U.S. Department of Energy - Vehicle Technologies Program
2008 Annual Merit Review

Advanced Vehicle Testing Activity (AVTA) – Non-PHEV Evaluations and Data Collection

Vehicle Systems Merit Review
Jim Francfort – INL AVTA Principle Investigator
Lee Slezak – DOE Sponsor

February 2008, Bethesda, Maryland
Vehicle Testing Objectives

• Overall vehicle testing objectives
  – Benchmark and reduce operational uncertainties of emerging vehicle technologies
  – Provide testing results to vehicle modelers and technology target setters in support of DOE technology development efforts, and to early adaptor fleet managers
  – Continue to utilize Phoenix area test tracks and fleet testing arrangements
Vehicle Testing Objectives – cont’d

- Hybrid Electric Vehicles (HEVs)
  - Reduce HEV battery and vehicle uncertainties and document life-cycle costs

- Hydrogen Internal Combustion Engine (HICE) Vehicles
  - Assess the safety, reliability and operating characteristics of 100% HICE vehicles
  - Identify any engine or vehicle system degradations when operating on hydrogen
Vehicle Testing Objectives – cont’d

• Neighborhood Electric Vehicles (NEVs)
  – Support the California Air Resource Board’s (CARB) decision to require all NEV models sold in California be tested by the AVTA in order to be eligible for CARB incremental funding and credits

• Electric Ground Support Equipment (eGSE)
  – Support the development, understanding and deployment of eGSE at domestic airports
FY07 Testing Accomplishments

- Hybrid Electric Vehicles (HEVs)
  - Completed baseline performance testing on 12 HEV models to date (five models during FY07)
  - As of September 2007, 3.2 million test miles have been accumulated (987,380 miles during FY07) on 19 HEVs in JPMorgan fleet (160,000 miles per vehicle in 3 years, minimum 2 vehicles per model)
  - Initiated end of life (EoL) battery testing on two Gen II Prius and two Escape HEVs, having previously completed EoL battery testing on two Gen I Prius, two Gen I Civic, and two Honda Insight HEVs
  - Collected fuel economy, maintenance, depreciation, operations (insurance and registration), and other life-cycle related vehicle costs in fleet missions to determine life-cycle costs
FY07 Testing Accomplishments – cont’d

- Hydrogen Internal Combustion Engine (HICE) Vehicles
  - Eight 100% HICE pickups (Roush CNG conversions) being fueled at the Integrated Waste Hydrogen Utilization Project (IWHUP) in Vancouver, BC
  - 16,000 total test miles and 20.1 miles per GGE with no safety problems
  - Faster exhaust gas oxygen sensor degradation
  - Increased presence of water in the engine oils due to lower combustion temperatures during lean-burn operations
  - Increased exhaust manifold corrosion
  - Roush 100% HICE pickup baseline performance tested in FY07 (total of 4 HICE and HCNG models tested to date)
FY07 Testing Accomplishments – cont’d

• Neighborhood Electric Vehicles (NEVs)
  – CARB and Wisconsin required all NEV models be tested to the AVTA’s NEVAmerica testing procedures
  – Initiated the testing of a new NEV from Global Electric Motors (GEM), a Chrysler subsidy

• Electric Ground Support Equipment (eGSE)
  – Completed baseline performance testing on electric pushback tractor
  – Developed economic payback model for baggage tractors, belt loaders, and pushback tractors propelled by electric motors or petroleum engines (including fueling infrastructure). Based on operations of two airlines at four airports. Partners: EPRI, SCE, SMUD, Georgia Power, Southwest and Delta Airlines
## HEVs in Testing

<table>
<thead>
<tr>
<th>Model</th>
<th>Test Rounds</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001 Honda Insight</td>
<td>6</td>
<td>Completed</td>
</tr>
<tr>
<td>2002 Gen I Toyota Prius</td>
<td>6</td>
<td>Completed</td>
</tr>
<tr>
<td>2003 Gen I Honda Civic</td>
<td>4</td>
<td>Completed</td>
</tr>
<tr>
<td>2004 Chevrolet Silverado (2- &amp; 4-WD)</td>
<td>2</td>
<td>Ongoing</td>
</tr>
<tr>
<td>2004 Gen II Toyota Prius</td>
<td>2</td>
<td>Completing</td>
</tr>
<tr>
<td>2005 Ford Escape (front &amp; 4-WD)</td>
<td>2</td>
<td>Completing</td>
</tr>
<tr>
<td>2005 Honda Accord</td>
<td>2</td>
<td>Ongoing</td>
</tr>
<tr>
<td>2006 Lexus RX 400h (front &amp; 2 AWD)</td>
<td>3</td>
<td>Ongoing</td>
</tr>
<tr>
<td>2006 Toyota Highlander (AWD)</td>
<td>2</td>
<td>Ongoing</td>
</tr>
<tr>
<td>2006 Gen II Honda Civic</td>
<td>2</td>
<td>Ongoing</td>
</tr>
<tr>
<td>2007 Saturn Vue</td>
<td>2</td>
<td>Ongoing</td>
</tr>
<tr>
<td>2007 Toyota Camry</td>
<td>2</td>
<td>Ongoing</td>
</tr>
<tr>
<td>2008 Nissan Altima</td>
<td>2</td>
<td>Ongoing</td>
</tr>
<tr>
<td>2008 GM 2-mode Tahoes</td>
<td>2</td>
<td>Starting</td>
</tr>
<tr>
<td><strong>Total test or in testing</strong></td>
<td><strong>39 to date</strong></td>
<td></td>
</tr>
</tbody>
</table>
3.4 Million HEV Onroad Test Miles

