Argonne NATIONAL LABORATORY

HEV, PHEV, EV Testing Activities

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Michael Duoba,
Henning Lohse-Busch, Kevin Stutenberg, Eric Rask
Argonne National Laboratory

U.S. Department of Energy
Energy Efficiency and Renewable Energy
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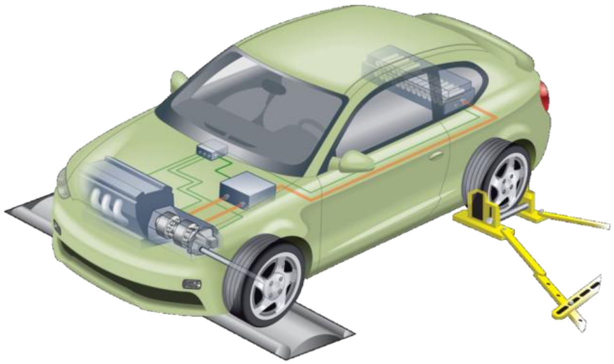
U.S. DEPARTMENT OF ENERGY

Advanced Powertrain Research Facility

Objective #1: Benchmarking

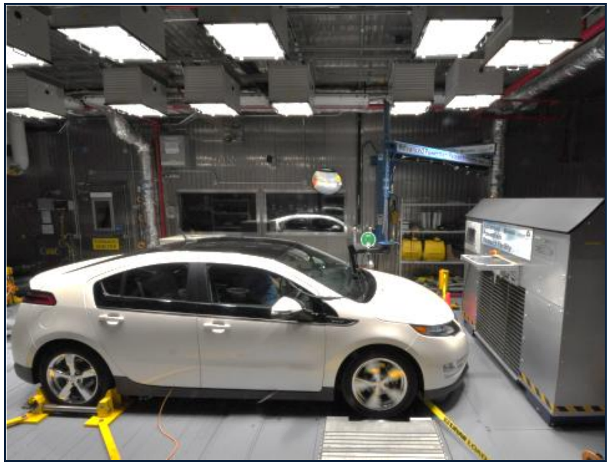
"Provide to DOE and Partners the Best Advanced Vehicle Test Data and Analysis"



Objective #2: Codes and Standards

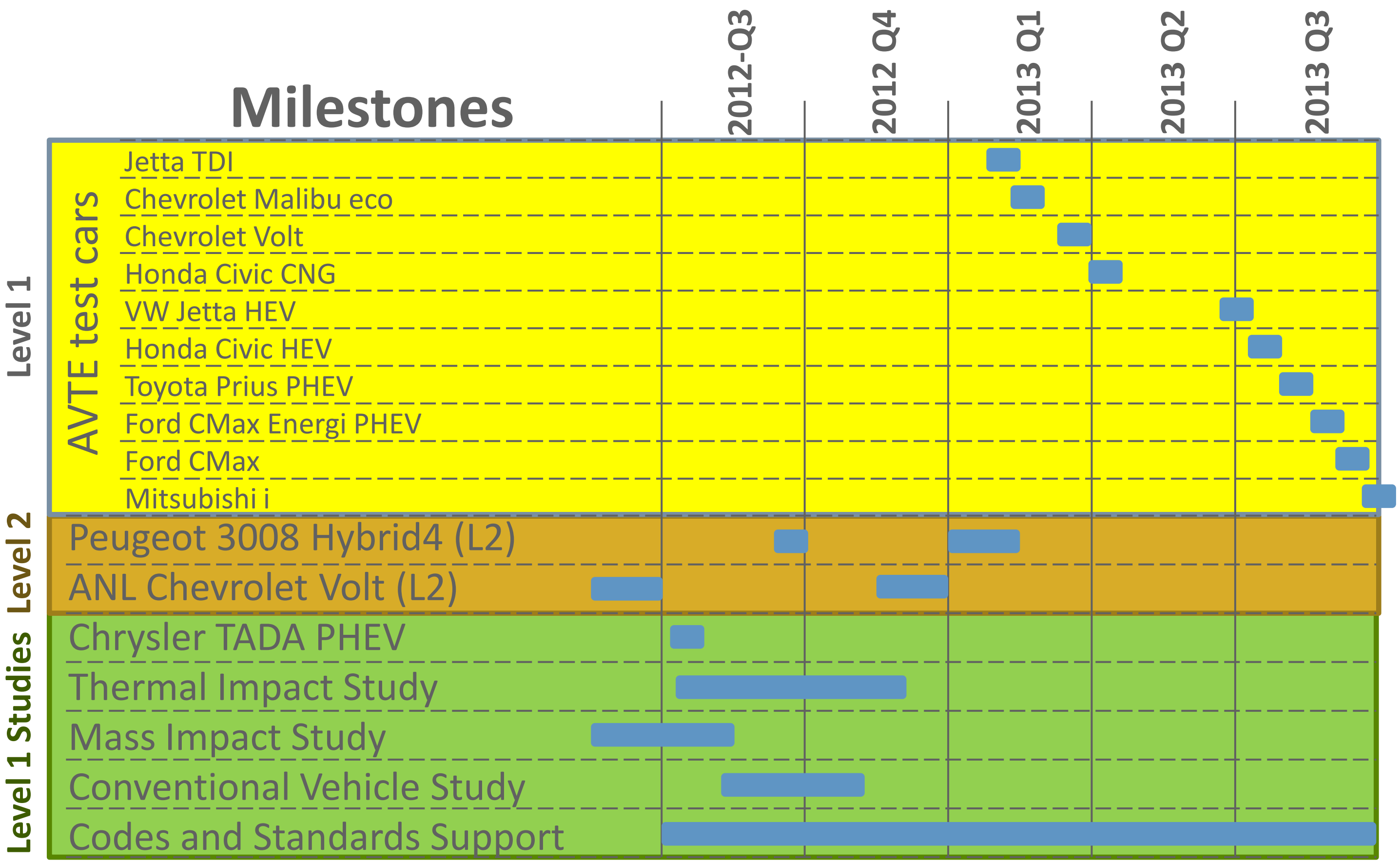
"Leading role in codes and standards development with public and independent research and data"

