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

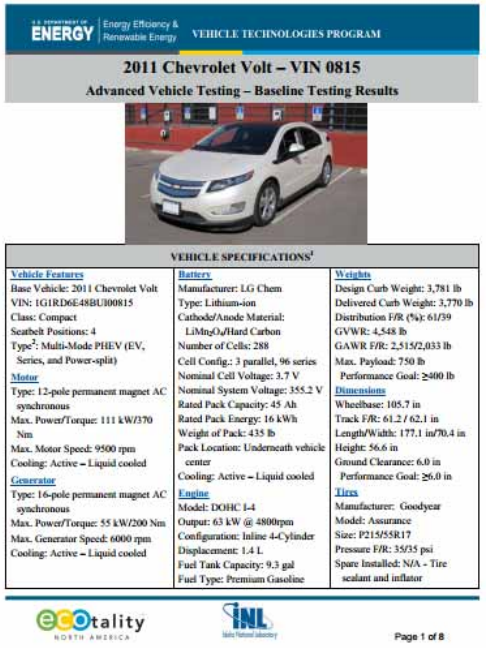
Data Collection Rate Considerations

- **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, H_2)**
  - **Advanced Internal Combustion**



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2011 Chevrolet Volt – VIN 0815

Advanced Vehicle Testing – Baseline Testing Results

VEHICLE SPECIFICATIONS[1]

Vehicle Features	Battery	Weights
Base Vehicle: 2011 Chevrolet Volt VIN: 1G1RD6E48BU800815 Class: Compact Seatbelt Positions: 4 Type[2]: Multi-Mode PHEV (EV, Series, and Power-split)	Manufacturer: LG Chem Type: Lithium-ion Cathode/Anode Material: $LiMn_2O_4$/Hard Carbon Number of Cells: 288 Cell Config.: 3 parallel, 96 series Nominal Cell Voltage: 3.7 V Nominal System Voltage: 355.2 V Rated Pack Capacity: 45 Ah Rated Pack Energy: 16 kWh Weight of Pack: 435 lb Pack Location: Underneath vehicle center Cooling: Active – Liquid cooled	Design Curb Weight: 3,781 lb Delivered Curb Weight: 3,770 lb Distribution F/R (%): 61/39 GVWR: 4,548 lb GAWR F/R: 2,515/2,033 lb Max. Payload: 750 lb Performance Goal: ≥400 lb
Motor Type: 12-pole permanent magnet AC synchronous Max. Power/Torque: 111 kW/370 Nm Max. Motor Speed: 9500 rpm Cooling: Active – Liquid cooled	**Engine** Model: DOHC I-4 Output: 63 kW @ 4800rpm Configuration: Inline 4-Cylinder Displacement: 1.4 L Fuel Tank Capacity: 9.3 gal Fuel Type: Premium Gasoline	**Dimensions** Wheelbase: 105.7 in Track F/R: 61.2 / 62.1 in Length/Width: 177.1 in/70.4 in Height: 56.6 in Ground Clearance: 6.0 in Performance Goal: ≥6.0 in
Generator Type: 16-pole permanent magnet AC synchronous Max. Power/Torque: 55 kW/200 Nm Max. Generator Speed: 6000 rpm Cooling: Active – Liquid cooled		**Tires** Manufacturer: Goodyear Model: Assurance Size: P215/55R17 Pressure F/R: 35/35 psi Spare Installed: N/A - Tire sealant and inflator

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AVTA Testing & Data Collection Sequence

Purchase Vehicle (2 - 4 of each make/model)

Install On-Board Data Logger

4,000 Miles for Break-In

Track Performance and Coast Down Testing

Dynamometer Testing

Data Collection During Fleet Operation

End-of-test Component and Performance Evaluation

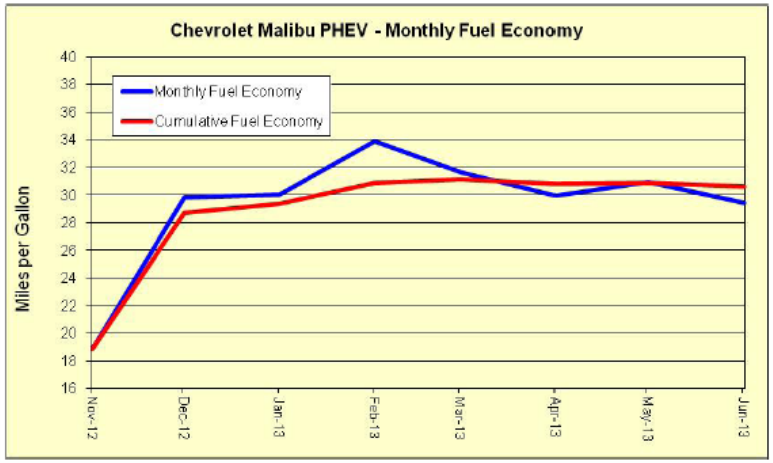
Telematics Use: AVTA Vehicle Performance Tests

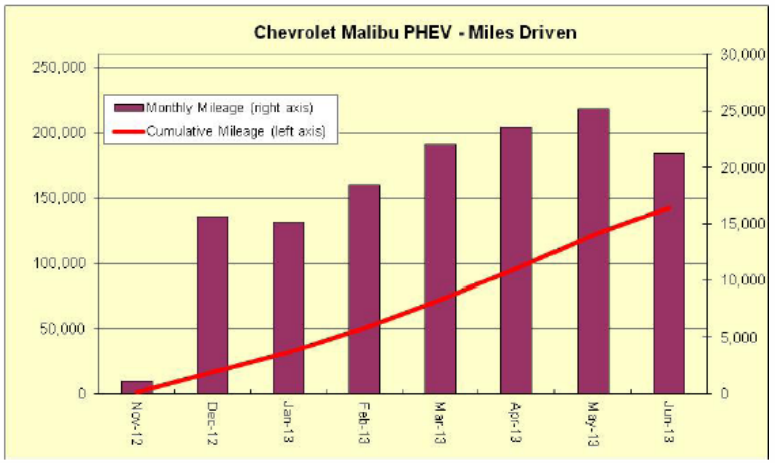
- **Closed Track Performance Tests**
  - 0-60 mph, ¼ mile, 1 mile acceleration
  - Coast Down for road-load determination
  - Braking
  - Battery transients during tests
  - Testing performed by ETEC Labs

