CALIFORNIA PATH

Program on Advanced Technology for the Highway
(1986 – 1991)

Partners for Advanced Transit and Highways
(1992 – 2010)
Partners for Advanced Transportation tecHnology
(2011 -)

PATH Creation

- Caltrans' 1985 study of future needs – cannot build our way out of congestion, but need technology
- 1986 Caltrans/Berkeley conference on future use of information technology for transportation operations – agreement with U.C. Berkeley Institute of Transportation Studies to create PATH
- First research program in U.S. on "intelligent vehicle-highway systems" – later broadened to "intelligent transportation systems"

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Institute of Transportation Studies

- **Created in 1948 by California Legislature, to lead research on transportation to support the state's post-war growth**
- **PATH is the largest research program in the Institute. The others are on:**
  - **Transportation Sustainability**
  - **Transportation Safety**
  - **Aviation Operations Research**
  - **Future Urban Transportation Systems**
  - **Economic Competitiveness in Transportation**
  - **Pavement**

PATH Goals

Developing Technologies to Help Solve (California's) Main Transportation Problems

- **Congestion/Mobility/Productivity of System**
- **Safety**

With Ancillary Benefits in:

- **Air Quality/Environment**
- **Energy Consumption**
- **Cost Effectiveness**
- **Regional/Statewide Economic Health**

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PATH's California Objectives

- **Conduct ITS research for Caltrans' Division of Research and Innovation and System Information (DRISI) and others**
  - **technology and policy research**
  - **proof-of-concept testing**
  - **design and evaluation of operational tests**
- **Bring best available minds to bear on solving California's surface transportation problems**
- **Train the next generation of transportation professionals**

PATH Program Management

- Combine faculty, graduate student and professional research staff activities so each does what it does best
- Collaborate closely with Caltrans to meet specific state needs for ITS research, development, testing and demonstrations
- Work directly on some U.S. DOT projects, and through Caltrans or prime contractors on other projects
- Private and international sponsorship of some projects, partnerships on other projects

PATH Leadership Team

Directors

Tom West

Trevor Darrell

Traffic Management

Alex Skabardonis

Transportation Safety

Ching-Yao Chan

Mobility Systems

Steven Shladover

New Initiatives

Wei-Bin Zhang

System Development

Joe Butler

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PATH Capabilities

- **Multi-disciplinary R, D & D projects**
  - **Civil, traffic, transportation engr.**
  - **Mechanical, electrical, industrial engr.**
  - **Computer science, software engr.**
  - **Human factors**
  - **Benefit/cost evaluation**
- **Large-scale experimental projects requiring continuous staff effort, including remote sites**
- **Development, prototyping and testing of infrastructure, vehicle and communication systems**