4WD chassis dyno with thermal chamber

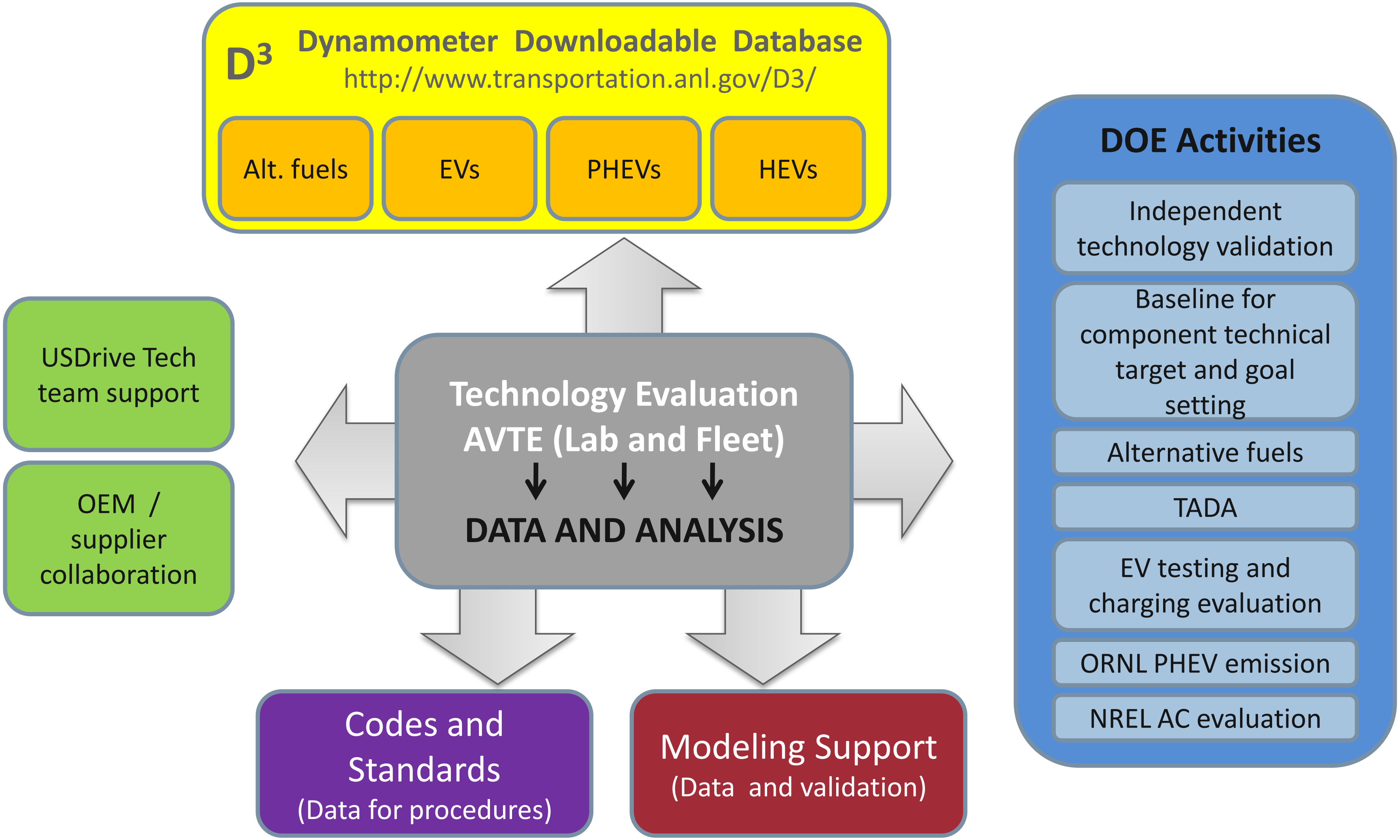


2WD chassis dyno

APRF Provides Data for a