

California PATH

Partners for Advanced Transit and Highways





CALIFORNIA
PATH

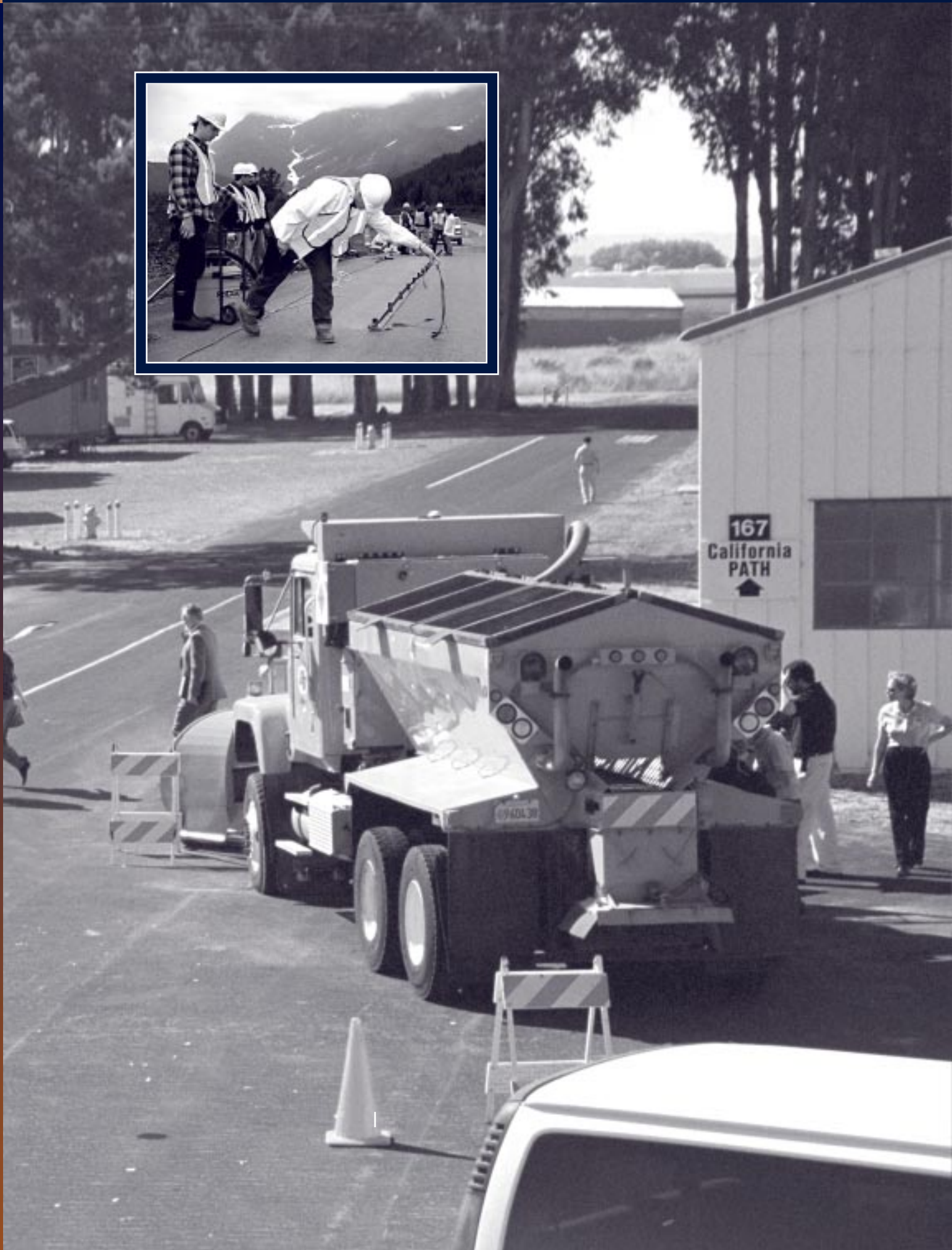
California PATH – Partners for Advanced Transit and Highways – is a collaboration between the California Department of Transportation (Caltrans), the University of California, other public and private academic institutions, and private industry. PATH's mission: applying advanced technology to increase highway capacity and safety and to reduce traffic congestion, air pollution and energy consumption.

MAKE A FASHION STATEMENT. 

California PATH

Partners for Advanced Transit and Highways

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Director's Introduction



The California PATH Program, a collaboration between Caltrans and the University of California, is a unique multidisciplinary research program that seeks advanced technological solutions to our worsening transportation problems. PATH's researchers and staff come from many countries and academic backgrounds and are spread across California's college campuses and into private industry. They are united by the goal of fulfilling the promise of ITS, Intelligent Transportation Systems, and finding solutions for today and tomorrow.

Caltrans and PATH share a vision of congestion relief through highway automation. PATH's demonstration of an eight-car fully automated platoon, as well as the Honda/PATH magnetic/computer-vision guided vehicles, were highlights of the most successful demonstration of vehicle automation technology ever held: Demo '97. PATH has since participated in follow-up automation technology demonstrations, including Demo '98 in the Netherlands, Demo '99 in Ohio, and Demo 2000 in Japan. Caltrans and PATH are currently planning for a major demonstration in 2003 that will showcase automation technology for heavy trucks and buses.

PATH's research activities in the area of Advanced Traffic Management and Information Systems (ATMIS) have greatly expanded in the last few years. An exciting new Center for Commercialization of ITS Technologies (CCIT) will open in the 2001 near the Berkeley campus. CCIT will team up University faculty and graduate students, private sector companies, and government transportation agencies in a new facility with the mission of facilitating the commercial deployment of advanced traffic information system technologies.

PATH brings together engineers and economists, geographers and urban planners, computer scientists and statisticians, among others. Its multidisciplinary atmosphere is responsible for shaping the "modern" transportation engineer, who is familiar not only with traditional disciplines but also with the emerging areas of sensors, communications, data structures, vehicle dynamics and control, and many other disciplines. We pride ourselves on the many students and postdocs who have "graduated" from PATH and gone on to influential positions at universities and in the public and private sectors, spreading the ITS vision. PATH's future looks bright as the need for intelligent transportation solutions becomes ever more clearly apparent. Bringing together the best minds in California to improve California's, the nation's and the world's transportation systems is PATH's goal!

A handwritten signature in dark ink that reads "Karl Hedrick".





A Word from Caltrans



The collaboration between Caltrans and PATH has now evolved into a world renowned transportation research program that investigates new technological methods to improve traveler safety, reduce traffic congestion, enhance the mobility of people and goods, and increase our transportation systems' economic productivity. PATH's future looks bright indeed as the need for deployed Intelligent Transportation Systems (ITS) becomes more clearly apparent.

Transportation demand continues to accelerate at a pace that has overwhelmed our ability to build additional capacity. This capacity can, however, be increased by efficiencies made possible by recent improvements in electronics, computers, communications, controls, sensors, and actuators that have made these technologies more usable in widespread ITS applications. Our prime objective now is to implement the research products that we have created in these past few years.

We are committed to building transportation systems that improve traffic flow, information gathering, and roadway safety. The Performance Measurement System (PeMS) project is one example that shows significant potential benefits. PeMS technology will make real-time traffic conditions available by converting raw loop detector data into information that is easily accessible and understandable by transportation system managers. This information will enable managers to make the right decision when choosing, for example, how to respond to an incident or when to schedule maintenance lane closures.

Despite our past successes, we know that further challenges remain if we are to maximize efficiency in the operation of our transportation systems.

In order to design safe and effective Advanced Vehicle Control and Safety Systems, designers will need to continue their efforts to derive solid quantitative knowledge of the driving environment and of how drivers will use these systems. A great deal of fundamental data gathering, design, and real-world test and evaluation will be necessary to expand the knowledge base. This important work will advance us beyond the stage of theoretical studies and towards practical experimentation. Caltrans and PATH also remain focused on our plan to demonstrate fully automated heavy vehicles in San Diego in the summer of 2003.

It is my firm belief that this demonstration of bus and truck automation will be a giant step forward in our goal to promote widespread deployment of Automated Highway Systems that support all vehicle types.

On behalf of the staff and management of Caltrans, I congratulate PATH on its substantial accomplishments during another successful year.

Caltrans Director Jeff Morales visited PATH in the spring and was so impressed with PATH research that he returned in the fall with the Caltrans District Directors and their staffs.



A handwritten signature in blue ink that reads 'Greg A. Larson'.

Greg Larson
Caltrans Management Liaison



Overview of California PATH

The California Partners for Advanced Transit and Highways Program (PATH) has been leading the way in ITS (Intelligent Transportation Systems) research since PATH's founding in 1986, before the term ITS or its predecessor IVHS (Intelligent Vehicle Highway Systems) had even been coined. PATH's purpose is to develop foundations for the widespread adoption of advanced technologies that will improve the operation of California's surface transportation systems. PATH'S primary goals are to reduce traffic congestion and improve traffic safety. By succeeding at these, we also expect to help reduce travel stress, pollution, and energy consumption, and contribute to enhancing the strength of California's economy.

Caltrans provides the seed funding for PATH's core research, based on its goal of promoting the development of new knowledge and new technology that can improve the productivity, safety, and environmental impacts of California's surface transportation systems.

PATH's charter includes the missions of conducting leading-edge research, evaluating operational tests, developing public/private/academic partnerships, and educating students as well as practitioners about ITS.

PATH focuses on research with the potential for dramatic improvements in the operation of California's transportation system, rather than diffusing its efforts in areas where only incremental improvements are possible. California's population and its transportation demands are growing so rapidly that the effects of incremental solutions would likely be absorbed by the time they could be implemented. Hence, PATH emphasizes relatively long-term, high-impact solutions. But PATH also addresses the progressive steps needed to achieve those long-term solutions. PATH research also attempts to identify impediments to progress, both technical and institutional, and to devise strategies for overcoming those impediments. Research and development done under PATH auspices include:

- identification of problems and needs
- basic research on enabling technologies
- applied technology research and development
- system-level design and evaluation
- experimental verification of design predictions
- evaluations of existing technologies or equipment
- evaluations of costs and benefits
- technology assessments
- predictions of users' behavioral responses
- predictions of the impacts of technologies' use
- evaluations of legal and institutional issues.

PATH is managed by the Institute of Transportation Studies of the University of California at Berkeley, which established the PATH Program Headquarters Office at the University's Richmond Field Station in 1986. Policy issues are addressed by the PATH Executive Committee, composed of representatives of the primary participating universities, and by the Caltrans-PATH Joint Management





Team, composed of program managers from both Caltrans and the University. PATH's day-to-day operations are managed by the headquarters staff.

PATH headquarters has about forty full-time staff members, including a core group of research staff members, plus program managers and administrators. A substantial body of research is done by the full-time research staff at PATH headquarters, but most PATH research work is done by faculty members employing graduate students on the campuses of the universities that form the PATH partnership. This work is 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 international. The product-development-oriented work of private companies complements the more basic work of the academic researchers, so that each group can concentrate on what suits it best. Publication of PATH research work is coordinated at PATH headquarters.

PATH Activities in National and International ITS Programs PATH has received substantial funding from the Federal Department of Transportation (USDOT), including support from the Federal Highway Administration, Federal Transit Administration, and National Highway Traffic Safety Administration on a variety of projects that predated current Federal ITS programs. PATH participation in USDOT ITS programs during the past year includes several projects within the Intelligent Vehicle Initiative (IVI) program:

- Evaluation of concepts for sensor-friendly vehicle and roadway systems, with Bechtel and Carnegie Mellon University.
- Defining the requirements for a transit bus Forward Collision Warning System, with the San Mateo County Transit District (SamTrans, Caltrans, and bus manufacturer Gillig.
- Transit bus Rear Collision Warning System requirements definition, with Ann Arbor Transit Authority and ERIM International.
- Development of threat assessment simulation software for Automotive Collision Avoidance System (ACAS) field operational test with General Motors and Delphi Automotive Systems.

PATH and Caltrans continued to participate in the Multistate Operations Research Program (MORIP), which includes Minnesota, Texas, and Washington. MORIP provides an opportunity for operations practitioners and researchers to share information on ITS-related efforts in the four states. In 2000, the group developed a business plan that, among other items, identified areas of common research interest. Subsequently, PATH and the Texas Transportation Institute (Texas

A&M University) have launched a joint investigation of the state of the practice in three areas: transportation systems performance measurement and data collection technology needs, data sharing policies and practices, and highway maintenance management systems.

PATH has worked closely with Caltrans on developing two multistate pooled fund projects to advance the state of the art of cooperative Advanced Vehicle Control Systems (AVCS), with USDOT participation. Within the IVI Infrastructure Consortium, Caltrans and PATH have teamed with counterparts in Minnesota and Virginia and automotive supplier Visteon to develop a cooperative intersection decision support system. Separately, as an outgrowth of the Phoenix Project, Caltrans and PATH have attracted ten other states to join in a Cooperative Vehicle-Highway Automation Systems (CVHAS) project, which we hope will revive national interest in automated highways.