- **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

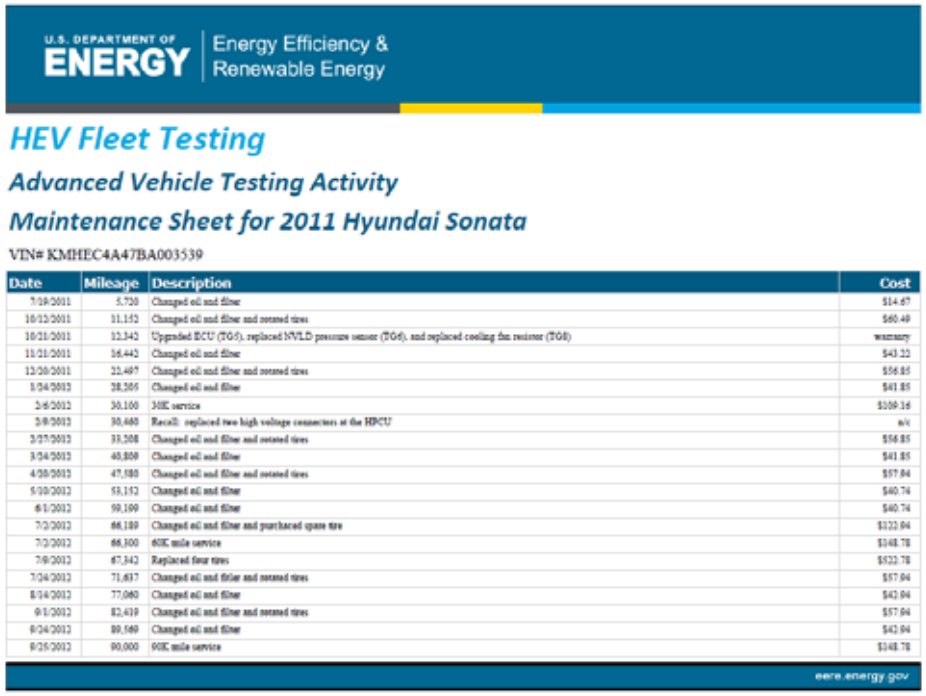
- Normally kWh captured onboard the vehicle
- Electricity fueling event noted by PEV via increase in battery state-of-charge
  - Mileage and date electronically collected
- Used to benchmark fuel used and miles driven = fuel efficiency
- Electricity metered by EVSE, collected from provider database, 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**



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HEV Fleet Testing

Advanced Vehicle Testing Activity

Maintenance Sheet for 2011 Hyundai Sonata

VIN# KMHEC4A47BA003539

Date	Mileage	Description	Cost
7/19/2011	5,720	Changed oil and filter	$54.67
10/12/2011	11,152	Changed oil and filter and rotated tires	$60.49
10/21/2011	12,342	Upgraded ECU (TG5), replaced NVLD pressure sensor (TG6), and replaced cooling fan resistor (TG8)	warranty
11/21/2011	16,442	Changed oil and filter	$43.22
12/20/2011	22,497	Changed oil and filter and rotated tires	$56.85
1/24/2012	28,505	Changed oil and filter	$41.85
2/6/2012	30,100	30K service	$109.16
2/9/2012	30,460	Recall: replaced two high voltage connectors at the HPCU	n/c
3/27/2012	33,208	Changed oil and filter and rotated tires	$56.85
3/24/2012	40,800	Changed oil and filter	$41.85
4/20/2012	47,180	Changed oil and filter and rotated tires	$57.84
5/10/2012	53,152	Changed oil and filter	$40.74
6/1/2012	59,109	Changed oil and filter	$40.74
7/2/2012	66,189	Changed oil and filter and purchased spare tire	$122.84
7/2/2012	66,300	60K mile service	$148.78
7/9/2012	67,342	Replaced four tires	$522.78
7/24/2012	71,637	Changed oil and filter and rotated tires	$57.84
8/14/2012	77,060	Changed oil and filter	$42.84
9/1/2012	82,419	Changed oil and filter and rotated tires	$57.84
9/24/2012	89,589	Changed oil and filter	$42.84
9/25/2012	90,000	90K mile service	$148.78

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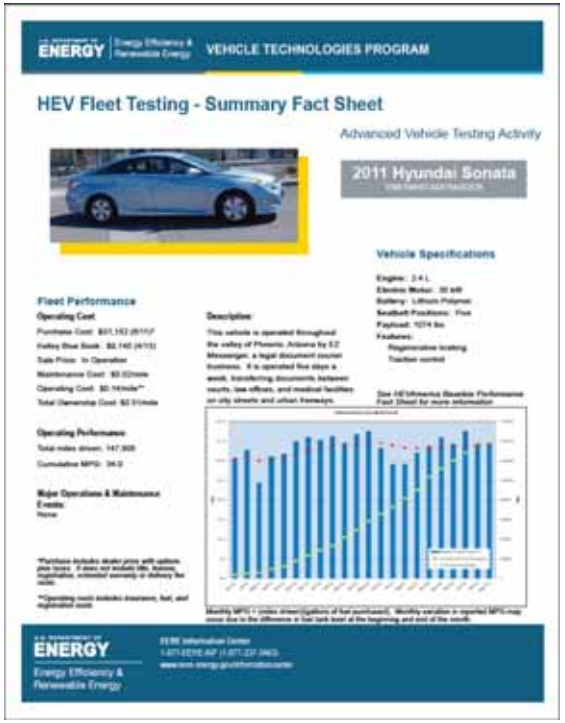

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HEV Fleet Testing - Summary Fact Sheet

Advanced Vehicle Testing Activity

2011 Hyundai Sonata

Vehicle Specifications

Fleet Performance

Operating Cost

Operating Performance

Major Operations & Maintenance Events

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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**

Signals	Column1	Units
AMB_TEMP		deg C
BATT_VOLT	12v bat volt	Volts
BattCoolFlwRate		%
BattCoolHtrCntrl		%
BattPkFanSpd		%
BattPkFanSpdTgt		%
BattSideCurr	DC bus side current during charge	Amps
BattSideVolt	DC bus side volt during charge	Volts
BattThrmState	Battery thermal state	
Cell_NumMaxVlt	Cell number of max volt 0 to 11	
Cell_NumMinVlt	Cell number of min volt 0 to 11	
CellTmpAvg		deg C
CellTmpMax		deg C
CellTmpMin		deg C
CellVltMax		Volts
CellVltMin		Volts
ChlrInletTemp	AC chiller inlet temp	deg C
ChrgSustn	Charge sustaining bit	
CmdIgnStat	Ignition status	
CmndAxleTorqPrdtd	Axle torque	Nm
CompStat	Compressor Status	
COOLANT_TEMP	Engine coolant temp	deg C
EnblChrg	Enable Charge event 1 = yes 0 = no	
ENG_RPM	Engine speed	RPM
EVSE_PilotStat		
HEV_RadFan	Cooling Fan	%
HVBatCrnt	HV Battery current	Amps
HVBatSOC	HV Battery SOC	%
HVBattClgInletTemp	Battery thermal cooling inlet temp	
HVBattClgOutletTemp	Battery thermal cooling outlet temp	
HVBatVlt	HV Battery voltage	Volts
J1772_ICA	J1772 input current available	Amps
J1772Stat		
Mod_NumMaxVlt	Module number for max voltage 0 to 7	decimal
Mod_NumMinVlt	Module number for min voltage 0 to 7	decimal
OBC_Md	Charging mode	
ODO	odometer	Km
PDL_POS	Accel pedeal position	%
ProxStat		
PrplsnSysAtv	Propsultion system active - drive cycle	
VEH_SPEED		Km/h