All HEVs - Miles Driven Monthly & Cumulative

Monthly Mileage (right axis)
Cumulative Mileage (left axis)
HEVs Baseline Performance Tested

Baseline Performance MPG (J1634 With & W/O Air)

- **MPG SAE J1634 Air On**
- **MPG SAE J1634 Air Off**

- Insight
- Gen I Prius
- Gen I Civic
- Gen II Prius
- Silverado
- Accord
- Escape
- Highlander
- RX400h
- Gen II Civic
- Camry
- Vue
- Average

Miles per Gallon
Percent HEV MPG Decrease - A/C on

Percent MPG Difference (J1634 With & W/O Air)

-30%
-25%
-20%
-15%
-10%
-5%
0%

Insight Gen I Prius Gen I Civic Gen II Prius Silverado Accord Escape Highlander RX400h Gen II Civic Camry Vue Average
Onroad Test miles per HEV model

Total HEV Fleet / Accelerated Reliability Test Miles - By HEV Model

- Civic
- Insight
- Gen I Prius
- Silverado Accords
- Gen II Prius
- Escapes
- Lexus
- Highlander
- Camry
- Gen II Civic
- Saturn Vue
Onroad Miles per gallon by HEV model

![HEV Fleet Accelerated Reliability Testing MPG By HEV Model](chart)

- **Gen I Civic**: 37.6
- **Insight**: 45.2
- **Gen I Prius**: 41.0
- **Silverado**: 17.7
- **Accords**: 28.1
- **Gen II Prius**: 44.2
- **Escapes**: 27.0
- **Lexus RX400h**: 23.6
- **Highlander**: 24.6
- **Camry**: 33.4
- **Gen II Civic**: 39.5
- **Saturn Vue**: 27.8
HEV Monthly Onroad MPG

HEV Monthly Miles per Gallon

- Insight
- Gen I Civic
- Gen I Prius
- Gen II Prius
- Silverado
- Escape
- Accord
- RX400h
- Highlander
- Camry
- Gen II Civic
- Vue
- Vue
Onroad HEV MPG vs. Old/New EPA MPG

HEV Fleet Testing MPG

- AVTA Fleet
- EPA New Combined
- EPA Old Combined
Onroad HEV MPG vs. Old/New EPA MPG

Percent EPA MPG > or < AVTA Fleet MPG

New EPA > AVTA  Old EPA > AVTA

-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%

-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%

-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%

-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%

-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%

-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%

-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%

-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%

-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%

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-12%  -10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%  12%  14%  16%  18%  20%  22%  24%  26%  28%  30%  32%  34%
HEV Fleet Testing
Advanced Vehicle Testing Activities
Maintenance Sheet for 2006 – Highlander

VIN # JTED21AA60006395

<table>
<thead>
<tr>
<th>Date</th>
<th>Mileage</th>
<th>Description</th>
<th>Cost</th>
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<tbody>
<tr>
<td>12/14/2005</td>
<td>6,855</td>
<td>Changed oil, rotated tires</td>
<td>$31.99</td>
</tr>
<tr>
<td>1/5/2006</td>
<td>9,952</td>
<td>Changed oil, rotated tires</td>
<td>$28.04</td>
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<tr>
<td>1/31/2006</td>
<td>15,749</td>
<td>15K service</td>
<td>$187.65</td>
</tr>
<tr>
<td>2/2/2006</td>
<td>29,788</td>
<td>Changed oil, rotated tires</td>
<td>$28.07</td>
</tr>
<tr>
<td>3/2/2006</td>
<td>29,197</td>
<td>Changed oil, rotated tires</td>
<td>$28.10</td>
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<tr>
<td>4/17/2006</td>
<td>51,578</td>
<td>30K service</td>
<td>$324.80</td>
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<tr>
<td>4/26/2006</td>
<td>56,682</td>
<td>Changed oil, rotated tires</td>
<td>$28.99</td>
</tr>
<tr>
<td>5/18/2006</td>
<td>42,113</td>
<td>Changed oil, rotated tires</td>
<td>$28.99</td>
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<tr>
<td>6/9/2006</td>
<td>47,475</td>
<td>15K interval service, 45K preventative maintenance</td>
<td>$200.67</td>
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<tr>
<td>7/25/2006</td>
<td>55,711</td>
<td>Changed oil</td>
<td>$38.44</td>
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<td>7/26/2006</td>
<td>59,652</td>
<td>60K service</td>
<td>$346.95</td>
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<tr>
<td>8/21/2006</td>
<td>65,947</td>
<td>Changed oil</td>
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<tr>
<td>9/12/2006</td>
<td>71,030</td>
<td>Changed oil, replaced wiper blades</td>
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</tr>
<tr>
<td>9/14/2006</td>
<td>71,053</td>
<td>Check engine light on - Code PA93 Inverter cooling system malfunction inverter coolant low</td>
<td>warranty</td>
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<tr>
<td>9/29/2006</td>
<td>73,015</td>
<td>Replaced windshield</td>
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<tr>
<td>10/6/2006</td>
<td>75,949</td>
<td>75K service</td>
<td>$200.67</td>
</tr>
<tr>
<td>12/6/2006</td>
<td>90,270</td>
<td>Changed oil</td>
<td>$39.60</td>
</tr>
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</table>
HEV Life-Cycle Costs per Mile