Evaluations of California ITS Operational Tests PATH has served as evaluator for the following Field Operational Tests: • TravInfo (Bay Area) • Smart Call Box (San Diego) • Adaptive Traffic Control (Anaheim) • Integrated Ramp/Signal Control (Irvine) • Mobile Surveillance (Orange County) • Wireless Spread Spectrum Communication (Los Angeles) • TransCal (Bay Area to Reno)

State-Funded Core Program of ITS Research The core of the PATH program is its collection of research projects funded by Caltrans' New Technology and Research Program. Currently there are about ninety-five such projects, selected on the basis of an annual Request for Proposals (RFP) and proposals submitted from throughout California. These involve the work of about forty professors, representing fifteen academic departments on fourteen different university campuses, supervising the research of more than one hundred graduate students and post-doctoral researchers. Projects are currently being conducted at: UC Berkeley, UC Davis, UC Irvine, UC Los Angeles, UC Riverside, California Polytechnic State University at San Luis Obispo, California State University San José, the Claremont Graduate School, the Massachusetts Institute of Technology, Ohio State University, Stanford, Texas A&M, the University of Michigan, and the University of Southern California.

New projects PATH attracted research support from a variety of sources during the past year. Some of the new projects under development, in addition to the IVI projects previously cited, include: • A new simulation and visualization model for evaluation of Bus Rapid Transit Systems (SmartBRT), under the joint sponsor-





ship of the Federal Transit Administration and Caltrans. • Development and evaluation of a variety of technologies for Bus Rapid Transit, under Caltrans sponsorship and in cooperation with the Santa Clara County Valley Transit Authority. • New technology approaches for railroad crossing warnings at uncontrolled crossings in the San Joaquin Valley, under sponsorship of the Caltrans Rail Transportation Program. • A precision automatic steering control system for a Caltrans rotary snow blower, under the sponsorship of Caltrans' Advanced Highway Maintenance and Construction Technology program (AHMCT). • A project on distributed autonomous agent networks of aerobots for the Office of Naval Research. • A testbed and automotive example application project for Model-Based Integration of Embedded Systems (MoBIES), under the sponsorship of the Defense Advanced Research Projects Agency (DARPA).

The Caltrans Traffic Operations Program supplemented PATH's core program with a package of special projects related to its Traffic Operations Plan Strategies (TOPS) initiative, including:

- Further development and extension of the Performance Measurement System (PeMS) to Caltrans District 7 (Los Angeles) and other districts.
- Initial quantification of TOPS impacts using PATH's ITS benefits/costs methodology and sample applications on the ATMS Testbed network in District 12 (Orange County) using the Paramics traffic simulation model and other Testbed simulation tools.
- Expansion of Testbed facilities to allow for transportation management center (TMC) operator training.
- Focused investigations of various freeway traffic flow and control issues and development of performance improvement approaches.

Other notable developments during the past year included: • Founding PATH's Center for Commercialization of ITS Technologies (CCIT), to encourage the intermediate steps that need to be taken between



Together with the Intelligent Vehicle Transportation Program, Caltrans and SamTrans, PATH's Forward Collision Warning System project defines requirements for a system to alert a public transit driver to unseen obstacles. Sensors mounted on the bus collect data. In developing an optimal system, radar, light radar, sonar or video may be employed.

research and deployment of ITS technologies and systems. Hamed Benouar was appointed CCIT Executive Director. • Receiving the ITS America Award for Best Research Project, awarded to PATH's Enhanced Loop Detector Project for its innovative use of inductive signature analysis techniques. • Participating in SmartCruise Demo 2000 in Tsukuba City, Japan, under the sponsorship of Japan's Ministry of Construction. One of only three non-Japanese organizations invited, PATH demonstrated how our magnetic marker guidance system can be used as the basis for integrated services of lane departure warning, lane departure prevention, driver lateral guidance, and automatic steering.



ATMS

Advanced Transportation Management Systems

Traffic Data Collection Technologies

New traffic data collection prototypes are continually being developed and field tested. New detection systems developed by the universities made their way to the freeways for real world testing.

Development and Testing of Field-Deployable Real-Time Laser-Based Non-Intrusive Detection System for Measurement of True Travel Time on the Highway

MOU 3005 – Harry Cheng, UCD
A laser-based field prototype was developed and tested on the highway. Several field tests were done with the prototype system on the highway: results verified that the principle of the detection system is technically sound and the system is reliable during all environments.

Field Investigation of Advanced Vehicle Reidentification Techniques and Detector Technologies

MOU 3008 – Stephen Ritchie, UCI
The loop signature system for vehicle reidentification was tested at a major signalized intersection to develop capabilities for on-line real-time intersection level of service estimation. The capability also provided the means to track the turning movements of the vehicles at the intersection.

Field Operational Test of GPS and Cellular Technologies for Vehicle Probes

MOU 3015 – Y.B. Yim, PATH
Cellular phone and GPS technologies were evaluated for the vehicle as probes concept in the San Francisco Bay Area. Two sample data sets provided by US Wireless demonstrated that cellular phone tracking show promise but needs further studies to determine its ability to produce reliable travel times. The GPS field tests demonstrated higher accuracy, but differentiating between freeways and frontage roads can be problematic.

Development of a Cost-Effective Surveillance System in Caltrans District 4

MOU 382 – Joy Dahlgren, PATH

The feasibility of using toll tag (FasTrak) equipped vehicles as probes to estimate travel times in the Bay Area was studied. The research found not only that using toll tag equipped vehicles as probes would indeed be feasible in many parts of the Bay Area, but that they generally cost less both in terms of capital and operating costs than many competing surveillance options such as loop detectors, microwave and video detection. The congested areas near the bridges, where loop detectors are not feasible, are prime candidates for toll tag probe readers.

Traffic Estimation

Using various advanced detection technologies will yield new and more accurate forms of traffic data to help manage the transportation network, and help develop and calibrate improved traffic flow theories and models.

Freeway Performance Measurement System, Phase II

MOU 3012 – Pravin Varaiya, UCB
PATH's freeway performance measurement system (PeMS) was implemented in more Caltrans districts, District 7 in Los Angeles being the latest. This allows Caltrans to measure their performance in real time. PeMS presents information in various forms to assist managers, traffic engineers, planners, freeway users, value added resellers (VARs), and researchers. The system also estimates travel times and fastest route for the driver.

Improving Operations, Driver Information and Safety Using Advanced Surveillance Metrics, Wireless Communication and Existing Traffic Detectors/Controllers

MOU 3010 – Ben Coifman, PATH
A new traffic surveillance strategy using existing detectors to identify when the link between two detector stations becomes congested was developed. A vehicle reidentification algorithm was developed for consecutive detector stations on a freeway matching a vehicle measurement made at a downstream detector station with the vehicle's corresponding measurement at an upstream station to provide travel time information. The method was illustrated using measured vehicle lengths from paired loop detector speed traps.

Real-Time Algorithms for Travel Time and Origin-Destination Estimates, Incident and Verification

MOU 353 – Alex Skabardonis, UCB
PATH has mounted 12 fixed video cameras and 2 pan/tilt/zoom cameras on the top of a 320 foot tall building adjacent to I-80 in Emeryville. The fixed cameras provide a continuous view of I-80 between the Bay Bridge approach and University Avenue over 2 miles of freeways, interchanges, and frontage road. The video is being used for research in video image processes and modeling traffic flow dynamics.

Traffic Data Measurement and Validation

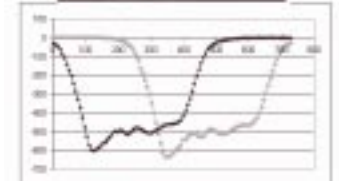
MOU 3000 – Ben Coifman, PATH
Many researchers have sought better estimates of velocity from single-loop detectors. Earlier work emphasized post-processing techniques to reduce the bias from long vehicles in mean velocity estimates. This project took a different approach, using a new aggregation methodology to estimate median velocity. It was shown that the estimate is less sensitive to the presence of long vehicles. Furthermore, the proposed method of estimating median velocity is simple enough that it was shown that it could be deployed on existing traffic controllers.

Traffic Management Strategies

It is a well known fact that it is very difficult to build or expand freeways because of land, environmental and other constraints. Therefore, it is vital to research ways to manage the existing transportation network as efficiently as possible.

Access Control Strategies to Manage Traffic Backups and Increase System Capacity

MOU 3004 – Carlos Daganzo, UCB
Extensive field observations of a multi-lane freeway traffic upstream of an oversaturated off-ramp was performed. It is based on empirical evidence from freeway I-880 (northbound) near Oakland, California. The main finding of this research is evidence that a bottleneck caused by an off-ramp on a multi-lane freeway can reduce the capacity downstream of the bottleneck significantly below the capacity of the freeway. Empirical evidence gathered during the



Loop Detector Signature Reidentification



Fastrak Transponder used as Traffic Probe



Cameras Placed on top of the Pacific Park Plaza Building



Ramp Metering



Increasing Bottleneck Capacity

first year of this study strongly suggests that new, “smart” traffic control approaches such as lane assignment can be used to relieve recurrent congestion caused by diverge bottlenecks.

Development and Evaluation of Adaptive Ramp Metering

MOU 3013 – Michael Zhang, UCD

A conceptual evaluation was done on existing ramp metering algorithms including SWARM, METALINE and the Ball Aerospace algorithm. Several existing ramp metering algorithms were chosen to be the most promising and were simulated using the Paramics traffic simulation. Under high demand pressure, critical conditions on the freeway demand lower metering rates, which often leads to long queues at metered ramps. When the size of the queue on metered ramps become long, it is customary for these algorithms to raise the entrance flow from ramps to a higher level till the long queues subside. This often creates a high/low cycle effect in ramp metering rates.

Development of Tools to Assess the Effects on Traffic Safety of Changes in Traffic Flow Conditions under ATMS Operations

MOU 3007 – Tom Golob, UCI

An evaluation tool was developed based on identification of the salient relationships between accident rates and characteristics and traffic flow patterns. The data for the underlying analyses involved one year of accidents on six major freeways in Orange County, combined with traffic flow conditions extracted from loop detectors near the accident. The data was analyzed and partitioned to different regimes such as time of day, weather and traffic conditions.

Examining How ATMIS Can Increase Freeway Bottleneck Capacity

MOU 3011 – Mike Cassidy, UCB

A study was performed to show how Advanced Transportation Management and Information Systems (ATMIS) might be deployed to increase bottleneck capacities. The study relied solely upon empirical observations from video taken in Orange County. A bottleneck with diminished capacity arose whenever queues from an off-ramp spilled over and occupied the segment’s mandatory exit lane. Notably, whenever the off-ramp queues were prevented

from spilling over to the exit lane (by changing the logic of a nearby traffic signal), much higher flows were sustained on the freeway segment, and a bottleneck did not arise there. These observations underscore the value of control strategies that enable diverging vehicles to exit a freeway unimpeded.

Simulation and Modeling

Traffic simulation and modeling is essential in answering “what if” scenarios for ATMIS applications. In the past year, emphasis was put on the Paramics model to simulate the benefits of ATMIS.

Integrating a Comprehensive Modal Emission Model into ATMIS Transportation Modeling Frameworks

MOU 381 – Matt Barth, UCR

Research done at UC Riverside has integrated a detailed emission model (CME/EC) with the Paramics simulation model. After successfully completing this integration, two case studies were carried out using this PARAMICS/CME-EC tool. The first case study examined the emissions impact of HOT lanes along the SR-91 corridor in Southern California. The other case study examined the emissions impact associated redesignating uphill lanes on I-60 near Riverside, California. These case studies can serve as examples as how to apply this new tool for creating microscale emission inventories.

Bay Area Simulation and Ramp Metering Study

TO 4106 – Joy Dahlgren, PATH

A project was initiated at PATH to evaluate ramp metering in the I-680 Sunol Grade corridor. The entire corridor was coded and carefully calibrated in Paramics and now is ready to assess the effects of ramp metering and any other strategies in the I-680 corridor.

ATIS

Advanced Traveler Information Systems

Will increase mobility and safety by informing travelers and commercial vehicle operators of travel conditions and alternatives.

ATIS for Ground-to-Air Connectivity

MOU 3003 – Randolph Hall, USC

A collaborative effort with United Parcel Service and Caltrans was done to evaluate information services targeted at assisting overnight carriers in routing their trucks, scheduling their shipments, and optimizing their departure times for the airport. Models were developed for the airport terminal as a queueing process with random bulk arrivals. From these models, performance measures were developed for the process.

