The State of Intelligent Transportation Systems

Charles Herget
Past President
IEEE Intelligent Transportation Systems Society

January 23, 2007

Scott's Seafood Bar & Grill
Jack London Square
Oakland, CA

IEEE Oakland-East Bay Power Engineering Society Chapter, in conjunction with the OEB Industry Applications Society Chapter and the OEB Engineering Management Chapter

Outline

History of IEEE activities in Intelligent Transportation Systems

Define ITS Technologies

Look at recent results in selected areas

- Intelligent Transportation Infrastructure
  - Freeway Management
    - Diamond Lanes
    - Ramp Metering
    - Variable Congestion Pricing
    - Vehicle Platooning and Automated Highways
    - Traffic Advisory Systems
  - Intelligent Vehicles
    - DARPA Grand Challenge

Conclusions

History: IEEE Activities in ITS

IEEE Vehicular Technology Society
Vehicle Navigation and Instrumentation Systems Conference

1989 Toronto, Ontario, Canada
1991 Dearborn, Michigan
1993 Ottawa, Ontario, Canada
1994 Yokohama, Japan
1995 Seattle, Washington

IEEE Industrial Electronics Society
Intelligent Vehicles Symposium

1992 Detroit, Michigan
1993 Tokyo, Japan
1994 Paris, France
1995 Detroit, Michigan
1996 Tokyo, Japan
1998 Stuttgart, Germany

History: IEEE Activities in ITS (cont.)

1993 IEEE Approves Committee on Intelligent Vehicle Highway Systems (IVHS), name changed later to Committee on Intelligent Transportation Systems (ITS)

1999 IEEE Approves formation of Council on ITS

1999 Council begins publication of a Newsletter

2000 Council on ITS begins publication of Transactions on ITS

2004 IEEE Approves ITS Society

2005 First year of Society Operation

Society continues to publish Transactions, Newsletter, hold an annual conference on ITS, hold an annual symposium on Intelligent Vehicles, and hold specialized symposia and workshops as requested.

Society is beginning to form local chapters.

IEEE Conference on ITS

1997 Boston, Massachusetts
1999 Tokyo, Japan
2000 Detroit, Michigan
2001 Oakland, California
2002 Singapore
2003 Shanghai, China
2004 Washington, DC
2005 Vienna, Austria
2006 Toronto, Canada
2007 Seattle, Washington

IEEE Symposium on Intelligent Vehicles

2000 Dearborn, Michigan
2001 Tokyo, Japan
2002 Versailles, France
2003 Columbus, Ohio
2004 Parma, Italy
2005 Las Vegas, Nevada
2006 Tokyo, Japan
2007 Istanbul, Turkey

IEEE ITS Newsletter

Free download from the Society's website, membership is not required.

http://www.ieee.org/itss

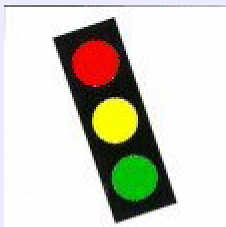
Activities in ITS

Major funding for Intelligent Transportation Systems in the United States comes from the US Department of Transportation, Federal Highway Administration (FHWA), ITS Joint Program Office

http://www.its.dot.gov

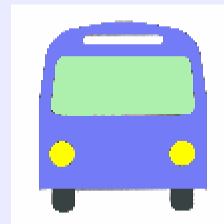
FHWA Defined Areas of ITS

Intelligent Infrastructure

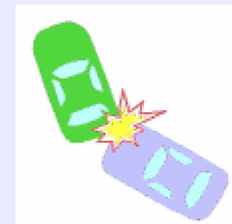


Arterial Management

Freeway Management



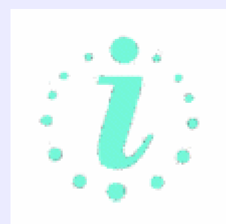
Transit Management



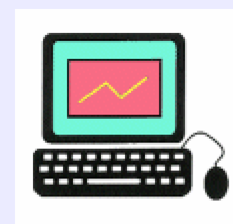
Incident Management

Emergency Management

Electronic Payment



Traveler Information



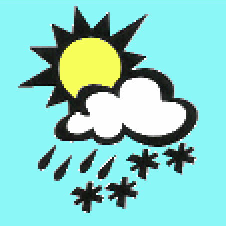
Information Management

FHWA Defined Areas of ITS (cont.)

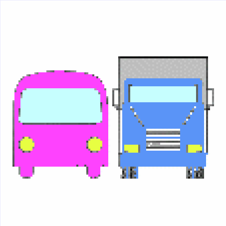
Intelligent Infrastructure (cont.)

Crash Prevention and Safety

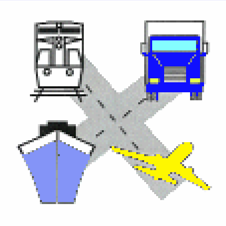
Roadway Operations and Maintenance



Road Weather Management



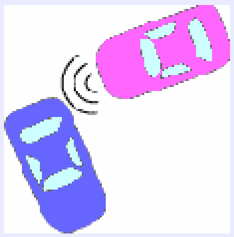
Commercial Vehicle Operations



Intermodal Freight

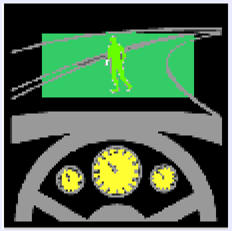
FHWA Defined Areas of ITS (cont.)

