partial to full automation occurs when automated lateral control is introduced into the system in conjunction with longitudinal control. It is at this stage of deployment that a fully automated collision avoidance system must also be in place. Any combinations of technologies that do not provide total collision avoidance will not free the driver from monitoring responsibilities. It was noted that a useful synonym for "fully automated" was "hands-off, feet-off, monitoring optional." (This issue was also raised during Session 3B, "Time-Staged Development and Deployment of AHS. ") However, there was no agreement as to what role the driver might play in each of the partial automation steps leading to full vehicle-highway automation.

A suggestion was made that driver roles confusion and driver system-state awareness are two candidate human factors principles for distinguishing among evolutionary system configurations. These principles were addressed in the Honeywell Function Allocation PSA report, and the Raytheon/USC Longitudinal and Lateral Control Analysis PSA report; in the latter report the principles were used to identify key issues.

<u>Technology Performance and Acceptance:</u>
Technology plays a pivotal role in the development and deployment sequence. If technology cannot provide an adequate level of collision avoidance, then this result steers one into concluding that dedicated lanes are required for an AHS. In other words, the decision as to whether to dedicate a lane will be influenced by the performance of AHS enabling technology.

In addition, the level of braking authority assigned to a partially automated system will be greatly different than that in a fully automated highway system. For example, one of the stakeholders estimated that only 25% of braking authority will be assigned to an adaptive cruise control system, whereas 100 % of the braking authority will be assigned to the automated system in the case of a fully automated collision avoidance system.

Moreover, it has been observed that false and nuisance alarms can affect driver performance and the driver's willingness to use or accept collision warning systems. It therefore appears that the performance of collision warning technology will affect the deployment and acceptance of an AHS if the AHS contains collision warning system technology. In a pre-full automation system, what would the collision warning system tell the driver?

ADDITIONAL FEEDBACK

Past studies have shown that humans perform poorly in situations in which they only perform monitoring functions and malfunctions are rare events.

Compared with piloting a plane, in the automobile, the driver has very little time to react. There is also very little time in which to test driver readiness to resume vehicle control tasks. Therefore, is it even reasonable to consider providing for driver intervention in AHS-operated vehicles? Honeywell performed AHS task analyses. These task analyses could be used to determine what response rates may be necessary in time-critical driving tasks.

The results of Honeywell's studies indicated the following:

— Drivers prefer "larger" gaps rather than "small" gaps. However, the absolute "comfortable" distance between two vehicles is not known. The experiments were conducted using the Iowa Driving Simulator.

— The carryover effect is strong with respect to vehicle spacing but not as strong with respect to speed.

— Drivers were not uncomfortable traveling at high speeds. However, other considerations need to be factored in before making any conclusions from these results, such as the effects on driver behavior and comfort given all vehicles traveling at the same speed versus large differences in speed between two adjacent vehicles. In this case, learning effects may become conditioned (and comfortable) with high-speed travel at close following distances for vehicle drivers.

STAKEHOLDER QUESTIONS

Responses to many of the following questions will be the result of future program activities.

Should one design the AHS to keep the driver vigilant?
What factors will affect driver vigilance during travel on an AHS?
Will any aspects of automated driving carry over to manual driving?
At what closing rates will the "typical" driver feel an unacceptable level of discomfort?
How would AHS users respond to the monitoring of their attentiveness and behavior?
In what ways can the driver-AHS interface be designed to minimize driver confusion?
Is it necessary for AHS to handle all emergency situations without driver intervention?
Will AHS users be comfortable with someone seeing them from another vehicle following in close proximity to their vehicles for long periods of time?

STAKEHOLDER REQUESTS

- There is concern within the human factors community that the Consortium will postpone the consideration of human factors issues until late in the requirements analysis and design process. The stakeholders recommended that the human factors requirements be inserted into the system requirements document as-soon-as-possible.

AHS WORKSHOP 3 - BREAKOUT SESSION 2D - STANDARDIZATION	
Date:	20 September 1996
Domain Experts:	Tom McKendree, Hughes
Moderator:	Jerry Sobetski, Lockheed Martin
Recorder:	Datta Godbole, PATH

SESSION

This session began with a presentation of its purpose and standardization ideas. A potential need for standardization of drivers in addition to roadways and vehicles was identified. The presentation also included standardization issues regarding vehicles and roadways only. This may be important from the liability perspective. Questions prepared by the Consortium helped seed the discussion.

