The National AHS Consortium (NAHSC) is moving automated highway technologies out of the lab and onto the road.

NAHSC Facts-at-a-Glance

Mission:

The National Automated Highway System Consortium (NAHSC) will specify, develop and demonstrate a prototype automated highway system (AHS). The specification will provide for an evolutionary deployment that can be tailored to meet regional and local transportation needs.

The Consortium will seek opportunities for early introduction of vehicle and highway automation technologies to achieve benefits for all surface transportation users. The NAHSC will incorporate public and private stakeholder views to ensure that an AHS is economically, technically and socially viable.

Goals:

- *Improve Highway Safety*
- *Increase Highway Throughput*
- *Reduce Environmental Impact*
- *Enhance Mobility*

Significant Milestones:

~ Demonstration of AHS technical feasibility in San Diego — August 1997

~ Selection of the AHS systems approach for the U.S. — March 1999

~ Demonstration of an AHS prototype in 2002

~ Development of the plan for AHS field testing — 2002

NAHSC Core Participants:

Bechtel

Caltrans (California Department of Transportation)

Carnegie Mellon University

Delco Electronics

General Motors

Hughes

Lockheed Martin

Parsons Brinckerhoff

The University of California (PATH) Program

~ In partnership with the U.S. Department of Transportation, Federal Highway Administration ~

NAHSC Associate Participants:

100+ AHS stakeholder organizations working to support and actively participate in the achievement of the NAHSC mission.

NAHSC

National Automated Highway System Consortium

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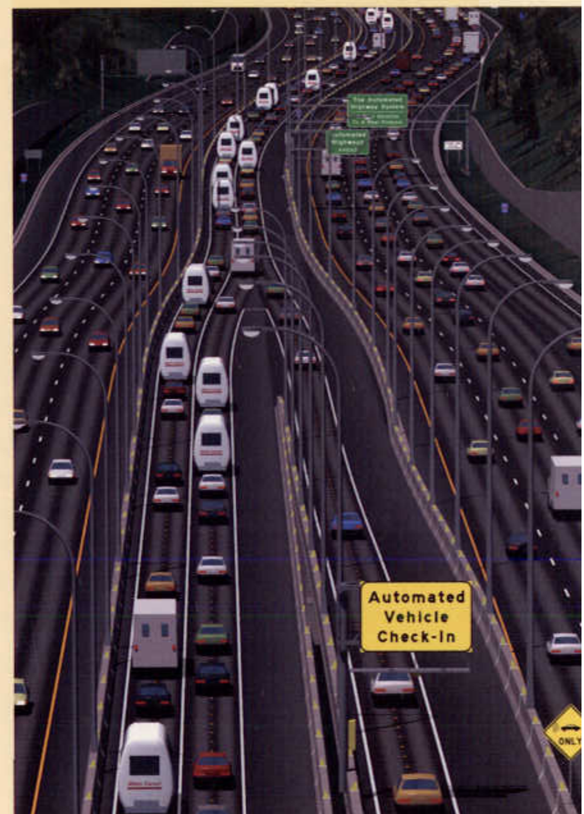
What is an Automated Highway System?



Hughes • Lockheed Martin • Parsons

Brinckerhoff • University of California

PATH • U.S. Department of Transportation

Automated Highway System ...

Since You Asked...

What is an AHS?

An automated highway system (AHS) is a specially equipped roadway on which vehicles can be operated automatically. These vehicles would be fully capable of operating under driver control on all roads and would be able to use many of the AHS features to improve safety on those roads. AHS will evolve from technologies and features that are expected to become available on vehicles and highways in the U.S. over the next 15 years.

Drivers who choose to use the AHS would steer their specially-equipped vehicle onto designated lanes of the highway, then release control of the vehicle to the system. The transfer of control may be similar to the way the "cruise control" feature on today's vehicles assumes control of the vehicle's speed. Command of the vehicle's throttle and brakes would ensure a safe distance from the vehicle in front and operation of the vehicle's steering would ensure that the vehicle remains safely in its lane. When the vehicle reaches the exit selected by the driver, it would be steered into a transition area where the driver would resume manual driving.

Passenger cars, buses and trucks could be equipped to use AHS lanes.

Why is an AHS Needed?

It is increasingly difficult for our vehicle-highway system to meet the growing travel demands and serve the increasing transportation needs of the public and commerce. This is reflected in motor vehicle accident statistics and in the increasing daily congestion on urban highways. In 1992, congestion cost the nation over $100 billion annually while crashes cost in excess of $150 billion annually. Congestion, and its associated costs, are predicted to continue increasing into the foreseeable future. As congestion increases, so do drivers' stress levels. In addition, highway safety continues to be a major concern as more and more drivers use the highways with varying skill and attention levels.

Research indicates that an AHS can significantly increase safety, reduce congestion, reduce stress and ensure shorter, more predictable travel times — often using the existing roadway right-of-ways. At the same time, smoother traffic flow with an AHS promises to reduce fuel consumption and exhaust emissions.

Would an AHS be Safe?

Driver error contributes to over 90 percent of all vehicle accidents. Automated vehicles, cooperating with the highway infrastructure, could eliminate many of these. A design goal of the AHS is to eliminate accidents during normal operation and to manage any faults to safeguard against system failure.

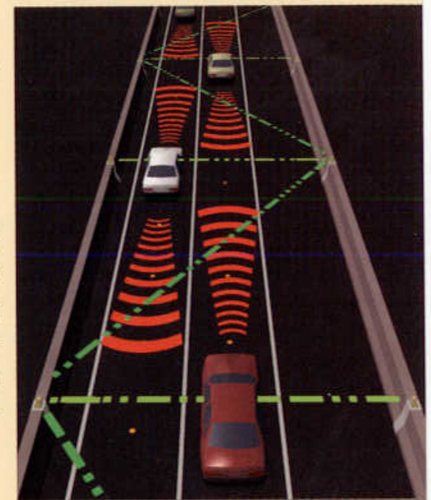
How Would AHS Relieve Traffic Congestion?

An AHS would reduce congestion by making more effective use of today's highway infrastructure. An automated lane could accommodate two to three times the number of vehicles on a manual lane, even in adverse weather. This is possible because AHS technology can:

- smooth out traffic disturbances caused by differing driving skills and styles;
- increase the number of vehicles that can travel safely in each lane through tighter operating tolerances possible with automated control;
- manage entries and exits so that AHS lanes maintain safe, efficient speed and spacing in heavy-demand traffic;
- greatly reduce congestion caused by traffic incidents.

This increased capacity can serve as a tool for traffic engineers to improve our surface transportation system to meet the future's increasing travel demand while reducing its impact on the environment.

Will Cars Need Special Equipment to Use the AHS Lanes?



Yes. Both the AHS lanes and the vehicles that operate on them would require special equipment. The vehicles would require sensors, controllers and communication devices.

The evolution of vehicle electronics over the next fifteen years should provide a natural transition path to AHS. It is expected that long before the first AHS is installed, the public will benefit from features that control their vehicles under special circumstances. Examples of these features already under development are adaptive cruise control (which controls a car's speed to keep a safe distance from a vehicle in front), lane tracking (which helps keep a car in its lane) and collision avoidance.

When Will There be an AHS in the U.S.?

Operational tests involving public use of AHS could begin within ten years. The addition of AHS equipment to highways would occur once it has been proven to be a safe and practical system. Only then will planners see it as a viable option for meeting a community's needs for improving the safety and capacity of its highways. This could occur within twenty years.

NAHSC

THE NATIONAL AUTOMATED HIGHWAY SYSTEM CONSORTIUM
WELCOMES YOU TO A MILESTONE IN THE HISTORY OF TRANSPORTATION

DEMO '97 OPENING CEREMONY

NAHSC

DEMO '97

THURSDAY, AUGUST 7, 1997
9:00-10:00 A.M.

DEMO '97 EXPO CENTER
MIRAMAR COLLEGE
SAN DIEGO, CA

Distinguished speakers include:

THE HONORABLE RON PACKARD, U.S. HOUSE OF REPRESENTATIVES, CALIFORNIA DISTRICT 48
MR. ANTHONY KANE, EXECUTIVE DIRECTOR, FEDERAL HIGHWAY ADMINISTRATION
MS. BARBARA WARDEN, DEPUTY MAYOR OF SAN DIEGO
MR. JAMES VAN LOBEN SELS, DIRECTOR, CALTRANS
DR. JAMES RILLINGS, NAHSC PROGRAM MANAGER
MS. TERRY QUINLAN, NAHSC DEMO '97 MANAGER

Color Guard Furnished by U.S. Marine Corps 4th Tank Division

DEMO '97 DAILY

NAHSC DEMO '97

National AHS Consortium Technical Feasibility Demonstration

The AHS Technical Feasibility Demonstration, San Diego

PROFILE

Who's who In The National Automated Highway System Consortium?

Demo'97 Daily reports on the Consortium's Core and Demo Participants

Toyota:

As today's passenger cars become safer and more fuel efficient, they're also becoming more intelligent. This week, Toyota has been demonstrating the features of several automated cars it has developed.

According to Scott Andrews, project general manager of the Intelligent Transportation System Group for Toyota Motor Corp., Toyota has divided automated driving functions into driver assist and fully automated driving functions.

The driver assist function includes a lane departure warning system that alerts the driver when the vehicle leaves the lane unintentionally without signaling a lane change. The system corrects the vehicle's path if the driver fails to respond to the lane departure warning. Also part of the driver assist system, an adaptive cruise control system automatically sets the following distance to the preceding vehicle, even if the cruise control is set to a higher speed than the prevailing traffic.

Toyota also is demonstrating long-term systems that will require more consumer acceptance and higher

Continued on the back page

NAHSC Welcomes You To Demo '97!

Welcome to Public Day at Demo '97! Heralded as the premier AHS event in history, this demonstration is presented by the National Automated Highway System Consortium.

There is a lot to see and do today. The Exposition Center provides visitors with an opportunity to learn how AHS can improve highway travel. The Center includes an Expo Hall, the NAHSC Learning Center and the Demonstration Presentation Center.

More than 40 organizations on the cutting edge of transportation technologies will display their latest in the Expo Hall. There is a 4,000-square-foot Learning Center exhibit hosted by the NAHSC where you can get the answers to your AHS questions and see how the technologies demonstrated can help solve the transportation problems of today and tomorrow.

There is also an opportunity for you to be one of the first to let the car do the driving for you. Adjacent to the Center is a half-mile, mini-demonstration track where leading companies in the development of AHS and ITS technologies will demonstrate automatic steering control, lane departure warning and automated maintenance and construction equipment (see Mini-Demonstration story on back page).

"We are excited to have the opportunity to show you what AHS is all about. What you see here today has the potential to change the way you travel, making each trip you take safer and more enjoyable. So please enjoy not Driving!"

Jim Rillings,
NAHSC Program Manager

The NAHSC is happy to offer you a look into the next century of transportation! ■

CALENDAR OF EVENTS

Sunday, August 10

Live Vehicle Demo
10:00am - 4:00pm

Expo Center
11:00am - 4:00pm

Outdoor Technology Demo
11:00am - 4:00pm

Tijuana Shopping with Lunch (fee)
9:00am - 3:00pm

Del Mar RaceTrack (invitation only)
11:30am - 6:30pm

Projected Benefits of an Automated Highway System

- Safety
- Traffic Congestion Relief
- Economic
- Environment
- Driver Comfort and Convenience
- Social and Institutional

While Enjoying Demo '97 Please Be Aware...

- Children under the age of 16 must be accompanied by an adult at all times.
- of vehicles moving within the Exposition area.

Mini-Demos:

A Glimpse into the Automated Highway System Technologies

In addition to the live demonstrations being auditioned at the HOV lanes of I-15, the Consortium has arranged to showcase a number of AHS technologies at Miramar College adjacent to the Expo Center. The mini-demos are designed to allow the viewers to experience automated travel without having to trek out to I-15 on these hot summer days. The demonstrations available for viewing and/or participation consist of a fully automated car operating on a magnetic system, a fully automated car using the vision system, static display on vehicles with various automatic control features, and an introduction to the automation of vehicles by some future automated highway system engineers from four Universities located around the country.

Below is a summary of each mini-demo participant scenario:

◆ ***PATH's*** car will demonstrate fully automated precision control cars going forward and backward, based on magnets buried in the middle of the road. The system is the same as the Platoon scenario demonstration at I-15.

◆ The ***Ohio State University*** automated car is a Honda Accord which has all the alternative sensing technologies found on OSU's I-15 demonstration cars. During the run, the car will be automatically controlling its speed, maintaining its lane, automated lane change, and slow down and stop operations. It will be using alternatively radar and radar reflective stripe, and vision based sensing for steering.

◆ ***3M*** Company will be demonstrating Magnetic Lateral Warning and Guidance Tape on the short track. The demonstration will manifest tapes ability to assist the human driver, and help build a magnetic path to the automated highway using existing infrastructure. Ohio State University will also be using #M radar guidance tapes in their demo.

◆ the ***Honda*** mini-demo features a hands-free, feet-free ride in an autonomous vehicle developed in conjunction with PATH. A visual lane tracking system controls the vehicle along a winding white line.

◆ The ***Advanced Highway Maintenance & Construction Technology Center (AHMCT)*** will showcase a newly constructed and designed teleoperation (remote control) system known as the *Teleoperated and Automated Maintenance Equipment Robotics (TAMER)* that operates a Case Model 621 front-end loader from a remote site.

◆ The ***Unmanned Ground Vehicle Demo (UGVD)*** will showcase the talents of four colleges; Oakland University in Rochester, MI, Virginia Tech in Blacksburg, VA, University of Colorado in Denver, CO, and Ohio State University in Columbus, OH.

