Session 8: Introduction to Vehicle Telematics, Data Handling and Reporting for Different Purposes and Data-Intense Projects

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Telematics Definition

• Broad definition is:
  *Combination of computer science, telecommunications, and vehicles, with the goal of controlling a vehicle or collecting vehicle data*

• For PEVs (plug-in electric vehicles), goals include:
  – Benchmarking a technology and petroleum reduction benefits
  – Understanding use (mission) patterns, including the use of charging infrastructure

• For ICE vehicles (internal combustion engine), telematics can be used to determine replacement suitability by PEVs
**Telematics Trade-offs**

- Vehicle telematics systems can be designed to:
  - Support intense data collection activities from a small sample of vehicles (AVTA example)
    - Expensive, with high logging rates (0.01 seconds), and many variables
  - Support large fleet data collection activity (2 examples)
    - Must be low-cost per vehicle, with a minimal number of variables from a large sample
    - Often on a per-trip basis, not second-by-second
    - May include multiple data sources
  - Support vehicle-based information needs (Examples in Sessions 9 and 10 Case Studies)
    - May include an entire fleet on a per vehicle basis
    - Costs have to be a consideration
- Always balance data costs versus minimum information needs
Data Collection Rate Considerations

- **Per-trip data (lower costs)** can be designed to:
  - Benchmark per trip, per day, and per year mileage to support replacement potential and use
  - Determine where vehicles congregate day and night to support placement of charge infrastructure
  - Determine maintenance schedules
  - Document peak speeds and idle times

- **Second-by-Second data (higher costs)** may be needed to:
  - All of the above
  - Determine routes
  - Alert fleet manager of accidents
  - Support security needs
  - Quantify vehicle performance and operations

- **Always balance data costs versus minimum information needs**
AVTA Vehicle Testing: Small Sample Size, Data Intense, High Fidelity, Telematics Systems
Small Sample, High Fidelity PEV Data Collection

- INL manages the light-duty vehicle aspect of the DOE Advanced Vehicle Testing Activity (AVTA)
- High cost per PEV activity = $5,000+ data logger hardware per vehicle, plus cellular service, engineering, and back office costs
- Test vehicles with high petroleum reduction potential
  - Electric Vehicles (Full size, urban, and neighborhood)
  - Plug-In Hybrid Electric
  - Hybrid Electric & Idle-Stop
  - Alternative Fuel (CNG, H₂)
  - Advanced Internal Combustion
AVTA Testing & Data Collection Sequence

1. Purchase Vehicle (2 - 4 of each make/model)
2. Install On-Board Data Logger
   - 4,000 Miles for Break-In
3. Track Performance and Coast Down Testing
4. Dynamometer Testing
5. Data Collection During Fleet Operation
Telematics Use: AVTA Vehicle Performance Tests

• **Closed Track Performance Tests**
  – 0-60 mph, ¼ mile, 1 mile acceleration
  – Coast Down for road-load determination
  – Braking
  – Battery transients during tests
  – Testing performed by ETEC Labs

• **Chassis Dynamometer Tests**
  – Drive cycle based fuel economy or energy consumption/range
    • UDDS, HWFET, US06, SC03 (US EPA Cycles) at 20°F, 72°F, 95°F
  – Steady-state speed fuel economy/energy consumption, gradeability
  – Testing performed by Argonne National Laboratory
Telematics Use: AVTA Data – Fuel & Electricity

- Normally kWh captured onboard the vehicle
- Electricity fueling event noted by PEV via increase in battery state-of-charge
  - Mileage and date electronically collected
- Used to benchmark fuel used and miles driven = fuel efficiency
- Electricity metered by EVSE, collected from provider database, with unique access cards for each vehicle
Telematics Supports Collection of Depreciation, Maintenance and Operating Costs

- Purchase, residual, and sale prices captured
- Maintenance and mileage is recorded and compiled
- Reports detail every maintenance item
- Operating costs based on capital costs, fuel costs, maintenance costs, insurance, and state registration
On Road Data Collection via Telematics