Consumer Research on ATIS Technologies: Surveys of ATIS Users

MOU 363 – Y.B. Yim, PATH

Two studies related to the TravInfo Evaluation project was conducted. The second wave of the Broad Area survey determined the effect TravInfo had on the general public after it had been operational for over a year. The second wave of the Traveler Advisory Telephone System (TATS) survey determined that people are still calling the TATS and are satisfied with the service.

Financing Plan for Public Supported ATIS

MOU 364 – Y.B. Yim, PATH

An institutional analysis was done about alternative approaches to sustaining publicly supported ATIS. Alternative revenue models were identified that may be able to support the operation of the newly created traveler information centers in the post-field operational test phase. The market potential for privately offered advanced traveler information services in the United States and Europe is; however, yet to be determined since consumer purchase behavior for traveler information is largely unknown.

APTS

Advanced Public Transportation Systems

To address the transportation needs of today and the future, California needs creative and innovative solutions that provide alternatives to reduce traffic congestion, promote equity and flexible travel, cut air pollution, and link customers to public transportation. The PATH vision integrates technologies and alterna-

tive transit strategies with conventional transit service to improve mobility and reduce congestion.

Assessing Opportunities for Intelligent Transportation Systems in California's Passenger Intermodal Operations and Services

MOU 375 – Mark Miller, PATH

A project was done to recommend strategies for the improvement of passenger intermodal operations and services, both by evaluating the current state of passenger intermodalism in California and by identifying ways that intelligent transportation systems can be used to enhance the services currently in place from both the user and institutional perspectives. A total of thirteen site visits were conducted at passenger intermodal transfer facilities in the San Francisco Bay Area, metropolitan San Diego, and the Sacramento Area. Each site visit considered four stages of the intermodal transfer experience: approach to the facility, the ticketing process, the transfer within the facility and departure from the facility.

Consumer Research on Personalized Demand-Responsive Transit Service

MOU 398 – Y.B. Yim, PATH

A study was done to conduct consumer research on personalized demand-responsive transit service (PDRT). The results of six focus groups and the survey indicate that the idea of a personalized transit service may appeal to commuters as well as non-commuters. There is significant potential to attract travelers to PDRT. A majority of these people were willing to pay between \$5-\$10 for a 30 minute trip.

Evaluating the Impact of ITS on Personalized Public Transit

MOU 3002 – Maged Dessouky, USC

An investigation was done on the use of ITS technologies to improve the service efficiency of demand responsive transit (DRT) providers and to evaluate the different opportunities it creates to improve the overall performance of DRT systems. Different technologies that have been implemented or are being considered for implementation by the transit providers were reviewed. Technologies that have been implemented include AVL, advanced wireless communication, MDT, computerized vehicle navigation, and geographic data-

base. Emerging technologies that have potential for implementation include internet dispatching, superphones, personal data assistants, and smartmaps. It is anticipated that the responsiveness and costs of demand responsive transit may be improved by utilizing these ITS technologies.

Expanded, Year-Two Carlink Demonstration: A User, Economic, and Institutional Evaluation of "Smart" Carsharing

MOU 3009 – Susan Shaheen, PATH

CarLink II is a pilot project with 27 Honda Civic vehicles in the Palo Alto area. It follows the successful demonstration of the carsharing concept of Carlink I in the Dublin/Pleasanton area with the BART system. Carlink II will determine its ability/potential to transfer viable smart technologies and business models to other locations. New business employers and Caltrain have been secure in the Palo Alto area for this project. Also, new technologies have been developed for the reservation system and tracking the vehicle usage.

Decision Support & Benefit Cost Analysis

Evaluation Methods for Measuring the Value of ITS Services and Benefits from Implementation

MOU 3001 – David Gillen, UCB

ITS transportation professionals face a difficult task in assessing benefits and costs associated with ITS projects and measuring system performance. This project undertook specific evaluations in two different areas of ITS application: (1) public transportation operations with specific consideration of AVL applications and (2) freeway service patrol and emergency management.

ITS Evaluation Website

MOU 355 – Joy Dahlgren, PATH

This was a year of maturing, redesign, and redirection for the website. The name of the site was changed from *LEAP* to the more descriptive *ITS Decision*. The page format has been redesigned and the home page now includes new graphics, new indexes, a featured new addition to the site, and information on new additions.

CarLink II



Vehicle Control

Control of Heavy Duty Vehicles

Robust Lateral Control Of Heavy Duty Vehicles

TO4201/MOU385–Masayoshi Tomizuka, UCB

This project implements and tests previously developed lateral control algorithms for heavy-duty vehicles, and enhances robustness and performance of lateral controllers. To enhance robustness, a physical model of the steering subsystem was derived and a nonlinear robust inner loop controller was designed. An adaptive robust controller was then designed and proved by simulation to be robust under large model uncertainties while maintaining ride comfortability. Simulations also showed that the controller was robust under various aerodynamic (crosswind) and loading conditions. Experimental evaluation of the robust controllers for lane following was also conducted. The emphasis for the experiments was to evaluate the robust controllers under varying road and loading conditions.

Integrated Longitudinal Control For Safe Automation Of Commercial Heavy Vehicles

TO4202/MOU393–Anna

Stefanopoulou, Univ. of Michigan; Christian Gerdes, Stanford

This project builds on the results of previous PATH projects on the longitudinal control of heavy-duty vehicles. The project considers two main objectives. The first objective deals with the robust longitudinal control design through on-line adaptation, so that the performance of the automated heavy truck will be insensitive to varying load and road conditions such as changes in vehicle mass, load variations, road grade, wind gusts, and engine tuning. Simulation modelling and sensitivity analysis of the longitudinal control law to changes in mass, grade, rolling resistance and aerodynamic drag have been completed. The results indicate that mass and grade are of significant importance to performance while variations in drag and rolling resistance are minor. Experimental verification on the new control modules will be performed. The second objective is to investigate the use of the engine brake and transmission retarder for

braking, and to design controllers that are capable of combining all the different brake actuators for optimal performance. To enhance the robustness and safety of the integrated compression braking mechanism with the friction brake controller previously developed, a model reference algorithm for the compression braking controller is developed. The PATH Freightliner truck is being instrumented for experimental testing and verification of the control designs.

Control Of Heavy-Duty Vehicles: Environmental And Fuel Economy Considerations

TO4203–Petros Ioannou, USC

This project evaluates the environmental performance of existing and previously developed heavy-duty vehicle following control systems, and develop new designs, where necessary, for environmentally efficient controllers using an emissions and fuel consumption model for heavy trucks being developed at UC Riverside with support from PATH and the U.S. EPA. The controllers will guarantee fuel efficiency and also stability of close vehicle following. The emissions model will first be used to examine the environmental impact of the current longitudinal control laws during traffic disturbances in a mixed traffic. The data and the environmental performance results will then be used to develop modifications to existing controllers or design new controllers. Simulations and a sequence of experiments using actual vehicles will be performed to validate the results.

Vehicle Control Under Abnormal Conditions Vehicle Lateral Control Under Fault In Front And/Or Rear Sensors

TO4204/MOU384–Masayoshi Tomizuka, UCB

This project evaluates the performance and robustness of the magnetometer-based lateral control system when either the front or rear set of magnetometers fails. The project has designed, simulated and experimentally tested lateral controllers that utilise only the front set and only the rear set of magnetometers. An Autonomous Lateral Controller (ALC) that is based on measurements of lateral error and yaw angle relative to a preceding vehicle is then designed to serve as backup system for the magnetometer-based controller. The ALC is implemented using a

scanning laser radar. Two controllers have been designed; one calculates the lateral deviation of the controlled vehicle relative to an online generated trajectory of the preceding vehicle based on the measurements of the laser radar, and the other utilises the yaw rate sensor along with the laser radar and the road curvature. The ALC will be integrated with the magnetometer-based lateral controller.

Fault Tolerant Lateral Control For Transit Buses And Trucks

TO4205 –Masayoshi Tomizuka, UCB

This project develops and implements fault tolerant lateral controllers for transit buses and trucks in preparation for the PATH Demo 2003. The focus is on the design of lateral controllers that are tolerant to lateral controller faults that include the yaw rate gyroscope, steering actuator, accelerometer, and magnetometers. The project will study the possibility of adding magnetometers for better fault tolerant properties. It will explore fault tolerant sensor fusion strategies and differential braking as a backup system in the event of a failure in the steering actuator. The sensor placement design problem of determining the type, number and location of sensors for fault tolerant lateral control has been addressed.

Automated Fault Tolerant Longitudinal Control Of Transit Buses

TO4206–Karl Hedrick, UCB

This project develops and implements fault tolerant longitudinal controllers for transit buses in preparation for the PATH Demo 2003. The project will develop a realistic model of a transit bus. This will involve the development of the mathematical models of the bus subsystems for longitudinal control. These subsystems include an engine model, a transmission and wheel dynamics model, and a pneumatic brake system model. The bus model will be simulated and verified using experimental data. A fault detection and diagnostic system and automated control laws which provide reliable operation under both nominal and faulty operating conditions will be designed. The fault tolerant controllers will be implemented and experimentally verified.

Vehicle Control Experiments and Field Tests

Vehicle Control Experimental Research And Support

TO4227–Dan Empey, UCB/PATH

A significant portion of the AVCSS work at PATH requires experimental vehicles to support the research, development, testing and validation of the control systems. This project continues the support that the Vehicle Control Experimental Group provides for ongoing automated vehicle research work needed by the various proposed and continuing projects at PATH. The group consists of specialists in control systems, communications, electronics, software development and implementation, as well as hardware development, integration and maintenance. The project covers general Task Order support, support of the heavy truck projects, fault-tolerant controls for buses and trucks, compression braking control, truck emissions and fuel consumption, integration of vehicle control and communication, integration of GPS/INS and magnets for vehicle control, adaptive cruise control experiments, communication systems, testing of fault detection algorithms, fault diagnosis for vehicle control, and evaluation of longitudinal range and range rate sensors. Maintenance and upgrading of the fleet of PATH test vehicles is required on a continuing basis, and is also covered under this project.

PATH Demo 2003

TO4228–Dan Empey, UCB/PATH

This project is intended to jumpstart the Demonstration 2003 of PATH development of heavy-duty vehicles. It will first develop the system requirements, such as actuator bandwidth and computer input-output specifications, of the demo vehicles. Vehicle development tasks that include the development of steering actuator and brake actuator will be initiated. Lateral and longitudinal control algorithms will be experimentally tested to verify their performance and robustness on an existing heavy-duty vehicle.

TO4229 — Dan Empey, UCB/PATH

Caltrans and PATH plan to conduct a large-scale demonstration in 2003 to showcase AHS technologies and innovative Bus Rapid Transit (BRT) and automated freight transport ser-

vices supported by these technologies. The demonstration would include three Class 8 trucks and two 40-ft and one 60-ft articulated transit buses, operating in full or semi-automatic modes, and is an important milestone in the development of vehicle highway automation technologies. While there is no doubt that PATH has the technical capability of developing the demonstration systems for Demo 2002, PATH will lack most of the OEM support and has to rely on PATH staff and subcontractors to develop and install all of the required equipment and subsystems. To support the development effort, the funding of this project will be used to hire additional engineers and technicians, and use subcontracts for some development work such as fabrication of sensor mounts and brackets. The project consists of several development steps: (1) system planning and design, (2) vehicle development, (3) control system development, (4) communication system development, (5) human-machine interface development, (6) software development, (7) maintenance and support, (8) system integration, (9) planning for the demonstration, (10) improvements of PATH facilities, and (11) planning for public relations.

Vehicle Safety

Vehicle Braking Control

Advanced Braking Methods For Longitudinal Control Of Commercial Heavy Vehicles

TO4200/MOU372–Anna

Stefanopoulou, Univ. of Michigan

This project develops models and analysis for integration and coordination of advanced compression braking methods with conventional braking systems for longitudinal control of heavy-duty vehicles. A detailed crankangle based diesel engine model and a low-order engine torque model for a Class-8 commercial heavy-duty vehicle has been developed. The model is based on energy conservation principles in addition to static engine maps provided by the manufacturers, and is capable of describing the intrinsic interactions between individual cylinder intake and exhaust processes, and turbocharger dynamics during combustion and braking modes and the transition between these modes. Longitudinal control algorithms were also developed to integrate the com-

pression brake actuator with the service brakes and gear ratio adjustments to accomplish aggressive braking maneuvers and control vehicle speed during large changes in the grade. The design technique is based on the Speed-Gradient approach, whereby a control action is selected in the maximum descent direction of a scalar function.