Telematics For A Second PEV Model

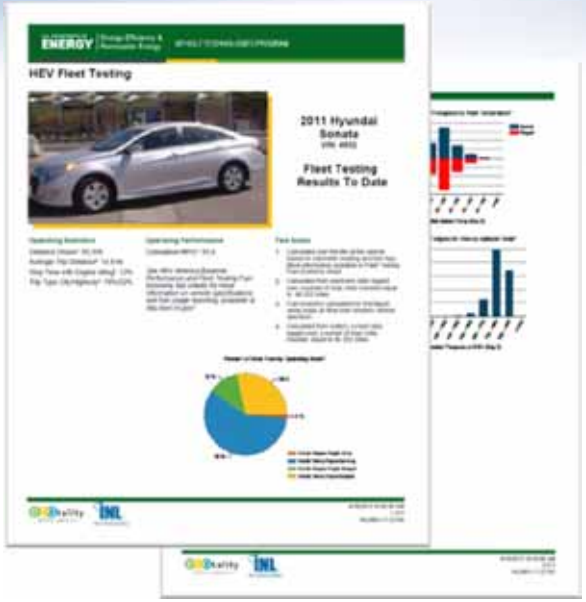
- **One benchmark project of 110 PEVs involved 91 unique metrics**
- **Onboard data collection sampled at 1/100 second, stored at 1/10 second**
- **Significant onboard data storage required**
- **Significant cellular bandwidth required**
- **Costs multiplied with data storage, quality controls, processing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