- Data is collected, second-by-second, by a mixture of OBD-2 and ‘Normal’ CAN messages, and custom meters
  - Speed
  - Engine speed
  - Fuel consumption
  - Battery current
  - Battery voltage
  - Battery temperature
  - Air conditioning usage
  - Coolant temperature
  - Ambient temperature
  - Catalyst temperature
  - Brake on/off
  - Accelerator pedal position

- Charging data is also collected for Plug-In Electric Vehicles

- Other interesting data is collected, as available, depending on the vehicle
  - i.e. electric motor torque, electric motor speed, transmission gear, brake pressure, etc
Telematics For A PEV Model

- Each PEV model has a unique data collection model (variables, hardware, software)
- INL’s minimum standard PEV data model has 30 variables
- At any one time, more than 25 different data models are being used, based on PEV technology and OEM data systems

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<td>BattPKFanSpdTgt</td>
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<td>BattSideVol</td>
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<td>Odometer</td>
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<td>PplsnSysAtv</td>
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<td>VEH_SPEED</td>
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<td>Km/h</td>
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Telematics For A Second PEV Model

• One benchmark project of 110 PEVs involved 91 unique metrics
• Onboard data collection sampled at 1/100 second, stored at 1/10 second
• Significant onboard data storage required
• Significant cellular bandwidth required
• Costs multiplied with data storage, quality controls, processing and reporting requirements
Telematics Use: Reporting

- Reports all link to telematics systems and databases
  - Baseline Performance Testing
  - Fleet Testing Fuel Economy
  - Maintenance History
  - On-Road Performance Results
  - Battery Report
  - Fact Sheet
  - Other reports for focused analysis
Fleet and Infrastructure Demonstrations: Small Number of Data Variables, Very Large Sample Size, Multiple Data Sources & Telematics Systems
Largest Use of Telematics for PEV / Infrastructure Research Used During ARRA Projects

Charging infrastructure demonstrations data totaled 25,000 PEVs and EVSE

- The EV Project
  - 8,300 Leafs, Volts and Smart EVs
  - 12,400 EVSE and (DCFC)
  - 124 million test miles
  - 4.2 million charge events

- ChargePoint America
  - 4,600 EVSE
  - 1.8 million charge events

- Using the $5,000 data logger would have cost $41.5 million just for the hardware
Telematics For Large Projects - EV Project

• Low cost per PEV / EVSE, with very large data samples
• Used existing OEM telematics systems (OnStar, Car Wings, and Daimler system)
  – Required negotiating several NDAs
• Develop lessons learned to support the future streamlined deployment of grid-connected electric drive vehicles
Diverse Locations

- Geographically broad data collection area required wireless and rigorous telematics systems
Infrastructure Reporting

• PEVs, EVSE and DCFC data from eight sources
• INL analyzed grid use and vehicle data for reporting
• **Supports the “what, when, and where” of grid infrastructure deployment decisions**
  – Documents impact when public EVSE costs money
  – Documents economic incentives to shift charge times
  – Documents drivers’ real-world grid-use decisions
  – Documents BEV versus PHEV grid use
  – Documents regional grid-use variations
  – Provides electric utilities with grid demand information specific to their service territory
EVSE Data Parameters Collected

1. Connect and disconnect times
2. Charge start and end times
3. Max instantaneous peak power
4. Average power
5. Total energy (kWh) per charging event
6. Rolling 15 minute average power
7. Date/time stamp
8. Unique ID for charging event
9. Unique ID for the EVSE

• And other non-dynamic EVSE information (GPS location, EVSE type, etc.)

• EVSE data collected for each charge event
Vehicle Data Parameters Collected

1. Odometer
2. Battery state of charge
3. Date/Time Stamp
4. Vehicle ID
5. GPS (longitude and latitude)
   - And other non-dynamic PEV information (PEV model, etc.)
   - Recorded for each key-on and key-off event
EV Project Data Complexity Was Significant

- Blended multiple data streams from multiple sources, all on different delivery schedules
- Just The EV Project had 44 databases
- Hundreds of algorithms and thousands of lines of code were required to generate 56,000 data parameters for 40 different monthly and quarterly reports
- Trade-offs between data logger costs and back office complexity and costs
eVMT (electric Vehicle Miles Traveled) Analysis: Data Variables Small, Very Large Sample Size, Multiple Data Sources & Telematics System
eVMT Used OEM Telematics