The students will demonstrate autonomous vehicle systems. The systems utilize vision systems and are totally autonomous without tethers or any other infrastructure support. The vehicles are required to be less than the size of a golf cart.

The objective of the demonstration is to navigate and complete the course at track D without any human intervention.

Feel free to observe all of th demonstrations and line up for a ride.

Your questions about the mini-demos can be addressed to any of the NAHSC participants who are identified by their Consortium polo shirts. ■

MINI DEMO SCHEDULE

<u>Sunday, August 10</u>

Track A:	
11:00am - 12:30pm	PATH
12:30pm - 2:00pm	3M
2:00pm - 4:00pm	PATH
Track B:	
11:00am - 4:00pm	Honda
Track C:	
11:00am - 4:00pm	AHMCT
Track D:	
11:00am - 4:00pm	UGVD

Profile

(Continued from the previous page)

levels of technology. These automated driving systems include a stop-and-go system that allows the vehicle to operate partially autonomously in heavy traffic and a lane keeping system that guides the vehicle within the lane without any driver input. They also feature obstacle avoidance which steers the vehicle around obstacles in the lane, cooperative vehicle following which allows similarly equipped vehicles to safely operate at reduced headway and relatively high speeds, and automatic emergency-stop braking to avoid or reduce the severity of collisions when there is no way to steer around an obstacle.

3M:

A new magnetic-based lateral warning and guidance tape from 3M alerts drifting drivers with electronic rumble strips and paves the way for automated highways.

Based upon unique adhesive and tape technology expertise developed in 3M's line of pavement marking tapes, 'smart' tape integrates magnetic medium into pre-formed, pressure sensitive pavement marking tapes that can be magnetized in a number of different ways. "The magnetic capabilities of this pavement tape make it an enabling technology for a host of applications," said Jeff Boehm, market development manager, 3M.

One application uses the tape as an electronic in vehicle "rumble strip" as part of a driver alert system. A vehicle-mounted sensor can detect the magnetic field of the tape from as far away as three feet and reduces an audible alarm if the vehicle drifts over an edge line.

Another application gives lateral warning and guidance to snow plow drivers. It is currently being tested by Minnesota Guidestar and 3M in Fergus Falls, Minn., which is a high snow drift region, to evaluate product performance and human factors.

That same tape can be used for lane keeping, which is a critical requirement for creating automated highways. ■

U.S. Department of Transportation

News:

Office of the Assistant Secretary for Public Affairs
Washington, D.C. 20590

Statement of U.S. Secretary of Transportation Rodney E. Slater
August 6, 1997

(Remarks prepared for Secretary Slater's video presentation August 4, 1997)

Good morning. Let me first begin by again thanking those of you who were with me Saturday for the demonstration of these groundbreaking technologies. You have truly achieved a remarkable milestone in the development of automated safety. Having ridden the automated bus this past weekend, I know you will feel -- as I did -- that the future has arrived.

As you know, in 1991, Congress directed the Department of Transportation to develop an automated highway and prototype vehicle by 1997. Today, I am proud to say you have done the job.

Today, we are witness to the transportation system equivalent of the "concept car" that manufacturers preview at auto shows to tantalize us, to make us dream of the future. But those cars aren't for sale, any more than the total concept of the automated highway is ready to roll out and use.

But this demonstration does represent a breakthrough in developing a transportation system for the 21st Century.

And we will need it. We will need the technologies demonstrated today to reduce congestion -- as we anticipate a 30 percent increase in travel demand in the next decade. And we will need these technologies to improve safety -- as 90 percent of current crashes are caused by human error.

This demonstration is just the beginning. I know you are wondering, "Where do we go from here?"

When Congress tasked us with developing a system to bring us into a new realm of automotive safety and efficiency, the consortium of private companies, universities, and state and Federal transportation agencies responded to that charge. Today, real buses and cars have demonstrated they can interact with each other, with the road, and with the environment.

- (more) -

Now we must examine our next steps. The President and Congress have also reached an historic milestone by balancing the Federal budget. We have a responsibility to the American public to invest technology dollars wisely and to meet our needs sooner rather than later.

Make no mistake, the Department of Transportation remains committed to Intelligent Transportation Systems and these new technologies. But today, with the passage of the balanced budget agreement, this is the occasion to will take full measure of the priorities and benefits for long-term investment in this area. So that we can focus on near-term solutions to our transportation needs.

Our aim must be to continue to provide Americans the opportunity to benefit from these and other advanced technologies.

The reasons are clear.

So our cars can move safely and efficiently in traffic.

So we will not find ourselves lost in an unfamiliar city, or on a country road.

So law enforcement and emergency services are notified automatically when an accident occurs.

So heavy snow or driving rain will not prevent us from staying the course.

So no family will ever again suffer the loss of a precious child who lingers in the blind spot of a car, bus, or truck.

All of this is possible with the technologies demonstrated today.

Even now, the investment we made in the Automated Highway System is providing dividends -- the technologies developed by the Consortium are real and can be made available in the cars we purchase early in the next decade.

And at the heart of these technologies is ITS, the Federal Government's commitment to intelligent transportation and intelligent vehicles. Under President Clinton's leadership, we plan to continue investing in these technologies. To date, we have invested 1.2 billion dollars in the ITS program. In 1998, we have proposed investing another 250 million dollars, with 53 million dollars for this research alone. Clearly, our investment is paying dividends for the Nation.

In closing, let me congratulate our partners, you, the members of the Consortium, for your hard work. My thanks to all of you for helping us reach our goal to bring these technologies to life.

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NAHSC

National Automated Highway System Consortium

DEMO '97

National AHS Consortium
Technical Feasibility Demonstration

WHERE THE RESEARCH MEETS THE ROAD...

Interstate 15 HOV Lanes

On-Lane Demo '97 Scenarios

Passengers of the Demo '97 scenario rides will be some of the first people in the world to experience the range of AHS technologies in a real-time/real-world setting — from "driver assist" modes to fully automated highway travel. Rider reactions and feedback will be gathered and used in the Consortium's continuing work to define the plan for deployment of AHS technologies in the U.S.

The NAHSC Participants are working together to show the world what the future of highway travel might be. These scenarios are not a prototype for a final AHS, but a look at the capabilities and potential benefits of AHS to solve mounting traffic problems such as decreasing safety and rapidly increasing congestion.

The Free Agent, Multi-platform automated vehicle lineup at Carnegie Mellon University.

Free-Agent, Multi-Platform Scenario

Carnegie Mellon University has teamed up with Metropolitan Transit Authority of Harris County (Houston Metro) to show vehicle-based AHS technologies used across different vehicle platforms and to demonstrate the potential of automated vehicles operating in non-automated traffic. Using two buses, one Oldsmobile Silhouette minivan and one Pontiac Bonneville, the scenario will showcase full automation, obstacle avoidance and collision warning, and will demonstrate an automated lane change and an operator/driver interface.

A line, or "platoon" of automated Buick LeSabres takes to the road at the Crow's Landing test site in preparation for Demo '97.

Platooning Scenario

The University of California PATH Program is leading the development of this scenario using eight specially-equipped Buick LeSabres to prove the feasibility of a transportation system designed to significantly improve the throughput on U.S. highways. The vehicles were modified by Delco Electronics, General Motors, Hughes and the University of California PATH. The cars will travel in a single-file formation guided by magnets imbedded in the roadway. As a group, they will accelerate, decelerate and the platoon will split to allow other vehicles to enter and then rejoin as one platoon. Drivers will receive vital information such as vehicle speed, current maneuver and distance to destination via a head-up display designed by Delco Electronics.

Maintenance Scenario

Caltrans is leading the development of the AHS maintenance operations scenario, using the Infrastructure Diagnostic Vehicle (IDV) and the Obstacle Removal Vehicle (ORV). The IDV, developed by Caltrans, Lockheed Martin and the AHMCT Research Center at the University of California-Davis, will use autonomous lateral control equipment and conventional cruise control for automated driving. The IDV will include diagnostic equipment to conduct monitoring, physical inspection and preventive maintenance to preserve the integrity of the AHS infrastructure. These maintenance operations will be performed while traveling under automated control at highway speeds. The ORV, developed for Caltrans and AHMCT by Pick-All, Inc., will demonstrate the automatic and safe removal of obstacles and debris from the AHS lanes.

Control Transition Scenario

Honda R & D will showcase two approaches to an AHS — an infrastructure-supported approach (where the car and the roadway are equipped with AHS technology) and an independent vehicle approach (where AHS technology is in the automobile only). Honda's two prototype AHS Accords will transition between these two approaches as they demonstrate: platooning, automated lane changes, automated start and stop, and obstacle detection and avoidance. Honda's AHS Accords will also demonstrate the use of multiple sensor systems to offer back-up technology for added performance and reliability.

Front view of one of the Honda AHS Accords, which can drive using their own video cameras (visible through the windshield) or magnetized "nails" (shown here in the roadway).

Alternative Technology Scenario

The Ohio State University will use one manually-driven car and two automated cars to show automated vehicle passing, while a manually driven car in this scenario highlights an additional technology for lateral lane-keeping control. Four miles of the HOV lanes are equipped with radar-reflective tape produced by 3M. This tape (instead of the magnets used in other scenarios) and a single camera-based vision system will be used for lateral control. A low-powered radar will be used for side vehicle detection and a laser system will be used for longitudinal (speed and braking) control.

Evolutionary Scenario

This scenario will showcase the evolution of vehicle automation. Toyota, in conjunction with the Toyota Technical Center, IMRA and AISIN, is leading the development of this scenario using existing highway infrastructure, two concept automated vehicles and two non-automated Toyota Camrys to consecutively demonstrate lane departure warning, obstacle detection warning, blind spot warning, longitudinal control, automated lateral control, obstacle avoidance and automated lane change maneuvers.

Top-level Functions	**Scenarios**							
	Evolutionary	Multi-Platform Free Agent		Control Transition	Maintenance		Platoon	Alternative Technology
		Passenger Vehicles	Buses		IDV	ORV		
Lateral Control	✔	✔	✔	✔	✔		✔	✔
Longitudinal Control	✔	✔	✔	✔			✔	✔
Obstacle Detection	✔	✔		✔		✔		
Collision Warning	✔	✔						
Obstacle Avoidance	✔	✔		✔				
Lane Departure Warning	✔	✔						
Communication	Vehicle to Vehicle	Vehicle to Vehicle		Vehicle to Vehicle	Infrastructure to Vehicle to Infrastructure	Vehicle to Infrastructure	Vehicle to Vehicle	

Questions & Answers

What can AHS offer in the near term?

Fully automated highway systems may be several years away, but many AHS applications are already road-ready or near ready. These include:

- Adaptive Cruise Control — This system senses vehicles ahead and alters speed accordingly.
- Obstacle/Collision Avoidance — Using radar, this system "sees" obstacles and other vehicles in the road and warns the driver and/or brakes.
- Lane Keeping — This system uses sensors to track markers in/on the highway lane and warns the driver when he/she drifts across a lane or road boundary.

How can AHS improve safety?

Crashes on our nation's highways cause more than 40,000 fatalities and more than five million injuries each year, costing more than $150 billion. In nine out of ten crashes, human error plays a leading role.

Fortunately, highway and vehicle automation promise to make highway travel significantly safer by correcting — or even eliminating — the element of driver error. Vehicles equipped with AHS technology will be safer because they will:

- Detect and avoid obstacles, reducing the number and severity of crashes.
- Communicate with other vehicles, enabling coordinated maneuvers.

How can AHS reduce congestion?

AHS promises to reduce congestion by dramatically increasing the efficiency of today's highways. An AHS lane will be able to double or even triple the capacity (in vehicles per hour) of a given stretch of highway. AHS can achieve this substantial improvement by:

- Providing uniform driving performance through significantly reduced erratic accelerations, decelerations and weaving typical on congested highways.
- Eliminating uneven traffic flow caused by human distractions, varying driver skills/impairments.

U.S. Senator John Chafee (R-RI), Environment and Public Works Committee chairman (center, left) discusses AHS with Consortium members and California Transportation Secretary Dean Dunphy (center, right).

The Infrastructure Diagnostic Vehicle (IDV) is an example of an intelligent maintenance vehicle that provides automated inspection and real-time monitoring of road-side electronics and other infrastructure elements to enhance public works agencies' cost-effective maintenance operations.

Projected Benefits of AHS

Safety

- Eliminates crashes caused by driver errors (which represent 90% of current crashes)
- Assists driver to avoid accidents on non-AHS roads
- Dramatically reduces the frequency and severity of crashes
- Significantly reduces the number of fatalities and severe injuries per vehicle-mile traveled

Traffic Congestion Relief

- Increases the capacity of existing freeways
- Reduces time wasted in traffic jams
- Reduces trip time uncertainty
- Reduces congestion on both automated and non-automated lanes
- Improves timeliness and reliability of transit service

Economic

- Reduces the need for construction of additional freeway lanes
- Helps just-in-time delivery of freight
- Improves productivity of commercial vehicle operations
- Provides an opportunity to develop a new export industry with U.S. leadership
- Helps international economic competitiveness by improving domestic transportation efficiency

Environmental

- Significantly reduces fuel consumption for a given trip
- Significantly reduces exhaust emissions for a given trip
- Reduces the need for additional highway construction

Driver Comfort and Convenience

- Reduces driver stress and fatigue
- Permits drivers to engage in work or leisure activities while traveling
- Provides safe, non-threatening freeway access to inexperienced and aging drivers

Social and Institutional

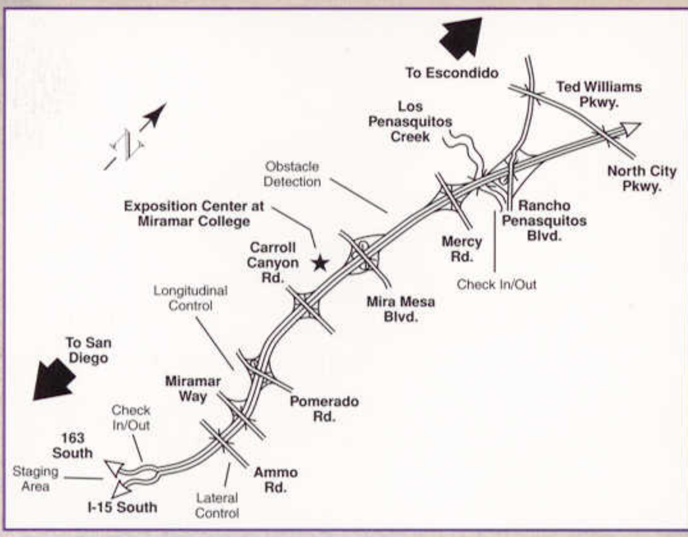
- Enhances mobility for all user groups
- Applies to urban, suburban, intercity and rural freeways
- Supports travel demand management policies
- Improves transit service
- Improves emergency service response time

NATIONAL AHS CONSORTIUM TECHNICAL FEASIBILITY DEMONSTRATION
AUGUST 7 - 10, 1997

Demo '97 will present a look at the future of highway travel with a series of live demonstrations of automated highway system (AHS) technologies on Interstate I-15 in San Diego, California.