KEY FEEDBACK

There was confusion between design specifications, performance specifications, and standards. It was pointed out that the Consortium is making no distinction at this point.

The relationship with ITS standards was discussed and it was agreed that AHS standards should be backward compatible with ITS standards.

It was brought to the attention of the group that enforcing standards by using federal funding does not always work at the local DOTs and MPOs, because this requirement may be avoided in many cases. This brought up the issue of compliance with AASHTO standards. It was pointed out that AASHTO standards are only used as guidelines by state and local agencies to develop their own standards.

Standardization should specify vehicle-vehicle and vehicle-roadside interfaces and let the market driven economy decide about in-vehicle standards. Standardization is necessary if the interface crosses stakeholders. Performance requirements on vehicles, such as safety-critical subsystem functionality and minimum deceleration capability should be standardized.

ADDITIONAL FEEDBACK

Establishment of standards would require a long time because it will need consensus among vehicle manufacturing companies. The standardization process must find a proper balance between level of specification and market freedom.

In planning for standardization, we should find a time that it is not too early and not too late—when competing standards are successful and need not compromise, but we do not know enough to set the right standard. Accordingly, timing will be instrumental when beginning the standardization process.

There should be nationwide standards for safety-critical systems in terms of performance specifications for critical subsystems, including vehicle-vehicle communication.

Standardization is needed for human-machine interface systems, particularly defining driver role at the time of regaining control after exiting the AHS.

NAHSC should produce a reference model early in the program to support the standardization process. Use of the ITS Council of Standards organizations to assign standard setting bodies is recommended.

STAKEHOLDER QUESTIONS

Is more than one type of AHS roadway acceptable? If so, what should these AHS roadway types be?

General consensus was that there must be a uniform standard for AHS roadways in terms of widths of lanes, entry ramps, etc.. It was felt that an AHS roadway is not defined in sufficient detail; it seemed to be acceptable if some local agency decides to implement narrow lanes that would accommodate only LDPV provided that the local agency does not use federal or state funding.

What is the minimum distance required between consecutive entrances on an AHS and what will be the effect of trucks and buses on this choice?

It was pointed out that this may potentially be similar to today's HOV environment with less access than other lanes.

What AHS options are needed for local applicability?

Urban Needs, Suburban Needs, Intercity Needs, Rural Needs

Which standards must be left to local decision makers?

CVO' s did compatibility testing on transponders for communication standardization. The FHWA handed out a list of areas needed for standardization. FHWA also surveyed the ITS community to obtain this information.

It was suggested that even though AHS might get implemented in the distant future, standards are being defined on infrastructure-based communication systems, such as toll tag identification. If AHS has specific needs, NAHSC should talk to the standard setting bodies so that they can take AHS-specific features into account.

It was determined that the ITS architecture provides a starting point and indicates which standards are needed. However, in terms of ITS implementation, SAE is working on protocols and communication architecture.

Why does AHS need flexibility to continue exploiting advancing technology?

We need flexible standards to continue to exploit new technology. However, standards that are too flexible require costly implementation, and standards that are too specific increase cost and may drive down competition.

To what extent should AHS standards be imposed (top-down) versus being left to emerge, (bottom-up)?

The most preferred way is to have bottoms-up standards for vehicles and a flexible infrastructure which will accommodate all of them.

There is a proper time (not too early, not too late) to standardize. If standardization is carried out to early, we may not be able to exploit technological advances. On the other hand if standardization is done too late, some of the many companies in the market will lose in the standardization process.

What should be standardized worldwide? Should the national AHS Standard be designed so that it can also be an international AHS Standard?

What should be standardized may depend upon who maintains the system, and who enforces it. e.g., military and civilian aircraft safety standards. What the driver needs to do when he/she has to regain the control at the exit should be a national standard. All wireless communication should be standardized by obtaining separate spectrum and side-band limitations from FCC. Performance requirements on vehicles such as minimum deceleration capability should be standardized. It was agreed that NAHSC may standardize interfaces between vehicle/vehicle and vehicles/roadway. Then market-driven economy will decide about in-vehicle standards, except for NAHSC-provided guidelines for safety requirements.

Do we need to worry about other standards in other parts of the world?

Yes, but we need human factors standards. For example, Japanese drivers should be able to drive cars in the United States. Many other countries currently do not enforce in-vehicle safety standards used in the United States.