• Calculated electric vehicle miles traveled (eVMT) for plug-in hybrid and battery electric vehicles
  – Ford Fusion Energi, Focus EV and C-Max Energi, Honda Accord PHEV and Fit EV, Toyota Prius PHEV and Leaf EV, Chevrolet Volt PHEV

• Data from the public’s on-road vehicle operation
  – 158,468,000 miles from 21,600 vehicles
  – Across the U.S. (i.e. widely varying regions and climates)
## eVMT Analysis Results

<table>
<thead>
<tr>
<th></th>
<th>Nissan LEAF *</th>
<th>Chevrolet Volt *</th>
<th>Ford Focus Electric</th>
<th>Ford C-Max Energi</th>
<th>Ford Fusion Energi</th>
<th>Honda Fit EV</th>
<th>Honda Accord PHEV</th>
<th>Toyota Prius PHEV</th>
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<tbody>
<tr>
<td>Number of Vehicles</td>
<td>4,039</td>
<td>1,867</td>
<td>2,193</td>
<td>5,368</td>
<td>5,803</td>
<td>645</td>
<td>189</td>
<td>1,523</td>
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<td>Number of Vehicle</td>
<td>35,294</td>
<td>20,545</td>
<td>12,622</td>
<td>38,096</td>
<td>32,022</td>
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<tr>
<td>Total Vehicle Miles</td>
<td>28,520,792</td>
<td>20,950,967</td>
<td>10,043,000</td>
<td>39,376,000</td>
<td>33,098,000</td>
<td>4,912,920</td>
<td>1,794,494</td>
<td>19,772,530</td>
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<td>Traveled VMT (miles)</td>
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<tr>
<td>Total Calculated</td>
<td>28,520,792</td>
<td>15,599,508</td>
<td>10,043,000</td>
<td>12,918,000</td>
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<td>Electric Vehicle Miles</td>
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<td>Avg. Monthly VMT</td>
<td>808.1</td>
<td>1,019.8</td>
<td>795.7</td>
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<td>1,033.6</td>
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<td>Avg. Monthly eVMT</td>
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<td>12,238</td>
<td>9,548</td>
<td>12,403</td>
<td>12,403</td>
<td>9,680</td>
<td>14,986</td>
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<td>estimated Annual eVMT</td>
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</table>

Minimally Charged Vehicles are *Not Excluded* from analysis. These data include 14% of Accord PHEVs that achieve between 0-50 monthly eVMT.

eVMT and VMT

Distance Bins: =0, >0 to 100, >100 to 200, >300 to 400, >400 to 500, etc.
Handling Telematics Data Internally
INL pulls with encrypted transmission

Parameters range check
Lame data check
Missing/empty parameter check
Conservation of energy check
SOC continuity
Transfer completion

Internal data quality reports

INL Protect Enclave - Project member access only
INL Internal firewall
INL DMZ Firewall

Fleet summary reports - public
AVT.INL.GOV

Vehicle and Charger Data
OEM Data Management Systems
OEM pushes using FTPS/SFTP
INL transmits reports to DOE And OEMs
Reports posted on WWW

Protected Data

Project FTPS/SFTP Server
Access restricted by firewall rules

INL Pulls with encrypted transmission

Project Team

INL Internal firewall

INL Protect Enclave - Project member access only
Data Warehouse Management

INL Vehicle Data Management System

File server

SQL Server data warehouse

Report generator

Individual vehicle reports

Fleet summary Reports - Public

Focused technical analyses and custom reports
Summary

• **Single vehicle data logger total annual costs** (hardware, cellular, labor – reporting, engineering, management) about $9,000 per vehicle
  – Deep dive, engineering study. Data costs not relevant
  – High per vehicle cost balanced by small sample size

• **Fleet type of telematics system total annual costs** (hardware, cellular, labor – reporting, engineering, management) about $725 per PEV and EVSE per year
  – Large sample required low cost per logger

• For both methods, signal validation and data quality assurance processes produce reliable results

• **Always balance data costs versus minimum information needs**

• **Is the use of OEM telematic systems an option with the Navy’s BEVs?**