GlidePath
Connected Automated Eco-Driving using Wireless V2I Communications at Signalized Intersections

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PR08: The Decarbonisation of Road Transport: How Can Eco-Driving Contribute?
AERIS Program Overview

- Vision – Cleaner Air Through Smarter Transportation
  - Encourage the development and deployment of technologies and applications that support a more sustainable relationship between surface transportation and the environment through fuel-use reductions and more efficient use of transportation services.

- Objectives – Investigate whether it is possible and feasible to:
  - Identify connected vehicle applications that could provide environmental impact reduction benefits via reduced fuel use, improved vehicle efficiency, and reduced emissions.
  - Facilitate and incentivize “green choices” by transportation service consumers (i.e., system users, system operators, policy decision makers, etc.).
  - Identify vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-grid (V2G) data (and other) exchanges via wireless technologies of various types.
  - Model and analyze connected vehicle applications to estimate the potential environmental impact reduction benefits.
  - Develop a prototype for one of the applications to test its efficacy and usefulness.
AERIS Operational Scenarios

**ECO-SIGNAL OPERATIONS**
- Eco-Approach and Departure at Signalized Intersections (uses SPaT data)
- Eco-Traffic Signal Timing (similar to adaptive traffic signal systems)
- Eco-Traffic Signal Priority (similar to traffic signal priority)
- Connected Eco-Driving (similar to eco-driving strategies)
- Wireless Inductive/Resonance Charging

**ECO-LANES**
- Eco-Lanes Management (similar to managed lanes)
- Eco-Speed Harmonization (similar to variable speed limits)
- Eco-Cooperative Adaptive Cruise Control (similar to adaptive cruise control)
- Eco-Ramp Metering (similar to ramp metering)
- Connected Eco-Driving (similar to eco-driving)
- Wireless Inductive/Resonance Charging
- Eco-Traveller Information Applications

**LOW EMISSIONS ZONES**
- Low Emissions Zone Management (similar to existing Low Emissions Zones)
- Connected Eco-Driving (similar to eco-driving strategies)
- Eco-Traveller Information Applications (similar to ATIS)

**ECO-TRAVELER INFORMATION**
- Connected Vehicle-Enabled Data Collection: Probe and Environmental Data
- Multimodal Traveler Information
- Eco-Smart Parking
- AFV Charging/Fueling Information, Reservations, and Payment
- Dynamic Eco-Routing
- Connected Eco-Driving – Gamified / Incentives-based Apps
- Gamified / Incentives-based Multimodal Traveler Information

**ECO-INTEGRATED CORRIDOR MANAGEMENT**
- Eco-ICM Decision Support System (similar to ICM)
- Eco-Signal Operations Applications
- Eco-Lanes Applications
- Low Emissions Zones Applications
- Eco-Traveller Information Applications
- Incident Management Applications
AERIS Research Approach

**Concept Exploration**
Examine the State-of-the-Practice and explore ideas for AERIS Operational Scenarios

**Development of Concepts of Operations for Operational Scenarios**
Identify high-level user needs and desired capabilities for each AERIS scenario in terms that all project stakeholders can understand

**Conduct Preliminary Cost Benefit Analysis**
Perform a preliminary cost benefit analysis to identify high priority applications and refine/refocus research

**Modeling and Analysis**
Model, analyze, and evaluate candidate strategies, scenarios and applications that make sense for further development, evaluation and research

**Prototype Application**
Develop a prototype for one of the applications to test its efficacy and usefulness.
Eco-Approach and Departure at Signalized Intersections

Application Overview

- Collects signal phase and timing (SPaT) and Geographic Information Description (GID) messages using vehicle-to-infrastructure (V2I) communications

- Receives V2I and V2V (future) messages, the application performs calculations to determine the vehicle’s optimal speed to pass the next traffic signal on a green light or to decelerate to a stop in the most eco-friendly manner

- Provides speed recommendations to the driver using a human-machine interface or sent directly to the vehicle’s longitudinal control system to support partial automation

Source: USDOT, November 2013
Eco-Approach and Departure at Signalized Intersections

[Diagram showing different phases of vehicle movement and analysis boundary with various scenarios.]
Variations

- **Signal timing scheme matters:** fixed time signals, actuated signals, coordinated signals
- **Single intersection** analysis and **corridor-level** analysis
- **Congestion level:** how does effectiveness change with amount of surrounding traffic
- **Single-vehicle** benefits and total **link-level** benefits
- **Simulation Modeling vs. Field Studies**
- **Vehicle Control:** driver advice vs. partial automation
- **Communications Method:** short range vs. wide-area
AERIS Modeling Overview

- A traffic simulation models (e.g., Paramics) was combined with an emissions model (e.g., EPA’s MOVES model) to estimate the potential environmental benefits.
- Application algorithms were developed by the AERIS team and implemented as new software components in the traffic simulation models.
- Modeling results indicate a possible outcome – results may vary depending on the baseline conditions, geographic characteristics of the corridor, etc.
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Modeling Network

- **El Camino Real Network**
  - Signalized, urban arterial (27 intersections) in northern California
  - 6.5 mile segment between Churchill Avenue in Palo Alto and Grant Road in Mountain View
  - For the majority of the corridor, there are three lanes in each direction
  - Intersection spacing varies between 650 feet to 1,600 feet
  - 40 mph speed limit
  - Vehicle demands and OD patterns were calibrated for a typical weekday in summer 2005 (high volumes on the mainline)
  - Vehicle mix (98.8% light vehicles; 1.2% heavy vehicles)
Summary of Modeling Results

- Summary of Modeling Results
  - 5-10% fuel reduction benefits for an uncoordinated corridor
  - Up to 13% fuel reduction benefits for a coordinated corridor
    - 8% of the benefit is attributable to signal coordination
    - 5% attributable to the application

- Key Findings and Takeaways
  - The application is less effective with increased congestion
  - Close spacing of intersections resulted in spillback at intersections. As a result, fuel reduction benefits were decreased somewhat dramatically
  - Preliminary analysis indicates significant improvements with partial automation
  - Results showed that non-equipped vehicles also receive a benefit – a vehicle can only travel as fast as the car in front of it
A field test was conducted at Turner Fairbank Highway Research Center (TFHRC) with a single vehicle at a single intersection with no traffic.