Wide Variety of Vehicle Technologies

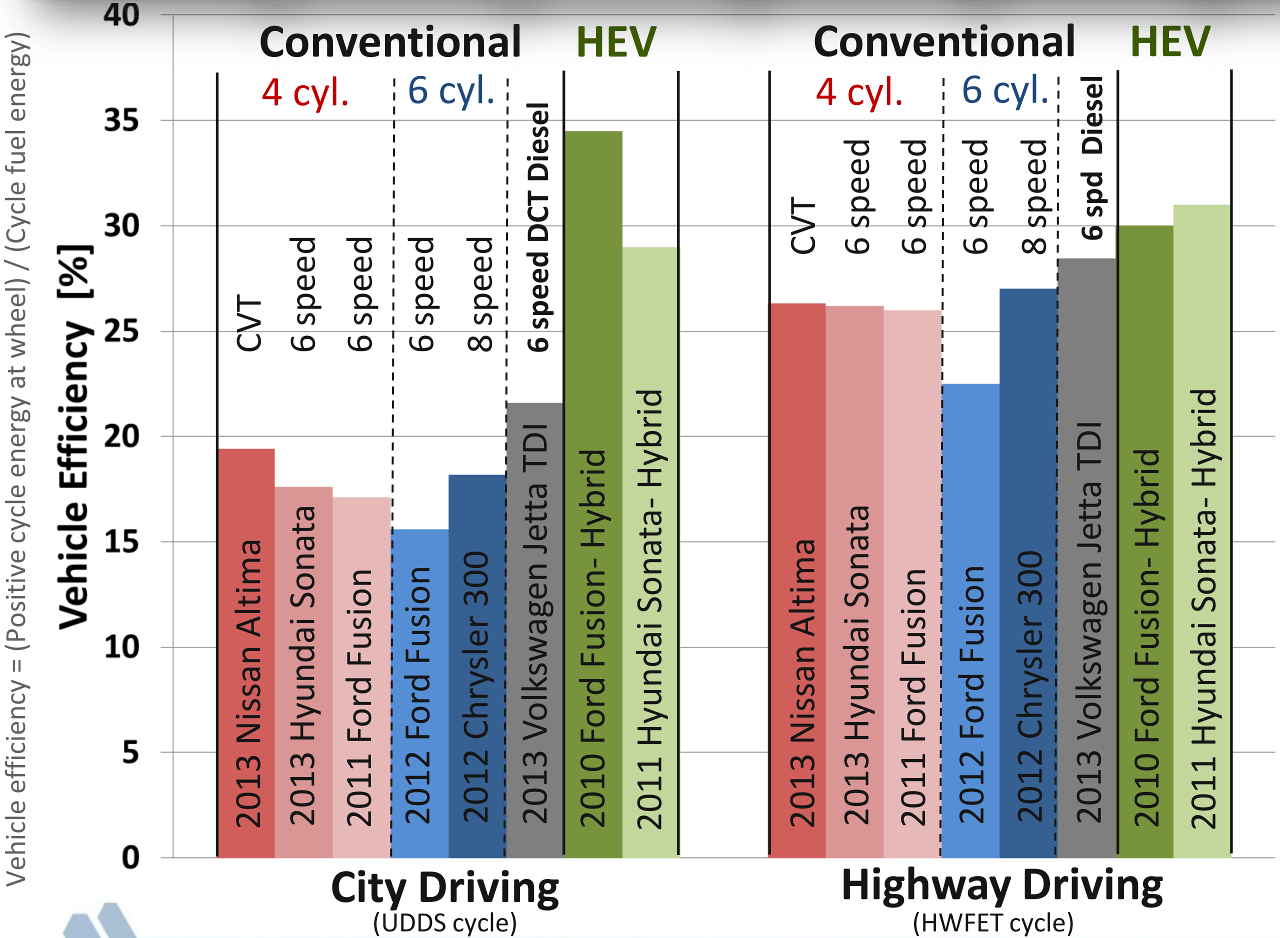


Technology Assessment and Data Dissemination