Intelligent Vehicles



Collision
Avoidance
Systems

Collision
Notification
Systems



Driver
Assistance
Systems

ITS Infrastructure

Freeway Management

Potential Ways to Relieve Freeway Congestion

Diamond (HOV) Lanes

Ramp Metering

Variable Congestion Pricing

Vehicle Platooning and Automated Highways

Traffic Advisory Systems

PATH: California Partners for Advanced Transit and Highways

California PATH was established in 1986. It is administered by the Institute of Transportation Studies (ITS), University of California, Berkeley, in collaboration with Caltrans.

Partial List of Public Agencies

California Department of Transportation (Caltrans)
Federal Highway Administration
Federal Transit Administration
National Highway Traffic Safety Administration
Metropolitan Transportation Commission
LAMTA (Los Angeles Metropolitan Transportation Authority)
California Highway Patrol

Partial List of Universities

Univ of California, Berkeley
Univ of California, Davis
Univ of California, Irvine
Univ of California, Los Angeles
Univ of California, Riverside
Claremont Graduate School
Univ of Southern California
George Mason Univ

http://www.path.berkeley.edu

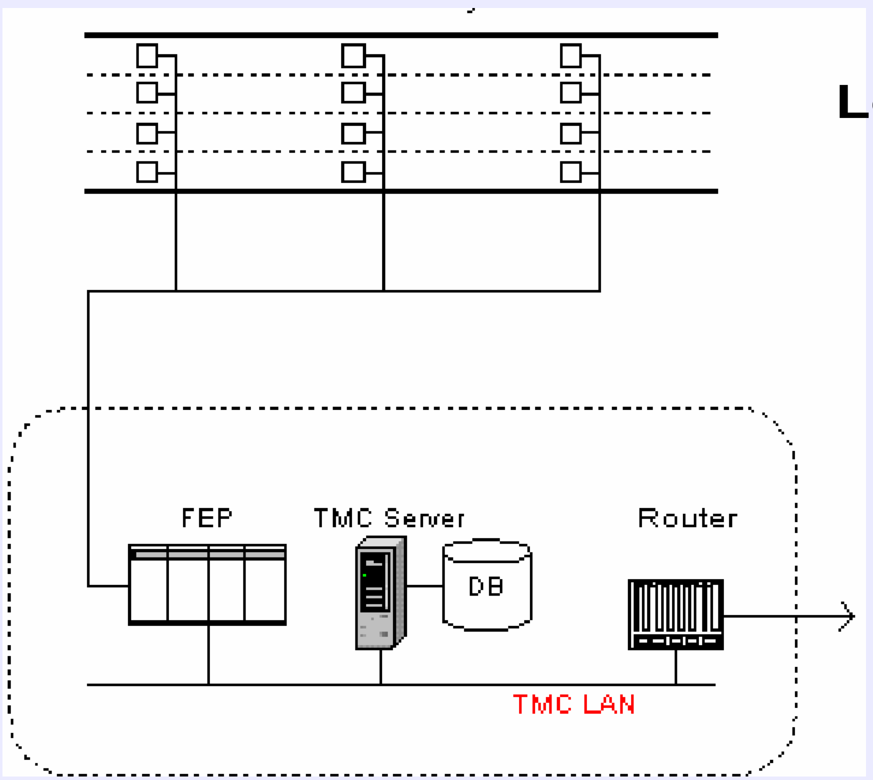
Freeway Performance Measurement System (PeMS)