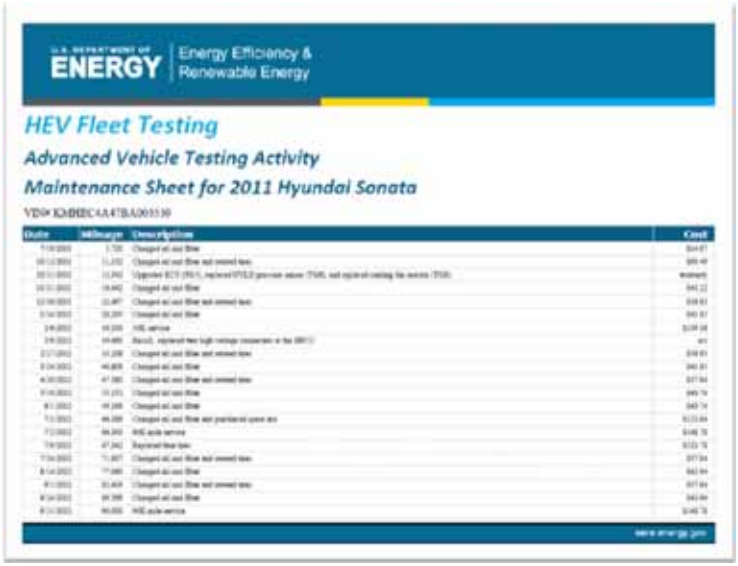
DS-PHEV DOE Signals

Signals	Description	Bits	Message	Potential Values	Signal Sample Rate (ms)
AC_GridTm	On-Board Charger Total AC Grid Support Time (Applicable to Vehicle-to-Grid)	16	OBCM_3D4h	0 - 196602 seconds	1000
AC_GridTmL	On-Board Charger Total AC Grid Support Time - Long (Cumulative) (Applicable to Vehicle-to-Grid)	16	OBCM_3D6h	0 - 65534 minutes	1000
AC_PwrFctr	A/C Power Factor (Calculated Signal - based on AC Volt and Current Input to Charger)	7	ProxInfo	0 - 1	1000
AC_SEL	Customer A/C Selection	1	KLA_410h	0 = No/SNA 1= Yes	1000
AC_SideCurr	AC Side (Input to Charger) Current	16	OBCM_3D2h	-50 - +65 Amps	1000
AC_SideVolt	AC Side (Input to Charger) Voltage	16	OBCM_3D2h	0 - 1000 Volts	1000
AccActPos	Accelerator Pedal Actual Position	8	PPEI_Engine_General_Status_1	0 - 100.000035 %	1000
ACCElecPow	A/C Compressor Electrical Power	8	EAC_100	0 - 10.16 KW	1000
AccPwrMdlInpCurr	Accessory Power Module Input Current	8	PPEI_Acc_Pwr_Mod_General_Status	0 - 25.5 Amps	1000
AccPwrMdlLowVoltage	Accessory Power Module Low Voltage	8	PPEI_Acc_Pwr_Mod_General_Status	0 - 20 Volts	1000
AccPwrMdlLowVoltOutCurr	Accessory Power Module Low Voltage Output Current	7	PPEI_Acc_Pwr_Mod_General_Status	0 - 254 Amps	1000
AMB_TEMP_AVG	Averaged Ambient Temperature	16	KOMBI_408h	-40 - +85 degC	1000
AvgFuelLvl	Average Filtered Fuel Level in Liters	9	CGW_2	0 - 255 L	1000
BalMd	Battery Pack Balance Mode In Progress	1	PHEV_210h	0 = False 1 = True	1000
BalTm	Balance Time for this specific balance of Battery Pack	8	PHEV_212h	0 - 2400 Minutes	1000
BATT_VOLT	System Voltage (12V Battery Voltage)	8	FCM_1	5 - 18 Volts	1000
BattSideCurr	Battery Side (Output of Charger) Current	16	OBCM_3D2h	-50 - +65 Amps	1000
BattSideVolt	Battery Side (Output of Charger) Voltage	16	OBCM_3D2h	0 - 1000 Volts	1000
BP_PackNum	Battery Pack Number	16	BP_PHEV_50Fh	0 - 65534	1000
CellTmpAvg	Average of the Temperature of all 96 cells in the Battery Pack	8	High_Volt_Battery_Information_2	-40 - +85 degC	1000
CellTmpMax	Temperature of the cell with the Maximum Temperature of all 96 cells in the Battery Pack	8	High_Volt_Battery_Information_2	-40 - +85 degC	1000
CellTmpMin	Temperature of the cell with the Minimum Temperature of all 96 cells in the Battery Pack	8	High_Volt_Battery_Information_2	-40 - +85 degC	1000
CellVltMax	Voltage of the cell with the Maximum Voltage of all 96 cells in the Battery Pack	13	PHEV_210h	0 - 5 Volts	1000
CellVltMin	Voltage of the cell with the Minimum Voltage of all 96 cells in the Battery Pack	13	PHEV_210h	0 - 5 Volts	1000
ChrgCurrAval	Output Charge Current available from the charger	8	OBCM_310h	0 - 63.5 Amps	1000
ChrgrCntctrVlt	Charger Contactor Voltage	9	PHEV_212h	0 - 511 Volts	1000
ChrgSustn	Charge Sustain Mode Status (True=1)	1	HCP25	1 = True 0 = False	1000
CmdIgnStat	Commanded Ignition Switch Status	3	ZGW_248h	0 = IGN_LK (Ignition Lock) 1 = IGN_OFF (Ignition Off - 5 pos SW) 2 = IGN_ACC (Ignition Accessory - 5 pos SW) 3 = IGN_OFF_ACC (Ignition Off & Acc - 4 pos SW) 4 = IGN_RUN (Ignition Run) 5 = IGN_START (Ignition Start) 7 = IGN_SNA (Signal Not Available)	1000
CompStat	A/C Compressor Status	2	EAC_100	0 = COMP_OFF (Compressor Off) 1 = COMP_ON (Compressor On) 2 = COMP_DEG (Compressor Degraded) 3 = COMP_SNA (Compressor Request SNA)	1000
COOLANT_TEMP	Engine Coolant Temperature	8	MS_608h	-40 - +214 degC	1000
DecelFuelCutAct	Deceleration Fuel Shut Off Active	1	MS_210h	1 = Active 0 = Not Active/SNA	1000
EnblChrg	Enable charging command from Hybrid Control Processor	1	High_Volt_Contactor_Control	0 = Disable 1 = Enable	1000
EnblDisChgMd	Enable Discharge Mode command from Hybrid Control Processor	1	High_Volt_Contactor_Control	0 = No Action 1 = Discharge Request	1000
ENG_RPM	Engine RPM	16	MS_308h	0 - 65534 RPM	1000
EngActStdyStTorq	Engine Actual Steady State Torque	12	EngTrqStat	-848 - + 1199.5 Nm	1000
EngSpd	Engine Speed	16	PPEI_Engine_General_Status_1	0 - 16383.75 RPM	1000
EstChrgTm	Estimated Active Charging time as calculated by the Hybrid Control Processor	8	HCP100	0 - 3600 Minutes	1000
EVSE_PilotStat	EVSE Pilot Status	2	OBCM_310h	0 = NO_EVSE (EVSE Not Present) 1 = CP_DET (Control Pilot Detected) 2 = VOOR (Voltage Out of Range) 3 = SNA (Signal Not Available)	1000
FUEL_USED	Vehicle Fuel Consumption	16	MS_608h	0 - 14200 µl/100ms	100
HCP_CurrRq	Hybrid Control Processor Current Request to the Onboard Charger	8	HCP25	-32 - +31.5 Amps	1000
HCP_DlyTmr	Delay Timer sent by the Hybrid Control Processor to the DRM - used for setting an internal DRM delay timer	4	HCP100	0 = ZERO (Minutes - 0) 1 = FIFTEEN (Minutes - 15) 2 = THIRTY (Minutes - 30) 3 = FOURTYFIVE (Minutes - 45) 4 = ONE (Hours - 1) 5 = TWO (Hours - 2) 6 = FOUR (Hours - 4) 7 = EIGHT (Hours - 8) 8 = SIXTEEN (Hours - 16) 9 = TWOFOUR (Hours - 24) 10 = FOUREIGHT (Hours - 48) 14 = PTS (No Delay - Prepare to Sleep) 15 = SNA (Signal Not Available)	1000
HVBatChrgPow	High Voltage Battery Available Charge Power	8	High_Volt_Battery_Information_3	0 - 63.75 KW	1000
HVBatDschrgPow	High Voltage Battery Available Discharge Power	8	High_Volt_Battery_Information_3	0 - 63.75 KW	1000
HVBatCrnt	High Voltage Battery current	10	High_Volt_Battery_Information_1	-256 - +255.5 Amps	1000
HVBatSOC	High Voltage Battery State of Charge	8	High_Volt_Battery_Information_3	0 - 100.000035%	1000
HVBatVlt	High Voltage Battery voltage	9	High_Volt_Battery_Information_1	0 - 511 Volts	1000
HybTransSt	Hybrid Transmission State	8	ETEI_Hybrid_General_Status_1	0 = INIT (Init) 1 = Neutral_Stable_State (Neutral stable state) 2 = EVT_Mode1_Stable_State (EVT Mode1 stable state) 3 = EVT_Mode2_Stable_State (EVT Mode2 stable state) 4 = Gear1_Stable_State (Gear1 stable state) 5 = Gear2_Stable_State (Gear2 stable state) 6 = Gear3_Stable_State (Gear3 stable state) 7 = Gear4_Stable_State (Gear4 stable state) 8 = G1_G2_SP (Gear1 to Gear2 Speed Phase) 9 = G1_G2_TP (Gear1 to Gear2 Torque Phase) 10 = G2_G1_SP (Gear2 to Gear1 Speed Phase) 11 = G2_G1_TP (Gear2 to Gear1 Torque Phase) 12 = G2_G3_SP (Gear2 to Gear3 Speed Phase) 13 = G2_G3_TP (Gear2 to Gear3 Torque Phase) 14 = G3_G2_SP (Gear3 to Gear2 Speed Phase) 15 = G3_G2_TP (Gear3 to Gear2 Torque Phase) 16 = G3_G4_SP (Gear3 to Gear4 Speed Phase) 17 = G3_G4_TP (Gear3 to Gear4 Torque Phase) 18 = G4_G3_SP (Gear4 to Gear3 Speed Phase) 19 = G4_G3_TP (Gear4 to Gear3 Torque Phase) 20 = EVT_M1_Gear1_SP (EVT Mode1 to Gear1 Speed Phase) 21 = EVT_M1_Gear2_SP (EVT Mode1 to Gear2 Speed Phase) 22 = EVT_M2_Gear2_SP (EVT Mode2 to Gear2 Speed Phase)	1000