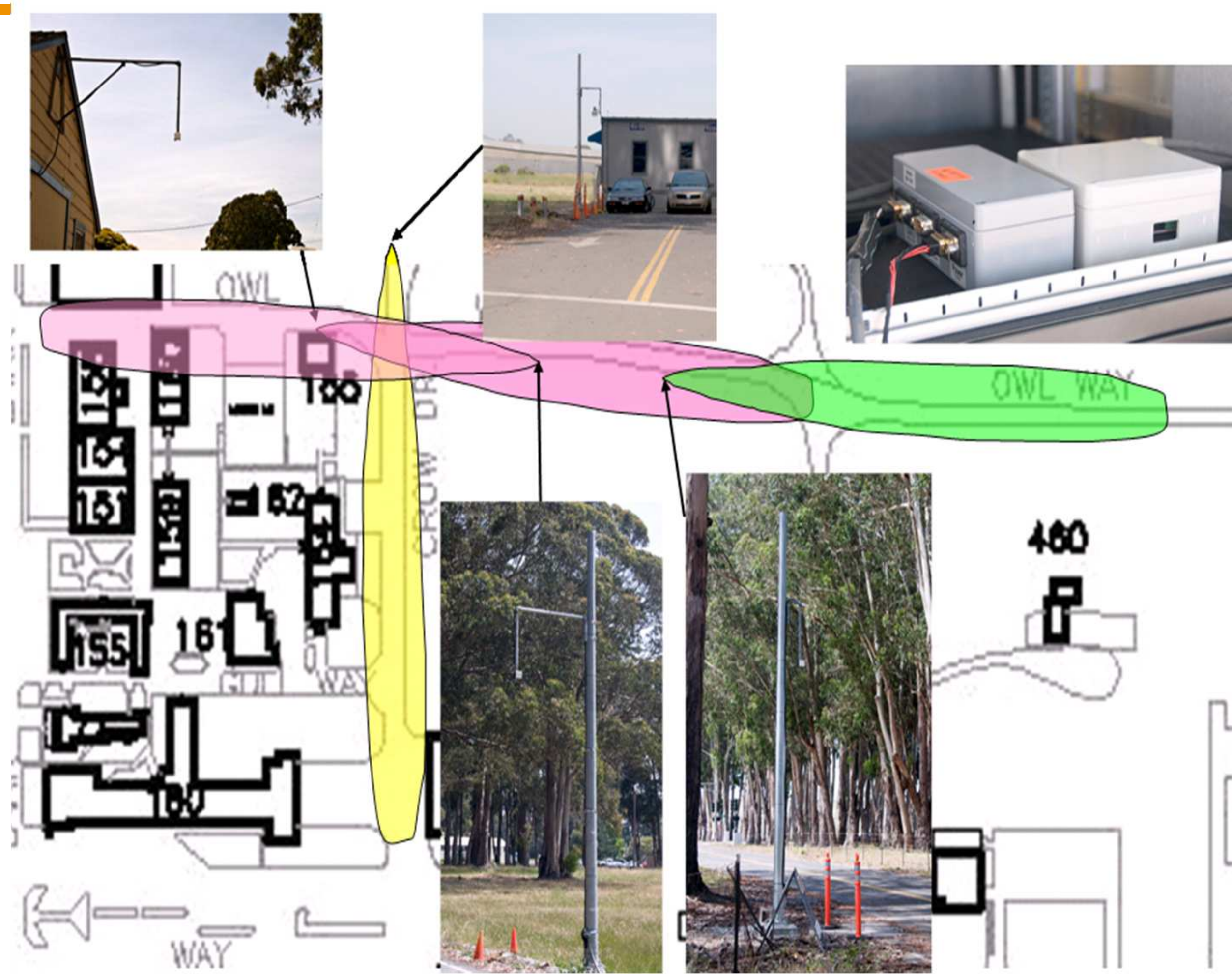
Experimental Infrastructure

- **Shop and laboratory space for work on both light and heavy duty vehicles**
- **Robert E. Parsons Traffic and Transportation Laboratory**
- **Wireless communications laboratory**
- **Experimental intersection**
- **Short test track**

- **Light and heavy duty test vehicles**

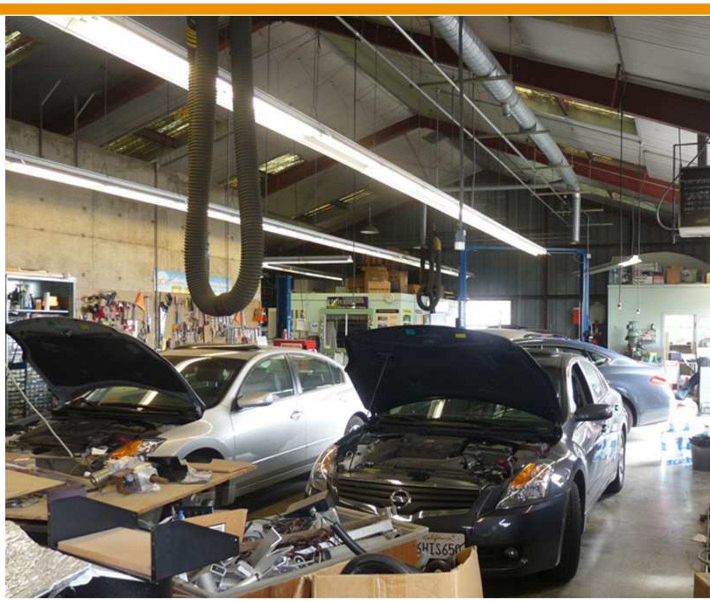
Instrumented Intersection and Short Test Track