Drivers were provided with speed recommendations using a Driver Vehicle Interface (DVI) incorporated into the speedometer (driver advisory feedback).

The field experiment resulted in up to 18% reductions in fuel consumption.

It was difficult for drivers to follow the recommended speed on the “speed advice speedometer”.

Having drivers follow speed recommendations also creates driver distraction.

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Avg. Fuel Savings (ml)</th>
<th>Avg. % Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>13.0</td>
<td>2.5%</td>
</tr>
<tr>
<td>25</td>
<td>111</td>
<td>18.1%</td>
</tr>
<tr>
<td>30</td>
<td>76.0</td>
<td>11.2%</td>
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<tr>
<td>35</td>
<td>73.8</td>
<td>6.3%</td>
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<tr>
<td>40</td>
<td>107</td>
<td>9.5%</td>
</tr>
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</table>
GlidePath Prototype Application

- **Project Objectives**
  - Develop a working prototype GlidePath application with automated longitudinal control for demonstration and future research;
  - Evaluate the performance of the algorithm and automated prototype (specifically, the energy savings and environmental benefits);
  - Conduct testing and demonstrations of the application at TFHRC

- **Period of Performance**
  - May 2014 through December 2015

_The GlidePath prototype is state of the art and the first of its kind_
GlidePath High-Level System Architecture

- **Component Systems**
  - Roadside Infrastructure
    - Signal Controller
    - SPaT Black Box
    - DSRC RSU
  - Automated Vehicle
    - Existing Capabilities
    - Additional Functionality
  - Algorithm
    - Objective
    - Input
    - Output
Roadside Infrastructure

Notes

1. Primary RSU is installed on the mast arm on the west side of the intersection and connected to Cabinet 6 of the Saxton roadside infrastructure.

2. Secondary RSU is installed on a pole and connected to Cabinet 1 of the Saxton roadside infrastructure along the entrance road from GW Parkway.

3. Econolite signal controller and SPaT blackbox location.

Note: Secondary RSU added to extend communications range caused by line of sight issues.
‘Automated’ Vehicle

- **Ford Escape Hybrid developed by TORC with ByWire XGV System**
  - Existing Capabilities
    - Full-Range Longitudinal Speed Control
    - Emergency Stop and Manual Override
  - Additional Functionality
    - Computing Platform with EAD Algorithm
    - DSRC OBU
    - High-Accuracy Positioning Solution
    - Driver Indicators/Information Display
    - User-Activated System Resume
    - Data Logging
# GlidePath Field Experiment

The field experimentation was organized into three stages

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>Stage II: Manual-DVI Driver</strong></td>
<td>Manual</td>
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<tr>
<td>(2012 AERIS experiment)</td>
<td></td>
</tr>
<tr>
<td><strong>Stage III: Automated Driver</strong></td>
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</tbody>
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- **Speedometer**
- **SPaT**
- **Tachometer**
- **Advisory speed**
- **Real-time MPG**
- **Distance to intersection**
- **Intersection location indicator**

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- **Stop Data**
- **EcoDrive Off**
- **Distance to Stop Bar**
- **Start**
- **Stop Bar**
- **End**
- **Selected Speed**
- **Current Speed**
Preliminary GlidePath Results

Table 2. Relative savings in fuel consumption (%) between different driving modes

<table>
<thead>
<tr>
<th>Phase</th>
<th>Green</th>
<th>Red</th>
<th>On</th>
<th>Average</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time in Phase (s)</td>
<td>2</td>
<td>7</td>
<td>12</td>
<td>17</td>
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<tr>
<td>D vs. U</td>
<td>11.80</td>
<td>11.75</td>
<td>7.59</td>
<td>5.20</td>
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<tr>
<td>A vs. U</td>
<td>4.67</td>
<td>7.55</td>
<td>35.25</td>
<td>20.94</td>
</tr>
<tr>
<td>A vs. D</td>
<td>14.73</td>
<td>17.27</td>
<td>29.93</td>
<td>16.60</td>
</tr>
</tbody>
</table>

- **Summary of Preliminary Results**
  - DVI-based driving provided a 7% fuel economy benefit
  - Partially automated driving provided a 22% benefit

- **Lessons Learned**
  - Minimizing controller lag is important
  - Precise positioning is important near the intersection stop bar
Next Steps

- **Opportunities for Future Research with the GlidePath Prototype**
  - Multiple Equipped Vehicles
  - Multiple Intersections / Corridor
    - Controlled Environment
    - Real-World Corridor with Traffic
  - Actuated Traffic Signal Timing Plans
  - Integration of Cooperative Adaptive Cruise Control (CACC) capabilities with the prototype

- **Continue to Engage the Automotive Industry**
  - AERIS initiated a project for CAMP to assess the Eco-Approach and Departure at Signalized Intersections application
Contact Information

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