Operating costs = fuel, insurance & registration
HICEVAmerica Roush Testing Fact Sheet
NEVAMerica GEM Testing Fact Sheet (Draft)
eGSEAmerica FMC Pushback Tractor Testing Fact Sheet
FY08 Overall Testing Plans

• Continue role as DOE’s whole vehicle system field tester
• Conduct baseline performance, accelerated and fleet testing on new vehicles with new technologies
• Continue to provide feedback to domestic automotive industry and other advanced technology stakeholders
• Continue presentations at industry and public events and disseminating testing results via the www
• FY08 budget is $1,800k, with ~$600k spent to date
FY08 HEV Testing Plans

- HEV accessory testing
  - Initial FY07 results from “parking lot test”
    - Camry exhibited \( \sim 1.5 \text{ kW} \) peak demand
    - Highlander exhibited \( \sim 3.9 \text{ kW} \) peak demand
    - Modeled assumptions are significantly lower
  - FY08 expanded testing to include Prius and Escape

HEV accessory load testing

- Power steering no input and at lock stop
- Air conditioning at full compressor load and defrost compressor load
- All optional accessories off at idle (initial condition) versus maximum blower speed, all accessory loads, power window operation, service brake operation and engine start
FY08 HEV Testing Plans – cont’d

• Initiate baseline performance testing of new HEVs available during FY08, including the Nissan Altima and two-mode General Motors Tahoe

• Initiate 160,000 accelerated testing on 2 of each Altima and Tahoe HEV models

• Continue accelerated testing on 2 Highlander, 2 Vue, 2 Civics, 2 Camry, and 2 Silverado HEVs

• Conduct beginning of life testing on Tahoe and Altima HEV batteries

• Conduct EoL HEV battery testing (at 160,000 miles) on Escape, Accord, Gen II Prius and Lexus RX400h HEVs

• Continue to analyze data from onboard data loggers

• Continue to provide 160,000-mile vehicles and components to other DOE laboratories for EoL testing
FY08 Testing Plans

- **HICE Vehicles**
  - Continue to operate the eight HICE vehicles fueled at IWHUP and document fuel use, vehicle performance, and any additional effects hydrogen has on vehicle subsystems
  - Continue to analyze vehicle performance from onboard data loggers
  - Continue to evaluate candidate test vehicles and when appropriate, perform baseline performance and fleet testing on them

- **NEVs**
  - Initiate testing on two more GEM NEVs, one ZEN NEV, and one Miles Automotive NEV
  - Given the potential of this market and the expanding use of NEVs, the AVTA will support CARB and continue to test new entrants
Vehicle Testing Summary

• Continue to utilize testing partnerships to provide maximum test value to DOE
  – All testing activities are cost shared with private sector, such as the JPMorgan fleet that operates HEVs for the AVTA
  – All NEV and eGSE baseline performance testing is cost shared with manufacturers

• Battery testing results are provided to the energy storage technical team

• HEV testing results are provided to domestic OEMs via the vehicle simulation and analysis technical team every other month

• Testing results and life-cycle costs are used by vehicle modelers

• Partnering with private sector testers provides low-cost access to many testing facilities on a per-need basis
Vehicle Testing Summary – cont’d

- NEV testing for CARB supports higher vehicle standards in this vehicle segment
- AVTA testing results provide independent analysis of emerging technologies to Federal and other fleets that are early adaptors of advanced vehicle technologies
- Public use of AVTA webpages increases every year
Acknowledgement
This work is supported by DOE’s Vehicle Technologies Program
Hybrid Electric Systems Leader, Tien Duong
Vehicles and Systems Simulation and Testing Leader, Lee Slezak

Additional Information
http://avt.inl.gov
or
http://www1.eere.energy.gov/vehiclesandfuels/avta/

INL/CON-08-13848