Welcome to the Saxton Transportation Operations Laboratory.

GWU Students!

April 15, 2014

U.S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

FHWA Connected Automation Research

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I-95 Corridor Coalition
Connected & Automated Vehicles Conference
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U.S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION
Outline

• What is Connected Automation
• FHWA Research Facilities & Partnerships
• Current FHWA Research Activities
• Next Steps
Automation Can Be a Tool for Solving Transportation Problems

- **Improving safety**
  - Reduce and mitigate crashes

- **Increasing mobility and accessibility**
  - Expand capacity of roadway infrastructure
  - Enhance traffic flow dynamics
  - More personal mobility options for disabled and aging population

- **Reducing energy use and emissions**
  - Aerodynamic “drafting”
  - Improve traffic flow dynamics

…but connectivity is critical to achieving the greatest benefits
Connected Automation for Greatest Benefits

Autonomous Vehicle
Operates in isolation from other vehicles using internal sensors

Connected Vehicle
Communicates with nearby vehicles and infrastructure

Connected Automated Vehicle
Leverages autonomous and connected vehicle capabilities
## Example Systems at Each Automation Level

<table>
<thead>
<tr>
<th>SAE Level</th>
<th>Example Systems</th>
<th>Driver Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Adaptive Cruise Control OR Lane Keeping Assistance</td>
<td>Must drive other functions and monitor driving environment</td>
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<tr>
<td>2</td>
<td>Adaptive Cruise Control AND Lane Keeping Assistance</td>
<td>Must monitor driving environment (system nags driver to try to ensure it)</td>
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<tr>
<td>2</td>
<td>Traffic Jam Assist</td>
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<tr>
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<td>Traffic Jam Pilot</td>
<td>May read a book, text, or web surf, but be prepared to intervene when needed</td>
</tr>
<tr>
<td>3</td>
<td>Automated parking</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Highway Autopilot</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Closed campus driverless shuttle</td>
<td>May sleep, and system can revert to minimum risk condition if needed</td>
</tr>
<tr>
<td>4</td>
<td>Valet parking in garage</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>‘Fully automated’ in certain conditions</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Automated taxi</td>
<td>No driver needed</td>
</tr>
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<td>Car-share repositioning system</td>
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Source: California PATH
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FHWA’s Saxton Transportation Operations Lab

Cooperative Vehicle-Highway Testbed

Concepts and Analysis Testbed

Data Resources

External Stakeholders, Applications, and Data

Living Laboratories
Development Platform for FHWA Innovation Research Vehicles

• Proof of Concept Vehicles
• Research Fleet Communications
  - 5.9GHz DSRC, Cellular/LTE, Corrected GPS
• On-board Technology
  - Connected Vehicle Data Collection and Processing
  - Stock Radar and Ultra-Sonic Sensors
  - Front and rear-facing cameras
Cooperative Vehicle Highway Testbed (Intelligent Intersection)

- CCTV
- DSRC
- Fixed time or actuated traffic signal control with pedestrian / bike displays
- Dedicated Ethernet & Wi-Fi communications
- Signalized intersection with SPaT / MAP
- Cabinet space with power & comms, available for future research
- Vehicle Pedestrian & Bike Detection
- Cadillac SRX with OBU, GPS, CAN bus integration
MOU with DHS
Federal Law Enforcement Training Center

Existing
A. Wire Mounted Traffic Signals
B. Closed-Loop Test Track
C. Ramps
D. Pole-Mounted Traffic Signal
E. Flat Space Open Testing
F. Skid Pad

Future:
DSRC / Wi-Fi
V2I Communications
Connected Automation Research

- Speed Harmonization
- Cooperative Adaptive Cruise Control (CACC)
- Lane Change / Merge
- Eco / Environmental
- Truck Platooning
Speed Harmonization Research

- **Research Question**: Can speed commands from a TMC, dynamically adjusted according to traffic conditions, and transmitted directly to connected automated vehicles – improve traffic flow conditions on a roadway with reoccurring congestion?

- **Objectives**: Develop, implement and test the effectiveness of speed harmonization strategies using automated vehicle speed control and I2V communication on a live roadway environment.

- **Work to Date**:
  - Project 1 (completed)
    - 20 prototype field runs conducted on I-66 near Washington, DC with 3 connected automated vehicles
    - 3 exploratory micro-simulation experiments
  - Project 2 (ongoing)
Speed Harmonization Research

- **RTMS Trailer**
- **Research vehicle**
- **Probe vehicle**

- Volume, speed, and occupancy data from trailers to server
- GPS, time, and speed data from probe vehicles to server
- Algorithm-calculated recommended speed from server to research vehicles

*Server currently located in the Saxton Lab*
Looking Forward..