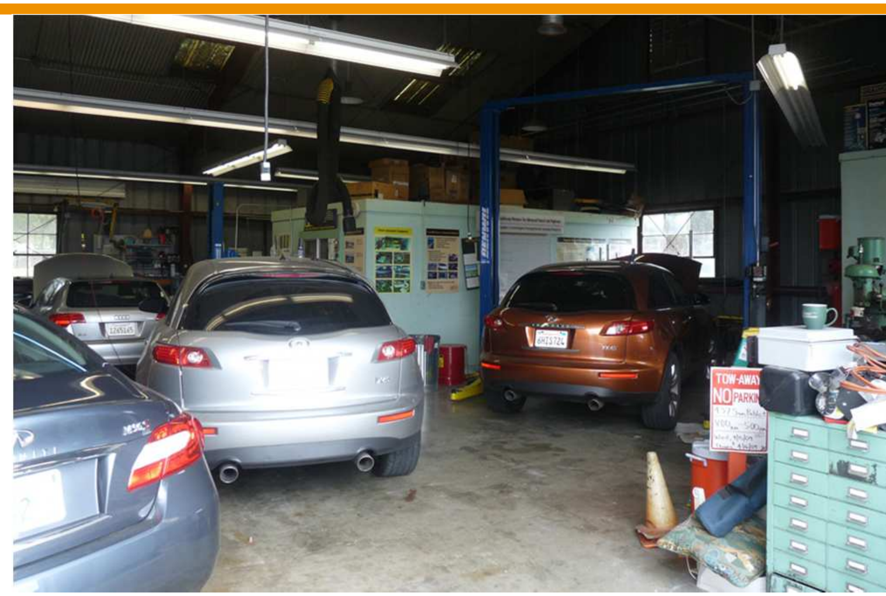
- Video image processor detector systems
- Radar pedestrian detector
- Sensys wireless detectors
- Wavetronix radar
- MS-Sedco InterSector radar for bike detection
- IR beam detectors
- Conventional and Type D inductive loops
- 3M Canoga micro-loops
- Savari and Arada DSRC RSEs



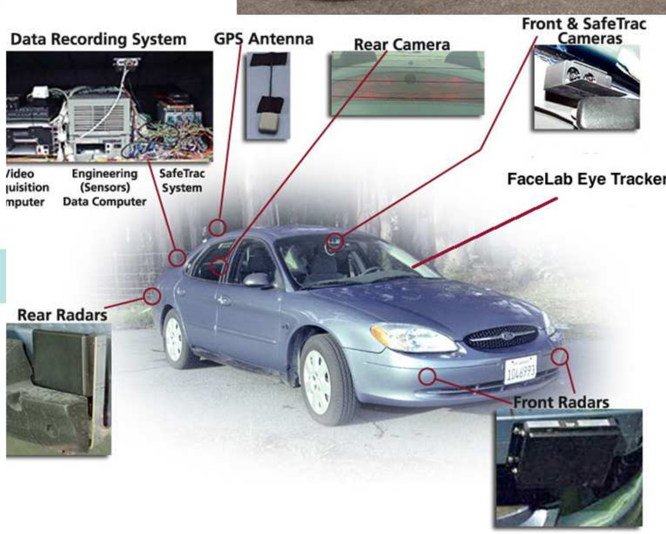
SMS radar coverage of all approaches

Shop Space for Vehicle Development





Experimental Vehicles



Vehicle Control and Automated Driving Research at PATH

- **Strong emphasis for 20 years → 600 labor years of PATH effort**
- **Approached from perspectives of vehicle dynamics and control and human factors**
  - **Deep understanding of mechanical dynamics of vehicles**
  - **Designing for both high positioning accuracy and smooth ride quality**
  - **Driver and passenger acceptance based on ride quality and user interfaces**
- **Experimental verification on full-scale vehicles (20+ passenger cars, 7 heavy trucks, 5 transit buses, 1 snowblower)**

Project Sponsorships

- **Primarily state and federal DOTs**
- **Automotive Industry Sponsors**
  - **Nissan Technical Center North America**
  - **VW/Audi Electronics Research Lab**
  - **Toyota InfoTechnology Center**
  - **BMW of North America**
  - **Renault**
  - **General Motors**
  - **Ford**
  - **Mercedes Benz Research & Development North America**
  - **Honda R&D North America**
  - **Visteon**

Automation is a Tool for Solving Transportation Problems

- **Alleviating congestion**
  - Increase capacity of roadway infrastructure
  - Improve traffic flow dynamics
- **Improving safety**
  - Reduce and mitigate crashes
- **Reducing energy use and emissions**
  - Aerodynamic “drafting”
  - Improve traffic flow dynamics
- **Using V2V and I2V connectivity to gain these benefits**