The NAHSC will demonstrate the technical feasibility of these AHS technologies and their near-term applications to substantially improve highway safety and efficiency.

Demo '97 includes several on-lane vehicle scenario demonstrations and a nearby Exposition Center.



The Demonstration will show currently available and emerging advanced vehicle control and safety system technologies and concepts that promise to be the building blocks of an AHS prototype.

A limited number of scenario rides will be given on the reversible high-occupancy vehicle (HOV) lanes of Interstate 15 using a variety of current model passenger and commercial vehicles.

Location: Miramar College
(adjacent to the I-15 HOV lanes)
10440 Black Mountain Rd.
Mira Mesa, California

The Exposition Center will detail the potential benefits and near-term deployment options of AHS technologies through exhibits, automated vehicle and equipment displays, computer simulations, vehicle demonstrations, presentations and literature.

Demo '97 Event; Location	Date	Time
On-lane Vehicle Demo Scenarios;	August 7	9:30am - 1:30pm
I-15 HOV lanes, San Diego	August 8	9:30am - 1:30pm
	August 9	9:00am - 5:00pm
	August 10	10:00am - 4:00pm
Exposition Center/Outdoor	August 7	9:30am - 5:00pm
Technology Presentations;	August 8	9:30am - 5:00pm
Miramar College, San Diego	August 9	10:00am - 5:00pm
	August 10**	11:00am - 4:00pm
Public Day		
SAE Future of Transportation	August 5	7:30am - 5:30pm
Technology Conference	August 6	7:30am - 5:30pm
Technical Sessions;	August 7	7:30am - 5:30pm
Miramar College, San Diego	August 8	7:30am - 5:30pm

*Please note all times are tentative. **Open to the public.

WHERE THE RESEARCH MEETS THE ROAD...

DEMO '97

PROJECT TEAM:

The Demo '97 Team is comprised of NAHSC Core and Associate Participants

CORE PARTICIPANTS

- Bechtel
- Caltrans (California Department of Transportation)
- Carnegie Mellon University
- Delco Electronics
- General Motors
- Hughes
- Lockheed Martin
- Parsons Brinckerhoff
- The University of California PATH Program

~ in partnership with the U.S. Department of Transportation ~

DEMO ASSOCIATE PARTICIPANTS

- Honda Research and Development
- Metropolitan Transit Authority of Harris County (Houston Metro)
- The Ohio State University
- Toyota Motor Corporation

CONTACT INFORMATION:

- For sponsorship information, contact Francis Dattilo at: (800) 687-7469.
- For exhibitor information, contact Jennifer Cenedella at: (800) 687-7469 or e-mail: ntp.sales@clark.net.
- For press information, contact Celeste Speier by fax: (248) 649-9569 or e-mail: speierc@nahs.org.
- To request Demo '97 attendance information, fax your name, mailing address and phone number to Heather Teger at: (703) 706-8229 or e-mail: ntp.info@clark.net.
- For information about the associated Society of Automotive Engineers (SAE) Future Transportation Technology Conference (August 6-9) call: (412) 772-7131 or e-mail: meetings@sae.org.
- For travel arrangements, call Par Avion at 800-927-8137 or 310-670-2970.

NAHSC

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Platoon Demonstration

Platoon Demonstration Scenario

The platoon demonstration scenario is designed to show how vehicle automation technology can be used to make a major contribution to relieving traffic congestion. Platooning enables vehicles to operate much closer together than is possible under manual driving conditions, so that each lane can accommodate a significantly higher volume of traffic than today's highway lanes. The high-performance vehicle control system also increases the safety of highway travel, significantly reduces exhaust emissions and energy consumption, reduces driving stress and tedium, and provides a very smooth ride.

The platoon demonstration will show the technical feasibility of operating standard automotive vehicles under precise automatic control at close spacings at highway speeds. This should make it possible to greatly reduce highway congestion by making it possible for each lane to carry at least twice as much traffic as it can carry today. The tightly coordinated operation of the platoon makes it possible to reduce the gap between vehicles significantly, while maintaining safety. At close spacing, aerodynamic drag is significantly reduced, which can also lead to major reductions in fuel consumption and exhaust emissions.

The primary feature that distinguishes the platoon demonstration scenario from the other Demo '97 scenarios is the use of eight vehicles operating in tight coordination to show how an automated highway system can provide a significant increase in highway throughput (vehicles per lane per hour moving along the highway). The eight vehicles of the platoon travel at a fixed separation distance of 6.5 meters (21 feet) at all speeds up to full highway speed. At the maximum cruising speed of 65 mph on I-15, eight-vehicle platoons at this spacing, separated by a safe inter-platoon gap of 60 m (about 200 ft.) would represent a "pipeline" capacity of about 5700 vehicles per hour. Reducing this by 25% to allow for the maneuvering needed at entry and exit points corresponds to an effective throughput of about 4300 vehicles per lane per hour, which compares very favorably to the approximately 2000 vehicles per lane per hour that could be achieved at this speed under normal manual driving conditions.

The short spacings between vehicles can produce a significant reduction in aerodynamic drag for all of the vehicles (leader as well as followers). These drag reductions are moderate at the 6.5-meter spacing of the Demo, but become more dramatic at spacings of half that length. Wind-tunnel tests at the University of Southern California have shown that the drag force can be cut in half when vehicles operate at a separation of about half a vehicle length. Analyses at UC Riverside have shown how that drag reduction translates into improvements of 20 to 25% in fuel economy and emissions reductions.

The tight coordination of vehicle maneuvering is achieved by combining range information from a forward-looking radar with information from a radio communication system that provides vehicle speed and acceleration updates 50 times per second. This means that the vehicles can respond to changes in the motions of the vehicles ahead of them much more quickly and accurately than human drivers. As a result, the space between the vehicles is so close to constant as to be imperceptible to the driver and passengers. This gives the illusion of a mechanical coupling between the vehicles, which is especially apparent going up the 3% grade leading toward the north end of the I-15 HOV facility. You will probably have the sense that the vehicle in front of you is pulling your car up the hill.

The vehicle-vehicle communication capability is used to coordinate maneuvering. These maneuvers include lane changing, in which a vehicle safely coordinates its lane change with adjacent vehicles, so that they do not try to occupy the same place at the same time, and platoon join and split maneuvers — decreasing the space between vehicles to form a platoon and increasing the space to separate from a platoon.

Tight coordination among vehicles also facilitates responses to malfunctions, enabling all vehicles in a platoon to learn about a malfunction within a fraction of a second, so that they can respond accordingly. The vehicles are equipped with malfunction management software, to automatically implement such corrective actions as increasing the separation between vehicles while warning the drivers.

The control system has also been designed with careful attention to passenger ride quality. Both the lateral (steering) and longitudinal (speed and spacing) control systems have been designed, tested, and proven to have higher performance than even highly skilled human drivers. The lateral control system keeps the vehicle to within a few inches of the lane center under virtually all conditions, which is much more accurate than human drivers' steering. The longitudinal control system maintains speed and spacing accuracy that exceeds that of all but virtuoso race-car drivers.

The accuracy and fast response of the longitudinal control system provides a reassuring, smooth ride. Although some people are initially startled by the "tailgating" aspect of vehicle following at close separations, most of them quickly adapt and develop a sense of comfort and security because of the constantly-maintained separation.

The human/machine interface on the Demo LeSabres has been carefully designed to enhance user acceptability. The steering-wheel control buttons can be used to activate and deactivate automation functions, and the flat-panel display in the center of the instrument panel provides timely status information. The latter is important so that the driver can be given assurance during fully automated driving that the system really "knows" what it's doing. Maneuvers that might be surprising are indicated in advance on the display so that there are no surprises and so that vehicle movements will seem natural and logical.

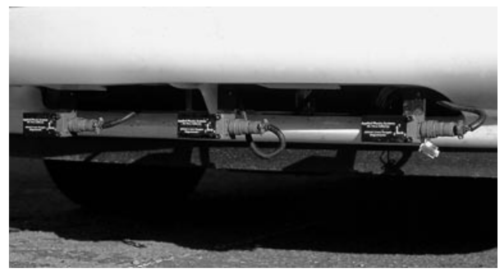
The platoon scenario does not include the full range of functions that would be needed for an operational automated highway system. However, it includes some capabilities that would not be needed in normal AHS operations. For example, the entire platoon starts from a stop at the start of the demo, and decelerates to a stop at the end, because of the physical constraints of the Demo site. In an operational system, individual vehicles would accelerate on the onramps to merge into the traffic stream and would decelerate on the exit ramps after lane changing out of a platoon, while the mainline traffic would be flowing continuously. Since the I-15 HOV facility does not have intermediate on- and off- ramps, the entire platoon starts and stops together.

The platoon demonstration gives a realistic sample of the experience of traveling in a fully automated AHS vehicle, and shows that comfortable, high-capacity, automated travel is technically feasible in the near future, as well as being a pleasant experience.

Lateral Control

For a vehicle to follow the road, the road has to be first marked by some indicators that define its boundaries. The vehicle then employs appropriate sensors to measure the corresponding physical properties of the indicators and to determine its relative location with respect to the road markings. On-board intelligence, based on the relative locations, commands the steering actuator to steer the vehicle and follow the road.

The PATH automatic steering control system uses magnetic markers buried along the road center 4 feet apart to define the roadway. By alternating the polarities of the magnetic markers, they also transmit such roadway characteristics as upcoming road geometry information, milepost locations, and entrance and exit information to the vehicle. Six three-axis fluxgate magnetometers, developed by Applied Physics, located below the front and rear bumpers of the vehicle, pick up the magnetic field emitted from the magnets. A signal processing algorithm, by comparing the measured magnetic field strength to the ‘magnetic field map’ of a magnet and eliminating the background noise, determines the relative position of the vehicle to the road center. This information is then provided to a Pentium computer to determine the desired steering command using a robust algorithm. A DC motor added to the steering column, developed by Delphi Saginaw, steers the vehicle according to the steering command.

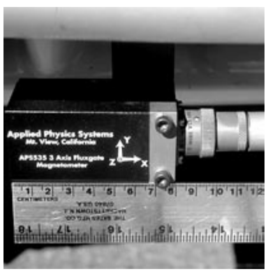


The result is an automatic steering system that tracks the roadway center with less than three inches of error with good passenger comfort. The major advantage of such a system is that it offers a relatively simple, potentially economical, and very robust automatic steering control system. The system works equally well under inclement conditions such as rain, snow, and low visibility.

Longitudinal Control

In the platoon demonstration, eight vehicles travel in close coordination under fully automated longitudinal and lateral control. The cars maintain a fixed spacing of 6.5 meters (21 feet) between themselves at all speeds up to full highway speed. The spacing is maintained with an accuracy of ± 10 cm. (4 inches) during cruising and ± 20 cm. (8 inches) during maneuvers like acceleration and deceleration. In the future, improved spacing accuracy achieved by the longitudinal control system should enable the spacing to be reduced to less than 2 meters (6.5 feet).

This short spacing between vehicles can increase the throughput of the highway, allowing it to carry as much as twice or three times as many vehicles than now. The other major advantages of the platooning system are increased safety and fuel efficiency. Safety is increased by the automation and close coordination between vehicles, and is enhanced by the small relative speed between the cars in the platoon. Because the cars in the platoon travel together at the same speed, a small distance apart, even extreme accelerations and decelerations cannot cause a serious impact between the



cars. The limited spacing constrains the maximum relative speed between cars in the event of a crash, and ensures the safety of passengers.

Accurate intercar spacing in the platoon is achieved by the longitudinal control system through the use of radar and radio communication between cars. Each car in the platoon uses its radar to measure the distance to the preceding car. The radio communication system provides each car with broadcast information on the velocity and acceleration of the preceding car and the lead car of the platoon. All of these signals are used by the longitudinal feedback control system to continuously determine the desired acceleration of each car. The throttle or the brake is then used to provide the desired acceleration. A knowledge of the dynamic behavior of the throttle and brake actuators ensures that they are expertly controlled so that the desired acceleration is achieved very accurately. The longitudinal control system updates the actuators at a rate of 50 times per second.