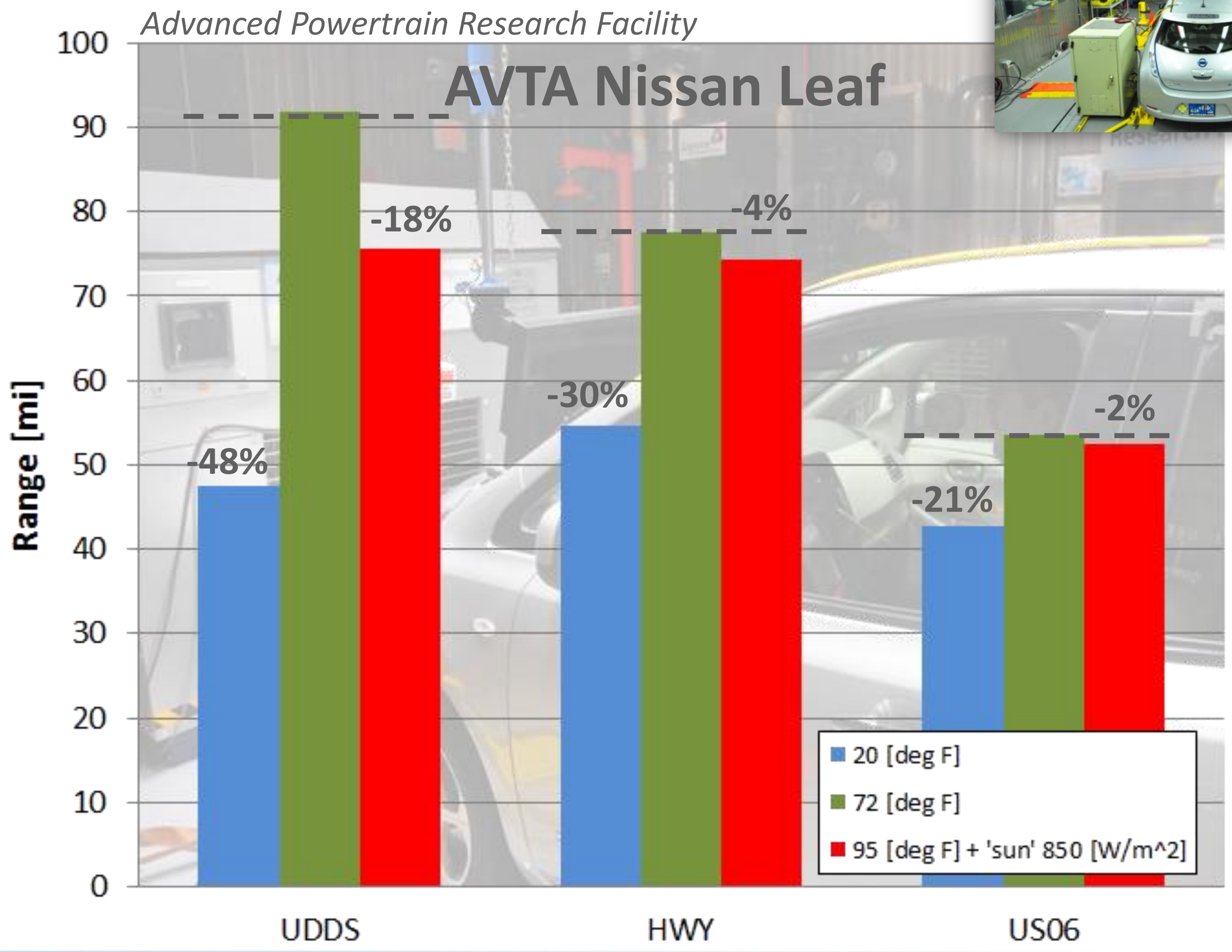
"Knowing how good you are requires an accurate picture of how good everybody else is"