University of California
Berkeley

http://pems.eecs.berkeley.edu

Freeway Performance Measurement System, PeMS

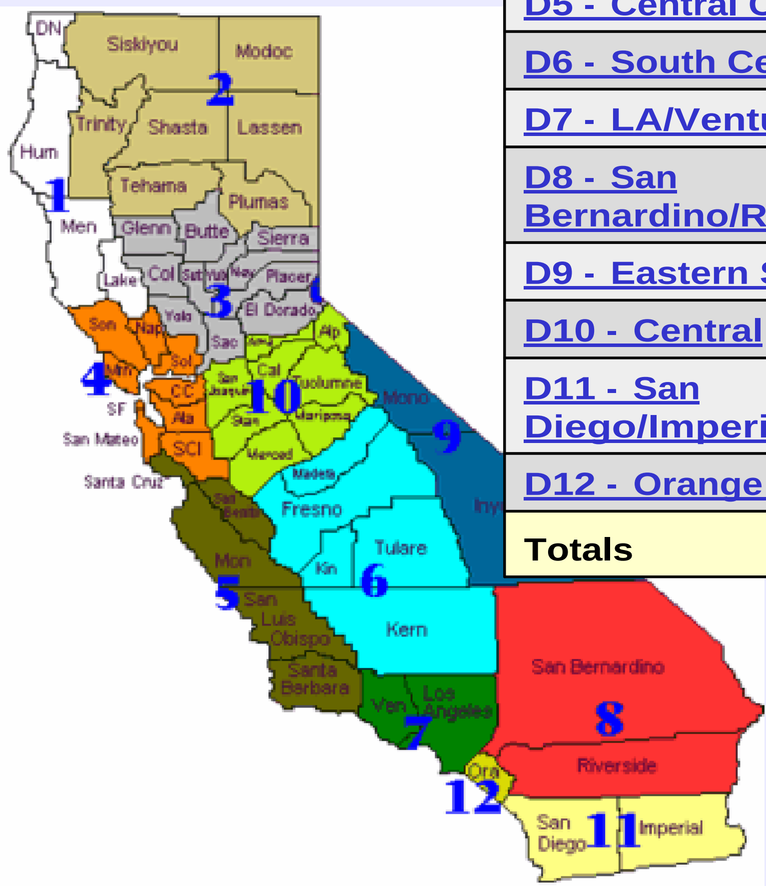
The Freeway Performance Measurement System, PeMS, is a real-time Archive Data Management System for transportation data. It collects raw detector data in real-time, stores and processes it, and provides a number of web pages that engineers can use to analyze the performance of the freeway system.



Loop Detectors in Freeway

To UC Berkeley

PeMS Detectors by District



District	Fwy Miles	# Fwys	# LDS	# VDS	# Loops
D1 - Northwest	1,889.3	23	0	0	0
D2 - Northeast	3,463.2	22	0	0	0
D3 - North Central	3,004.4	32	253	587	1,345
D4 - Bay Area	2,870.9	51	917	1,207	4,578
D5 - Central Coast	2,333.2	30	10	10	23
D6 - South Central	4,072.7	36	7	14	42
D7 - LA/Ventura	2,318.2	44	1,189	3,783	8,543
D8 - San Bernardino/Riverside	3,851.7	37	359	739	1,792
D9 - Eastern Sierra	1,478.4	16	0	0	0
D10 - Central	2,653.2	24	117	117	280
D11 - San Diego/Imperial	2,059.8	25	542	1,065	3,096
D12 - Orange County	577.9	17	556	2,050	4,642
Totals	30,572.7		3,950	9,572	24,341

VDS: Vehicle Detector Station
LDS: Loop Detector Station

PeMS Data Collected

PeMS obtains 30-second loop detector data in real-time from each Caltrans District Transportation Management Center (TMC). The data are transferred through the Caltrans wide area network (WAN) to which all districts are connected.

The 30-second data received by PeMS consist of counts (number of vehicles crossing the loop).

PeMS Performance Measures

Vehicle Miles Traveled (VMT): for a given unit of time and a given section of the freeway, the sum of the miles of freeway driven by each vehicle

Vehicle Hours Traveled (VHT): for a given unit of time and a given section of freeway, the amount of time spent by all of the vehicles on the freeway.

Delay: the amount of additional time spent by the vehicles on a section of road due to congestion. This is the difference between the travel time at a non-congestion speed and the current speed. The congestion, or threshold, speed is usually 35MPH.

Travel Time Index (TTI): the ratio of the average travel time for all users across a region to the free-flow travel time. The free-flow travel time is taken to be the time to traverse the link when traveling at 60MPH.

Effectiveness of Diamond (HOV) Lanes

HOV actuation imposes a 20% capacity penalty: the maximum flow at 60 mph on an HOV-actuated lane is 1,600 vehicles/hour, compared with 2,000 vehicles/hour when it is not HOV-actuated;

the HOV restriction significantly increases demand on the other lanes causing a net increase in overall congestion delay;

HOV actuation does not significantly increase person throughput (nationally in 2001, 83% of carpools consisted of people from the same household); and

Both short-term (daily) and long-term (yearly) carpooling responses are insensitive to travel-time savings.

"Effectiveness of High Occupancy Vehicle (HOV) Lanes in the San Francisco Bay Area"

Jaimyoung Kwon
Department of Statistics
California State University, East Bay

Pravin Varaiya
Department of Electrical Engineering
and Computer Science
University of California, Berkeley

85th Annual Meeting
Transportation Research Board
January 2006
Washington, D.C.

Ramp Metering

Ramp metering has been found to be effective

Pushes freeway congestion off to the on ramps

Effectiveness limited by putting an upper time limit on red lights

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"Design, Field Implementation and Evaluation of Adaptive Ramp Metering Algorithms: Final Report"

Roberto Horowitz, Xiaotian Sun, Laura Muñoz, Alex Skabardonis, Pravin Varaiya, Michael Zhang, Jingtao Ma

UCB-ITS-PRR-2006-21
California PATH Research Report
October 2006

Variable Congestion Pricing

Route 91 Express Lanes (Orange County, CA)

$130 million privately financed

10-mile, four-lane toll project

Fully automated facility

Located within the median of an existing eight-lane freeway between State Route 55 in Orange County and the Riverside County line

Opened to traffic on December 27, 1995

America's first toll road to employ variable congestion pricing

Tolls vary during the day with traffic volumes, directional flow and other factors

World's first fully automated toll road utilizing electronic transponders to collect tolls.