Vehicle Safety Assessment and Safety Enhancement

Enhanced AHS Safety Through The Integration Of Vehicle Control And Communication

TO4210–Karl Hedrick, UCB

The project is focused on estimating and communicating the friction characteristics of the road to roadside for performing safe vehicle controls. There are three main problems: (1) tire/road friction estimation, (2) first contact problem of locating a vehicle and inter-vehicle communication, and (3) coordinated emergency vehicle control. Currently, all single-vehicle friction estimation tasks are completed. The key estimation algorithm is based upon so-called “slip curves” which are plots of normalised longitudinal force versus longitudinal slip. For the communication problem (2), two communication architectures have been developed, namely, a Distributed Architecture and an Infrastructure Supported Architecture. The Infrastructure Supported Architecture requires some roadside infrastructure while the Distributed Architecture realises the networking service through the peer-to-peer interaction of vehicles alone. An emergency platoon controller will be developed, focusing on the improvements that communications can offer, to allow emergency maneuvers of a platoon of vehicles.

Safety Performance And Robustness Of Heavy Duty Vehicles

TO4211/MOU390–Christian Gerdes, Stanford

The purpose of the project is to make robust claims about the performance of heavy trucks with AVCSS technologies in safety-critical conditions, with the consideration of the complexity of truck model dynamics that has made it difficult to establish what constitutes a safe truck. A list of mechanical properties has been compiled for heavy truck components such as tires and suspension. Tire properties include cornering stiffness and longitudinal stiffness. Suspen-



Trucks to be used in Demo 2003

sion properties include roll stiffness, roll center height, and lateral stiffness. A literature review has been completed to catalog variations in parameter values. This provides a basis for developing models with physically realistic parameter values. It has also gathered information concerning the possible variations in physical parameters such as configuration and loading. A set of metrics to quantify safety measures for heavy trucks has been established. Some of the more common measures include braking efficiency, friction demand, static rollover threshold, and load transfer ratio. Using a dynamic model, sensitivity analysis has been performed to determine which parametric variations produce the most significant impact on the safety metrics. A model of a heavy truck with greater level of kinematic and dynamic fidelity than previously available at PATH has been developed. This is built using commercial multi-body dynamics software in order to reflect the state-of-the-art currently available in industry. Experimental validation of the multi-body truck model is underway. Work has also started in energy-based reduction techniques of the model.

Detection And Avoidance Of Collisions: The Assessment Of Collision Threat (ACT) Model
TO4220–George Andersen, UCR

The project investigates the visual information (such as angle of collision) used by drivers to detect and avoid collisions. Failure to detect and avoid collisions can be the result of a number of factors including excessive speed, vehicle malfunction, or hazardous road conditions. However, a central factor in all of these factors is the ability of the driver to correctly perceive, attend to, and avoid potential collisions. Psychophysical experiments using a driving simulator are conducted to derive the relevant model parameters of an Assessment of Collision Threat (ACT) model. The ACT model will then be evaluated in different driving scenarios, and microsimulations of driver's perception of threat of impending collisions will be developed. The research focuses on understanding the perceptual and attentional limits of driver information for collisions. It includes examination of visual and attentional factors that lead to decreased accuracy in threat assessment by drivers.

Safety Assessment Of Advanced Vehicle Control And Safety Systems (AVCSS): A Case Study
TO4225–Wei-Bin Zhang, Ching-Yao Chan, UCB/PATH

This project continues the collaboration between PATH and INRETS in France in performing safety analysis and evaluation of advanced vehicle control and safety systems (AVCSS) such as vehicle longitudinal and lateral control systems, so that errors in the process of specification, design, development and integration can be revealed prior to the implementation of the new technologies and hazardous consequences can be prevented. PATH contributes expertise in vehicle control and failure analysis to identify, analyse and classify the risks inherent in each part of an AVCSS system. INRETS provides expertise in safety analysis and assessment. The project also considers sensor reliability and diagnosis, and develop a system architecture to include fault tolerance and fault detection. As a case study, a transit bus is used as a study platform. The next emphasis is on evaluation of collision warning system sensors and development of safety verification and certification methods to apply to Demo 2003.

Fault Diagnosis and Management

Development And Implementation Of A Vehicle-Centered Fault Diagnostic And Management System For The Extended Path-AHS Architecture

TO4207/MOU373–Masayoshi Tomizuka, Roberto Horowitz, Karl Hedrick, UCB

This project develops and implements a comprehensive fault diagnostic and management system for the extended PATH-AHS architecture designed for fault tolerant lateral and longitudinal control systems. Fault tolerant lateral controllers and fault diagnostics for the lateral control system, and the detection and processing of the multiple faults in the longitudinal control system have been developed. The fault tolerant lateral control scheme will be integrated into the existing fault management scheme. The overall hierarchical structure consisting of the health signals, fault tolerant controllers and the fault detection and identification system will be completed in the final phase of the project. Implementation and

experimental testing of the combined fault diagnostic and management system will also be completed.

Development Of Integrated Meso/Microscale Traffic Simulation Software For Testing Fault Detection And Handling In AHS

TO4208/MOU383 –Roberto Horowitz, UCB

This project develops an integrated meso-scale and micro-scale simulation package for efficient simulation of a large scale AHS at the physical, regulation, coordination and link layers. The simulation provides information on the impact of the AHS technologies on system safety and capacity. It studies and evaluates how faults in a vehicle impact the overall AHS performance and capacity, how the roadside control systems can react to faults and perform degraded-mode activities, and how the roadside control system can detect faults either in the vehicle or in its own infrastructure. The existing SmartAHS framework was extended to simplify and improve communication system simulations, incorporate link layer control and improve simulation speed. The meso-scale SmartCAP and micro-scale SmartAHS simulation programs are integrated to include link layer capability and improve the performance of the coordination and regulation layer simulations.

Testing And Evaluation Of Robust Fault Detection And Identification For A Fault Tolerant Automated Highway System

TO4209–Jason Speyer, UCLA

This project performs experimental implementation and verification of fault detection and identification algorithms developed under previous projects. The fault monitoring systems detect and identify failures in any actuator or sensor onboard the PATH Buick LeSabre test vehicles. A robust fault monitoring system has been implemented. It has been tested and fine tuned using nonlinear simulation. It works well when the vehicle travels at both constant and variable speeds. The system will also be evaluated using empirical vehicle data. The fault monitoring system will be written in C code and evaluated in real-time on a laptop connected to the computer onboard a PATH test vehicle.

Enabling Technologies

Advanced Vehicle Location

Integration Of GPS/INS And Magnetic Markers For Advanced Vehicle Control
TO4213/MOU391–Jay Farrell, Matthew Barth, UCR

This project designs, develops and evaluates the robustness of a vehicle positioning system by integrating the magnetometer system developed at PATH with a GPS/INS system developed under a previous project to achieve the performance and reliability necessary for automated vehicle control. The integrated system fuses information from the magnetometer and GPS/INS systems to reliably maintain the vehicle control state. The fusion algorithm is derived using optimal estimation methods, and C codes has been implemented. MATLAB-based observability and covariance analysis are also performed to determine the soundness of the integrated sensing system for various combinations of the available sensors. The scope includes design, analysis, implementation and evaluation of the integrated system. In addition, the system is designed to achieve the increase reliability necessary for successful commercialisation. As a final deliverable, a demonstration of closed loop vehicle control based on data from the integrated system will be performed on a PATH vehicle.

Communication Systems

A Robust Communication Link And Architecture Design For The AHS
TO4212/MOU389–Andrea Goldsmith, Stanford

This project investigates the different communication requirements and quality of service (such as messages of varying lengths and priorities) for data access in AHS communications. It designs robust communication link and data access protocols by considering the problem that the overall communication architecture for an AHS is complicated by (i) the propagation environment of the signals, (ii) the existence of multiple interference signals, and (iii) the mobility and dynamic character of platoons. The time-varying propagations of the signals between vehicles, between platoons, and from platoons to roadway infrastructure have been characterised. Commercial LANs and their performance have

also been investigated. The impact of packet loss and delay on the string stability of platoons has also been studied. The research is now focused on ensuring the robustness of the communications link and channel access given the propagation environment and the potential interference signals. This will be accomplished by investigating the performance of the platoon control protocols under packet delays and loss.

Path Laboratory

TO4224–Raja Sengupta, Chin-Woo Tan, UCB/PATH

This project includes two activities led by two principal researchers, one on navigation and one on wireless communication. The navigation activity involves developing signal processing algorithms for a gyroscope-free inertial navigation system and integrating it with a GPS system in a new way so that the errors are reduced compared to other alternatives previously developed. The wireless communication activity extends the work on vehicle-vehicle communication protocols to vehicle-roadside protocols and wireless roadside infrastructure, with particular relevance to the current national Dedicated Short Range Communication (DSRC) standardisation efforts, in which PATH has become an important participant representing the more advanced safety applications. The vehicle-vehicle communication research is continued in support of the needs of Demo 2003.

Human Driver Models

Human Driver Model Development
TO4222–Delphine Delorme, UCB/PATH

This project continues and extends the effort on human driver modelling development that started under a previous PATH project. The goal is to provide other researchers with a tool for analysing the effects of ITS systems on conventional driving performance in terms of throughput by reproducing the information processing string developed by the driver. The project has extended and refined the capabilities of the human driver model by developing more processing mechanisms that assess the effectiveness of other driving assistance systems. The next focus on the model refinement is to represent them in forms that are suitable for computer simulation, with a plan

to implement the models with the SmartAHS structure. The project also increases the number of driving parameters that the human driver model should incorporate, and validates the model using data collected during real driving of a test vehicle being developed under TO 4223.

Development Of A Vehicle Data Acquisition System For Naturalistic Driving Data Collection
TO4223 –Scott Johnston, UCB/PATH

In this project, a vehicle data acquisition system (DAS) is being developed to collect data about how human drivers actually drive. The data will be used to help calibrate and validate the human driver model that is being developed under Task Order 4222. The DAS is designed to be unobtrusive to the driver of the test vehicle and drivers of other vehicles. It is capable of recording many driving parameters such as throttle position, acceleration, longitude and latitude, range rate, and presence of adjacent vehicles. Under this project, the needed components for the DAS are purchased, and data collection and analysis software are developed and refined, and they will be integrated on a late model passenger car on loan from Caltrans.

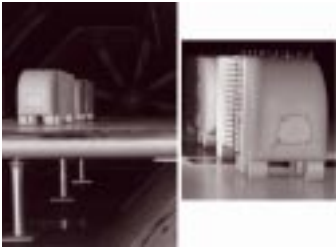
Human-Machine Interactions

Automated-Manual Transitions: Human Capabilities And Adaptive Cruise Control
TO 4221–Theodore Cohn, UCB

This project deals with automated-to-manual transition of an ACC vehicle when the vehicle in front suddenly applies maximum braking. It develops experiments using a driving simulator to investigate a human operator's ability to detect the closing intervehicle spacing and the time to collision. The driver examines the visual information and determines the need to assume manual control. A literature review of how humans judge headway and its change is completed. Person-in-the-loop microsimulation apparatus has been developed. Simulation studies of the human detection of headway reduction following abrupt braking by a lead vehicle will soon begin. A series of studies that examines which of the available cues is used by the human observer to detect gap or headway reduction will also be con-



GPS/INS and Magnetic Markers



Aerodynamics of Heavy Trucks



Refinement of Magnetic Reference/Sensing System

ducted. Based on the data, a module will be developed and appended to the PATH's Human Driver Model which predicts human behaviour in the scenarios studied in this project.

Aerodynamics

The Aerodynamics Of Heavy Trucks TO4214/MOU387 –Fred Browand, USC

This project focuses on two important aerodynamic components for heavy-duty vehicles. The first task is to carry out wind tunnel measurements of drag and potential fuel savings for two scale-model tractor-trailers in tandem at short headway. The second task is to derive sufficient vehicle roll stability margin for safe handling of Class 8 trucks at high speeds and under strong cross-wind and abnormal road conditions (such as a wet highway). The measurements are made on static tractor-trailer configurations, and yield estimates of the quasi-steady limit forces. The wind tunnel experiment describes 6-component force and moment data measured for both the cab and the trailer of a simplified model truck. The results show that two trucks in tandem always present less drag than the same two trucks operated in isolation. The saving in drag depends upon the value of the truck drag coefficient in isolation. The measurements employ not just a single truck shape, but a variety of simple truck shapes.

Real System Deployment

Analyses Of The Response Of Pavements Containing Plugs For Vehicle Guidance

TO4219–Carl Monismith, UCB

This project examines the influence of magnets on pavement performance, especially cracking, by considering the effects of traffic loading and temperature changes through a series of pavement simulations of representative pavement structures with magnets currently in use. Analyses are performed using different sensor sizes and placement within the pavement structure. The initial phase of the project is devoted to the analyses of pavements containing magnets of different configurations. Three-dimensional finite-element idealisations of the selective pavement structures and sensor sizes and locations are being developed. Traffic is limited to representative truck axles and associated legal axle loads. The stresses applied by the tires in-

clude both longitudinal and transverse shear as well as normal stresses. The effects of rate of loading (truck speed) will be evaluated. A range of temperature conditions will also be examined.