Important Data Across Many Types of Technologies



- Vehicle efficiency is dependent on driving style
  - City driving: transient with lower loads and idle time impacts efficiency
  - Highway driving: higher steady engine loads result in greater average efficiency
- Technology observation
  - Engine size: smaller engine→ higher average efficiency
  - CVT & 8 speed: enables optimized engine loading in city driving
  - Diesel: highest vehicle efficiency of conventional technology
  - HEV: increased freedom to leverage engine operation

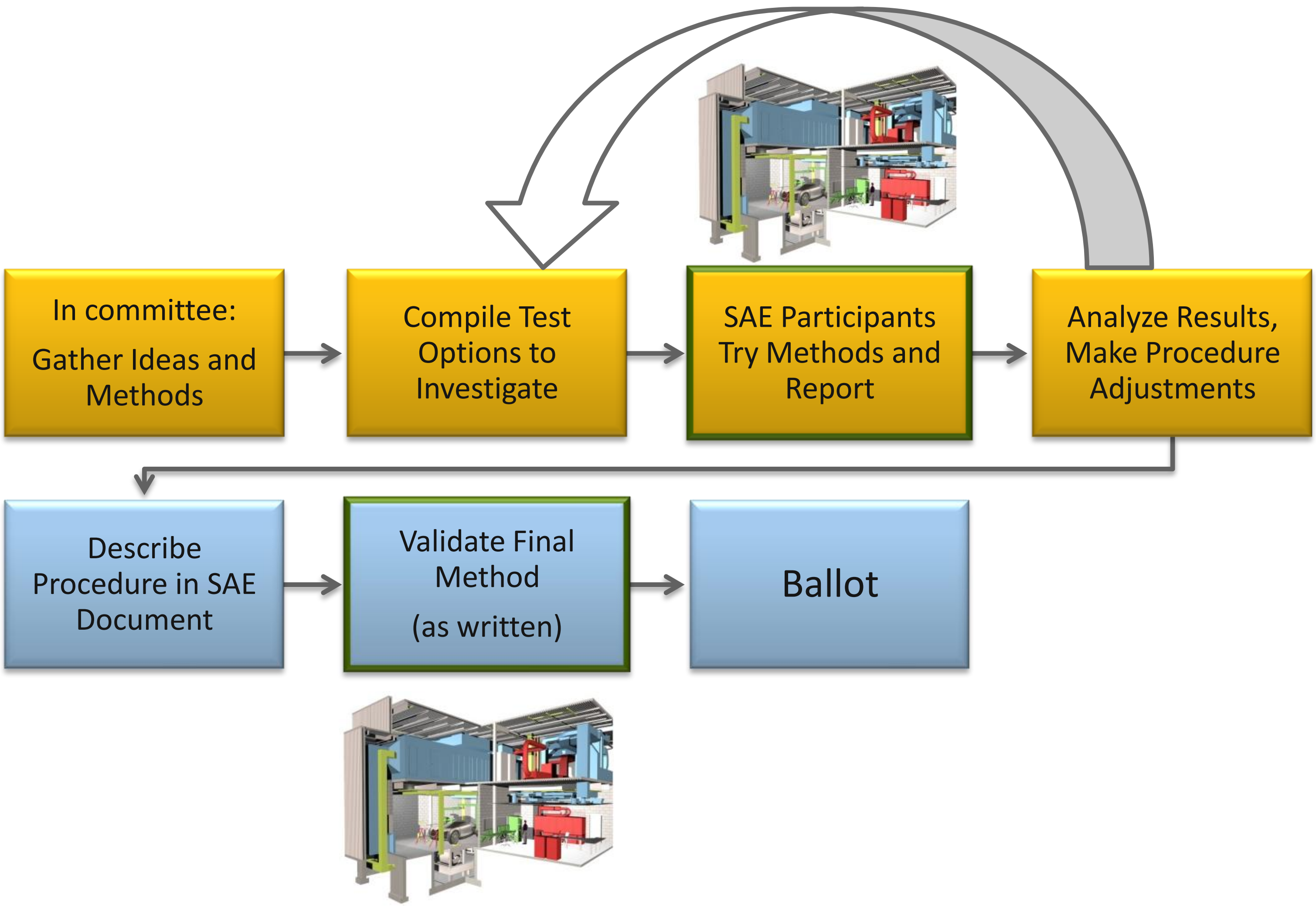
Impact of Temperature on BEV Range



Standards Activities Background

- **J1711: HEV/PHEV** dynamometer test procedures
  - Rewrite focused on PHEV procedure (published in 2010)
- **J1634**: **BEV** dynamometer test standards (consumption and range)
  - Rewrite for modern BEVs (published in 2012)
- **ISO 23274-2**: **PHEV** dyno testing in depleting mode
  - 23274-1 is testing in the sustaining mode (completed in 2012)
- **J2951**: **Drive Quality** Evaluation for Chassis Dynamometer Testing
  - Fuel economy variations based upon driver performance (New, published in 2011)