• Infrastructure
  – V2I information could provide much richer real-time traffic information (e.g., high-resolution vehicle trajectories) than traditional traffic sensors for real-time traffic control
  – Automation will eliminate need for some infrastructure (e.g., VSL signs and DMS)

• Market penetration
  – Given a substantive market penetration, exclusive lanes could be established for connected automated vehicles. CACC and speed harmonization techniques could improve flow and smooth speeds
Cooperative Adaptive Cruise Control (CACC) Evolution

Three different types of cruise control

Current Market Penetration

- Standard Cruise Control
  - Throttle

- Adaptive Cruise Control
  - Throttle Radar

Future of Cruise Control

- Cooperative Adaptive Cruise Control
  - Throttle Radar Communication

Cooperative Adaptive Cruise Control (CACC) Evolution
CACC Simulation Study

• Create a high-speed and high-capacity managed CACC lane

• Examine the impacts of different CACC operational strategies
  ➢ Dedicated Lane **VS** Shared Lane
  ➢ Car-following headway
  ➢ Platoon size
  ➢ Market penetration levels
  ➢ On- and Off-ramp volume
  ➢ Lane-changing criteria between CACC and GP lane
Build the Simulation Testbed
--- CACC Site Selection

- Major urban corridor for commuters
- Severe congestion problems
- Four lanes in each direction
- Existing HOV-2 lane
- Six interchanges
CACC Simulation Take-Aways

• The dedicated lane’s **capacity increases** from 1650 to 3800 veh/hr/ln (0.6s headway)

• CACC lane has shorter and more **reliable travel time**, which will promote CACC technology

• Cooperative lane-changes are important, especially under high speed differentials
CACC Physical Performance Testing

• Saxton Lab fleet
  – 5 vehicle platoon, all same make and model
  – Testing under various operating conditions
  – Improving algorithms

• Crash Avoidance Metrics Partnership (CAMP)
  – 4 vehicle platoon
  – Each a different make and model
  – First step – hardware in the loop simulation
Automated Lane Change / Merge

- **Research Question:** Can the use of automated control, V2V, I2V, and/or vehicle sensors to execute traffic movements such as lane change and merge maneuvers assist in fully realizing the identified mobility and safety benefits of other connected automated applications (e.g., CACC)?

- **Work to Date:** A connected, automated lane change maneuver was successfully demonstrated on a close course with three vehicles.
  - The maneuver took approximately 10 s to complete
  - The vehicles were able to maintain desired spacing with minimal error (within 2 m), speed oscillation, or passenger discomfort.

![Diagram of automated lane change and merge maneuvers](image)
Automated Lane Change / Merge

- Automatic control of vehicle acceleration and braking to create a gap for the merging vehicle to enter
- DSRC to exchange messages about the status of the merge between vehicles
- Forward-facing radar to sense the distance between vehicles
- A tablet computer to display the status of the merge (i.e., DSRC messages)
Background: Completed AERIS Proof of Concept Testing (Fall 2012)
A field test was conducted at TFHRC with a single vehicle at a single intersection with no traffic
Preliminary GlidePath Results

- HMI-based driving provided a 7% fuel economy benefit
- Partially automated driving provided a 22% benefit
- Minimizing controller lag is important
- Precise positioning is important near the intersection stop bar
Eco Adaptive Cruise Control

With automated and connected vehicle

Automated Vehicle
- Automated speed control
- Automated gear selection
- Automated battery power control
- Automated braking system

Fuel reductions 5.0% to 8.9%, mild slopes & 15.7% to 16.9% on steep slopes for uninterrupted single hybrid vehicle.
Truck Platooning

- Two projects underway
  - Auburn U/Peterbilt (2-truck platoons)
  - Caltrans/UC Berkeley/Volvo (3-truck platoons)
- Concept: longitudinal control only; all drivers steer
Next Steps

• Continued Research (examples)
  – CACC
    • CAMP physical tests of 4 vehicle platoon (different makes & models)
    • Communication and performance characteristics of mixed vehicle platoons (e.g., trucks and cars)
  – Eco Approach & Departure with actuated signals and other vehicles

• Continued Partnerships
  – In discussions with I-495 Express Lanes operator
  – Others?
To Learn More

• Visit
  – FHWA Office of Operations Website: http://ops.fhwa.dot.gov/
  – Turner-Fairbank Highway Research Center Website: http://www.fhwa.dot.gov/research/tfhrc/offices/operations/

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