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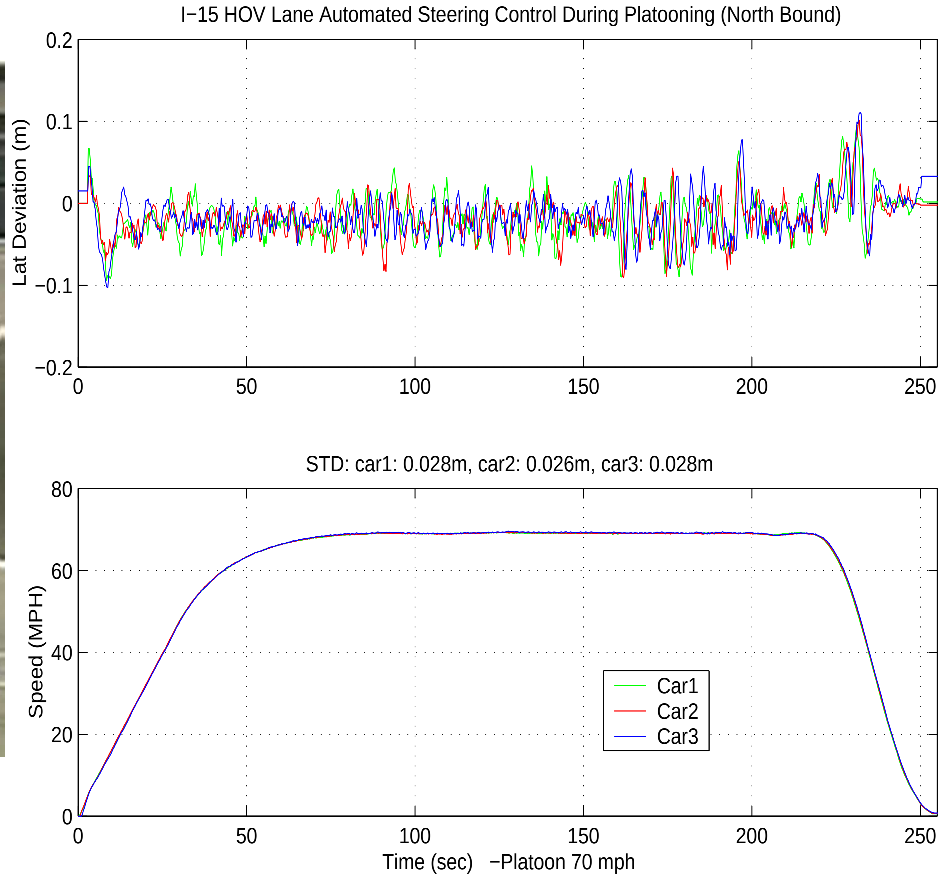
PATH Automation Milestones

- **1988 – Basic AHS concepts defined**
- **1991 – Hierarchical information architecture**
- **1992 – First automated vehicle experiments (4-car longitudinal control platoon, one car automated steering control) and first FHWA funding support**
- **1993 – AHS Precursor System Analyses**
- **1994-8 – National AHS Consortium (including Demo ’97)**
- **1998 – Demo ’98, Netherlands**
- **2000 – Demo 2000, Japan**
- **2003 – Bus and truck automation demonstrated**
- **2007-11 – Mobility Applications for VII project (FHWA)**
- **2013 – New CA DMV and FHWA EARP projects**

Consistent, Accurate Steering on Highway



- **3 cm lateral variations at every location at highway speeds**

Vehicle Assist and Automation (VAA) – Automatic Steering Control of Buses

- **Objectives**
  - Implement VAA applications using two guidance technologies (magnetic & DGPS-based)
  - Address VAA deployment issues and assess benefits and costs in revenue-service operations

- **Team**
  - FTA, Caltrans, 2 transit operators, PATH, industrial contractors
- **Transit revenue service**
  - Lane Transit District (LTD) Franklin EmX BRT service (Eugene, OR):
    - A 2-mile route, with 3 intermediate stations, round trip
    - Public revenue service in 2014

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Automatic Longitudinal (Platoon) Control

- **Engines and brakes of conventionally powered vehicles can be controlled accurately enough for precision vehicle following in platoons (20 cm accuracy)**
- **Precise vehicle following can be done with smooth ride quality**
- **Vehicles can be driven in close-formation platoons (3 – 5 m gaps) without exposing occupants to exhaust gases or impeding cooling air to radiators**
- **Vehicles can merge into the middle of a passing platoon, using wireless coordination**

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Automated Platoon Longitudinal Control and Merging

1997

2000

PATH V2V Truck Platoons (2003, 2010)

2 trucks, 3 to 10 m gaps

3 trucks, 4 to 10 m gaps (6 m in video)

Current Automation Projects

- **FHWA EARP – Partial Automation for Truck Platooning**
  - With Volvo Trucks, Caltrans, LA Metro
  - Experimental implementation on new Volvo platform – cooperative ACC, testing driver acceptance and energy savings
- **FHWA EARP – Using Cooperative Adaptive Cruise Control to Form High-Performance Vehicle Streams**
  - With TU Delft as subcontractor
  - Simulations of high-level control strategies
  - Estimating traffic impacts of CACC
- **California DMV automation regulations support**
  - Technical advice to state developing regulations for testing and public operation of AVs

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