Refinement Of Magnetic Reference/Sensing System In Preparation For Commercialization TO4226–Ching-Yao Chan, UCB/PATH

This project explores several critical issues with regard to the magnetic marker positioning system, so that it can be commercialised and used in real system deployments. The issues to be researched include: (1) The measurement of background magnetic fields at various roadway sites. (2) The comparison of magnetic markers and magnetic tape provided by 3M. (3) The testing of alternative magnetic sensors. (4) The optimisation of a complete magnetic reference/sensing system. (5) The development of a standard coding scheme for magnetic marker installation. (6) The development of roadmap and opportunities for early implementation of PATH lateral control technologies.

Emissions Models

Development Of A Heavy-Duty Diesel Modal Emissions And Fuel Consumption Module For Smart AHS

TO4215–Matthew Barth, UCR

This project develops and verifies models for emissions from heavy-duty diesel engines. Heavy-duty vehicle modal emission models have not yet been developed to data primarily due to the lack of appropriate second-by-second emissions data. Under a project sponsored by the U.S. EPA, an emission trailer is being developed to measure instantaneous emissions. Using the measured emissions data, an emissions model will be developed and verified. The design of a heavy-duty diesel emissions model architecture is well underway. As an initial design for the architecture, the original comprehensive modal emissions model architecture for light-duty vehicles is used. This architecture is modified to include the differences in some of the key modules and associated analytical equations. Once the model is reasonably complete, it will be integrated with PATH's ITS simulation tools (such as SmartAHS) and used to evaluate numerous automation

scenarios that can involve passenger cars, buses, and trucks. The emissions model will also be combined with USC's automatic control system simulation tools to evaluate various ITS scenarios such as intelligent cruise control.

System Operations

AHS Deployment

The AHS/Street Interface Effects Of Capacity Concentrations On System Performance

TO4216/MOU386 –Randolph Hall, USC

Automated highways offer the potential to increase throughput on highways. But in order for such improvements to be effective at reducing total trip travel time, it must be possible to absorb these increases in throughput on the streets that interface with the AHS. This project designs AHS/street interface to accommodate the high volume of AHS traffic that would occur in the vicinity of AHS access/egress points. The study provides guidance to determine: (i) proper spacing between interchanges, (ii) traffic control strategies to prevent queue backup onto the mainline, (iii) localised street improvements to accommodate flows, and (iv) upper bounds on sustainable highway traffic flows, accounting for street bottlenecks. The project has three principle tasks: (i) strategic modelling, (ii) operational modelling, and (iii) site specific analysis. Work is underway on the effects of entrances and exits on platoon formation and dispersion. Specifically, the research examines the effectiveness of sorting vehicles into destination groups, with respect to queuing, entrance/exit design and highway throughput. Both analytical and simulation models have been created. Analysis of specific exit/entrance locations is also underway. A GIS database has been developed for a set of urban freeways, including demographic characteristics of surrounding zones, and characteristics of the freeways. This has been created in the ArcView environment.

Evaluation Of The Effects Of Intelligent Cruise Control Vehicles In Mixed Traffic TO4217/MOU392–Petros Ioannou, USC

This project conducts experiments using actual vehicles to evaluate the effects of Intelligent Cruise Control (ICC) vehicles in mixed traffic. It was

shown in MOU317 that the presence of ICC vehicles in traffic flow improves traffic flow characteristics, air pollution levels and fuel efficiency. The ICC vehicles do not contribute to the slinky-type effects observed in manual traffic due to its accurate position and speed tracking. The smooth response of ICC vehicles filters traffic disturbances and significantly reduces fuel consumption and levels of pollutants during situations when the lead manual vehicles perform rapid acceleration maneuvers. This has been demonstrated using validated car following and ICC models. The results of the experiments will then be used to study the effects of ICC vehicles on the macroscopic behaviour of mixed traffic. Issues such as stability of traffic flow and attenuation of shock waves due to the presence of ICC vehicles in mixed traffic will be analysed.

Conceptual Development And Performance Assessment For The Deployment Staging Of Advanced Vehicle Control And Safety Systems

TO4230–Mark Miller, UCB/PATH
This project represents a bridge between PATH research that is nearing completion (MOU 366) and Demo 2003. MOU 366, in its investigation of deployment staging leading to automated highway systems, has modeled the effects of driver control assistance systems relative to human driving, including both autonomous and cooperative cruise control systems, evaluated the effects of such systems on highway traffic flow capacity, and examined institutional issues. The proposed work will focus on three areas of investigation: 1. Evaluation of the effects of driver control assistance systems relative to human driving for the multilane highway case with light duty passenger vehicles, 2. Conceptual development for similar and eventual modeling and evaluation of trucks and buses, and 3. Review of the state of international research (including simulation and evaluation) and technology demonstrations of vehicle-highway automation systems. These three tasks will help fill the gaps in knowledge about deployment staging toward cooperative vehicle-highway automated systems and provide a more complete picture at Demo 2003.

Bus Rapid Transit

Definition And Evaluation Of Bus And Truck Automation Operations Concepts TO4218–Jacob Tsao, Jan Botha, San Jose State Univ.

The project develops and evaluates operating concepts for a fully automated bus-truck AHS, and the immediate steps that will facilitate the development of such AHS. Operating concepts are developed and some benefit-cost elements are then identified for a more detailed benefit-cost analysis in the future. The focus is on those major cost-benefit elements that differ significantly among the alternatives. Operating concepts will be evaluated for transportation corridors only. This project compares some aspects of the implementation of a bus-AHS to their counterparts of an existing light-rail system in California; it also compares a bus-AHS to a conventional busway with respect to similar aspects. The conventional freight-transportation alternatives include addition of a conventional lane, addition of a truck lane, addition of an exclusive AHS truck lane, and intermodal rail.



Response of Pavements Containing Plugs

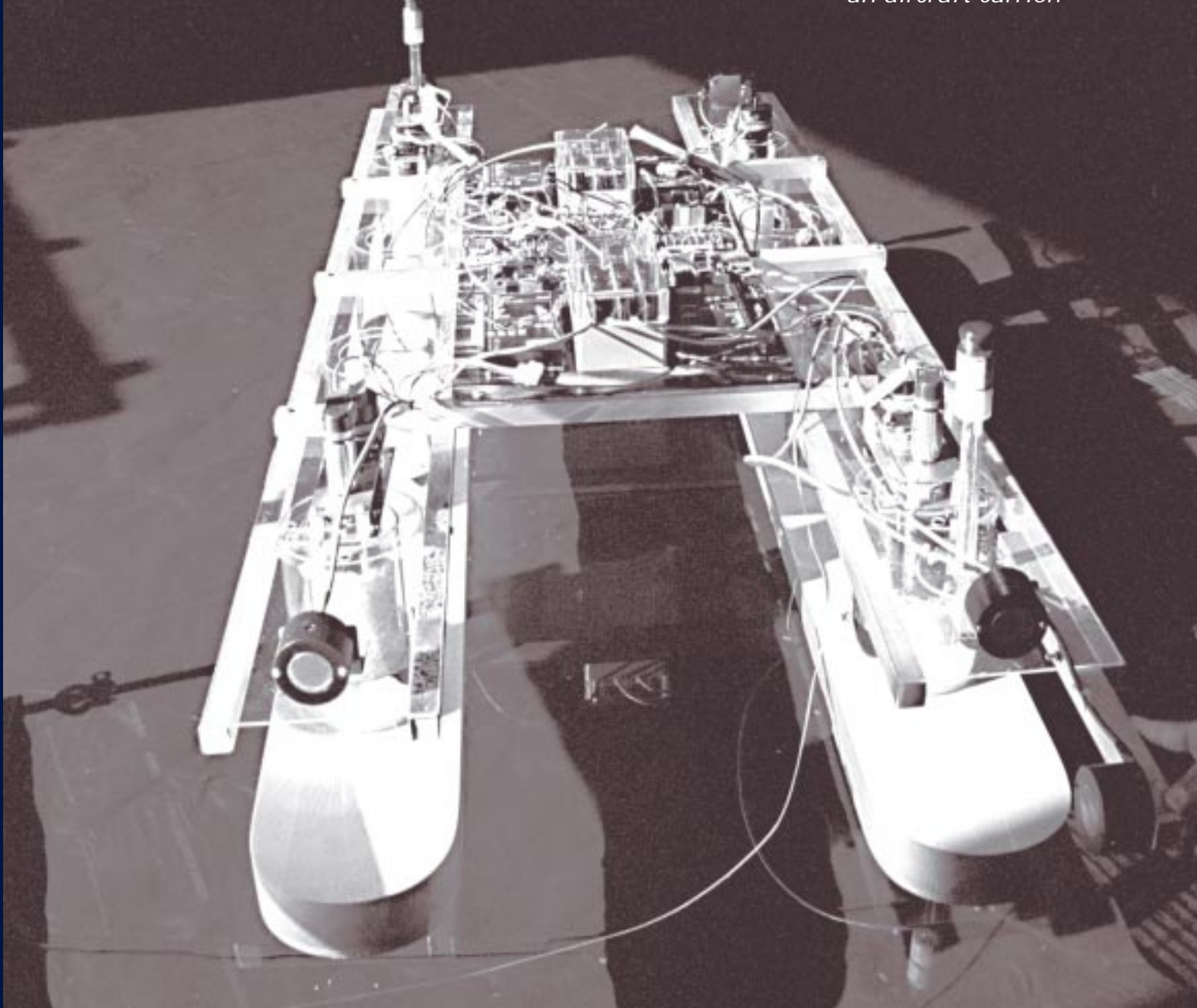


Heavy-Duty Diesel Modal Emissions and Fuel Consumption Module





PATH's Mobile Offshore Base (MOB) project, developed for the US Office of Naval Research, consists of three two-meter-long modules, each of which emulates a semi-submersible vessel the length of an aircraft carrier.



Mobile Offshore Base (MOB)

Karl Hedrick, William Webster – UCB
Using cooperative vehicle control technology, integrating communications and hybrid control, develop, test and demonstrate a control system for “dynamic positioning” of semi-submersible vehicles. This project for the Office of Naval Research has led to a scale-model test, in the towing tank at UCB/RFS, of the MOB vehicles, showing that they can be “platooned” accurately enough to produce a virtual runway at sea for the landing of large transport aircraft.

Model-Based Integration of Embedded Software (MoBIES)

Pravin Varaiya, Karl Hedrick – UCB
With funding from the Defense Advanced Research Projects Agency (DARPA), PATH is supporting this program to facilitate the transition of real-time control system designs from the current state of practice of multiple analysis, simulation, coding and test environments to the target of model-based end-to-end real time implementations with minimum effort and maximum accuracy. PATH vehicles are being equipped to serve as the test beds for the automotive sample problems in vehicle-vehicle communication, focusing on “cooperative” adaptive cruise control with some forward collision avoidance functionality as well.

Distributed Autonomous Agent Networks

Raja Sengupta (Project Manager) – UCB/PATH

This project is developing wireless ad-hoc networking and service networking technologies for the cooperative operation of unmanned air and ground vehicles, under the sponsorship of the Office of Naval Research (ONR). The project is also developing a theory of networked control, i.e., multi-vehicle control that is robust to the uncertainties inherent in wireless data communications.

A Rural Field Test of the RoadView System

Dan Empey (Project Manager) – PATH

The lane guidance assistance system developed for the Advanced Snowplow Project is being tested in winter operations in both California and Arizona to collect data regarding its use by drivers and how it

helps them drive better in poor visibility conditions.

Development of the Advanced Rotary Plow for Snow Removal Operations

Dan Empey (Project Manager) – PATH

A large rotary snow blower is being equipped with the PATH magnetic guidance sensing system and a steering actuator so that it can be steered automatically for low-speed operation on California highways, where it is used to clear heavy snow accumulations close to the guard rails. The automatic steering system is intended to avoid the damage that is currently incurred by guard rails when drivers use them for mechanical guidance in poor visibility conditions.

Railroad Grade Crossing Safety

T. Cohn – UCB, Jim Misener – PATH

Description: This is a laboratory and field investigation of what causes grade crossing crashes along the San Joaquin corridor from two points of view, driver perception and driver cognition. The perception investigation consists of an investigation of incandescent signals vs. LED, both in the laboratory and in the field. The cognition investigation consists of equipping a Caltrans-owned Amtrak locomotive with surveillance cameras to understand, then model, behaviors of drivers that immediately precede grade crossing incursions.