There is an ITS subcommittee looking at standards in other countries and trying to synchronize them. Also, ITS is trying to standardize with Canada and Mexico in conjunction with NAFTA.

We need to keep an eye on emerging AHS standards from other countries. Given that other countries in Europe and Japan have their own AHS programs, do we know if we are going to be first in terms of implementing an AHS?

Who should set the Standards; Vehicle-to-Vehicle communications, Vehicle-to-Infrastructure communications, Vehicle Behavior, AHS Roadway, and/or standards for the allowable configurations of the infrastructure intelligence?

Vehicle-vehicle communication is a national safety issue such as commercial aviation and should be dealt with by someone like NHTSA. It was pointed out that federal standards might involve politics and may be more time consuming than voluntary. If it is only a minimum safety standard such as standard on airbag deployment or braking, then it is acceptable.

ITS Council of Standards Organizations can be used to assign standard-setting bodies. Regulatory standards should be set by the government, voluntary standards will be set by the manufacturers.

Human factors, in-vehicle displays could be set by SAE, which is working on navigation displays. Human factors on infrastructure such as VMS and traffic control devices, could be set by AASHTO.

Are there any aspects of AHS we have not yet covered that you feel are absolutely critical either as a standardize or made an option? What should the standards or options be, and why?

Finding the SWEET SPOT in time to form standards is extremely important.

Is standardization going to be an explicit item in terms of next year's program?

No.

STAKEHOLDER REQUESTS

- There should be inflexible requirements on safety-critical systems in standardization. This can be a performance requirement rather than a design standard, similar to minimum safety requirements in the aircraft industry. In such a case, verification of compliance with the safety standard by the manufacturer was identified as a difficult problem.

AHS WORKSHOP 3 - BREAKOUT SESSION 3A - TIME-STAGING OF AHS DEVELOPMENT AND DEPLOYMENT	
Date:	20 September 1996
Domain Experts:	Tom McKendree, Hughes
Moderator:	Jim Misener, PATH
Recorder:	Steve Schuster, Hughes

SESSION

This session began with each attendee making statements regarding deployment and thereby forming the major basis for the discussion. Near the end, the group decided that it was inappropriate for the Consortium to select among the three deployment approaches. What was determined appropriate, and indeed necessary, was for the Consortium to provide a compelling case that deployment will be feasible for the AHS as defined. At the end, the various breakout questions were reviewed by the group. It was agreed that those questions had been addressed by the earlier discussion. Specific comments, grouped by subject, are shown below.

KEY FEEDBACK

Incremental Deployment:
A number of stakeholders prefer incremental deployment, however, some seemed concerned about driver disengagement. Other stakeholders prefer a bootstrapping approach. It was suggested, the system will need short-term improvements, like automated distance control, which will improve throughput.

Incremental deployment was suggested to be used in the following ways:
— Use incremental deployment to gain public acceptance.

— Use incremental deployment with particular attention to incremental benefits of steps.

— Use incremental deployment and concentrate on CVO's and dedicated corridors.

Mixed with Manual:
Start with "mixed traffic" to gain public acceptance - a dedicated lane might become unnecessary.

Human factors problems concerning mixed with manual are far more complex than those of dedicated lanes. Also, the system will not get dramatic throughput improvements in mixed traffic.

Evolutionary/Market-Driven:
Near-term product success is the key to public acceptance of AHS. Market will drive deployment in some areas, but some goals like environmental protection are very difficult to achieve with market forces. However, many favor a stakeholder-driven approach and an evolutionary deployment/market driven approach.

Deployment plans need to be built on stakeholder needs, but representation to-date at workshops has not been satisfactory; need to engage broader spectrum of stakeholders. The Consortium should be in closer touch with regional transportation organizations and their needs.

Parallel Paths:
The deployment sequence must vary locally. It is too early to close either option (mixed or dedicated). Local tailorability is needed to solve specific transportation problems.

The two deployment approaches are not mutually exclusive; we should continue both lines of development. Market-driven evolution will happen, but will fail to increase throughput and will not free drivers for other activities—dedicated lanes will be needed for dramatic improvement.

The market will drive deployment for a while, but then the government must start automated lane deployment to move things over the hump.

Particular Segments:
Some stakeholders favored incremental deployment. Particularly with initial efforts directed at CVOs and dedicated corridors. Accordingly, the following ideas were suggested:

— We should focus on trucking. A driver centered automation system is currently under development. We must prove a concept first to sell it to the CVOs.