InptVolt	Input Source Voltage (AC Side)	10	OBCM_310h	0 - 600 Volts	1000
J1772_ICA	J1772 Input Current Available - Duty Cycle of the PWM from the EVSE determines the available charge current	9	OBCM_310h	0 - 300 Amps	1000
J1772Stat	J1772 Status broadcasted by the On-Board Charger	3	OBCM_310h	0 = STATE_A (Vehicle Not Connected) 1 = STATE_B (Connected , Not Ready) 2 = STATE_C (Connected, Ready, Ventilation Not required) 3 = STATE_D (Connected, Ready, Ventilation required) 4 = STATE_E (EVSE Issue 1) 5 = STATE_F (EVSE Issue 2) 7 = SNA (Signal Not Available)	1000
KWattHrs_Chg	KiloWatt Hours of Battery Pack Charge - Cumulative	24	BP_PHEV_504h	0 - 36000 KWh	1000
KWattHrs_DisChg	KiloWatt Hours of Battery Pack Discharge - Cumulative	24	BP_PHEV_504h	0 - 36000 KWh	1000
MtrA_Spd	Motor A Speed	15	ETEI_Trans_Clutch_Commands_2	-16384 - +16383 RPM	1000
MtrB_Spd	Motor B Speed	15	ETEI_Trans_Clutch_Commands_2	-16384 - +16383 RPM	1000
OBC_ChrgTm	On-Board Charger Total Charging Time	16	OBCM_3D4h	0 - 196602 Seconds	1000
OBC_ChrgTmL	On-Board Charger Total Charging Time - Long (Cumulative)	16	OBCM_3D6h	0 - 65534 Minutes	1000
OBC_Ctrl_Mth	On-Board Charger Commanded Control Method	2	HCP25	0 = CURRENT (Current) 1 = VOLTAGE (Voltage) 2 = POWER (Power) 3 = SNA (Signal Not Available)	1000
OBC_IdleTm	On-Board Charger Idle Time	16	OBCM_3D4h	0 - 196602 Seconds	1000
OBC_IdleTmL	On-Board Charger Idle Time - Long (Cumulative)	16	OBCM_3D6h	0 - 65534 Minutes	1000
OBC_Md	On-Board Charger Mode	3	OBCM_310h	0 = IDLE (Idle) 1 = CHARGE (Charge the HV battery) 2 = AC_PNL (AC Power Panel Mode) 3 = AC_GRD (AC Grid Mode) 4 = UTC (Unable to Charge) 5 = STOP (Stop due to fault) 7 = SNA (Signal Not Available)	1000
OBC_MdRq	On-Board Charger Mode Request from Hybrid Control Processor	3	HCP25	0 = IDLE (Idle) 1 = CHARGE (Charge the HV battery) 2 = AC_PNL (AC Power Panel Mode) 3 = AC_GRD (AC Grid Mode) 7 = SNA (Signal Not Available)	1000
OBCM_WU_Stat	On-Board Charger Wakeup Status	2	OBCM_310h	0 = WU_FLT (OBCM Wake-up is faulted) 1 = OFF (OBCM Wake-up is Off) 2 = ON (OBCM Wake-up is On) 3 = SNA (Signal Not Available)	1000
ODO	Odometer Reading	24	CGW_1	0 - 1677721.4 Km	1000
PcmBrkSw	Powertrain Control Module Brake Switch Status	2	MS_212h	0 = BRAKE_OFF (Brake Not Operated) 1 = BRAKE_ON (Brake Operated) 3 = SNA (Signal Not Available)	1000
PDL_POS	Throttle Pedal Position (Calculated)	8	MS_210h	0 - 100 %	1000
PlndAvlDays	Planned Availability - Days (Delta days from current time to scheduled charging time as determined by the DRM)	4	HCP_PlndAvl	0 - 14 Days	1000
PlndAvlTm	Planned Availability - Minutes (Delta minutes, in addition to days, from current time to scheduled charging time as determined by the DRM)	9	HCP_PlndAvl	0 - 1440 Minutes	1000
PlndSOC	Planned End SOC for the HV Battery	8	HCP_PlndAvl	0 - 100 %	1000
PlugInStat	Plugged In Status	3	PHEV_210h	0 = NOT_READY (Not ready) 1 = READY (Ready for command) 2 = CAC (Charge - Allow Current) 3 = CDC (Charge - Disallow Current) 4 = DAC (Discharge - Allow Current) 5 = DDC (Discharge - Disallow Current) 6 = COMPLETE (Complete) 7 = SNA (Signal not available)	1000
PP_FltInd	Power Panel Fault Indicator	2	OBCM_310h	0 = IND_LMP_OFF (Indicator lamp off) 1 = IND_LMP_ON (Indicator lamp on) 2 = IND_LMP_FLASH (Indicator lamp flashing) 3 = SNA (Signal not available)	1000
PP_Stat	Power Panel Status	4	OBCM_310h	0 = PPOFF (PP Off) 1 = RQ_PP_ON (Request PP On) 2 = PPCO (PP contactors open) 3 = PPCCNV (PP contactors closed, no voltage available) 4 = PPCCV (PP contactors closed, voltage available) 5 = PPIF (PP internal Fault) 6 = PPCF (PP GFCI or end-user fault) 7 = PPOC (PP end user overcurrent) 15 = SNA (Signal not available)	1000
PPOC_PhaseA	Power Panel Output Current - Phase A	7	PP_Stat	0 - 50 Amps	1000
PPOC_PhaseB	Power Panel Output Current - Phase B	7	PP_Stat	0 - 50 Amps	1000
PPOV_PhaseA	Power Panel Output Voltage - Phase A	9	PP_Stat	0 - 150 Volts	1000
PPOV_PhaseB	Power Panel Output Voltage - Phase B	9	PP_Stat	0 - 150 Volts	1000
PRND_STAT	PRND Status	3	GS_418h	0 = LVR_P (Lever in position "P") 1 = LVR_R (Lever in position "R") 2 = LVR_N (Lever in position "N") 4 = LVR_D (Lever in position "D") 5 = NOT_R (Not in reverse - manual trans only) 7 = LVR_SNA (Signal not available)	1000
ProxStat	Proximity (plug-in) status	2	OBCM_310h	0 = NO_PROX (Proximity not present) 1 = PROX (Proximity present) 2 = VOOR (Voltage Out of range) 3 = SNA (Signal not available)	1000
PrplsnSysAtv	Propulsion System Status	1	ETEI_Hybrid_General_Status_1	0 = Not Active/SNA 1 = Active	1000
PwrPnlTm	On-Board charger total power panel time	16	OBCM_3D4h	0 - 196602 Seconds	1000
PwrPnlTmL	On-Board Charger total power panel time - Long (Cumulative)	16	OBCM_3D6h	0 - 65534 Minutes	1000
RdyForChrg	Ready for Charge - from Battery Pack Control Module	1	PHEV_210h	0 = False 1 = True	1000
RdyForDsChrg	Ready for Discharge - from Battery Pack Control Module	1	PHEV_210h	0 = False 1 = True	1000
SysPwrMd	System Power Mode	2	PPEI_Platform_General_Status	0 = C_OFF (Off) 1 = C_ACC (Accessory) 2 = C_RUN (Run) 3 = C_RQ (Crank Request)	1000
TotChrgTm	Total Charge Time (including delays)	8	PHEV_212h	0 - 2400 Minutes	1000
VEH_SPEED	Vehicle Speed	16	VEH_SPEED	0 - 511.984 Km/Hr	1000
VIN_DATA	VIN Digits	56	VIN		1000
VoltFreq60	Input AC Voltage Frequency	1	ProxInfo	0 = 50 Hz 1 = 60 Hz	1000
VoltPhase3	Input AC Voltage Phase	1	ProxInfo	0 = 1 Phase 1 = 3 Phase	1000
VoltTypAC	Input AC Voltage Type	1	ProxInfo	0 = DC 1 = AC	1000
WHrAC	Watt Hours AC Power (Calculated - AC Charge used per event)	16	OBCM_3D9h	0 - 65534 WHrs	1000
WHrChrg	Watt Hours of Charge (Calculated - Output of charger - Per Event)	16	OBCM_3D9h	0 - 65534 WHrs	1000