SmartCruise 21 Demo 2000

Han-Shue Tan (Project Manager) – PATH

PATH was one of only three non-Japanese participants invited to demonstrate vehicles at the SmartCruise 21 Demo 2000 in Tsukuba City. The Buick test vehicle was used to compare magnetic sensing performance of the original PATH system and a new sensor configuration from a Japanese supplier, and to show how we could use the magnetic marker infrastructure installed in the Japanese test track, even though it is significantly different from our magnetic markers. The demonstration included driving the test vehicle around the 6 km test track and a tunnel filled with fog under a combination of lateral control modes – driver assisted by a graphical display based on that developed originally for snowplow guidance, lane departure warning,

lane departure prevention and completely automatic steering. Performance data were recorded for all of these conditions over a wide range of speeds and roadway conditions, and with frequent switching among control modes.

Transit Bus Forward Collision Warning System Requirements Definition

Wei-Bin Zhang (Project Manager) – PATH

The operating environment for urban transit buses is much more complicated than the highway environment for which commercial collision warning systems are designed. This Intelligent Vehicle Initiative (IVI) project involves instrumenting a Samtrans (San Mateo County Transit Authority) bus with multiple sensors to develop a comprehensive characterization of its operating environment, and then using the extensive data gathered using those sensors to support development of prototype collision warning software, which can serve as the basis for defining the performance requirements for a deployable system.

Transit Bus Rear Collision Warning System

T. Cohn – UCB

Prof. Theodore Cohn is supporting the development of a rear collision warning system for transit buses under the IVI program by testing the effectiveness of alternative configurations of warning lights intended to be mounted to the back of a bus belonging to the Ann Arbor Transit Authority.

Automotive Collision Avoidance System (ACAS)

Steve Shladover, Jim Misener – PATH

PATH has developed a threat-assessment simulation system to be used by researchers at General Motors and Delphi Automotive to support their development of the ACAS warning algorithms. This software is built on the foundation of existing SHIFT and SmartAHS simulation software, but includes implementation of a variety of new modules to represent alternative sensor characteristics and hazard environments, together with graphical animation and integration of sensor data with video imagery of the driving scene.



Rotary Snowblower



Railroad Grade Crossing Safety



Rural Snowplow Testing



SmartCruise 2000, Japan

Identification of Drivers Under the Influence

Scott Johnston (Project Manager) – PATH

Under funding from the California Office of Traffic Safety, PATH is exploring the feasibility of automatic screening of special-purpose traffic surveillance camera images to identify vehicles whose erratic movements may indicate an increase probability of drivers who are under the influence of alcohol or drugs. When such erratic movements are detected by the image processing system, officers stationed downstream on the bridge or highway would then be alerted to look out for a vehicle fitting the description of the one that was moving erratically.

Collision Recording and Documentation

Ching-Yao Chan (Project Manager) – PATH

Description: This project, under the sponsorship of the California Office of Traffic Safety, is exploring how ITS technology can be used to expedite the process of collision documentation and analysis to reduce the working hazards (for Highway Patrol officers) and the lane closure times (for the public) associated with post-crash reporting. Efforts are concentrating on development of hardware and software to facilitate surveying and documenting the collision scene.

The Use of Combined Physical and Situational Models for Data Fusion in ACC Systems

Karl Hedrick – UCB/PATH

Adaptive Cruise Control (ACC) systems need to be able to adjust their performance to address a wide variety of traffic conditions, especially if they are to be usable in stop-and-go traffic. In this project, we explore how to use the data already available from the forward-looking radar of the ACC system, combined with vehicle inertial sensors, GPS and a map database, to characterize the driving environment, as well as to diagnose sensor faults. Following analysis and simulation stages, the proposed data fusion approach is to be tested on an ACC vehicle provided by the industrial sponsor of the project.

The Development of an Inertial Measurement Unit and a Human-Machine Interface for Motorcycle Navigation Systems

Karl Hedrick – UCB/PATH

This project designs, develops and evaluates an integrated Inertial Measurement Unit (IMU) and Human-Machine Interface (HMI) prototype system for motorcycle navigation. The IMU will provide uninterrupted motorcycle state information. The HMI is aimed at providing navigation information to the driver so that the perceptual and cognitive demands are safe and convenient for motorcycle riding.

Development of SmartBRT

Jim Misener – PATH

SmartBRT simulates the operation of a Bus Rapid Transit (BRT) system and evaluates operation parameters and system performance measures. This will allow user-defined BRT concepts to be evaluated. The core of Smart BRT is a microsimulation, complete with appropriate bus and infrastructure geometric libraries and high-fidelity photo-realistic 3D graphics. This will allow computation and visualization of the incremental effect of adding ITS technologies to bus rapid transit operation, but without the high capital investment of field tests.

Research to Support the Deployment of Bus Rapid Transit (BRT) Systems

Wei-Bin Zhang – PATH

PATH has initiated a cluster of new research projects to help support the development and deployment of Bus Rapid Transit (BRT) systems. These include development of an adaptive bus signal priority control system, precision docking, an advanced bus stop with high-accuracy traveler information, and assessment of the institutional challenges and opportunities associated with BRT. This work brings together AVCSS and ATMIS researchers in PATH, together with new partners in the Caltrans Division of Mass Transportation, the Santa Clara Valley Transportation Authority and the FTA-sponsored BRT Consortium.

Evaluation of Sensor-Friendly Vehicle and Roadway Systems

Jim Misener – PATH

This is a preliminary evaluation of the opportunities to facilitate target detection and discrimination by the sensors used in automotive collision warning and control assistance sys-

tems. Under funding from the USDOT IVI Program, subcontracted through Bechtel, PATH researchers have studied the feasibility of “tagging” and “masking” vehicles and roadway infrastructure elements so that they are more recognizable by in-vehicle sensors, making possible simpler and more effective signal processing. Some experiments on a few promising candidate technologies were followed by a preliminary assessment of the benefits that could be gained from use of these technologies.

Demo 2000



At Demo 2000, PATH showed how a magnetic marker guidance system can be used to provide drivers with a guidance display to help steer their vehicles accurately. PATH also demonstrated a new feature that lets drivers switch automatic steering on and off. The Japanese implementation of magnetic marker technology differed from PATH's implementations in the United States in a number of important ways. See www.path.berkeley.edu on the web for the full story.





Recent PATH Publications

Research Reports, Working Papers, and Technical Notes from January 1-December 31, 2000 are listed below. Those marked with an asterisk can be found on the Web at <http://www.path.berkeley.edu/PATH/Publications>

Advanced Traffic Management Information Systems

PATH's Berkeley Highway Lab boasts 14 video cameras that perch atop an Emeryville building skirting Highway 80 and afford spectacular vistas that range from Richmond to the San Francisco Bay Bridge approach and the Oakland maze. These eyes in the sky collect traffic pattern data for research and monitoring purposes, and to be used as ground truth for information caught by loop detectors imbedded in the roadway below. Berkeley Highway lab's website

<http://www.cs.berkeley.edu/~zephyr/freeway/> will tell you more.

ATMS (Advanced Transportation Management Systems)

Automated Travel Time Measurement Using Vehicle Lengths From Loop Detector Speed Traps

Benjamin Coifman, Michael Cassidy
Presents a vehicle reidentification algorithm for consecutive detector stations on a freeway. In this methodology, a vehicle measurement made at a downstream detector station is matched with the vehicle's corresponding measurement at an upstream station. The algorithm is intended to improve freeway surveillance by measuring the actual vehicle travel times, thus making it possible to quantify conditions between widely spaced detector stations.

UCB-ITS-PRR-2000-12*
August 2000, 76 pages, \$15

Database Environment for Fast Real-time Simulation of Urban Traffic Networks with ATMIS

R. Jayakrishnan, Phillip Sheu, Taehyung Wang, Min-Hua Xu
Describes a project that developed the environment for using the DYNASMART simulation model with accompanying graphical user interface (GUI) for real-time traffic simulation and scenario analysis with feedback from a real urban network. A database management system to handle data for multiple processes during parallel simulation was designed to complete the environment for simulation-based analysis of Advanced Traffic Management and Information Systems (ATMIS) in real-time at the Caltrans/PATH Testbed at UC Irvine.

UCB-ITS-PWP-2000-4*
March 2000, 52 pages, \$15

Determining the Capacity Benefits of Real-time Signal Control at Intersections

Alexander Skabardonis, Brian R. Gallagher, Kartik P. Patel
Traffic responsive control strategies are increasingly being implemented to improve intersection performance. Critical intersection control (CIC) is using real-time traffic data to better assign green times to conflicting movements. However, the benefits of CIC have not been assessed. The effectiveness of CIC was evaluated at seven

signalized intersections in the City of Los Angeles. Findings indicate that CIC generally improves traffic operations.

UCB-ITS-PWP-2000-25*
December 2000, 18 pages, \$5

Dynamic Origin/Destination Estimation Using True Section Densities

Carlos Sun, Himanshu Porwal
Demonstrates the feasibility of analyzing the potential benefits of using section density as a measure for estimating dynamic origin/destination demands. Simulations are performed using network and demand levels that are based on the Caltrans/PATH ATMIS testbed at UC Irvine. Two traffic assignment schemes were studied: one based on simulation (DYNASMART) and the second based on the DTA analytic scheme. Kalman filtering and Least Squares optimization methodologies were used to minimize the errors between the predicted and the true section measures.

UCB-ITS-PRR-2000-5*
March 2000, 148 pages, \$20

Experimental Characterization of Multi-lane Freeway Traffic Upstream of an Off-ramp Bottleneck

Juan Carlos Muñoz, Carlos Daganzo
Describes field observations of multi-lane freeway traffic upstream for an over saturated off-ramp, using data from the I-880 freeway near Oakland, California. Two diagnostic tools reveal hidden features of the traffic stream. Concludes with an assessment of the vehicle-hours of delay caused by the bottleneck, and proposes congestion mitigation strategies.

UCB-ITS-PWP-2000-13*
August 2000, 63 pages, \$15

Incident Dispatching, Clearance and Delay

Randolph W. Hall
Focuses on response and dispatch time of incident crews, and the effect these variables have on congestion and delay. The authors model response times and delays for highway incidents, accounting for spacing between interchanges and the time penalty for changing directions, enabling a response vehicle to reach an in-

cident on the opposite side of the highway. The report demonstrates that any reasonably robust dispatch strategy must take into consideration the trade-off of greater certainty in response time against stability at higher utilization levels.

UCB-ITS-PWP-2000-14
August 2000, 7 pages, \$5

INCISIM: Users' Manual

Heng Liu, Randolph Hall
INCISIM is a computer program that simulates the occurrence of highway incidents, the dispatching of emergency vehicles, and the traffic flow on the network. The program can represent multiple types of emergency vehicles. Incidents are represented by type classifications and profiles. Delay is calculated as a function of these variables, along with traffic flows and highway capacities. INCISIM produces a complete log of incidents that occurred during the simulation along with statistics of highway delays.

UCB-ITS-PWP-2000-15*
August 2000, 4 pages, \$10

Investigation in the Use of Inductive Loop Signatures for Vehicle Classification

Carlos Sun
Presents an advanced traffic surveillance technique that is based on pattern recognition and the use of current inductive loop technology. The feasibility of using loop signatures for obtaining vehicle classification information on a network-wide level was studied using different pattern recognition techniques, such as classical decision theoretic approach and advanced neural networks. Classification rates of greater than 80 percent were obtained.

UCB-ITS-PRR-2000-4*
March 2000, 38 pages, \$20

Methodology for Developing a Traffic Surveillance Investment Program: An Application to Caltrans District 4

Joy Dahlgren
The complicated decision structure for deciding where and when to install traffic surveillance and what type of surveillance to install is broken down into a series of steps: identifying information needs, determining which can be met by traffic surveillance, setting

criteria for and evaluating the benefits of surveillance in various locations, identifying alternative surveillance methods and estimating their capabilities and costs, comparing the ratios of benefits to costs, and finally matching cost-effective investments with available funds.

UCB-ITS-PWP-2000-23*
November 2000, 5 pages, \$5

New Aggregation Strategies to Improve Velocity Estimation From Single Loop Detectors

Benjamin Coifman, Zu-Hsu Lee

Presents a new approach, using aggregation methodology, to estimate velocity and reduce the impact of long vehicles in the original traffic measurements. The authors first present a review of the state of the practice and the related shortcomings of parameter estimation from single loop detectors. This is followed by a description of the proposed alternative method for estimating velocity. The report concludes by contrasting the new approach with conventional estimates.

UCB-ITS-PWP-2000-12*
August 2000, 7 pages, \$5

New Methodology for Evaluating Incident Detection Algorithms

Karl Petty, Michael Ostland, Jaim-young Kwon, John Rice, Peter J. Bickel

The new approach is a cost benefit analysis where cost mimics the real costs of implementing an algorithm and benefit is in terms of reduction in congestion. The authors contend that these rates are of more practical interest than traditional rates. This approach can be used to fine tune the parameters of an incident detection algorithm and to compare different types of incident detection algorithms.