— We should focus on trucks, especially to address rural issues; I favor mixed traffic deployment.

— We should try for deployment to fleet vehicles first, use off-the-shelf technology, and assist the driver but not take control away.

— We should look into convoys with a professional driver in lead vehicle

Dedicated Lanes:
We should separate existing lanes into express and local, then convert one express lane into a dedicated lane. If only a fraction of trip time is on dedicated lane, then any improvement will be diluted by time spent on surface streets. Dedicated lanes are a non-starter. New funding sources are needed for construction and maintenance of dedicated lanes. Governments cannot afford to pay for dedicated lanes.

Methodology:
Our three fundamental goals should be safety, mobility, and efficiency.

The three proposed models of deployment are too restrictive, a deployment tool kit is needed to show the three different deployment sequences to establish feasibility.

With regard to the role of the driver, we should look for analogies in other industries and technologies, such as aircraft.

We must also compare the cost/benefit of dedicated lanes and mixed mode.

We need to establish deployment feasibility, but we cannot expect deployment to happen exactly as predicted.

"Brain-Off":
Left lane should be infrastructure assisted but not limited to AHS. This may become possible with brain-off. However, some consider brain-off too difficult a problem, and any efforts to solve the problem are misplaced emphasis.

Brain-off requires a high degree of confidence in whoever and/or whatever is in control. People will be reluctant to accept it until the system has established a good safety record over time.

ADDITIONAL FEEDBACK

Government Role:
The government is needed to monitor safety, and also to ensure that no single user segment benefits at the cost of other groups.

DOT's need some guidance concerning when the public sector investment will be required.

Deployment sequences will vary by region; the federal government should set standards to ensure interoperability.

Bootstrap Approach:
The bootstrap sequence is oversimplified - things will not happen sequentially.

Incremental deployment is needed to get drivers to give up control (a little at a time).

Add overlap in time to the bootstrap sequence, and draw it on two axes.

AHS WORKSHOP 3 - BREAKOUT SESSION 3B - TIME-STAGING OF AHS DEVELOPMENT AND DEPLOYMENT	
Date:	20 September 1996
Domain Experts:	Bill Stevens, NAHSC Program Office
Moderator:	Jim Lewis, Hughes
Recorder:	Bret Michael, PATH

SESSION

Jim Lewis gave an overview of development and deployment staging issues, followed by a presentation of policy-driven, market-driven, and bootstrapping sequences. The stakeholders appeared to be ill at ease with the bootstrapping sequence, although the reasons for their uneasiness with the bootstrapping concept were never explicitly stated.

Before discussing the candidate development and deployment sequences, the breakout session participants discussed which level of obstacle detection, collision avoidance, and other functionality are viewed as necessary for an AHS to be safe. Many of the session attendees voiced strong support for the belief that moving to full automation will necessitate a close coupling between automated lane-keeping and collision avoidance, primarily due to driver vigilance considerations. (This issue had already been raised in Session 2-C, "Humans Factors Issues: Partially and Fully Automated Systems.") Another conclusion put forward is that lane-keeping and collision avoidance functions should be closely tied to dedicated lanes, i.e., AHS-only.

KEY FEEDBACK

The stakeholders pointed out that an advantage of the policy-driven sequence is early standardization: policies can be used to set standards for AHS functionality and performance. An AHS implementation would then have to meet the minimum of the AHS functionality and performance standards. In addition, a policy-driven sequence will encourage earlier implementation and standardization. In contrast, a market-driven approach could result in a poorly performing system or an inconsistent set of standards.

Turning to the topic of a market-driven sequence, the stakeholders stated that one of the advantages of a market-driven sequence is that it permits one to postpone "pouring concrete" as late in the deployment sequence as possible. This postponement affords stakeholders the opportunity to incrementally develop and market the technological steps, thereby reducing technical and market risk.

Other advantages attributed to the market-driven sequence are its provisions for accommodating shifts in public policy, and allowance for local, scaled deployment as market penetration of AHS increases.

One reason that the market-driven approach appeared favorable in comparison to the policy-driven approach was the highway transportation community's past failures at introducing lane-use policy changes, such as the Santa Monica (California) High Occupancy Vehicle (HOV) Project. This project failed due to under-utilization in response to the public's perception and lack of acceptance of HOV lanes. Also, someone mentioned that one problem with a barriered dedicated lane is that you cannot just put in one lane—it has to have at least a hard shoulder, in which case you might as well add two lanes.