Vehicle Platooning and Automated Highways

Reversible Center Lanes, I-15
San Diego
August 7-10, 1997

Eight-vehicle platoon at the National Automated Highway Systems Consortium Technical Feasibility Demonstration

http://www.path.berkeley.edu/PATH/Publications/Media/FactSheet/VPlatooning.pdf

Vehicle Control in the Platoon

Lateral Control

The PATH automatic steering control system uses magnetic markers buried along the road center 4 feet apart.

The automatic steering system tracks the roadway center with less than three inches of error.

Longitudinal Control System

Accurate intercar spacing is achieved by the use of radar and radio communication between cars.

Each car in the platoon uses its radar to measure the distance to the preceding car.

The radio communication system provides each car with the velocity and acceleration of the preceding car and the lead car of the platoon.

1997 Platoon Demo

http://www.path.berkeley.edu/PATH/Publications/Videos/

Conclusions on Vehicle Platooning

At Demo ’97, the eight vehicles of the PATH platoon traveled at a fixed separation distance of 6.5 meters (21 feet) at all speeds up to full highway speed.

At this spacing, eight-vehicle platoons separated by a safe interplatoon gap of 60 m (about 200 ft.) and traveling at 65 mph would represent a “pipeline” capacity of about 5700 vehicles per hour.

Reducing this by 25% to allow for the maneuvering needed at entry and exit points corresponds to an effective throughput of about 4300 vehicles per lane per hour.

Throughput under normal manual driving conditions at this speed would be approximately 2000 vehicles per lane per hour.

**Traveler
Information**

511

Metropolitan Transportation Commission
California Highway Patrol
California Department of Transportation

http://www.511.org

511 SF Bay Area

511 is a free phone and Web service that consolidates Bay Area transportation information into a one-stop resource. 511 provides up-to-the-minute information on

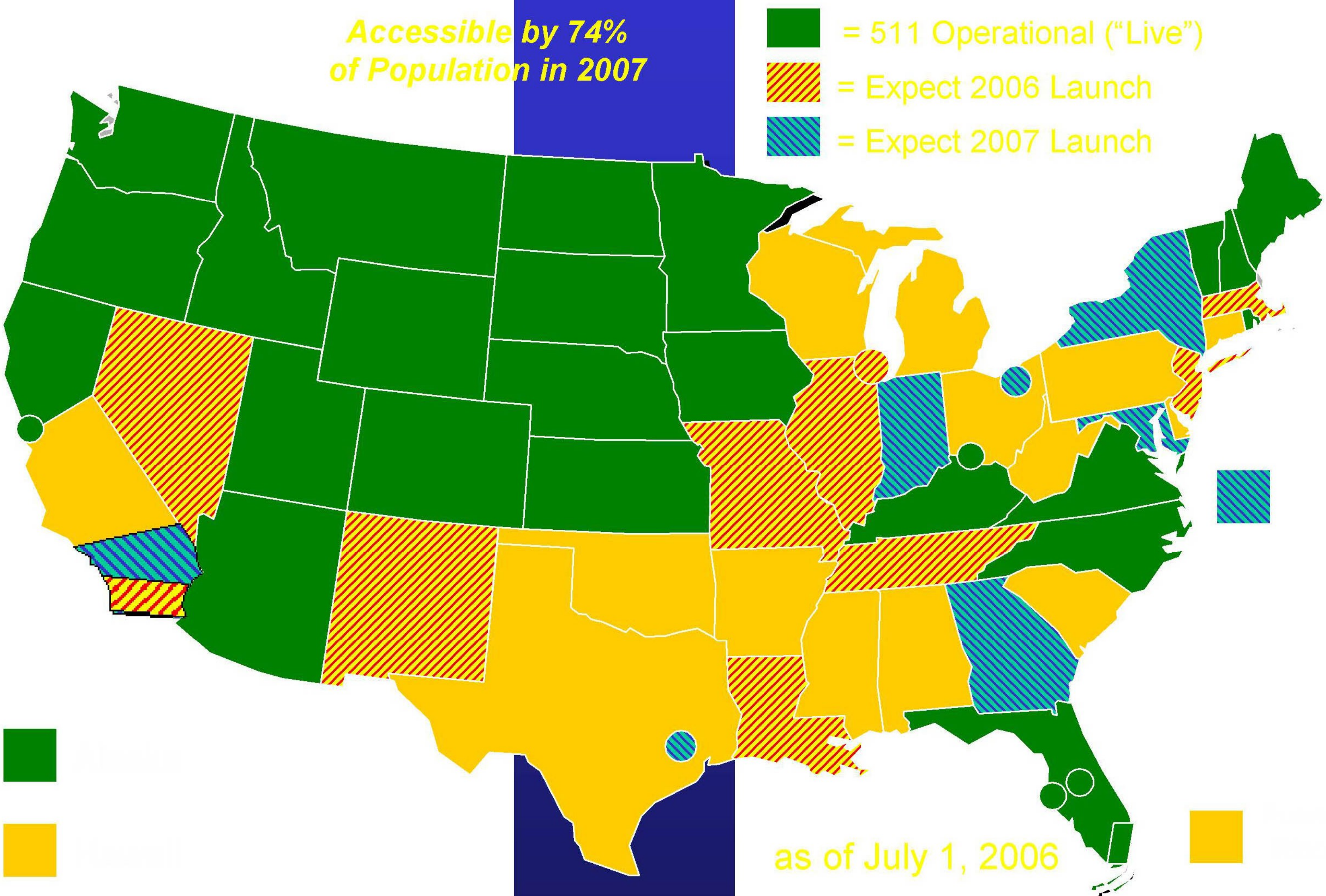
- traffic conditions
- incidents and driving times
- schedule, route and fare information for the Bay Area's public transportation services
- instant carpool and vanpool referrals
- bicycling information and more.