The platoon demonstration also shows how a car can leave or join the platoon at any desired time. The radio communication system is used to coordinate such maneuvers within the platoon. A car that desires to leave the platoon informs the lead car, and is then given permission to drop back to a larger spacing from the preceding car. The car immediately behind also drops back to a larger spacing. The exiting car then makes an automated lane change to the adjacent lane. (If there were an off-ramp available on the test facility, this vehicle could have then exited to go to an intermediate destination.) All the cars in the rear of the platoon then speed up to join those in the front, so that the original spacing between all cars is restored. After a mile of cruising in the other lane, the car that split from the platoon rejoins it. The split car slows down and matches speed at the tail of the platoon, makes one more lane change, and then accelerates to rejoin the platoon as its very last car. This is the way a car entering the system at an on-ramp would join the passing platoon.

Fault Management

A very important feature of the vehicle control system is the automated fault management system. The fault management system will both detect and handle failures in the sensors and actuators. Failures are typically detected within a fraction of a second of the time they occur. Some failures are handled without any perceptible change being noticed by the passengers. In some cases, however, for instance in the case of a radio communication system failure, passengers will notice that the spacing between some cars in the platoon is enlarged to as much as 15 meters. In the rare event of an actuator failure (throttle or brake failure), the driver of the car will be informed that his intervention is necessary.

When a failure is detected in any vehicle, appropriate action messages are broadcast to all the vehicles in the platoon to coordinate their response. Even a malfunction like a complete breakdown of the computer system in a car will trigger a fault management response in the other cars in the platoon, thereby avoiding a crash. This is possible because a computer breakdown in any car causes the car behind it to stop receiving appropriate radio messages, thereby enabling it to detect that a fault has occurred. The fault management system ensures greater safety even in the case of a malfunction in any of the hardware.

Platoon Demonstration Participants

The Platoon Demonstration is the product of years of labor, including many long days and nights preceding Demo '97, by many people from industry and academia across the country. The following pages credit those people and their roles in making this part of Demo '97 a reality.

University of California PATH Program

PATH researchers designed the operational concept and control systems for the Platoon Scenario, and specified the hardware performance requirements. They developed the magnetic reference sensor system for lateral control, the electronic throttle actuation system, the communication protocols for vehicle-to-vehicle communication, and the malfunction management software. PATH researchers also integrated all the in-vehicle software, and debugged and tested the complete vehicle control system.

Program Manager
Wei-bin Zhang (narrator)

Longitudinal Control System Development



Rajesh Rajamani, lead (narrator)
Sei-bum Choi, Farokh Eskafi, communication protocol development

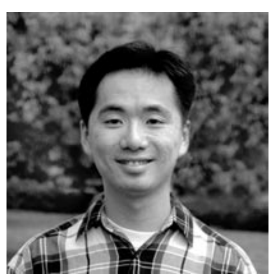
Lateral Control System Development




Han-shue Tan, lead (narrator)
Chieh Chen (driver), Jürgen Guldner (narrator), Satyajit Patwardhan

Software Development and Implementation

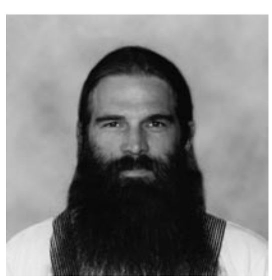





Paul Kretz, lead
Benedicte Bougler, system administrator (driver, narrator), Boon Law, communication protocol development (driver), Andrew Segal, radar evaluation & configuration management

Vehicle System and Experimental Support






Jay Kniffen, lead (driver, narrator)
Sonia Mahal, electronic interface debugging (driver, narrator), David Nelson, hardware support (driver), Robert Prohaska, vehicle hardware design & integration

General Motors

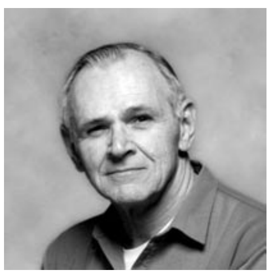
• Research and Development Center

General Motors Research and Development Center arranged to obtain 10 Buick sedans and their steering and braking actuators for the platoon demonstration. GMR&D provided systems engineering support for the PATH development effort. GMR&D also provided extensive engineering and technical assistance both in initial design and construction and subsequent support of the vehicles, including wiring, circuit boards, magnetometer covers, radar mounts, equipment packaging, cooling, power supply designs, and grille modification.









First row: Jack Beard, Mike Briggs, Tom Brown, George Clancy, and Vince Fong

Second row: Shelby Jett, James McKenna, Gene Suchenek,and Carl Witkowski

• Delphi Chassis Systems

Bryan Riddiford, Ryan Wright, Wes Bogner, and Ernst Baumgartner from Delphi Automotive designed, built, tested and supported the brake-by-wire systems on the demonstration vehicles. Current state-of-the-art brake system technology developed by Delphi Automotive was applied and adapted in innovative ways to successfully match demonstration vehicle brake requirements.




Ernst Baumgartner, Wes Bogner, Bryan Riddiford, and Ryan Wright

General Motors (cont.)
• Delphi Saginaw Steering Systems

Delphi Saginaw Steering Systems developed, designed, installed, and maintains the steering actuator for the Demo ’97 Platoon Demonstration system.

First row: Aparna Amberkar, Farhad Bolourchi, Karen Boswell, Craig Hennings, and Julie Kleinau

Second row; Scott Milsap, Eric Pattok, Larry Swiercz, and Reeny Sebastian

Not pictured: Tim Kaufmann

• Buick Motor Division

The Buick Motor Division of General Motors provided the ten Buick LeSabres used in the platoon scenario demonstration, and provided vehicle support as well.

Buick General Manager Robert E. Coletta commented as follows on Buick’s support of Demo ’97: “The automated highways previewed here will offer an important technology that will provide for more efficient use of freeways and more stress-free and safe travel, among other benefits. Buick is a perfect fit for the automated highway demonstration because both Buick and the demonstration are focused on comfortable, convenient, and safe travel.”

Mike Doble, Concept Vehicles & Technology Manager, Cross Brand Team

Delco Electronics

Delco Electronics has contributed key AHS vehicle components, including the Automotive Radar, Powertrain Control Module, Steering Controller, Fiber-Optic CAN bus and the Driver Interface. The Driver Interface consists of a Flat Panel Display, a Head-up Display and Steering Wheel Controls. The information on these displays is supplemented with audio messages to keep the occupants of the vehicle informed of the state of the vehicle.




Adil Ansari, Joy Beeler, Ron Broniak, and Gordon Cheever




Dave Curry, Steve Ewbank, Wally Fahling, and Mark Hewitt




Tom Jaworski, Ashok Ramaswamy, Steve Skiver, and Rob Perisho

Zhaihing Zhang

Hughes Aircraft Company

The Hughes team is responsible for development of the vehicle-to-vehicle communication system. Hughes designed the over-the-air protocol and message format and specified its implementation in a commercially available spread spectrum product marketed by Utilicom, Inc. Hughes specified the radio interface card for the on-board computer and modified the software driver to support high speed data transfers. Hughes also developed integration software that tests the over-the-air performance of each radio in the platoon and displays diagnostics for analysis.

Ron Colgin

Not pictured: Aimee Cochran, Fred Mangarelli, and Eric Reichelt

Caltrans

Since 1986, the California Department of Transportation has funded and supported the California PATH program's research into longitudinal and lateral control systems for automated highway system vehicles, culminating in the Platoon Demonstration.

Caltrans District 11 and the Caltrans New Technology and Research Program designed, surveyed, and installed the magnetic markers on Interstate 15, as well as providing continued support and additional infrastructure for Demo '97 needs.




Lynn Barton–Project Manager, John Isaak–Construction, Richalene Kelsay–Environmental Analysis, and Hanh-Dung Khuu–Project Report




Bruce Lambert–Minor Contracts Design, Tarbell Martin–Traffic Management Center, Jon Mehtlan–Structures Construction, and Joy Pinne




Barbara Rinkleib–Traffic Management Center, Dave Sanderfer–Project Report, Pat Thomas–Officer Engineer, and Tim Vasquez–Environmental Analysis


Tom Westbrock–Minor Contracts Design, and Randy Woolley

Not pictured: Leon Edmonds–Officer Engineer, and Karen Wallace, Debra Warnholtz, Evora Ogden, Marcus Cinco of the Traffic Management Center

Survey Group: Bruce Urquhart, Ramon Vasquez, Molly Wollam, Randy Haralson, Vance Breshears

Minor Contract Design Group: Dan Goldberg, Tonya Jackson, Victor Piaz, Sandro Bermudez, Frank Thomas, Harwell Ontor, and Jim Haines. Not pictured is Jeff Scott.

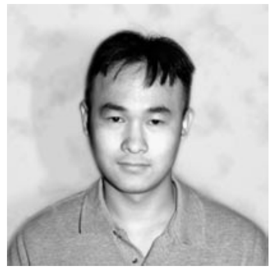
Budgets Group: Janet Desmond, Karyn Farr, Barbara Kuehnert, and Carmen Wendall. Not pictured is Christine Valle.

Additional Drivers

• Aberdeen Proving Ground Staff

Specially trained officers of the United States Army Aberdeen Proving Ground staff act as drivers of the Platoon Demonstration vehicles.





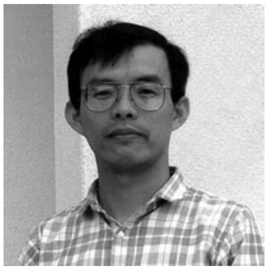

Chay Blount, Luis Gonzalez, Hai Dzu Lee, and John Suthard

• Southern California Automobile Club

John Gallisath from the Southern California Automobile Club has been specially trained as a driver for the Platoon Demonstration.

John Gallisath

Additional Narrators




PATH Narrators Ching-Yao Chan, Akash Deshpande, Datta Godbole, and Aleks Gollü



PATH Narrators: James Bret Michael, Mark Miller, and Jim Misener

PATH Deputy Director Steve Shladover

Credits: designed by Esther Kerkmann. Text by Rajesh Rajamani, Steve Shladover, and Han-shue Tan. PATH photos by Bill Stone, Gerald Stone, Jay Sullivan, and Fred Browand. Other photos courtesy of each organization

CALIFORNIA PATH

California PATH–Partners for Advanced Transit and Highways–is a joint venture of the University of California, other public and private academic institutions, Caltrans, and private industry, with the mission of applying advanced technology to increase highway capacity and safety, and to reduce traffic congestion, air pollution, and energy consumption.

Caltrans

NAHSC

DEMO '97

National AHS Consortium
Technical Feasibility Demonstration

National Automated Highway System Consortium

University of California PATH Program

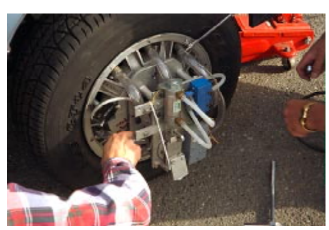
The University of California PATH programs's participation in National Automated Highway System Consortium (NAHSC) is defined by our legacy of close to a decade of continuous work as the preeminent research center for Automated Vehicle Control Systems (AVCS)–especially as it relates to Automated Highways. From this basis, we perform work focusing on concept development, creation of analytical tools and simulations, providing enabling technologies, and leading a demonstration of platoon operations for the 1997 Feasibility Demonstration. Future PATH activities in Automated Highway Systems (AHS) will include prototype development and evaluation.

The PATH research team combines in-depth technology and vehicle experiment expertise with a solid understanding of the operational, economic and institutional framework within which any transportation system must function.

Coordinated Longitudinal Control

Precision Lateral Control

AHS Simulation Animation



Tire Burster for Testing Emergency Control

Roadway Magnet for Lateral Control

CALIFORNIA PATH *California Partners for Advanced Transit and Highways*

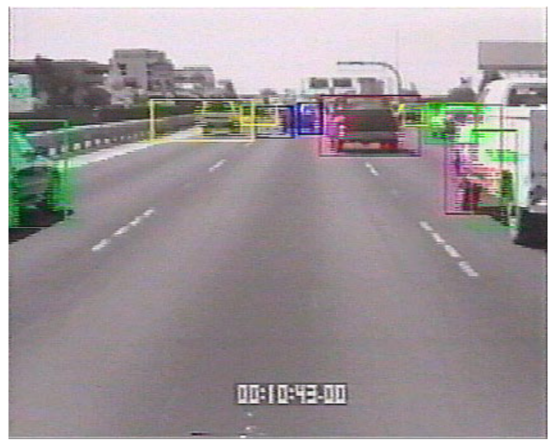
University of California PATH Program

The University of California PATH Program in collaboration with the California Department of Transportation (Caltrans) has been leading the way in Intelligent Transportation Systems (ITS) research since its founding in 1986, before the terms ITS or IVHS had even been coined.

The purpose of the PATH Program is to develop the foundations for the widespread adoption of advanced technologies that will help improve the operation of California's surface transportation systems.

The PATH charter includes conducting leading-edge research, evaluating operational tests, developing public/private/academic partnerships, and educating both students and practitioners about ITS.

Prototype inertial sensor system for vehicles



Machine Vision Based Obstacle Detection System

PATH has about 50 full-time staff members, but the majority of the PATH research is conducted on the campuses of the university partners, employing graduate students supervised by faculty members. These are supplemented by subcontracts to private companies as needed and by cooperative research agreements with a variety of organizations, including private companies as well as public institutions, both domestic and overseas. The more product development-oriented work of the private companies can serve to complement the more basic work of the academic researchers, so that each can concentrate on that to which it is best suited.

California PATH Program
University of California, Berkeley
1357 South 46th St., Bldg. 452
Richmond, California 94804

Steve Shladover (510) 231-9537, Fax (510) 231-9565
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CALIFORNIA PATH

Automated Driving Mini-Demonstration

What are we demonstrating?

The Buick LeSabre test vehicle drives itself around the demonstration course under completely automatic control, with no intervention from the driver. It follows the intended path very smoothly, accurately, and consistently.

What is the significance of this mini-demonstration?