Two stakeholders considered the market-driven sequence biased toward vehicle-borne automation. They argue that it is imperative that "we bring the infrastructure and vehicle [systems] along together." They also stated that the market-driven approach works against standardization; each vehicle manufacturer may have to have its own approach.

As an alternative to picking a "winner" among the three sequences, it was suggested that the Consortium consider development and deployment sequences in terms of a decision tree, where each possible development and deployment sequence is simply a path through that tree. The breakout session participants coined the decision-tree approach for sequence selection as Reactive Adaptive Management Portfolio (RAMP).

In this approach, the market-driven sequence could be chosen to be the default sequence, with the policy-driven sequence kept in reserve and implemented if technical developments or the political climate makes the policy-driven sequence a better alternative to pursue, for example, if the price-performance of a dedicated-lane AHS becomes especially attractive relative to that for mixed traffic, or public opinion is in favor of converting existing manual lanes into dedicated AHS lanes. Alternatively, the decision could be to spark AHS interest and standardization with a policy-driven implementation, and then let the market-driven evolution take over.

John Lathrop described RAMP as a decision-tree-based strategy to develop a toolbox of AHS technology. The tools within the toolbox are analogous to building blocks. The building blocks can be used to tailor AHS to accommodate local needs and varying degrees of AHS market penetration. The building blocks to be developed by the RAMP approach should be identified after a survey of what is apt to be built anyway. The survey would identify the gaps and shortfalls that need to be addressed, and the standards called for to assure interoperability.

There was a sense of agreement among the breakout session participants that the deployment sequence decisions should be postponed until after the first three blocks in the three deployment sequences (i.e., the steps described by "today's vehicles, adaptive cruise control, and vehicle position and speed information from other vehicles and infrastructure"). There was also agreement that the success of any of the sequences, including the RAMP approach, depends on early standardization.

John Lathrop pointed out that the "adaptive management" part of the RAMP approach comes into play when the decision tree analysis is used to defer concrete-pouring actions until as much data is collected as possible about AHS technical performance, cost, market penetration, and public acceptance. That deferral would have to be balanced against any penalties for later service dates. Likewise, uncertainty-reducing actions could be pulled to the front of the tree.

Another advantage of the decision tree is that the Consortium can use it to demonstrate that it has a plan all the way to final delivery, yet without committing itself to a particular pathway or a particular endpoint.

Jim Rillings said "The automobile manufacturers will not do it alone. There must be a visible, concerted effort from other stakeholders to bring AHS to fruition." He then posed the question, "Would any of the other stakeholders in the breakout session support some level of instrumentation of all of a highway's lanes if it is not feasible or acceptable to dedicate one or more lanes to an AHS." There were no straightforward answers given to this question. Some stakeholders stated that they believe the decisions to dedicate lanes to AHS will be made separately by each local transportation authority, and that these decisions will be based to some extent on the results of major investment studies (MIS).

John Hickey suggested that some transportation authorities, such as the Pennsylvania Turnpike, might be willing to dedicate a lane in each direction for use exclusively by light-duty passenger vehicles. He gave an example in which a long distance dedicated lane appears to be a desirable and cost effective alternative to general purpose lanes. He noted that some Turnpike customers are not comfortable traveling in the same lane as large trucks and buses (e.g., due to splash, spray, blockage of view of roadway area in front of the truck). In addition, some potential customers, such as older drivers and those drivers with physical impairments, avoid using the Turnpike due to their perception that they will not be able to safely operate their vehicles on lanes in which vehicles of different classes mix. Therefore, one possible path to setting aside lanes for AHS use may be to physically separate vehicles of different classes into class dedicated lanes, with the decision to dedicate a lane based on marketing and human factors issues in addition to an MIS.

John Hickey also pointed out that organizations such as the Pennsylvania Turnpike Authority must look at the bottom line—these organizations determine the return on investment—when making system development and deployment decisions. A more important factor, in his opinion, is that it may turn out that transportation planners find that they need different development/deployment sequences for each class of vehicle.

Following up on the different sequences per vehicle class thread of conversation, another stakeholder pointed out that there may also be different implementation rates for different classes of vehicles and types of roadways. It was argued that light-duty passenger-vehicle-only (LDPV-only) lanes have some advantages over lanes carrying two or more classes of vehicles. For example, LDPV-only lanes may be less expensive to construct, since they will not need to be constructed to accommodate the weight and width of coach buses and heavy articulated trucks. Hence, dedicating a lane for AHS may be preceded by a shift in public opinion toward establishing single-class or similar-class use lanes.