Available 24 hours a day, 7 days a week

511 is managed by a partnership of public agencies led by the Metropolitan Transportation Commission, the California Highway Patrol, and the California Department of Transportation.

Phone: 511
Web: 511.org

511 Deployment Status



511 Interoperability Quick Tips
2006 NRITS Session A2
Heather Young, ITS America

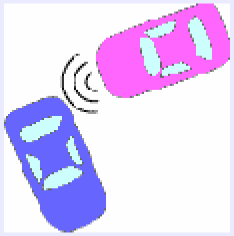
511

511 Traffic snapshot

Jan 19, 2007
5:50 PM

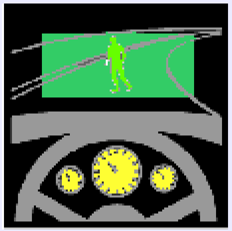
- No congestion
- Moderate
- Heavy
- Stop and go
- No data

Intelligent Vehicles



Collision Avoidance Systems

Collision Notification Systems



Driver Assistance Systems

US FHWA Intelligent Vehicle Initiative

Final report issued September 2005

Each year, over six million crashes occur on U.S. highways.
More than 42,000 people are killed
Approximately three million are injured, and
Cost is more than $230 billion per year
Driver error is the leading cause of highway crashes.

Topics Identified for Research in Current Program:
VEHICLE INFRASTRUCTURE INTEGRATION (VII)

Driver assistance and collision avoidance
Automated operation
Collision warning
Imminent Crash Research
- Rear-End Collisions
- Road Departure Collisions
- Lane Change and Merge Collisions
- Intersection Collisions

Crash Prevention and Congestion Relief Through
Vehicle-to-Vehicle and Vehicle-to-Roadside Communication

http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_PR/14153_files/ivi.pdf

US Department of Defense

Defense Advanced Research Projects Agency (DARPA)

Intelligent Vehicles

The 2004 Grand Challenge

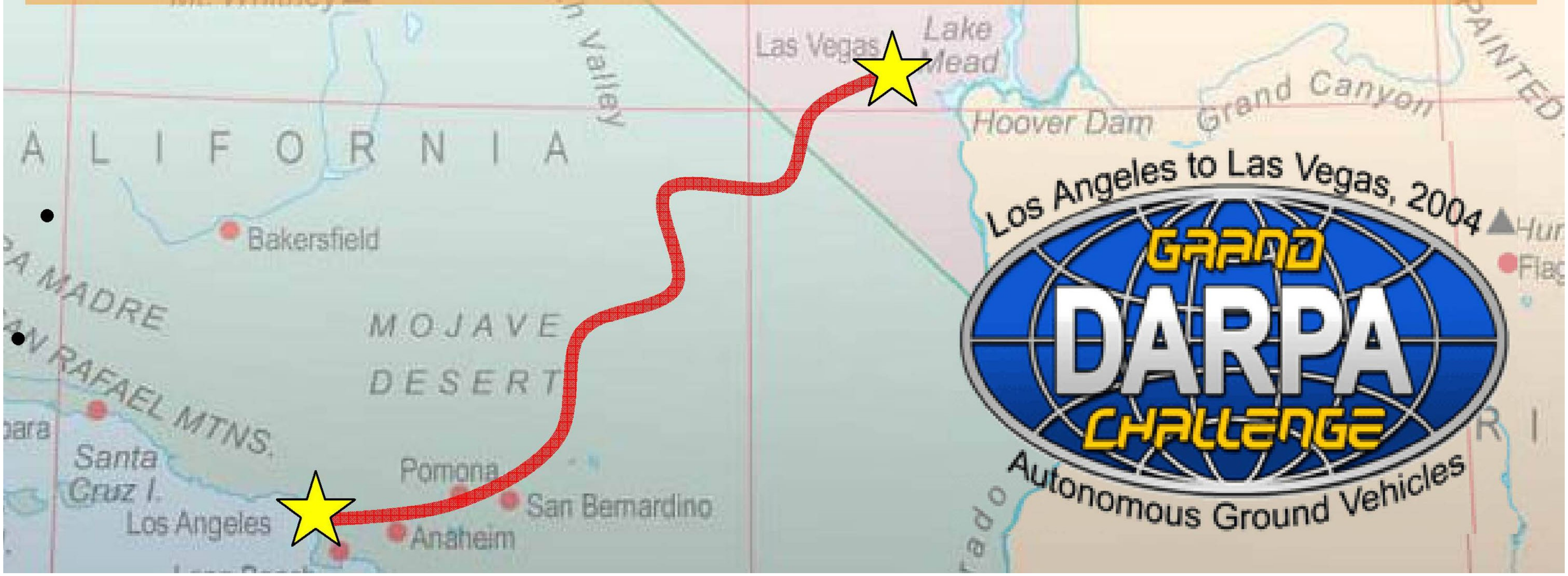
140 miles of tough desert terrain in under 10 hours