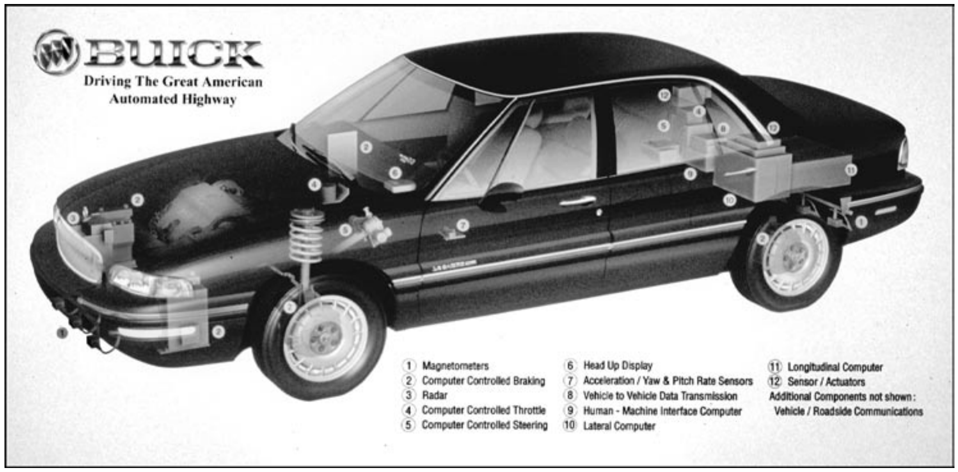
This mini-demo shows the capabilities of modern sensor, actuator, computer, and control technologies for controlling vehicle motion. The curvature and lateral accelerations on the mini-demo course are more severe than would be encountered in normal highway operations, so if we can prove good performance under these conditions, the performance should be even better on the highway.

How does this relate to development of an Automated Highway System (AHS)?

The Buick LeSabre used for this mini-demo was one of the vehicles used in the automated platoon demonstration scenario at the National Automated Highway System Consortium (NAHSC) Demo ’97 in San Diego, California. At that demonstration, this vehicle performed a series of highway driving maneuvers under fully automated control. It is equipped with all the technologies needed for fully automated lateral control (steering) and longitudinal control (speed and spacing) in a suitably equipped highway lane. The same software that controlled it in the NAHSC demo controls it in this mini-demo.

Why is the demonstration not on a highway?

This test vehicle does not have all of the sensors and software that would be needed to detect all roadway hazards. The radar sensor in the front grille is designed only to detect another vehicle ahead of it, not obstacles, or other vehicles that might be approaching too fast from the rear, sideswiping, aggressively cutting in front, etc. Those capabilities are not likely to become available for decades, so automated vehicles need to be protected from such hazards for the foreseeable future by being separated from the normal driving environment.



How does it work?

The vehicle is steered by measuring its position relative to a sequence of simple permanent magnets buried just beneath the pavement surface. This magnetic marker reference system provides extremely accurate and reliable measurements of vehicle position under all weather conditions. Measurement accuracy is better than 1 cm, and steering accuracy within a few cm. The magnets have been installed every 1.2 m along the path that the vehicle follows.

A set of three flux-gate magnetometers mounted under the front bumper and a similar set mounted under the rear bumper detect the magnetic fields of the magnets. A Pentium computer in the trunk processes these measurements to determine the lateral position and yaw angle of the vehicle relative to the desired path. That information is then used to generate commands to an electric motor mounted in the steering column, which turns the steering wheel by an appropriate amount to steer the vehicle back to the desired path. The polarity of the magnets (north or south pole up) is used to tell the vehicle how far it is along the path, so that it knows where to stop.

The speed profile for the vehicle was predetermined for demonstration purposes and is stored in the computer, which issues commands to the throttle and brake actuators. The throttle actuator is an electric stepper motor mounted to the throttle, and the brakes are controlled by an electronic actuator as well.

What else can this vehicle do?

This vehicle can drive itself in reverse around the mini-demo course at much higher speeds than human drivers can manage. This shows the ability of the automatic control systems to drive in ways that human cannot. You may also be able to observe some reverse driving.

This vehicle can also follow other vehicles at very close spacings as part of an automated platoon. At Demo ’97, it was part of an eight-car platoon that operated at full highway speed with separations as small as 5 m between the cars, maintaining the separation to within an accuracy of 20 cm on flat road and 50 cm when driving on a slope. These accuracies are so good that passengers in the cars did not perceive the differences in separation, and felt as if there was a mechanical coupling between the cars.

NAHSC

CALIFORNIA PATH

PATH (Partners for Advanced Transit and Highways) is a joint venture of the University of California, Caltrans, private industry and other public and privite academic institutions.

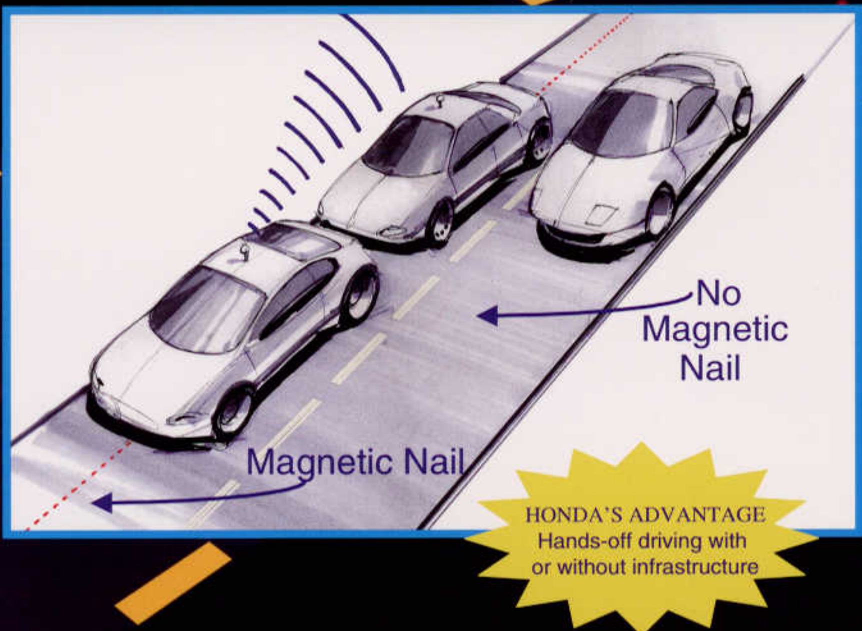
HONDA

TECHNOLOGY

DRIVING YOU INTO THE FUTURE

MOVING TOWARD THE 21ST CENTURY WITH AHS

THE AHS DRIVING FUTURE



In the "AHS future," cars will have the potential to drive safely at high speeds on special automatic highways. One possibility is that cars will drive in "platoons" or convoys like the one shown here, where steering, braking and acceleration are done automatically by the car. Such AHS systems may vastly improve the efficiency of our highways, increase the safety of driving and reduce stress associated with driving in traffic. These driving benefits are key to Honda as the company continues to engineer the future direction of its brand of AHS.

HONDA & PATH

Honda has partnered with UC Berkeley's California Partners for Advanced Transit & Highways (PATH) to develop the vehicles for Demo '97. Throttle, brake and steering actuators and laser radar systems were developed by Honda R&D, while PATH provided machine vision systems, magnet nail sensing hardware, control computers and steering and speed control software.

HONDA & THE NAHSC:

Honda is a member of the National Automated Highway System Consortium (NAHSC). The NAHSC was created in response to a U.S. Department of Transportation request for approaches to build and test an automated highway system.

AHS

CALIFORNIA PATH

HONDA

HONDA

TECHNOLOGY

HONDA WELCOMES YOU TO THE AUTOMATED FUTURE

HONDA'S BRAND OF AHS

THE FUTURE OF DRIVING

As our nation's roadways become increasingly congested and traffic jams continue to impact the quality of life and the amount of time available for business or leisure, Honda and other leading auto makers are looking to the future for solutions. One possible solution to the traffic issues of the 21st century may be contained in Automated Highway System (AHS) technology.

WHAT IS AHS?

To pursue the goal of automated highways for the next century, Honda Research & Development Americas and the California Partners for Advanced Transit and Highways (PATH) formed a joint partnership in 1996 to demonstrate the possibilities of future automated automobile transportation.

The AHS technology developed by Honda and California PATH adds additional automation to the driving experience that helps to make driving safer and more enjoyable. At the same time, additional automation helps to regulate and standardize highway driving so that traffic can move more quickly and safely with fewer "jams," particularly in urban areas. More efficient driving also conserves energy and helps the environment.

WHAT IS AHS?

For Honda, AHS is a technology that enables the car to become "smarter," allowing the car to do more of the driving or to act as a co-pilot to the driver.

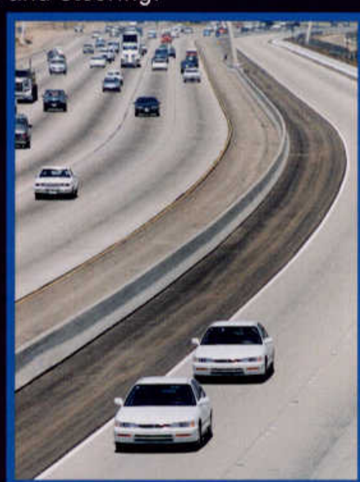
WHY AHS IS IMPORTANT

AHS has the potential to add new levels of safety and convenience to driving as a "driver support system."

In the future, AHS can help to reduce roadway congestion, improve highway efficiency and positively impact the environment.

HONDA'S AHS APPROACH IS UNIQUE:

Honda Research & Development has engineered two prototype AHS Accord sedans which can perform basic driving functions automatically, including accelerating, braking and steering.



Honda's unique approach to AHS allows the AHS Accord to do <u>both</u> of the following: 1) Drive itself on "smart" AHS highways with magnet markers in the road surface; 2) Drive itself on "ordinary" highways using the car's own special technology to guide it.

BENEFITS OF HONDA'S AHS APPROACH:

-- Honda's AHS works with or without AHS roadways.

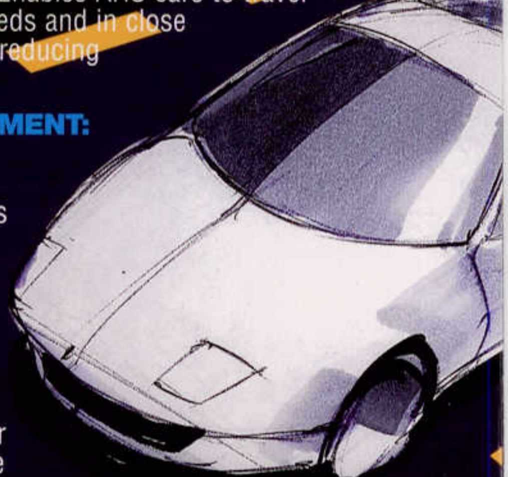
-- As a result, Honda's AHS offers maximum flexibility as the future of AHS technology progresses.

-- Example of flexibility: If, in the future, AHS roadways are in urban areas where congestion is greatest, but not in rural areas, Honda can deliver AHS driving in either area - regardless of the road.

HONDA'S AHS TECHNOLOGY

AHS ACCORD FEATURES

- **Adaptive Cruise Control:** Senses vehicles ahead and alters speed accordingly, keeping a consistent distance from the vehicle in front.
- **Automatic Lane Centering:** The vehicle automatically keeps a centered lane position.
- **Automatic Lane Changing/Obstacle Avoidance:** The vehicle automatically detects obstacles in front of it, and executes a lane change, if necessary, to avoid them.
- **Platooning:** The vehicle "locks" on the car in front and keeps a common speed and separation. Enables AHS cars to travel safely and efficiently at high speeds and in close proximity in "convoys," thereby reducing congestion.



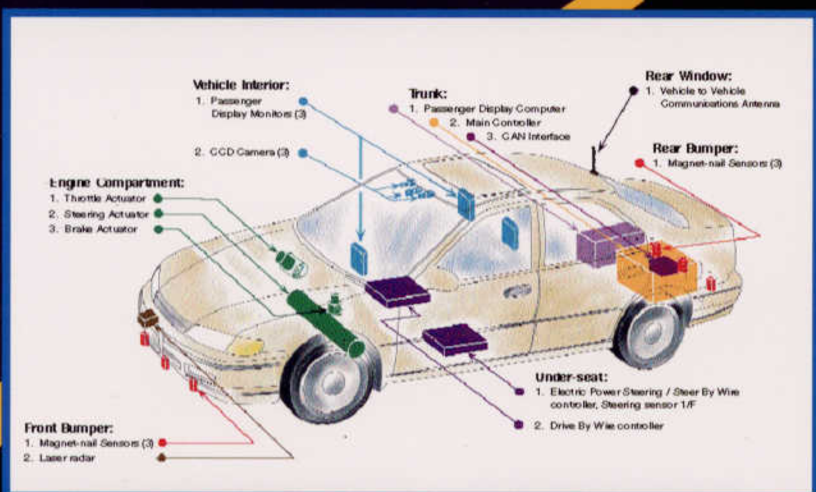
HONDA AHS ACCORD EQUIPMENT:

Magnetic sensors that read special magnetized markers built into AHS roadways. The magnetic markers provide the car with information about the road so that the car can "drive itself."

A video camera mounted inside the windshield, which provides the car with visual images of the roadway that enable it to "drive itself" with or without the magnetic markers in the road.

Laser radar under the front bumper senses obstacles in the road, and measures the distance to the car ahead.

Main & local controller system, which are specialized computers that guide the vehicle along the highway.



HOW DOES IT ALL WORK?

Information about the roadway, other traffic, the vehicle itself and the vehicle's relationship with the roadway is collected from the AHS Accord's magnetic sensors, laser radar, video camera and other special sensors. This information is processed by a central computer system, which sends signals to the throttle, brake and steering actuators to enable the car to "drive itself."