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**

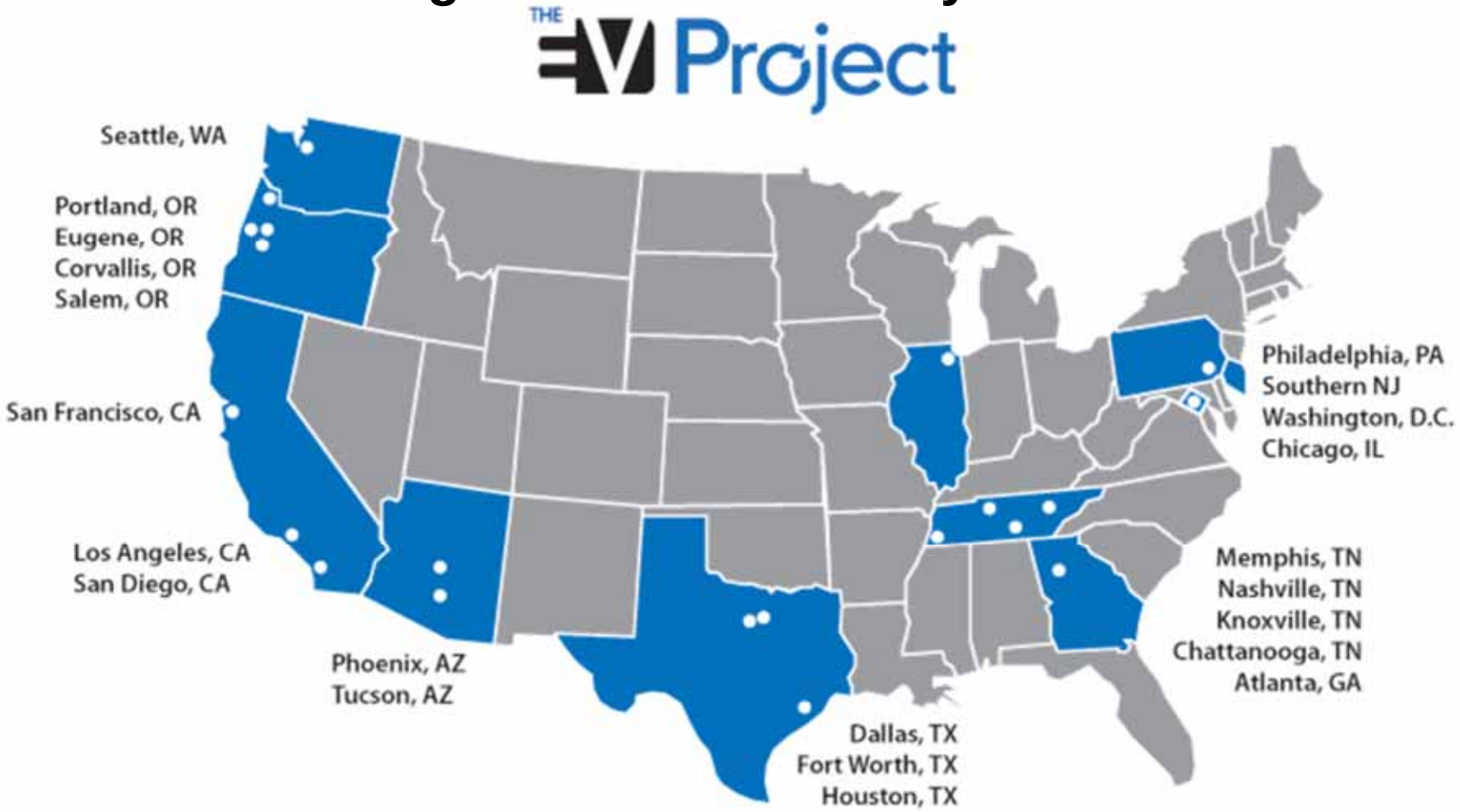
- **Using the $5,000 data logger would have cost $41.5 million just for the hardware**