The stakeholders discussed some of the possible influences proprietary information may have on the development and deployment of an AHS. Tom Reid championed the proposal that the Consortium set product-independent standards and system performance criteria. He argued that non-proprietary standards and performance criteria are needed to avoid the introduction of proprietary technology into the AHS specifications and designs: its introduction may be detrimental to a free and open competition among potential AHS system developers, suppliers, operators, and other stakeholders. There was disagreement within the breakout session group as to how much proprietary information will find its way into specifications and designs, and the session ended without a resolution of the divergence in opinion on the role of proprietary information in AHS.

The breakout session group did reach a consensus that standardization should proceed with a global perspective. The rationale behind this viewpoint is that there are AHS development, deployment, and interoperability initiatives already underway in Japan and Europe. Furthermore, there is already a push for global standardization of intelligent transportation systems (ITS), of which AHS is one of the ITS user services.

A member of the Japanese delegation acknowledged that new dedicated lanes in Japan will be relatively rare due to current land use policy, but he believes that most of the AHS applications in Japan will provide for mixing of automated with manually driven vehicles. He did not elaborate on Japans AHS research and prototyping effort to support non-dedicated lane, mixed traffic operation.

John Hickey expressed concern about the 1997 AHS technology demonstration. He asked the Consortium members how they intend to tell the deployment story. Jim Rillings responded that an AHS exhibition center will be used for such purposes. He added that the Consortium will do all that they can to encourage the demonstration attendees and the media to attend the AHS exhibition center.

At the end of the breakout session, Dick Bishop and Jim Lewis conducted a straw poll to determine the preferences of the stakeholders regarding sequences and RAMP. The results of the poll are shown in the table below. In contrast to the policy and market driven sequences, there was no discussion during the breakout session of the bootstrapping sequence. This may have influenced the voting results in that the session participants did not take an opportunity to compare against one another all four deployment alternatives.

ADDITIONAL FEEDBACK

Table 1. Results from Development and Deployment Sequence

Sequence/Approach	Votes in Favor
Policy-Driven	*4*
Market-Driven	*4*
Bootstrap	*2*
*RAMP**	*12*

* assumes early action on standards

WORKSHOP 3 - BREAKOUT SESSION 3C - TIME-STAGING OF AHS DEVELOPMENT AND DEPLOYMENT	
Date:	20 September 1996
Domain Experts:	Carol Jacoby, Hughes
Moderator:	Jerry Sobetski, Lockheed Martin
Recorder:	Asfand Siddiqui, Caltrans

SESSION

This session addressed the question of the deployment sequence for AHS, specifically the steps that can reasonably get us from where we are now to a full AHS. There is a "chicken and egg" problem between equipping roadways and vehicles -- neither is of use without the other. Three candidate deployment sequences were presented for discussion. The policy-driven sequence builds dedicated AHS lanes as soon as adaptive cruise control and cooperative systems are in place. The market-driven sequence builds on driver aids to get fully automated driving in mixed traffic, and dedicates lanes when many vehicles are equipped. The bootstrapping sequence dedicates lanes for AVCSS vehicles, and then adds technology to build up to AHS.

KEY FEEDBACK

If we offer AHS technology to operate on a HOV lane, we might see some benefit and people might start using AHS vehicles without dedicated lanes.

Mixed traffic will have to be implemented first. If you have to add capacity to the current highway system it needs to be HOV, AHS, etc., but adding a lane is certainly not an option because it is too expensive.

Trip lengths are important. Longer trip lengths makes sense because why would someone spend extra money only for 10 minutes trip time savings. We should decide what we are trying to achieve. Are we trying to reduce trip lengths from 20 minutes to 10 minutes or from 60 minutes to 30 minutes.

By starting with vehicles first, we will end up with very expensive vehicles and the market growth will not increase unless there is some form of government intervention. Therefore, the vehicle industry needs to see that buyers have government incentives to spend money on AHS equipped car. The government will need to make decisions whether to provide electronics to the infrastructure in cases where small numbers of AHS cars are operating on a portion of roadway.

ADDITIONAL FEEDBACK

Time line shown is not realistic. These events might happen faster.

As an incentive AHS vehicles may be allowed to travel on existing HOV lanes.