HONDA AHS "BUILDING BLOCKS"

HONDA'S "ROAD" TO AHS IS PAVED WITH "INTELLIGENT TECHNOLOGIES:"

Honda has been developing intelligent technologies for decades in an incremental or "building block"- style approach.

Intelligent technologies already developed by Honda, and featured on Honda production cars include: anti-lock brakes, traction control, throttle-by-wire and electric power steering.

These technologies are paving the way for the ultimate level of technology needed for full AHS automation.

FUTURE INTELLIGENT TECHNOLOGIES FROM HONDA:

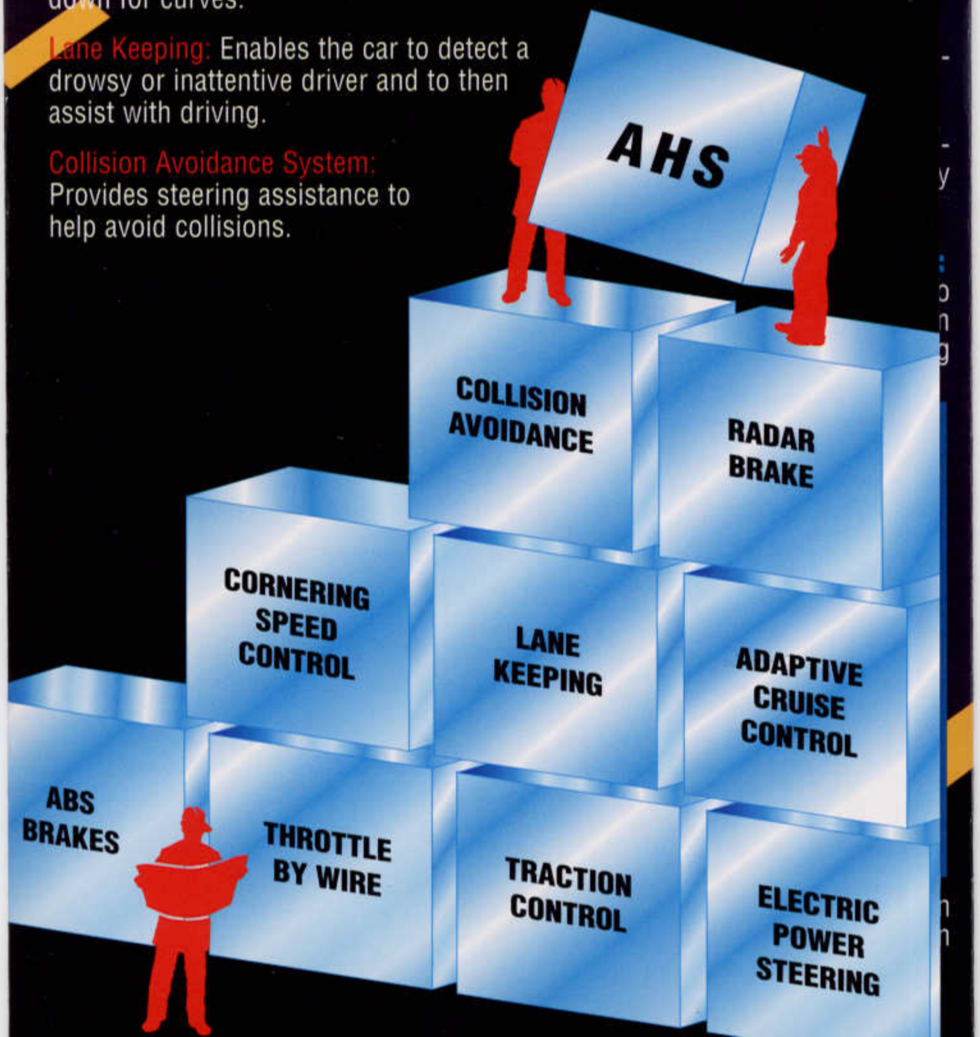
Adaptive Cruise Control: An AHS prototype feature to reach consumers in the next decade.

Radar Brakes: Uses radar to "see" obstacles in the highway ahead and alerts the driver, and/or applies brakes.

Cornering Speed Control: Reads the road ahead and slows the vehicle down for curves.

Lane Keeping: Enables the car to detect a drowsy or inattentive driver and to then assist with driving.

Collision Avoidance System: Provides steering assistance to help avoid collisions.



The Honda-PATH Control Transition Demonstration

In 1996 Honda R & D North America, Inc. and California PATH (Partners for Advanced Transit and Highways), a University of California/Caltrans research partnership, launched a joint venture with the goal of demonstrating several aspects of Automated Highway System (AHS) technology. Honda supplied three Accords equipped with throttle, brake, and steering actuators, as well as forward-looking laser radar. PATH engineers provided a machine-vision system for lane tracking, a magnetic marker sensing system for steering control, the steering and speed control software, and the control computer.

From August 7-10, 1997, the three automated Accords were demonstrated at the National Automated Highway Systems Consortium Technical Feasibility Demonstration – "Demo 97" – in San Diego, California. Two of the cars were run on the reversible express lanes of the Interstate 15 freeway north of downtown San Diego, and one car was run as a "mini-demo" at the Demo '97 Exposition site. The mini-demo car demonstrated vision-based lateral control by literally driving itself around a small peanut-shaped course consisting of a single white line that was tracked by the vehicle's vision system. The two cars used on I-15 demonstrated a "Control Transition" scenario: they not only drove themselves, using the systems described above to find the center of the lane, but also used them to detect and avoid obstacles, and to follow other cars at a specified distance. Both demonstrations were very successful. Approximately 1200 people rode in the mini-demo vehicle, and more than 100 rode in the two control-transition cars.

HONDA

CALIFORNIA PATH

The Control Transition Scenario

For the AHS technical feasibility demonstration, Honda and PATH chose to emphasize "control transition:" transition from a rural environment with no AHS infrastructure support to an urban environment with infrastructure. In this scenario, the two cars act as independent but fully autonomous vehicles. Steering is controlled via input from the vision system, and longitudinal spacing is controlled by input from the laser radar. The vehicles independently see a stationary obstacle and make an automatic lane change to avoid it, demonstrate adaptive cruise control and platooning, and finally, while in a platoon, transition from steering by machine vision to steering by sensing magnetic markers. Both vision-based and magnetic-marker based lane-tracking systems use sophisticated software running on off-the-shelf computer chips to find the lane markers (lines) in the video image and feed back this information to the vehicle controller, which steers the vehicle to the center of the lane via commands to an electromechanical actuator. These systems are being developed by researchers from PATH and the Elecrical Engineering and Computer Science Department of the University of California at Berkeley.

Stereovision cameras used in the Honda-PATH vehicles . The small cameras on the left and right are a stereo or binocular pair that allow the vehicle to see much like a person (the large camera is not currently used). A computer can compare the pictures from the two cameras and uses triangulation on objects in the image to determine the distance, which is useful for keeping a safe distance from the vehicle in front. (This system, still under development, is currently being tested.)

Steering by Machine Vision

The lane-tracking system based on machine vision captures images from one of the video cameras mounted in front of the rear view mirror and looks for features that could be lane markers in each picture.

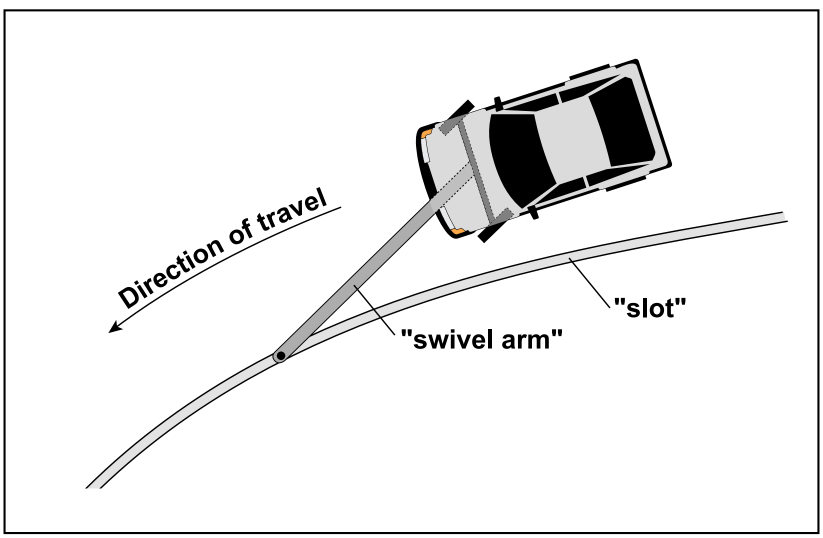
This system uses the positions of these markers in the image, as well as the measurements it receives from the on-board fiber optic gyroscope and the speedometer, to form an estimate of the position and orientation of the vehicle within the lane and the curvature of the roadway. By using robust estimation techniques, the system is able to reject markings that are not lane markings. It performs well in a variety of road surfaces and lighting conditions.

The vision-based steering-control system uses the information returned from the lane-tracking system to compute an appropriate steering command. The system tries to match the curvature of the road and to keep the vehicle in the center of the lane. Since the vision system is looking ahead of the vehicle, it is able to make steering commands in anticipation of changes in curvature of the roadway. This allows the system to do a better job of controlling the vehicle

The magnetic field of magnets installed in the pavement is continuously monitored by a magnetometer array located at the vehicle front end. As the car passes directly over a magnetic marker, an on-board computer determines the marker's position relative to the array's center based on the measured magnetic field strengths and directions.

Steering by Sensing Magnetic Markers

The magnetic marker sensing technology employed by the Honda-PATH AHS vehicles utilizes a three-point sensor arrangement that provides extreme accuracy and robustness against external noise. From measurements of the marker's magnetic field at the two closest sensor locations, the distance, as well as the magnet's orientation (i.e., north or south pole up), are computed. The distance estimates are important for lane-keeping, and the sequence of field orientations (e. g., north-south-north-south) are used to encode important travel information, such as mileage markings and roadside services.

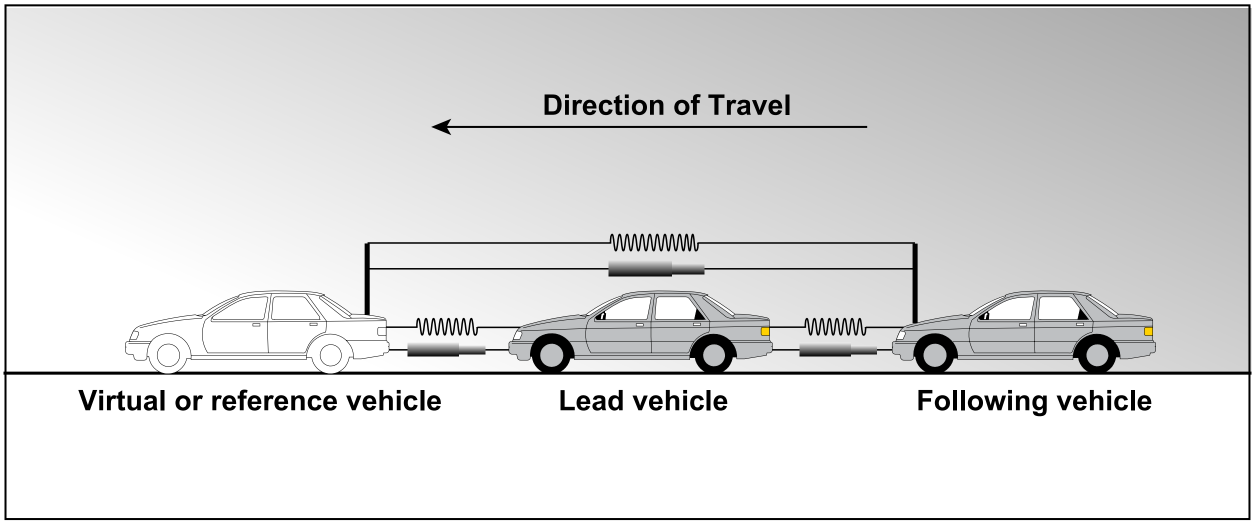


The length of the "control arm" is governed by the particular referencing system utilized. Vision systems, which provide "look-ahead" referencing, allow for longer arm lengths than magnetic marker sensing systems, which provide "look-down" referencing. Longer arm lengths yield more heavily damped behavior, i.e. smaller oscillations.

Control Systems

Lateral control

Automatic lateral control can be conceptually represented by the mechanical linkage system shown above. The slot represents the road center, while the swivel arm is analogous to the control law, which in reality is an algorithm or logic set by which the computer determines the commands required to keep the vehicle centered within the lane. Positioned at the top of the information system hierarchy, the controller draws information from the sensors (velocity, yaw rate, acceleration, lateral displacement, and current steering angle) and outputs the commanded steering angle to the steering actuator. At an update rate of 20 milliseconds, the controller can quickly respond to changing conditions and unexpected contingencies, e. g. obstacle avoidance, despite a wide range of speeds (0 to > 150 kph or 90 mph) and road conditions.



Under cooperative cruise control, both leading and following vehicles are electronically "tied" to a virtual reference vehicle, as well as to each other. Under noncooperative cruise control, the connection between the following vehicle and reference vehicle is cut.

Longitudinal control

Automatic longitudinal control—control of the gap between vehicles—is also a software realization of a mechanically-linked system. The virtual spring and shock absorbers generate the forces required to position the vehicle relative to its predecessor. The virtual spring displacements are obtained from the laser radar. Thevirtual shock absorber closing rates are obtained either from successive laser radar measurements (non-cooperative cruise control), or by comparing the velocities of the leading and following vehicles via radio communication between the two vehicles (cooperative cruise control). The stiffness of the control, or conversely, the comfort level, can be tuned by varying the spring and damper parameters. As a general rule, stiffer control results in smaller spacing errors. At highway cruising speeds, errors made by the Honda-PATH cooperative cruise control system are typically much less than those made by the average human driver.