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

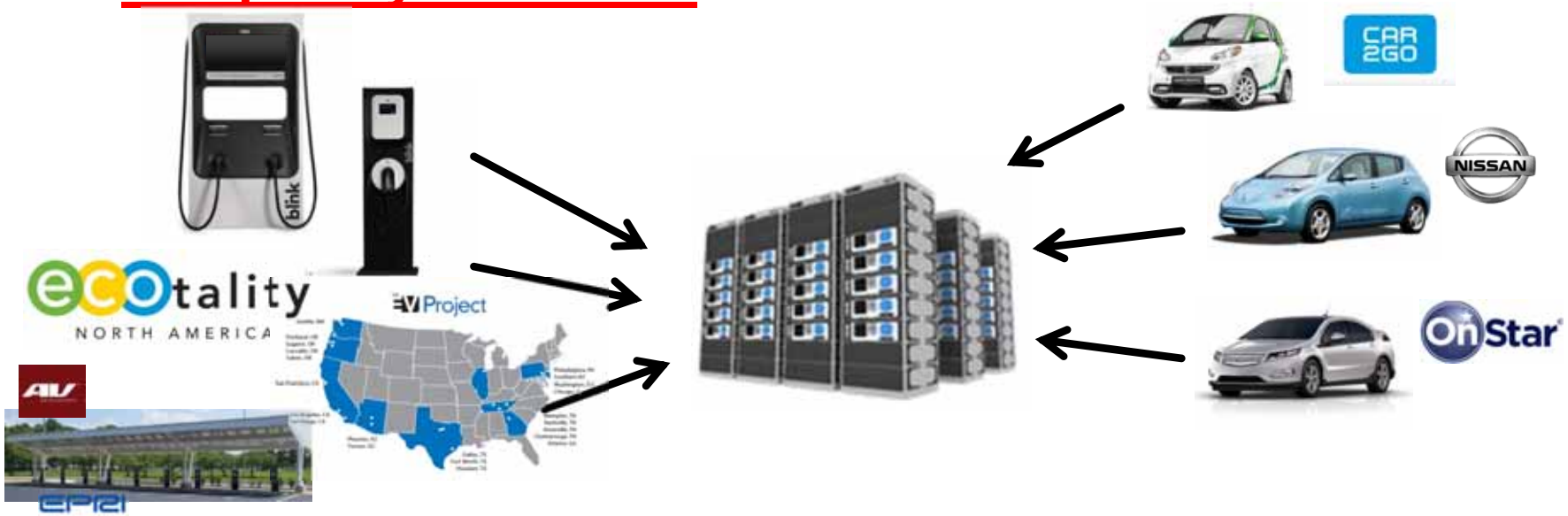
Vehicle Data Parameters Collected

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

Idaho National Laboratory

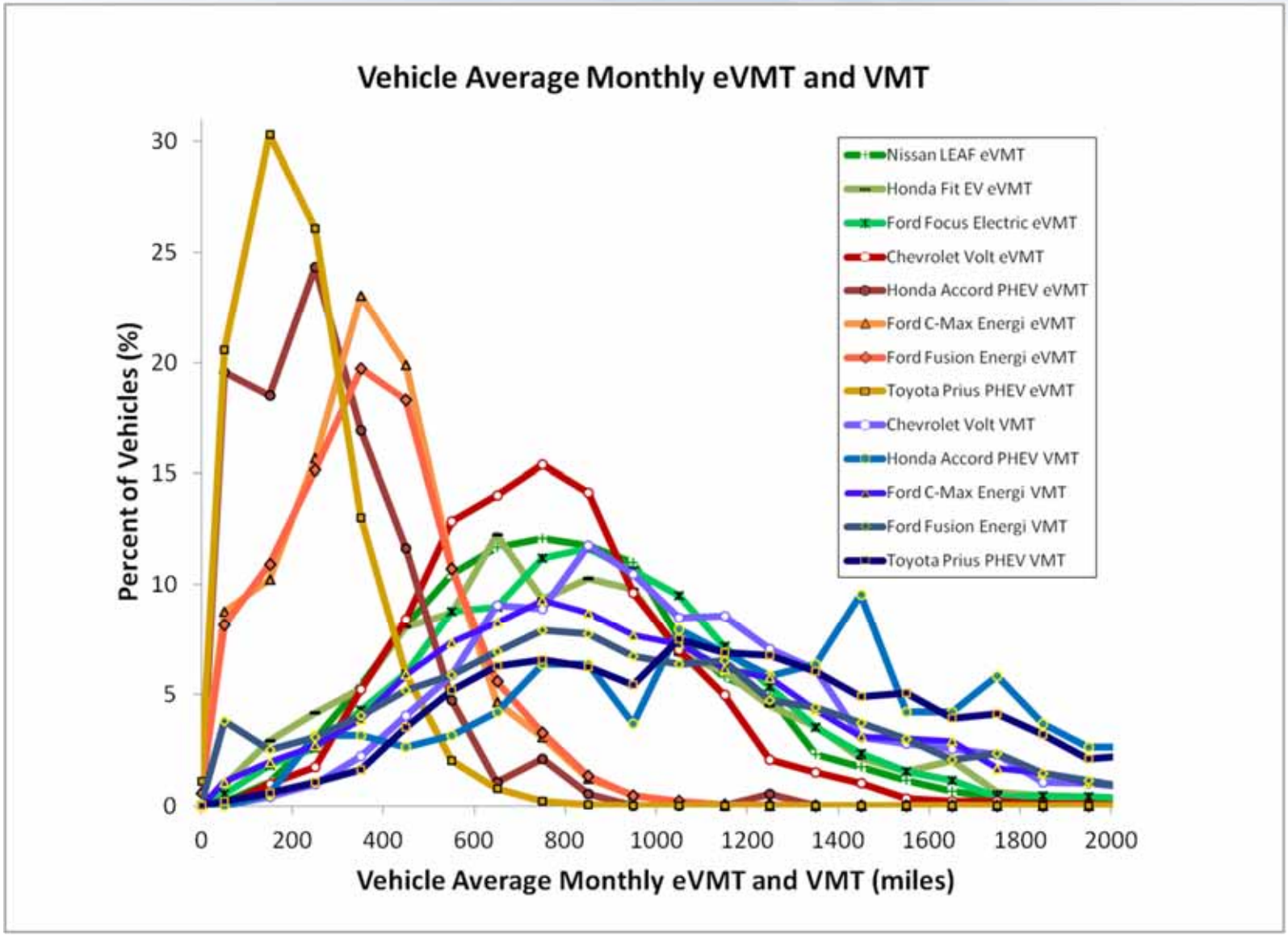
	Nissan LEAF *	Chevrolet Volt *	Ford Focus Electric	Ford C-Max Energi	Ford Fusion Energi	Honda Fit EV	Honda Accord PHEV	Toyota Prius PHEV
Number of Vehicles	4,039	1,867	2,193	5,368	5,803	645	189	1,523
Number of Vehicle Months	35,294	20,545	12,622	38,096	32,022	6,090	1,437	15,676
Total Vehicle Miles Traveled *VMT* (miles)	28,520,792	20,950,967	10,043,000	39,376,000	33,098,000	4,912,920	1,794,494	19,772,530
Total Calculated Electric Vehicle Miles Traveled *eVMT* (miles)	28,520,792	15,599,508	10,043,000	12,918,000	11,572,000	4,912,920	399,412	3,224,981
Avg. Monthly VMT	808.1	1,019.8	795.7	1,033.6	1,033.6	806.7	1,248.8	1,261.3
Avg. Monthly eVMT	808.1	759.3	795.7	339.1	361.4	806.7	278	207.0
estimated Annual VMT	9,697	12,238	9,548	12,403	12,403	9,680	14,986	15,136
estimated Annual eVMT	9,697	9,112	9,548	4,069	4,337	9,680	3,336	2,484

Data Format Description	Key-On / Key-Off	Key-On / Key-Off	Enhanced Key-On / Key-Off	Trip Summary		Trip Summary
Geographic Characterization	CA, OR, WA, AZ, TX, TN, GA, D.C., PA, IL	CA, OR, WA, AZ, TX, TN, GA, D.C., PA, IL	Nationwide	CA, OR, NJ, MD, CT, MA, RI, NY	CA, NY	ZEV States and other states