The best autonomous robotic vehicles America can build

$1 million cash prize

13 March 2004

Winner takes all



The Rules

The route is not disclosed to the participants until approximately two hours prior to the start of the event.

The route is no longer than 175 miles. It may include paved roads, unpaved roads, trails, and off-road desert areas.

The route definition data file (RDDF) is the official definition of the route and defines the corridor through which all vehicles are required to travel. The RDDF contains waypoints, lateral boundary offsets, and maximum speed limits.

Each team will receive a compact disc (CD) containing the RDDF approximately 2 hours prior to the start of the event.

After the start of the race, there will be no communication with the vehicle except by a DARPA official following each vehicle in a DARPA supplied chase vehicle.

Communication shall be through a government supplied E stop.

The E-stop system has three modes: a RUN mode, a PAUSE mode, and a DISABLE mode.

2004 Grand Challenge Results

106 Teams applied for the competition

20 teams qualified to enter

None finished the race

The longest distance traveled was about 26 miles

2005 Grand Challenge

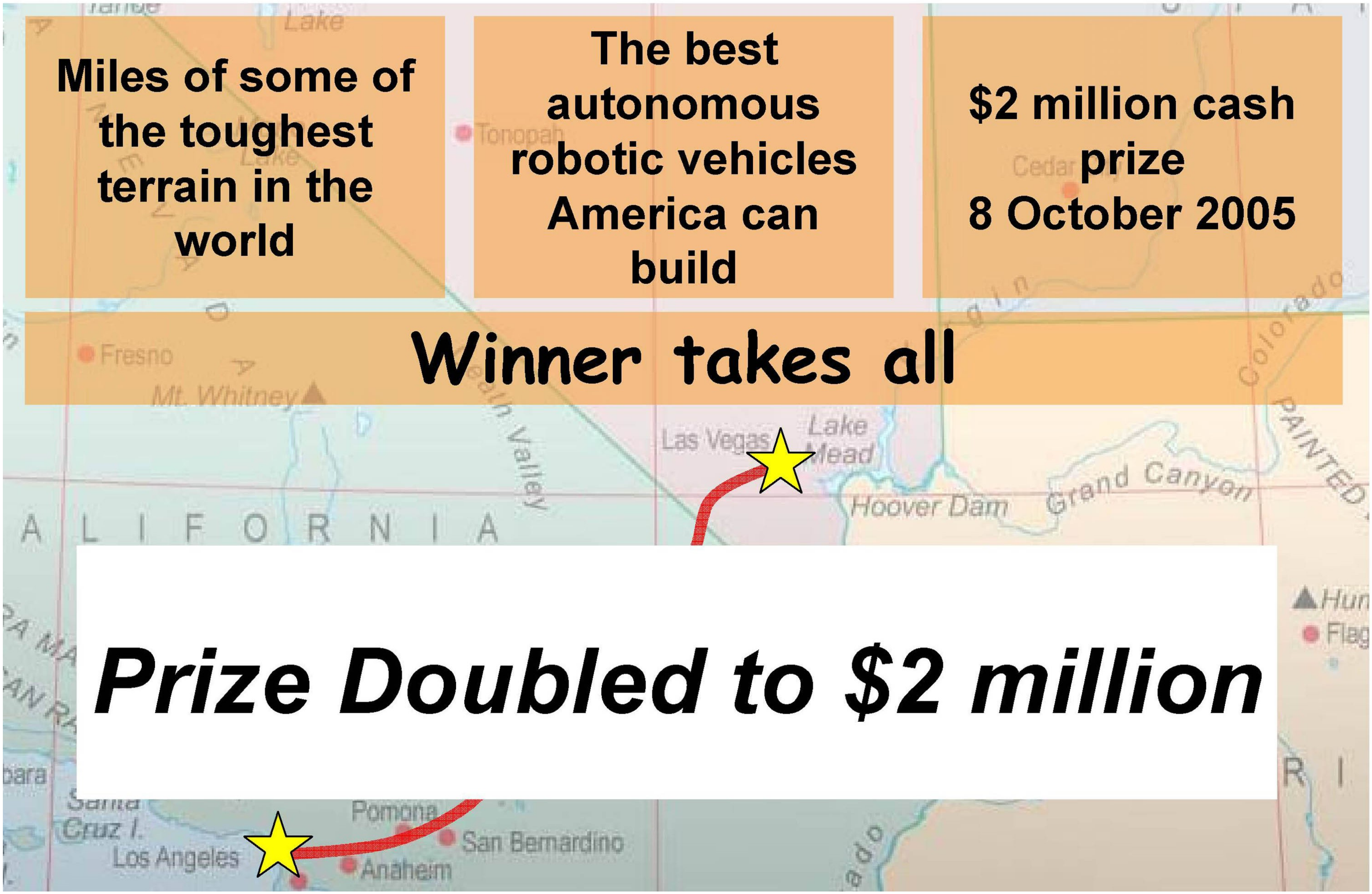
Miles of some of the toughest terrain in the world