The Research Team

Honda R & D:
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PATH/UC Berkeley:
Robert Blasi, Wonshik Chee, Dan Empey, Jana Kosecka, Phillip McLauchlan, Jitendra Malik, Hung Pham, Angie Pham, C. J. Taylor
Delco Electronics:
Chris Zell

HONDA
CALIFORNIA PATH

Why is Houston METRO interested in automated highway technology?

Automated Highway System (AHS) technology represents a cost effective opportunity to reduce traffic congestion in Houston by increasing the number of vehicles that use the region's network of High Occupancy Vehicle (HOV) lanes. The more HOV throughput METRO can achieve, the less congestion there is on main lanes.

Our first foray into the science of AHS is contained in two New Flyer 40-foot low-floor buses on display here at the National Automated Highway System Consortium (NAHSC) Demonstration '97 in San Diego, California. These buses might look like regular transit vehicles, but they contain high-tech automation systems that allow us to glimpse the transit system of the future.

Each of METRO's demonstration buses has been outfitted at Carnegie Mellon University with computer hardware and software that controls their steering, brakes and headway maintenance while avoiding collision with vehicles that occupy the same roadway.

AHS will produce faster, safer commutes.

METRO has more than 67 miles of HOV lanes built on five freeway corridors. Ultimately, the system will have 104 miles of HOV lanes. Every business day, the HOV lane system moves about 80,000 people—the same traffic volume as 19 freeway main lanes.

HOV lanes are popular among Houston area commuters, and they promise to become more attractive as the region's economy continues to grow. Under such positive conditions, it is obvious that HOV capacity must be maximized, and that's where AHS solutions can be best applied in Houston.

These technologies will allow buses to travel automatically along an HOV lane before departing for other destinations. Because these buses can operate so closely together, an HOV lanes capacity can be increased. All these ideas improve commute times and they accomplish this feat safely, a major concern at Houston METRO.

METRO plans to remain at the forefront of transportation technology.

Our participation in the NAHSC Demonstration '97 places Houston at the leading edge of transportation innovation, including METRO's involvement in law enforcement.

During the demonstration, METRO also will display a police car (METROCar) equipped with a geographic information system (GIS) computer and database, a global positioning system (GPS), wireless data communications and digital video transmission/reception. Designed to respond to accidents and clear them as efficiently as possible, METROCar and its new systems were configured by the Texas Transportation Institute (TTI).

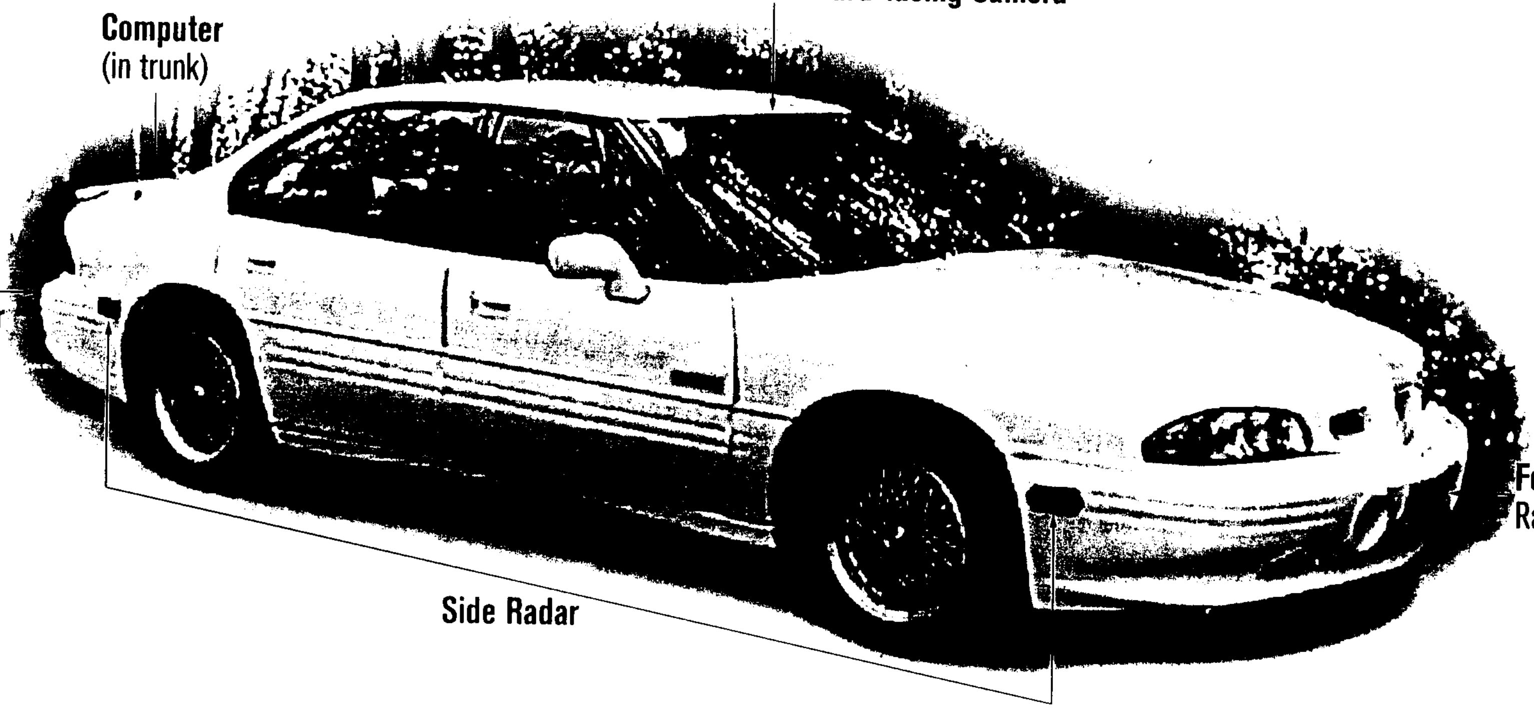
"Our commitment to projects like the National Automated Highway System Demonstration '97 is one reason METRO is considered a leader in the transportation industry," says Holcombe Crosswell, Chairman of METRO's Board of Directors. "And in the transit business, if you're not planning well into the future, you quickly get left behind."

For more information about this program, you may call 713-739-6091.

METRO

TEAM NAVLAB

Carnegie Mellon



NAVLAB 7

Navlab 7 was the second AHS vehicle delivered to CMU and the first to be equipped with a realistic driver interface. This interface is a glimpse of how information might be presented to the driver when autonomous capabilities become available on commercial vehicles. The interface consists of customized steering wheel controls, a color flat panel display integrated into the dashboard, a head up display unit, and audio alert capability. This equipment has been integrated with the autonomous control systems to present information to the driver about other nearby vehicles, control actions such as lane changes, and control transitions into and out of autonomous mode. Like Navlab 6, Navlab 7 is equipped with a complete sensor suite.

Official Stats

Year	1996
Model	Pontiac Bonneville
Length	202"
Width	75"
Height	56"
Actuators	Steering-Throttle-Brake
Top Speed	100+
Autonomous miles	5000+
Seating Capacity	5
Computing Power	Pentium Pro PC
Sensors	Forward Camera Forward/Side Radar Rear Laser

www.navlab.org


ALTERNATIVE
THE OHIO STATE UNIVERSITY
Tomorrow's automotive technology ... at The Ohio State University today
College of Engineering
Automated Vehicle Check-In
TECHNOLOGIES

Imagine making that normally tedious highway commute to work in an automated vehicle. You just head for the special automated-vehicle lanes and relinquish the driving.

No leaving early to avoid traffic — your driving time is predictable and consistent. And there's no need to steel your nerves for the bad habits of your fellow drivers. The automated system commands the throttle, brakes and steering, keeping you moving at a safe speed in your lane. You can read the newspaper, enjoy your morning coffee, or just relax on the way to work.

No, it's not some impossible dream. The technology exists today. Operational tests involving public use of an automated highway system (AHS) could begin within 10 years, and AHS could be integrated into existing highways within 20 years.

The Ohio State University is an educational leader in "intelligent" transportation research. Ohio State is one of only four non-core members of the National Automated Highway Systems Consortium chosen to take part in the "live" portion of the 1997 Automated Highway System Technology Demonstration, August 7–10 in San Diego. The Consortium, selected by the U.S. Department of Transportation to lead the development and demonstration of a prototype automated highway system, is a unique partnership among government, industry and universities.

Ohio State is demonstrating its radar-reflective stripe technology on the high occupancy vehicle (HOV) lanes of I-15. The test vehicles are Honda Accords, equipped with special radar sensors and control systems that use the stripes to guide the vehicles.

The radar-reflective stripe is an Ohio State innovation, as are the computer algorithms that control the mechanisms that regulate vehicle speed, steering and braking. Ohio State's research team is comprised of faculty, staff and students in the College of Engineering who work together in the classroom, the laboratory and on the road.

"The university environment is ideal for this type of groundbreaking work," said Ümit Özgüner, professor of electrical engineering and leader of the automated highway work at Ohio State. "Students are involved in every aspect of intelligent transportation research. They work in teams with researchers to create technologies with practical applications. These aren't solutions for the future; these are workable resolutions to current problems of highway congestion and safety."

An automated highway system (AHS) is a specially equipped roadway on which vehicles can be operated automatically. These vehicles would be capable of operating under driver control as well. Drivers would steer their vehicles onto designated AHS lanes of the highway, releasing control of their vehicle to the system. Upon exiting the AHS lanes, the driver again takes control of the vehicle.

AHS Benefits:

- less traffic congestion
- fewer accidents and injuries
- shorter, more predictable travel times
- lower level of driver stress
- improved fuel economy
- reduced vehicle emissions

THE STRIPE

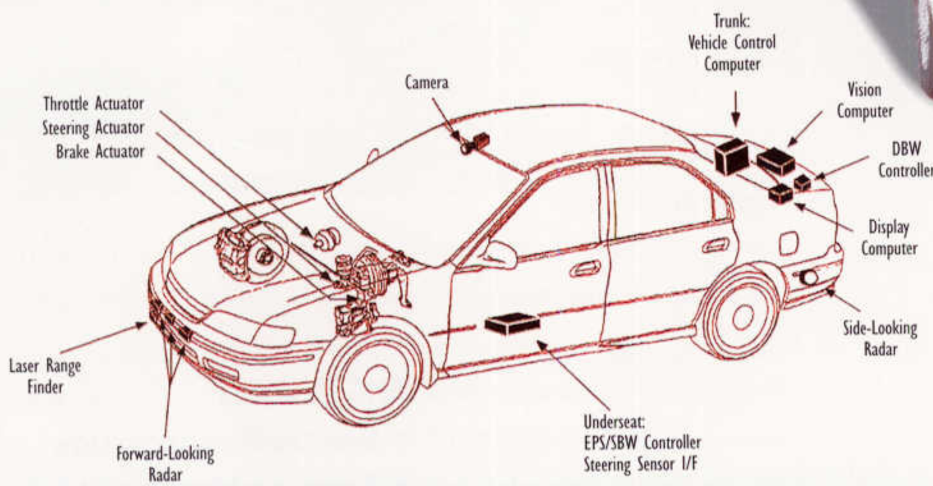
The radar-reflective stripe, designed at Ohio State and manufactured by 3M, looks fairly unremarkable on the highway, but it is a crucial part of automated technology. Special radar sensors and control systems on-board the vehicle use the stripes to guide the cars through basic maneuvers, such as driving the car in the center of the lane, changing lanes to pass, and then returning to the original lane. Another plus: There's minimal impact on the roadway itself. The stripes are laid down the middle of the lanes or at the edge of the lanes.

OHIO STATE'S ALTERN

THE VISION

The "vision system" on the Ohio State vehicles provides a backup to the radar-reflective stripe technology. It uses existing highway lane divider markings in tandem with the vehicle's hidden radar and laser devices to determine the proximity of other vehicles.

This fusion of technologies — radar, vision and laser — helps accommodate a variety of traffic situations that include automated and non-automated vehicles, and provide extra control for improved safety.



THE SCENARIO

In the "live" portion of Demonstration '97, Ohio State is showcasing the use of radar-reflective stripe technology in a test sequence involving three vehicles: two special and one conventional Honda vehicle.

Car #1 is manual and drives at a steady 40 mph throughout, simulating a slow-moving non-automated car. Cars #2 and #3 are automated. Car #2 cruises at 55 mph, senses car #1, matches its speed and falls in behind it. Car #3 does the same, falling in

THE STATUS

Status displays mounted in the headrests and in the center of the instrument panel are not part of the automated highway system equipment. The automated technologies are virtually transparent on the Ohio State cars. The status displays were installed to keep passengers informed of what is happening at any given moment. By watching the displays, they can see whether the car is under manual or automatic control, which sensor is operating, and what the car "notices" about adjacent vehicles.

TIVE TECHNOLOGIES

THE BRAINS

What makes the system tick are the "brains" in the trunk. Radar waves bounce off the stripes, providing information to the computer, which applies algorithms that steer the car.

behind car #2. All three cars are maintaining a speed of 40 mph.

Car #2 has been programmed to pass slower moving vehicles. After using the built-in AHS features to check for safe conditions, car #2 passes car #1, continues forward until a safe distance ahead, checks for clearance in front of car #1, and then moves back into its original lane. Car #3 closes the gap to car #1, but is not programmed in this scenario to pass.