* http://avt.inel.gov/pdf/EVProj/eVMTMay2014.pdf

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

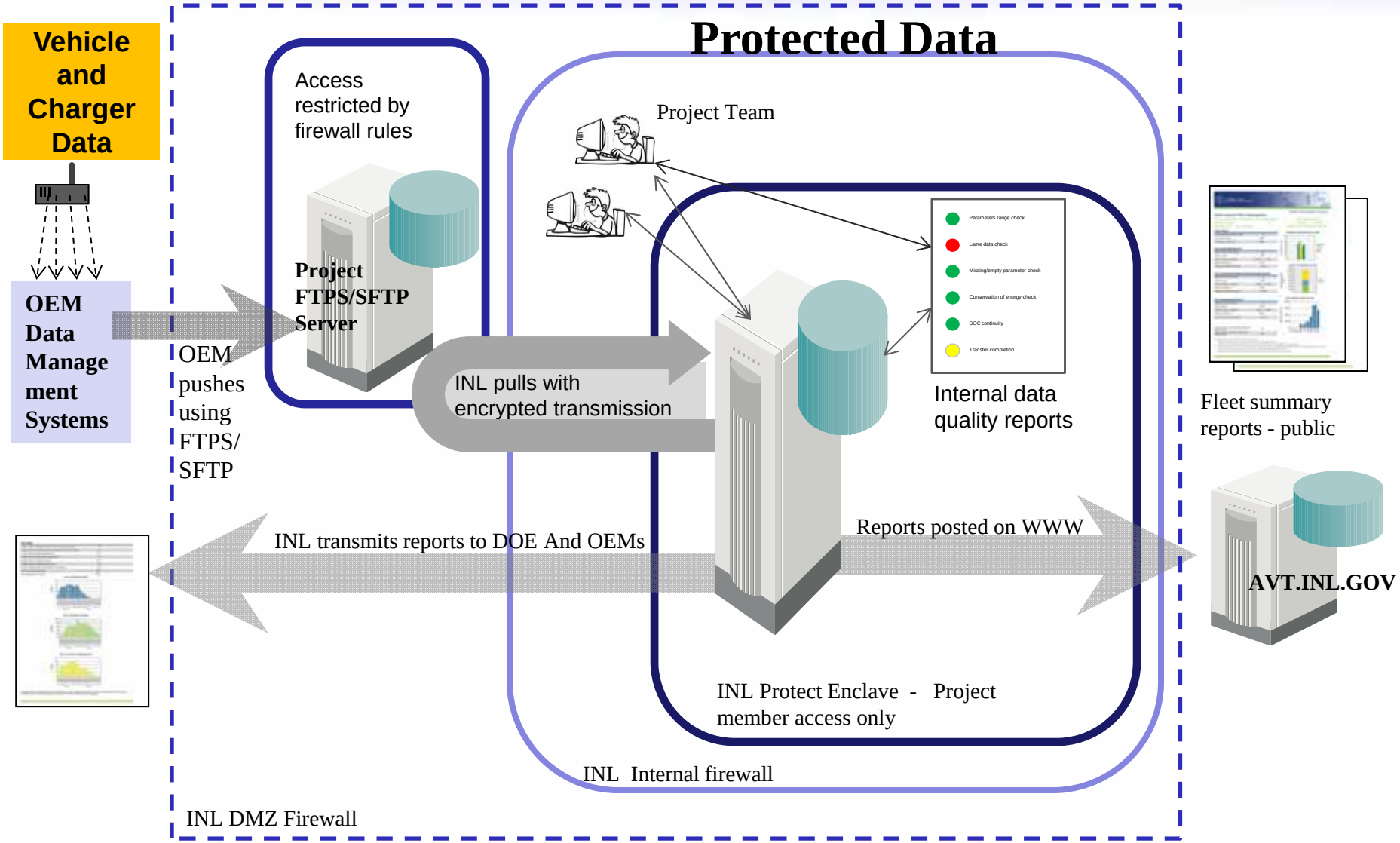
eVMT and VMT



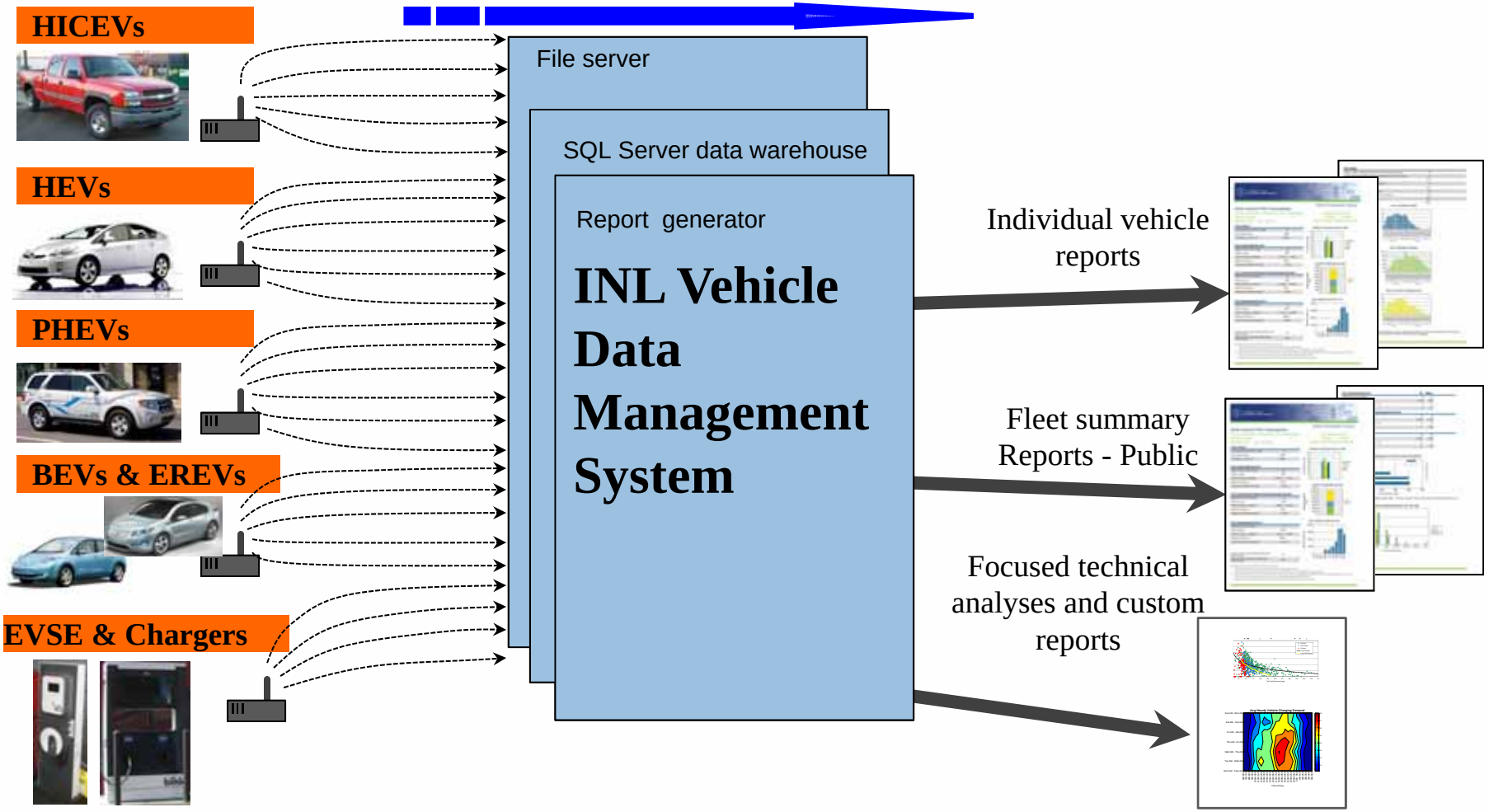
Distance Bins: =0, >0 to 100, >100 to 200, >300 to 400, >400 to 500, etc.

Handling Telematics Data Internally

Security


Vehicle and Charger Data
OEM Data Management Systems
OEM pushes using FTPS/ SFTP
Protected Data
Access restricted by firewall rules
Project FTPS/SFTP Server
Project Team
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
Fleet summary reports - public
INL transmits reports to DOE And OEMs
Reports posted on WWW
AVT.INL.GOV
INL Protect Enclave - Project member access only
INL Internal firewall
INL DMZ Firewall

Data Warehouse Management



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?**