The best autonomous robotic vehicles America can build

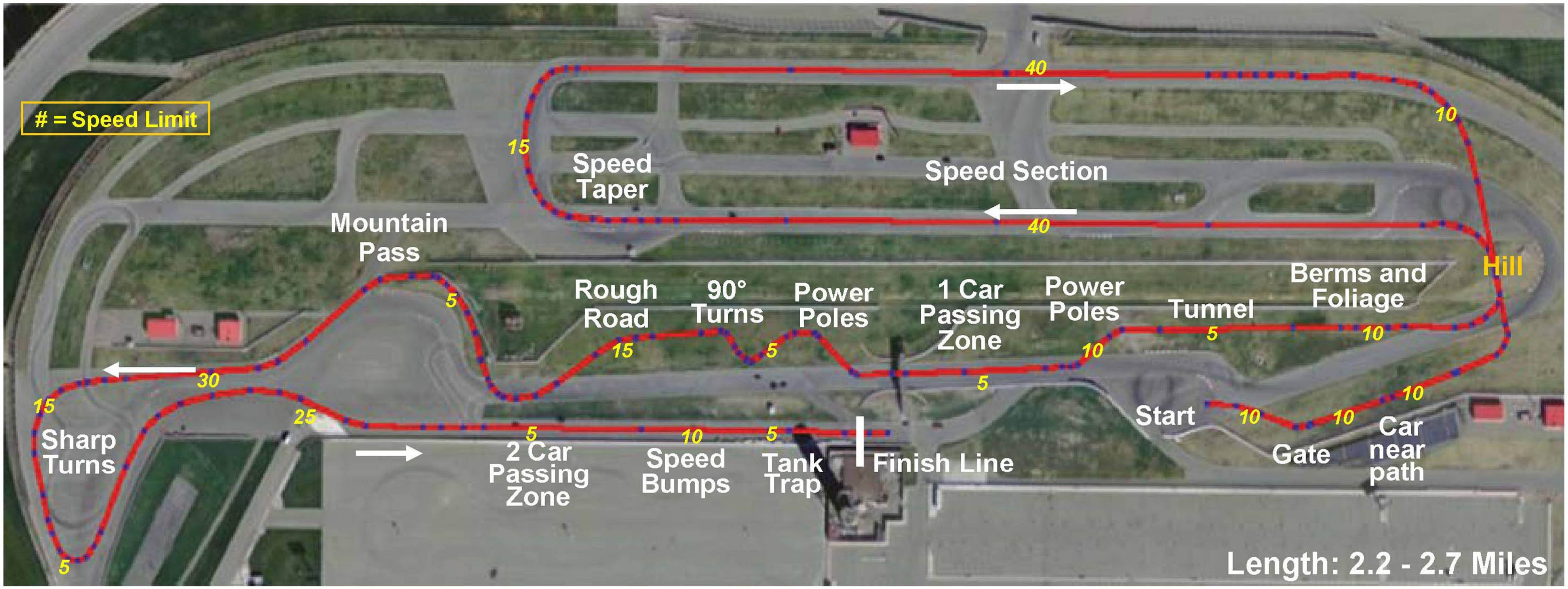
$2 million cash prize
8 October 2005

Winner takes all

Prize Doubled to $2 million



National Qualification Event Track



Start Chute

Tunnel

Tank Trap

DARPA Grand Challenge

National Qualification Event

http://www.darpa.mil/ grandchallenge/ gcvideos.asp

National Qualification Event- Part 1 (Courtesy of CarTV.com)