There should be a separate deployment strategy for rural and urban areas.

In rural areas lane departure warning is more important than throughput.

Poll Results:	
Bootstrapping	*4*
Market Driven	*4*
Policy Driven	*1*
Poll For Commercial Vehicle:	
Bootstrapping	*7*

We should be looking at the mid-income families as a target market for AHS. Reason being is that mid-income families generally live in suburban areas and they have long commutes to work.

There is no mention of when a driver will be able to take control back from the computer. People are not ready to give up control to computer systems to take control of the vehicle. There is no market for such an item.

STAKEHOLDER QUESTIONS

How can we add a lane if we do not have enough market penetration?

This is the key concern with dedicated lanes. Initial deployments may need to be subsidized to prime the pump. The government has to take initiative, at least to provide a few AHS corridors in the country to trigger AHS deployment.

How can the policy-driven strategy simplify technological issues?

The policy-driven strategy has automated vehicles operating only on dedicated, controlled lanes. This means that all other vehicles are predictable and under system control. Operation in such an environment is much simpler than in a mixed traffic environment. Developing a system that can respond safely to anything a manual driver may do is an extremely difficult technological challenge.

Both cars and lanes have to come together. How can we put technology on a vehicle which has very limited application on dedicated lanes?

The initial dedicated lanes will need to be placed where users will be motivated to equip their vehicles because they use them repeatedly. Examples are commuter routes, truck routes and transit routes.

Will there be a difference if we look at commercial market driven strategy including transit?

The commercial market is a promising way to start deployment since the heavy use of the vehicles and often repeated use of the same routes make equipping them cost-effective.

From step 2 (2004) to step 3 (2015) what is the population of cars with adaptive cruise control?

It is difficult to give a specific answer. It is expected that in 2004 it will be available, and by 2015 it will be widely used, probably on most vehicles.

AHS WORKSHOP 3 - BREAKOUT SESSION 3D - TIME-STAGING OF AHS DEVELOPMENT AND DEPLOYMENT	
Date:	20 September 1996
Domain Experts:	Jacob Tsao, PATH
Moderator:	Alan Lubliner, Parsons Brinckerhoff
Recorder:	Raja Sengupta, PATH

SESSION

This session addresses stakeholder concerns about AHS deployment, including the mature AHS (hands-off and feet-off driving on dedicated freeway lanes), possible intermediate stages and the transition among stages. It also solicits feedback about three different deployment paths developed by the Consortium, namely the policy-driven, bootstrap and market-driven deployment paths.

KEY FEEDBACK

AHS must develop through an incremental, market-driven process. Mixed traffic operations should be an intermediate stage in the deployment process. The incremental process will evolve to where all highways and vehicles will be automated. This is the end-state, which is several decades in the future.

At each AHS deployment step there should be a lowest common denominator of system capabilities. The set of capabilities should be ACC, collision avoidance (including communications for the same), lane keeping, and traffic management. Providing facilities to help trucks, buses, and commercial fleets offers tremendous opportunities for initial AHS marketing and deployment. However, private vehicles should not be ignored. AHS capabilities can be used to prevent rural problems like road run-off. AHS capabilities should be marketed as also solving such problems.

At each step in the incremental process it is necessary to enhance throughput, reliability, travel time, safety, other personal and societal benefits. To realize an incremental process that evolves through mixed traffic operations we may have to accept lesser safety improvements along the way. However, AHS should never make safety less than today.

Different jurisdictions will have different goals and objectives. Each jurisdiction should be able to use the systems that benefit it. For example, urban and rural areas will likely have different requirements.

The Consortium should develop a set of systems that can be combined in different ways. National standards are a suitable policy instrument for top level safety requirements and interstate interfacing requirements. All other AHS features should be locally definable.

ADDITIONAL FEEDBACK

During normal operating conditions the primary role of AHS should be to assist the driver for improving safety and reduce driving stress. The driver should remain in control, however, under emergency conditions the automated system should take over. Another individual predicted that AHS would be primarily an inter-urban mobility service competing with air traffic.

A straw-poll was conducted on the three deployment paths developed by the consortium. The endorsement of the bootstrap path included a caveat, i.e., obstacle exclusion could not be achieved. One person expressed dissatisfaction with all three deployment paths.

Deployment Paths	Votes in Favor
Policy Driven	*0*
Bootstrap	*4*
Market Driven	*7*