DEMONSTRATION '97 TEAM

The Ohio State University
- Ümit Özgüner
- Brian Baertlein
- Kim Boyer
- Chris Cavello
- Carol Duhigg
- David Farkas
- Robert E. Fenton
- Mangu Gungor
- Cem Hatipoglu
- John Herridge
- Judy Kauffeld
- Seth Lytle
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- Keith Redmill
- Scott Schneider
- Eric Walton
- Jon Young

Transportation Research Center
- Teri Elliot
- Mark Heitz

M.P. Stovsky & Associates
- Michael Stovsky

Honda R&D
- Hidehiko Anzai
- David Domine
- Junichi Kimura
- Raj Manakkkal

OHIO STATE SPONSORS

Our thanks to:

Honda Research and Development, for building special cars with drive-by-wire capability and for financial help

Transportation Research Center Inc., for test facilities, equipment, and extensive management support

3M, for developing stripe manufacturing technology and providing the stripe

dSpace, for support in real-time computing

Visionex, for image processing hardware

OHIO STATE & TRC: TRANSPORTATION PARTNERS IN EDUCATION, RESEARCH AND TESTING

Transportation Research Center Inc. (TRC) and Ohio State are partners in Demonstration '97. TRC's facilities and the expertise of its employees have been crucial to Ohio State's interdisciplinary research program in intelligent transportation research.

TRC, located in East Liberty, Ohio, just northwest of Columbus, is one of the largest, most technologically advanced independent testing facilities in the world. The 7,500-acre proving ground offers large-scale testing roadways and an impact testing laboratory for the analysis of passenger vehicles, heavy duty trucks, military vehicles, buses, RVs, motorcycles, and utility vehicles.

TRC's customers include more than 600 companies worldwide engaged in the manufacturing and regulation of transportation vehicles, components, and materials. Research, analysis, performance, and compliance testing is conducted in a controlled and proprietary environment. Customers may test autonomously or have TRC provide full program support.

Among TRC's unique features that lend themselves to the safe and repeatable testing of intelligent transportation systems are its high-speed test track, a four-lane, 7.5-mile loop that tests the limits of driver and vehicle, its 9,000-foot-long, six-lane wide skid pad that provides for lane-changing scenarios, and its 50-acre vehicle dynamics area that permits vehicle maneuverability, obstacle avoidance, and braking.

In 1988, when the property of the Transportation Research Center of Ohio was sold by the State of Ohio to Honda of American Manufacturing, TRC became a nonprofit corporation affiliated with Ohio State. TRC continues to operate the proving ground as an independent operation. The Ohio State/TRC partnership supports a range of transportation research projects for industry, and projects originating in Ohio State's College of Engineering, all of which contribute to educating tomorrow's engineers and solving today's challenges.

Transportation Research Center Inc.
East Liberty, Ohio 43319-0367
(937) 666-2011 • FAX (937) 666-5066

TEST CAPABILITY FOR:
- SAFETY
- ENERGY
- FUEL ECONOMY
- EMISSIONS
- DURABILITY
- PERFORMANCE
- NOISE
- CRASH SIMULATION
- CRASHWORTHINESS

AUTOMOTIVE ENGINEERING AT OHIO STATE: A SAMPLER

Ohio State's College of Engineering is ideally suited for automotive research. Faculty have expertise in such areas as materials processing and synthesis, eletro-mechanical systems, intelligent transportation systems, manufacturing, noise and vibration, power trains and combustion. Our wide range of automotive activities provides research and educational opportunities for the nation's future automotive engineers.

The Ohio State Campus Bus Location and Information System (OSU BLIS) provides real-time bus location information on all 18 campus buses using a global positioning system (GPS) and wireless networks. Users locate buses on a web site map and note arrival time at selected bus stops.

Emissions and other automotive controls are tested in the Powertrain Control and Diagnostics Laboratory. Hydrocarbon sensors for automotive engines are under development at the Center for Industrial Sensors and Measurements, an NSF center at Ohio State.

Driving simulators help researchers improve vehicle design and safety. Ohio State researchers built this quarter-scale tabletop simulator and are developing a full-scale model with a steering wheel, brakes and accelerator as a prototype for a commercial machine. The larger version will suggest the sensations of auto acceleration, deceleration and turning by tilting a person in the seat forward, backward and side-to-side.

Faculty and students use the hemi-anechoic chamber at Ohio State's Center for Automotive Research to study automotive noise, vibration and harshness (NVH) control. The chamber is installed around a 150-horsepower chassis roll dynomometer.

Other studies supported by various car manufacturers investigate: vehicle dynamics modeling, simulation and controller design, and anti-lock brake system design and verification. System integration studies include stability and optimality issues affecting total car behavior.

Work at the Gear Dynamics and Gear Noise Research Laboratory includes studies of gear noise excitation, gear dynamics analysis and measurement, gear rattle, transmission error prediction and measurement analysis, finite element analysis of gears, and gear noise sound quality analysis.

ENGINEERING AND THE OHIO STATE UNIVERSITY

The College of Engineering at Ohio State is one of the largest engineering colleges in the nation, with more than 5,000 students and 250 faculty members. Degree programs are offered in 23 areas at the bachelor's, master's and Ph.D. levels.

Many research centers and specialized labs within the College of Engineering enrich our ability to educate students and conduct research. Our research and instructional activities reflect a focus on key technology areas that cut across traditional academic department lines and contribute to the economic and social well-being of Ohioans and the nation.

Transportation is one of six key technology areas in the college, which houses an interdisciplinary program in intelligent transportation research. The program serves as a clearinghouse for information about automated highways systems technology, sharing information about activities and developments within the university community and with external audiences.

Founded in 1870, The Ohio State University is widely recognized as one of America's distinguished major universities. Since enrolling its first students in 1873, Ohio State has awarded more than 465,000 degrees. With a regular faculty of more than 2,900, the nation's largest single-campus enrollment of some 48,300 students (54,700 on all campuses), and a comprehensive curriculum of more than 11,000 courses, Ohio State offers a learning environment few universities can match. Research funding for the 1995–96 academic year was in excess of $207 million.

Students in Ohio State's College of Engineering are involved in a range of projects that test their talents and skills in the automotive arena. Students put their "smart car" studies to work to compete with an Autonomous Robotic Transporter, placing first in a 1996 international competition. The Formula Lightning Electric Race Team won the 1996 and 1997 University Specification Series. Ohio State placed fifth (out of 12 invited schools) in the FutureCar Challenge, a competition to design an energy efficient family-sized car. Other teams include Formula SAE and Mini-Baja, as well as Sunrayce, in which teams build and road race in a solar vehicle.

INFORMATION

Intelligent Transportation Research
(614) 292-4530; http://er4www.eng.ohio-state.edu/citr/

College of Engineering:
(614) 292-2651; http://www.eng.ohio-state.edu

The Ohio State University:
(614) 292-6446; http://www.ohio-state.edu

TOYOTA TEAM

EVOLUTIONARY AUTOMATED HIGHWAY SYSTEM . . .

SIMPLE STEPS TO A BOLD VISION

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TOYOTA TECHNICAL CENTER, U.S.A.
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IMRA AMERICA, INC.

TOYOTA TEAM

AUTOMATED HIGHWAY SYSTEM DEMONSTRATION

"EVERYTHING SHOULD BE MADE AS SIMPLE AS POSSIBLE, BUT NOT SIMPLER."
—ALBERT EINSTEIN

The Philosophy

Simple Steps: Technically Feasible, Socially Acceptable, Economically Affordable

Step 1

Warning and Simple Control Systems

Description
- Adaptive cruise control
- Obstacle warning
- Lane departure warning

Benefits
- Technically feasible
- Socially acceptable

Step 2

Selective Automatic Control Systems

Description
- Lane departure control
- Stop-and-go longitudinal control
- Obstacle avoidance braking

Benefits
- Reduced collision risk
- Increased social acceptance
- Increased number of AHS-equipped vehicles

Step 3

Mixed Mode Operation

Description
- Operation with non-AHS vehicles
- Lateral and longitudinal control

Benefits
- Transport convenience
- Low cost, deployable

Step 4

Dedicated Lane Operation

Description
- Specialized infrastructure
- Lateral and longitudinal control
- Dedicated lanes with intervehicle communication

Benefits
- High level of convenience
- High density operation

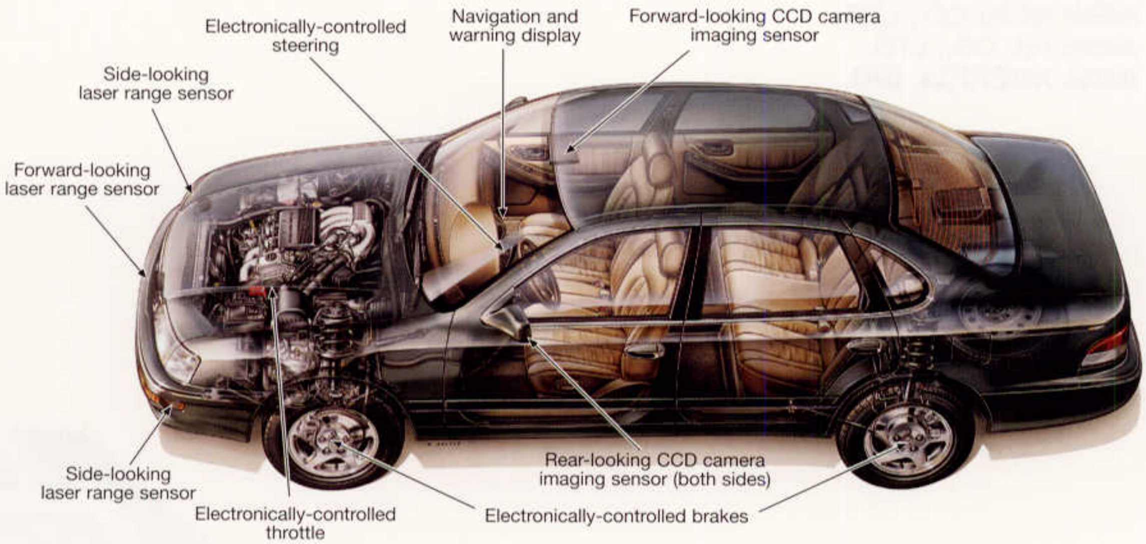
The Technology

Image processing systems
- Lane sensing
- Blind spot object sensing
- Vehicle and stop lamp recognition

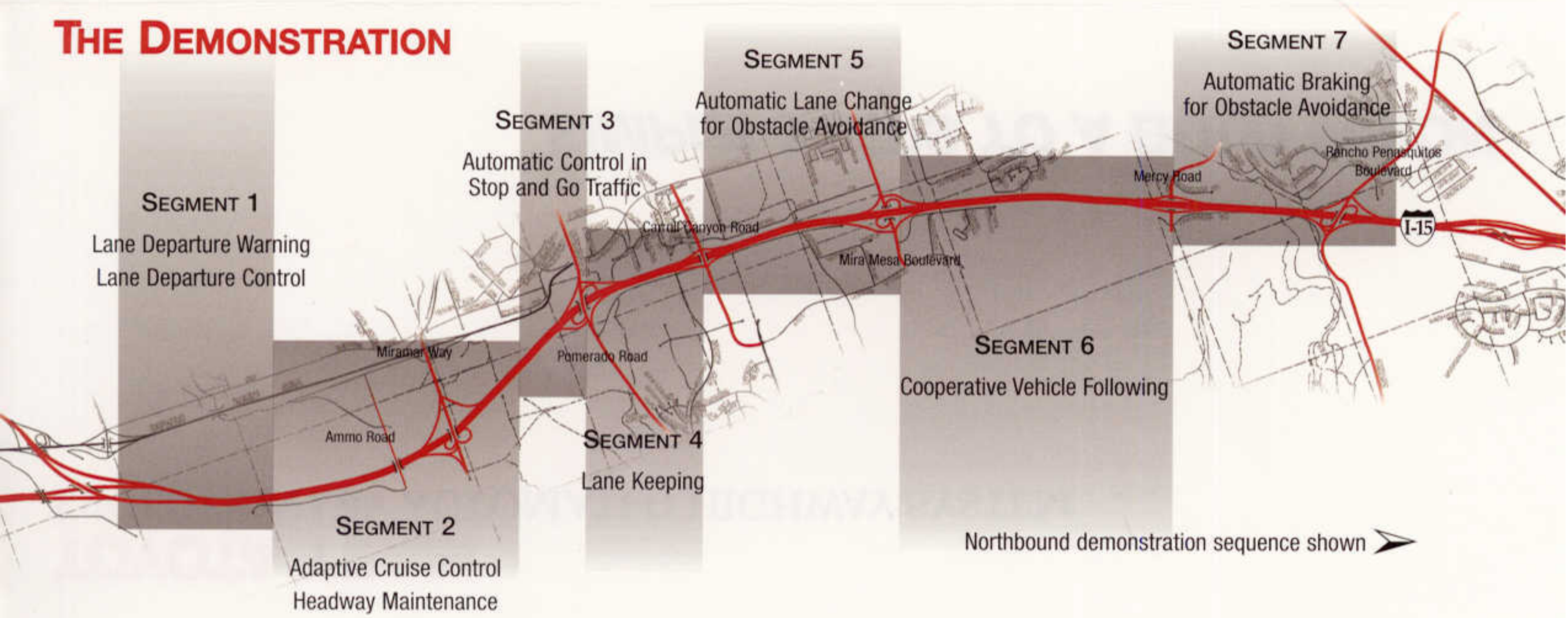
Laser ranging systems
- Lateral distance
- Forward object distance

Electrically controlled actuators
- Braking and throttle
- Driver over-ride capability

Wireless communications
- Vehicle-roadside-vehicle communications for long range obstacle pre-warning



The Demonstration



TOYOTA TEAM AHS VEHICLE