UCB-ITS-PWP-2000-11*
August 2000, 5 pages, \$5

Structure of the Transition Zone Behind Freeway Queues

Juan Carlos Muñoz, Carlos Daganzo

Observations of freeway traffic flow are usually quite scattered about an underlying curve when plotted versus density or occupancy. Although increasing the sampling intervals can reduce the

scatter, whenever an experiment encompasses a rush hour with transitions in and out of congestion, some outlying data stubbornly remain beneath the "equilibrium" curve. The existence of these non-equilibrium points is an ill-understood phenomenon that appears to contradict the simple kinematic wave (KW) model of traffic flow. This paper provides a tentative explanation of the phenomenon, based on experimental evidence.

UCB-ITS-PWP-2000-24*
November 2000, 7 pages, \$10

Study of Freeway Traffic Near an Off-Ramp

Michael J. Cassidy, Shadi B. Anani, John M. Haigwood

Shows that a disruptive freeway bottleneck can be averted by keeping an off-ramp from becoming over-saturated and spilling over to the exit lane. This is achieved by changing the logic of a nearby traffic signal. This then leads to higher flows being sustained on the freeway segment and preventing bottlenecks from occurring.

UCB-ITS-PWP-2000-10*
August 2000, 4 pages, \$5

Travel Time Estimation on the San Francisco Bay Area Network Using Cellular Phones as Probes

Jean-Luc Ygnace, Chris Drane, Y.B. Youngbin Yim, Renaud de Lacvivier

Discusses the associated institutional environment in which cell phones are used, followed by a review of cellular positioning techniques, reports on results from analytical and simulation models, and concludes with a discussion regarding how a field trial could be implemented.

UCB-ITS-PWP-2000-18*
September 2000, 4 pages, \$15

ATIS (Advanced Traveler Information Systems)

Evaluation of TravInfo Field Operational Test: Final Report

Y.B. Youngbin Yim, Mark A. Miller

TravInfo is a regional traveler information system in operation in the San Francisco Bay Area. TravInfo differs from other advanced traveler information systems (ATIS) in that the program was organizationally structured as a public/private partnership, and it featured an open architecture which provided a database that was accessible to all information service providers. This report focuses on evaluations of the institutional re-

lationships, technology, and traveler response to TravInfo, with recommendations and conclusions.
UCB-ITS-PRR-2000-7*
May 2000, 81 pages, \$15

Operations at Regional Traveler Information Centers: The Case of the TravInfo Field Operational Test – Final Results

Mark A. Miller, Dimitri Loukakos

The evaluation of the Traveler Information Center (TIC) consisted of technical and institutional elements. The technical component examined system reliability, the communications interface, operator work setting, and operator performance. The institutional analysis element examined the TIC's operational effectiveness from an organizational perspective, including the identification of both areas of achievement as well as barriers to successful TIC operations.

UCB-ITS-PWP-2000-20*
September 2000, 2 pages, \$15

TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study: Operator Response Time Analysis

Mark A. Miller, Dimitri Loukakos

Response time, defined as the time elapsed from information's being collected from the Highway Patrol's computer-aided dispatch system until its dissemination to the public, averaged eleven minutes, though there were significant response time differences among the operators. Once TravInfo operations have become more automated, operator response times should be reduced and overall operator productivity increased.

UCB-ITS-PWP-2000-9*
August 2000, 4 pages, \$10

TravInfo Field Operational Test Evaluation: Information Service Providers Customer Survey

Y.B. Youngbin Yim

The survey addressed the usage of Web site information and the travel behavior of Web site users. The key finding is that Web site service may significantly influence travel behavior. The study showed that drivers who encounter traffic congestion on a frequent basis are likely to access information on a regular basis.

UCB-ITS-PWP-2000-5*
May 2000, 3 pages, \$5

TravInfo Field Operational Test Evaluation: Target Study Final Results

Ronald Koo, Y.B. Youngbin Yim

Focus of the study was threefold: 1) understanding the extent to

which incident information influences travel decision; 2) measuring the effects of incident information on overall travel patterns; and, 3) assessing the benefits of incident reports to travelers. It was found that although commuters tended to believe that their normal travel plans were faster or as fast as alternate plans, traffic information was valued for intangible benefits, such as reducing driver anxiety or stress.

UCB-ITS-PWP-2000-3*
March 2000, 6 pages, \$5

TravInfo Field Operational Test Institutional Evaluation Final Results

Y.B. Youngbin Yim, Elizabeth Deakin

Final analysis of a three part series dealing with institutional evaluations of the TravInfo Field Operational Test. The evaluations examined TravInfo's open architecture and its collaborative public private partnership in disseminating traveler information and fostering privately offered advanced traveler information services in a commercial market.

UCB-ITS-PWP-2000-2*
February 2000, 8 pages, \$15

User Response to the Telephone Advisory Traveler Information System in the San Francisco Bay Area: Based on TravInfo Caller Survey Wave 1

Jean-Luc Ygnace, Ronald Koo, Y.B. Youngbin Yim

Key findings of the survey reveal that those who called for either traffic or transit information were satisfied with the service. Approximately one third of those who called TravInfo modified their travel behavior after making their call.

UCB-ITS-PWP-2000-8*
July 2000, 8 pages, \$10

Vehicle to Roadside Communications Architecture for ITS Applications

Tetiana Lo, Pravin Varaiya

Presents a framework for assisting Intelligent Transportation Systems (ITS) providers in deploying ITS user services that require wide-area wireless communications. The SHIFT programming language was used to investigate the uplink performance of Cellular Digital Packet Data, a leading wireless candidate. Focus was on examining its ability to support vehicle-to-roadside ITS applications during normal peak-period conditions and during a major incident.

UCB-ITS-PRR-2000-3*
March 2000, 05 pages, \$30

Carlink—A Smart Carsharing System Field Test Report

Susan Shaheen, John Wright, David Dick, Linda Novick

Results from the field test of CarLink, a smart carsharing system that combines short-term rental vehicles with communication and reservation technologies to facilitate shared-vehicle access. Results include: operational understanding, participant profiles, behavioral findings, economic viability, and directions for future research.

UCB-ITS-PRR-2000-10*

May 2000, 200 pages, \$25

Field Survey of Site Visits to Passenger Intermodal Transfer Facilities in California

Chris Mitchell, Mark A. Miller

Thirteen site visits were conducted at passenger intermodal transfer facilities in the San Francisco Bay Area, San Diego, and the Sacramento area. Each visit considered four stages of the intermodal transfer experience: approach to the facility, ticketing, transfer within the facility and departure from it. Comparisons and contrasts are made across regions and modes leading to the formation of generalized hypotheses regarding intermodalism that will be tested later in the project.

Tech Note 2000-1*

July 2000, 2 pages, \$10

Institutional Aspects of Bus Rapid Transit—A Macroscopic Examination

Mark A. Miller, Stephen M. Buckley
Investigates the institutional aspects of Bus Rapid Transit through a macroscopic examination of relevant issues ascertained through a literature review, a series of project team brainstorming meetings, and input from members of the Federal Transit Administration's Bus Rapid Transit staff. Several dozen issues were grouped into nine categories: intergovernmental and inter-organizational; intra-transit agency; political; public relations and marketing; funding and finance; labor; safety and liability; planning and land use; and the physical environment.

UCB-ITS-PWP-2000-7*

July 2000, 25 pages, \$10

Personalized Demand Responsive Transit Systems (PDRT)

Y.B. Youngbin Yim, Asad J. Khattak

We examine factors likely to influence people's decision to take "on-demand" PDRT (like an airport shuttle service, where a van makes multiple stops) and "fixed-schedule" PDRT (pick-ups and drop-offs made at fixed, convenient locations). The results of six focus groups and the survey indicate that a reliable, reasonably priced PDRT service can be successful. Respondents were quite realistic in their expectations about the PDRT service attributes, especially the longer travel times and wait times involved in using PDRT.

UCB-ITS-PWP-2000-22*

October 2000, 2 pages, \$5

Decision Support and Benefit/Cost Analysis

Cost-Benefit Analysis of Home-Based Telecommuting

Kevan R. Shafizadeh

Evaluates costs and benefits of home-based telecommuting. Combining empirical data from the literature with a Monte Carlo simulation technique, a distribution of cost-benefit ratios is produced from three perspectives: the employer, the telecommuter, and the public sector. This report identifies situations during which telecommuting is most attractive as a travel demand measure to its primary stakeholders: the telecommuter and the employer.

UCB-ITS-PRR-2000-20*

November 2000, 137 pages, \$20

Costs and Benefits of Telecommuting: A Review and Evaluation of Micro-Scale Studies and Promotional Literature

Kevan R. Shafizadeh, Patricia L. Mokhtarian, Debbie A. Niemeier, Ilan Salomon

Four small-scale telecommuting pilot project studies that take into account costs and benefits are reviewed for their methodology and assumptions. The report identifies common inputs, critical assumptions, and limitations of the studies. Major findings of each study are presented and compared to claims found in promotional literature. It is found that few pilot evaluations contained cost-benefit results.

UCB-ITS-PRR-2000-13*

August 2000, 58 pages, \$15

Deploying Electronic Tolls

David Levinson, Elva Chang

Examines the deployment of electronic toll collection (ETC) and develops a model designed to maximize social welfare associated with

the toll plaza. A payment choice model is developed to estimate the share of traffic using ETC as a function of delay, price, and a fixed cost of acquiring the in-vehicle transponder. The model is applied to the Carquinez Bridge in California. The authors conclude the study with the recommendation that the pace of deployment on the bridge take into account the number of dedicated ETC lanes and the appropriate ETC discount.

UCB-ITS-PRR-2000-11*

May 2000, 29 pages, \$10

Measuring the Aggregate Productivity Benefits from ITS Applications: The California Experience

David Gillen, Matt Haynes

Focuses on the productivity effects of Intelligent Transportation Systems (ITS). Two types of models are used to measure productivity. The first involves a production function estimate using county level data for California. The second method is to calculate total factor productivity measures and determine the impact of the introduction of ITS applications on a county's productivity.

UCB-ITS-PWP-2000-17*

September 2000, 05 pages, \$20

PATH ATMIS: State of the Research Annual Report Fiscal Year 1999/2000

Robert Tam

In each of the brief project descriptions we state the objectives of the project and outline its status and some of its principal results. Taken together, the collection of project descriptions should give the reader an overview of the entire ATMIS research program. In general we have described only projects that have been completed or have produced specific results and report; thus a number of projects in progress are not cited.

UCB-ITS-PWP-2000-19*

October 2000, 4 pages, \$10

Productivity Benefits and Cost Efficiencies from ITS Applications to Public Transit: The Evaluation of Automatic Vehicle Location (AVL)

David Gillen, Elva Chang, Doug Johnson

Examines the impact of AVL applications on productivity and resource in transit agencies by using Total Factor Productivity (TFP) techniques. Data used from the Federal Transit Commission's database is augmented with information on AVL applications. Concludes that AVL has a positive impact on transit firm productivity

when output is measured as revenue vehicle miles or passenger miles.

UCB-ITS-PWP-2000-16*

September 2000, 8 pages, \$15

Whence Induced Demand: How Access Affects Activity

David Levinson, Seshasai Kanchi

As a result of additional highway capacity, workers spend less time traveling. Non-workers, by contrast, travel more. This points out the differences in discretionary and non-discretionary activities for workers and non-workers. It also suggests that there are real gains from capacity in people's lives, at least in the short term, as it is time, and not vehicle miles traveled, that individuals base decisions on.