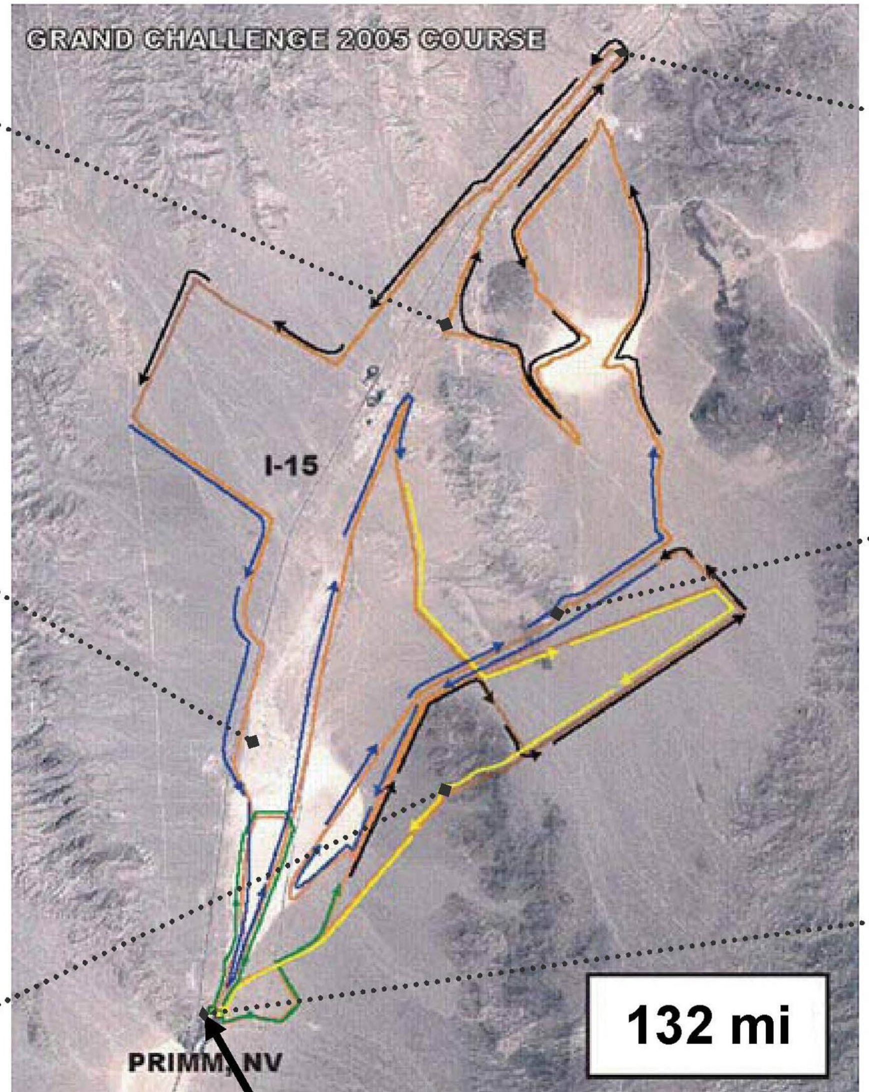
DARPA GRAND CHALLENGE

The Course

Narrow Underpass

Lake Beds

Rough Roads

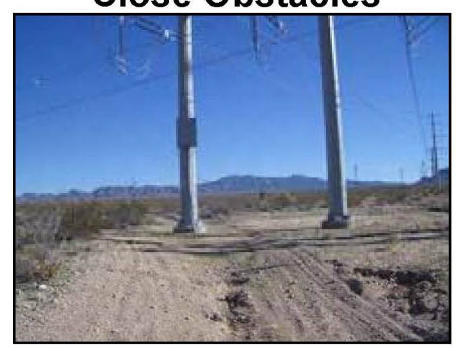


Start/Finish

Long Tunnels

Narrow Gates

Close Obstacles



DARPA Grand Challenge

Grand Challenge

http://www.darpa.mil/ grandchallenge/ gcvideos.asp

Final Event (Provided courtesy of CarTV.com)

5 Cars Cross the Finish Line

Car	Team	Time	Ave speed
Stanley	Stanford	6 hr 53 min	19.1 mph
Sandstorm	Carnegie Mellon	7 hr 4 min	18.6 mph
Highlander	Carnegie Mellon	7 hr 14 min	18.2 mph
KAT-5	Gray Matter	7 hr 30 min	17.6 mph
TerraMax	Oshkosh	12 hr 51 min	10.2 mph

Course: 131.7 miles

DARPA GRAND CHALLENGE

Stanley

Vehicle	**Stanley**
Team	**Stanford Racing Team**
Hometown	**Palo Alto, California**
Team Leader	**Michael Montemerlo**
Finishing time	**6h 53m (19.2 mph)**

Stanley

The vehicle is a diesel-powered Volkswagen Touareg R5, modified with full body skid plates and a reinforced front bumper. Stanley is actuated via a drive-by-wire system developed by Volkswagen of America's Electronic Research Lab.

Sensors take measurements from GPS, a 6DOF inertial measurement unit, wheel speed, four laser range finders, a radar system, a stereo camera pair, and a monocular vision system.
All sensors acquire environment data at rates between 10 and 100 Hertz.

All processing takes place on seven Pentium M computers, powered by a battery-backed, electronically-controlled power system mounted in the trunk.

Stanley's position is known within 2 inches.

Lasers mounted on the roof continuously scan the ground in front of the vehicle looking for cattle gates, ditches, barbed-wire fences or disabled cars (possibly competitors) on the course.

Conclusions

ITS Technology is being developed in major areas:

Infrastructure – to reduce traffic congestion

Intelligent Vehicles – to make driving safer.

Current technology is available to make significant advances in both of these areas.

These technologies need to be deployed.

Deployment will require acceptance by the public, acceptance of the cost, and mandate by the government.