UCB-ITS-PWP-2000-21*

October 2000, 1 pages, \$5

Advanced Vehicle Control and Safety Systems

Advanced Vehicle Location

Aggregation of Direct and Indirect Positioning Sensors for Vehicle Guidance

Alice Agogino, Susan Chao, Jiangxin Wang, Xinyan Deng
Advanced Vehicle Control Systems (AVCS) require large numbers of sensors for different levels within the control hierarchy. Whereas all sensors contain uncertainty to some degree, different sensors are particularly useful for specific environmental conditions. Therefore, sensor redundancy is essential to achieving high sensor data fidelity for use in real-world, non-ideal, unpredictable environments. In this work, a positioning sensor system, which includes Global Positioning System (GPS) receivers, a radar sensor, and a linear transducer is investigated. UCB-ITS-PRR-2000-24*
December 2000, 47 pages, \$10

Feasibility of a Gyroscope-free Inertial Navigation System for Tracking Rigid Body Motion

Chin-Woo Tan, Kirill Mostov, Pravin Varaiya
Examines the feasibility of designing an accelerometer-based gyroscope-free inertial navigation system that uses only accelerometers to compute the linear and angular motions of a rigid body. A model for a micro-machined accelerometer is developed and the accelerometer output equation is derived to relate the linear and angular motions of a rigid body

with respect to a fixed inertial frame. An algorithm is developed to compute both the angular and linear motions. UCB-ITS-PRR-2000-9*
May 2000, 5 pages, \$10

Integration of GPS-aided INS into AVCSS

Jay Farrell, Matthew Barth
Results of an effort to implement and analyze the performance a vehicle control system using control state information obtained from a carrier phase Differential Global Positioning System (DGPS) aided Inertial Navigation System (INS). Advantages include: no changes to the highway infrastructure are required; knowledge of a vehicle's DGPS position allows the use of more path preview information than alternative systems; the navigation system would output position, velocity, and attitude, plus inertial measurements, at significantly higher rates than alternative navigation systems. UCB-ITS-PRR-2000-22*
December 2000, 8 pages, \$15

Aerodynamics

Field Experiments Demonstrate Fuel Savings for Close-Following

Mark Michaelian, Fred Browand
Describes field experiments which show that fuel savings for individual vehicles in a platoon varied from 0-10 percent, depending upon the number of vehicles, vehicle spacing, and vehicle position within the platoon. Fuel savings increased with additional vehicles and with shortened vehicle spacings. Interior vehicles were shown to gain the greatest benefits. The average vehicle drag and average fuel consumption are decreased by close-following. UCB-ITS-PRR-2000-14*
August 2000, 5 pages, \$10

Transient Platoon Aerodynamics During Passing Maneuvers and In-line Oscillations

L. Tsuei, Ö. Savas, J.K. Hedrick
Investigates transient effects as a vehicle model is moved longitudinally parallel to a four-car platoon. Drag and side forces experienced by each platoon member are measured using strain gauge balances. Effects of the lateral spacing and relative velocity between the platoon and the passing vehicle are investigated. UCB-ITS-PRR-2000-26*
December 2000, 7 pages, \$15

AHS Tools Development

Roadway and Work Crew Conspicuity

Joseph E. Barton, James A. Misener
Quantitatively addresses the measurement of conspicuity of highway features and Caltrans work zones—from the perspective of driver detection. The method focused on acquiring and operating on a computational visual signature analysis tool, but it evolved into evaluating the detection process, then selecting and exercising human perception-acquisition models suitable for development into a tool for conspicuity measurement. A composite, quantitative model of conspicuity was developed, verified, and applied to some sample roadside scenes. UCB-ITS-PRR-2000-23*
December 2000, 89 pages, \$15

SmartAHS and SHIFT Enhancements, Persistence and Query Interpretation

James Misener
Describes the fine-tuning of the development of SmartAHS, a software system for microsimulation of automated highway systems (AHS) design and scenarios. SmartAHS is used for design, analysis and evaluation of AHS. SHIFT, the SmartAHS/Hybrid Systems Tools Interface Format, is the simulator for user-defined AHS architectures. SHIFT also provides specifications for a high-level language used to specify AHS-specific models for highway layout, vehicle dynamics, actuators and sensors. UCB-ITS-PRR-2000-6*
March 2000, 8 pages, \$15

AHS Concepts

Safety and Throughput Analysis of Automated Highway Systems

Datta N. Godbole, John Lygeros
Investigates the effect of different design alternatives on the safety and throughput that can be expected if automated highway concepts are implemented. The authors identify intervehicle coordination, on-line braking capability estimation, and platoon organization as the most important parameters in braking capability. UCB-ITS-PRR-2000-1*
January 2000, 9 pages, \$10

AHS Deployment

Systematic Design for Roadway Interfaces with Application to Automated Highways

Randolph Hall
The central concept explored in this report is how to design a roadway system that comprises multiple layers, some of which are designed for accessibility, and others of which are designed more for the purpose of speed and capacity. The interface between an automated highway system and conventional roadways presents new challenges for interface designed, which are explored in this paper. UCB-ITS-PWP-2000-26*
December 2000, 7 pages, \$15

Communication Systems

Vehicle to Roadside Communications Architecture for ITS Applications

Tetiana Lo, Pravin Varaiya
Presents a framework for assisting Intelligent Transportation Systems (ITS) providers in deploying ITS user services that require wide-area wireless communications. The SHIFT programming language was used to investigate the uplink performance of Cellular Digital Packet Data, a leading wireless candidate. Focus was on examining its ability to support vehicle-to-roadside ITS applications during normal peak-period conditions and during a major incident. UCB-ITS-PRR-2000-3*
March 2000, 05 pages, \$30

Control of Heavy Duty Vehicles

Lateral Control of Heavy Duty Vehicles for Automated Highway System: Experimental Study on a Tractor Semi-trailer

Pushkar Hingwe, Jeng-Yu Wang, Meihua Tai, Masayoshi Tomizuka
Describes the experimental validation of a linear model for tractor-semitrailer combinations and the implementation of a linear robust controller. The goal of the project is to demonstrate lane following by automatic steering for tractor semitrailer vehicles. The report describes the hardware development, the actuators and the open loop response of the steering actuator, and the results of the open loop tests. UCB-ITS-PWP-2000-1*
January 2000, 7 pages, \$10

Human Driver Models

Model of Human Vehicle Driving – A Predictive Nonlinear Optimization Approach

Günther Prokop

Driving is seen here as a model predictive control task where the driver accumulates knowledge about the vehicle's handling properties. Human behavioral optimization is reflected by using the prediction model to optimize control inputs. Prediction models and criteria are shown to depend on the current driving situation and personal driver preferences. Results from experiments performed in real world and in a driving simulator are reported.

UCB-ITS-PRR-2000-19*

October 2000, 67 pages, \$25

Vehicle Braking Control

Advanced Braking Methods for Longitudinal Control of Commercial Heavy Vehicles

Lasse Moklegaard, Anna G. Stefanopoulou

Describes research on the longitudinal control of commercial heavy vehicles (CHVs) equipped with novel retarding actuators. The authors present nonlinear dynamic models and longitudinal control algorithms that coordinate variable compression brake mechanics with service brakes for CHVs.

UCB-ITS-PRR-2000-8*

May 2000, 50 pages, \$10

Vehicle Control

Dynamic Modeling and Simulation of Snowplow: Normal Operation and Icepack Impacts

Kun Zhou, Masayoshi Tomizuka, Wei-Bin Zhang

A general method of deriving dynamic models for any multi-blade snowplow is presented. A snow model is presented to estimate the casting forces, which act on the blades. Finally, an icepack-impact model is presented to simulate the dynamic performance of the snowplow under impact caused by the icepack. It is shown that by changing the rear tire stiffness after impact, the yaw motion and the lateral motion of the snowplow can be remarkably reduced.

UCB-ITS-PRR-2000-21*

December 2000, 28 pages, \$10

Vehicle Control Experiments and Field Tests

Experimental Studies on High Speed Vehicle Steering Control with Magnetic Marker Referencing System

Han-Shue Tan, Bénédicte Bougler

Describes research focusing on conducting robust automatic vehicle steering control at highway speed based on a look-down lateral sensing system. Examines the validity of the installation of additional magnetometers to create a virtual sensor in front of the vehicle to improve the look-ahead capability. Details the general development of the automated steering vehicle based on roadway magnets, and analyzes results of the influence of the suspension roll dynamics to vehicle steering control.

UCB-ITS-PWP-2000-6*

May 2000, 76 pages, \$15

Modeling, Design and Implementation of Longitudinal Control Algorithm for Automated Vehicle Merging

Xiao-Yun Lu, Han-Shue Tan, Steven E. Shladover, J. Karl Hedrick

Focuses on the implementation of a newly developed algorithm for general merging of vehicles into a highway. A general longitudinal control problem for vehicle merging is first proposed. A general real-time adaptive closed-loop algorithm that generates a smooth reference trajectory for the merging vehicle according to the speed of the main line vehicle is then presented. The concept of virtual platooning is proposed to make the algorithm adapt to different road layouts and to increase safety.

UCB-ITS-PRR-2000-16*

September 2000, 1 pages, \$10

Nonlinear Longitudinal Controller Development and Real-time Implementation

Xiao-Yun Lu, Han-Shue Tan, Dan Empey, Steven E. Shladover, J. Karl Hedrick

A dynamic sliding mode controller and a dynamic back-stepping multiple surface controller are implemented and compared to a previously implemented adaptive sliding mode controller. The dynamic back-stepping controller features a new type of integral filter that was used to filter measured signals and estimating the derivative of these signals in real-time. The controllers were implemented in real-time code and tested at low and high speeds.

UCB-ITS-PRR-2000-15*

September 2000, 5 pages \$10

Vehicle Control Under Abnormal Conditions

Vehicle Lateral Control Under Fault in Front and/or Rear Sensors

Jihua Huang, Guang Lu, Masayoshi Tomizuka

Study of the behavior of existing vehicle lateral control systems in the event of magnetometer failures, with an eye to designing controllers that use the output from only one set of magnetometers, and developing an autonomous lateral control scheme that uses no magnetometers.

UCB-ITS-PRR-2000-25*

December 2000, 8 pages, \$10

Vehicle Safety Assessment and Safety Enhancement

Conditions for Safe Deceleration of Strings of Vehicles

John Lygeros, Nancy Lynch

Presents a model that can account for the possibility of repeated collisions between vehicles in a string, and that specifies safe conditions when the string performs a simple emergency deceleration maneuver. Discusses implications of the results for safe vehicle platooning.

UCB-ITS-PRR-2000-2*

January 2000, 41 pages, \$10

Safety Evaluation of Vehicle Following Operations by Fault Tree and Sensitivity Analysis

Ching-Yao Chan

Using the software tool CAFTA for Windows, the author evaluated fault-tree analysis of two different scenarios: 1) vehicle-following collision fault tree analysis; and, 2) lane-keeping fault tree analysis.

UCB-ITS-PRR-2000-18*

September 2000, 7 pages, \$10

Studies of Collisions and Control Strategies in Vehicle Following Operations by Two-Dimensional Impact Simulation

Ching-Yao Chan

Describes the investigation by simulation of the problem of applying steering control in vehicle-following collisions. The feasibility of maintaining vehicle trajectories following a collision was investigated with a vehicle collision model and a feedback controller. The collision controller design is formulated as an impulse disturbance rejection. A look-ahead steering controller is then pro-

PATH Publications

posed, based on the performance requirements of the steering control in collisions.

UCB-ITS-PRR-2000-17*

September 2000, 8 pages, \$10



Roadway and Work Crew Conspicuity



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PATH Database

The California PATH Database provides access to the largest and most comprehensive collection of bibliographic information on Intelligent Transportation Systems (ITS). The Database is now accessible on the Internet through a partnership between the California PATH Program and the Transportation Research Board.

The Database, created in 1989, is sponsored by Caltrans and the Federal Highway Administration. It is maintained by the Harmer E. Davis Transportation Library (HEDTL) at the Institute of Transportation Studies, University of California at Berkeley. The web site is administered by the Transportation Research Board and is updated monthly.

SCOPE AND COVERAGE

The Database contains references to all aspects of Intelligent Transportation Systems, ranging from historical materials dating back to the 1940s to topics of current and international research and applications. It reflects a wide coverage of information on ITS, including monographs, journal articles, conference papers, technical reports, theses, web sites, and selected media coverage. Currently, there are over 25,000 records with abstracts contained in the Database. Full bibliographic information is provided, and URLs are included for documents that are available in electronic format. The majority of the indexed items are held at the Harmer E. Davis Library.

ACCESS AND AVAILABILITY

To access the California PATH Bibliographic Database, go to:
<http://www4.nationalacademies.org/trb/tris.nsf/web/path>

To access the Harmer E. Davis Library web site, go to:
<http://lib.berkeley.edu/ITSL/>

The "New Acquisitions in Intelligent Transportation at the Harmer E. Davis Transportation Library" list is a compilation of records that have been added to the Database in the previous month. To access the New Acquisitions list, go to:

<http://lib.berkeley.edu/ITSL/newbooks.html>

For information regarding the availability of documents held at other University of California at Berkeley libraries, go to:

<http://www.lib.berkeley.edu/ILS/nonuc.html>

Loans and photocopies of materials are available to persons affiliated with the University of California and California PATH sponsors. For others, information on interlibrary loans or photocopies may be obtained at the HEDTL web site. Questions regarding the Database may be directed to:

Seyem Petrites, PATH Database Manager at:

spetrite@library.berkeley.edu

Michael Kleiber, PATH Database Librarian at:

mkleiber@library.berkeley.edu

The PATH Magnetic Marker Guidance System has now been installed for testing or demonstration in California, Arizona, Alaska, Texas, The Netherlands and Japan.





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DESIGN BY SHARON SKOLNICK
PHOTOS BY GERALD STONE, BILL STONE, JAY SULLIVAN
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