- **J1715**: **HEV Terminology** ("to EREV or not to EREV")
  - Updated from version several years ago
- **J2711**: Dyno testing of **MD/HD** vehicles including HEV
  - Phase 1 = dyno procedures (Phase 2 & 3 are HIL and "powerpack" testing)
- **J????**: **Powertrain power** standards
  - Committee not yet formed. M. Duoba chairing.

Argonne SAE Standards Committee Process



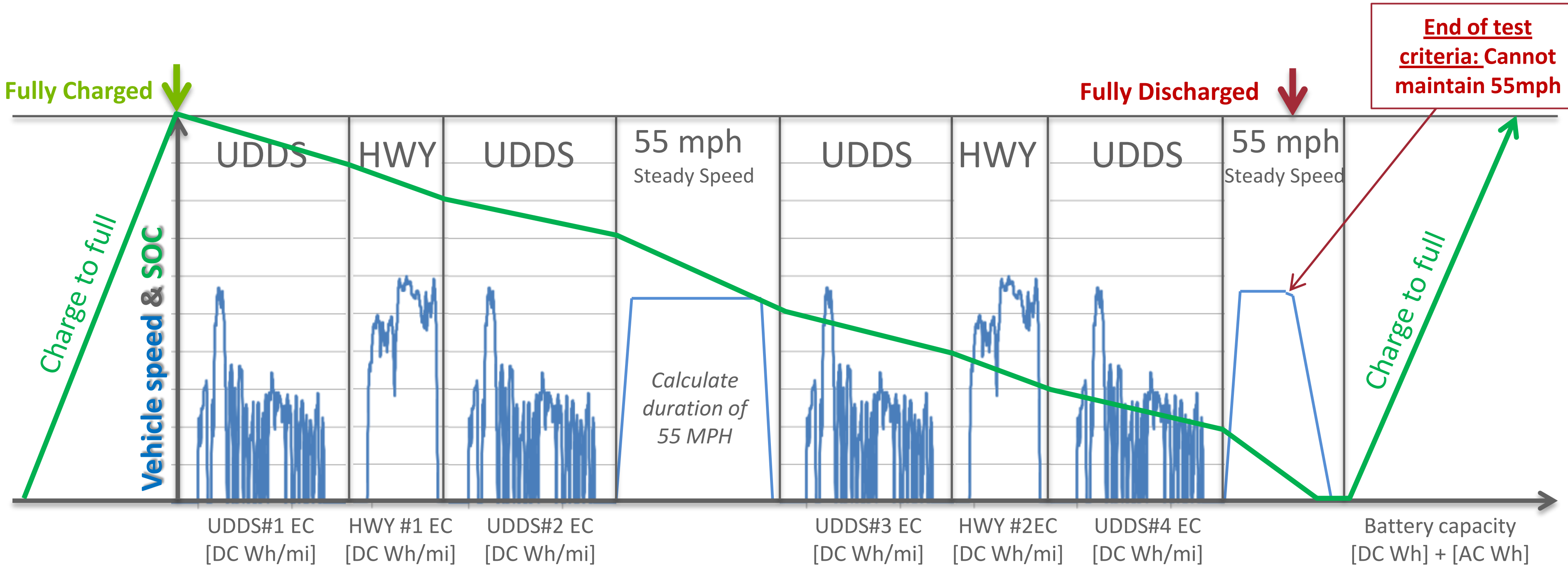
Recent Accomplishments: Validation of SAE Procedures with Newly Available OEM Vehicles

- **SAE J1634**
  - Nissan Leaf and Tesla Roadster were testing using SAE J1634 procedure concepts
  - Upcoming work will investigate results from Focus Electric (with active thermal management)
  - Future work on Hot/Cold corrections for BEVs

- **SAE J1711**
  - Old J1711 procedure not adequate for today's PHEVs
  - Testing Volt validated J1711's sophisticated approach to range calculations
  - Testing Prius PHV validated J1711 generic approach that works for EREVs and Blended PHEVs
  - Current work focused on hot and cold testing in charge-depleting mode

J1634 BEV Testing Procedure

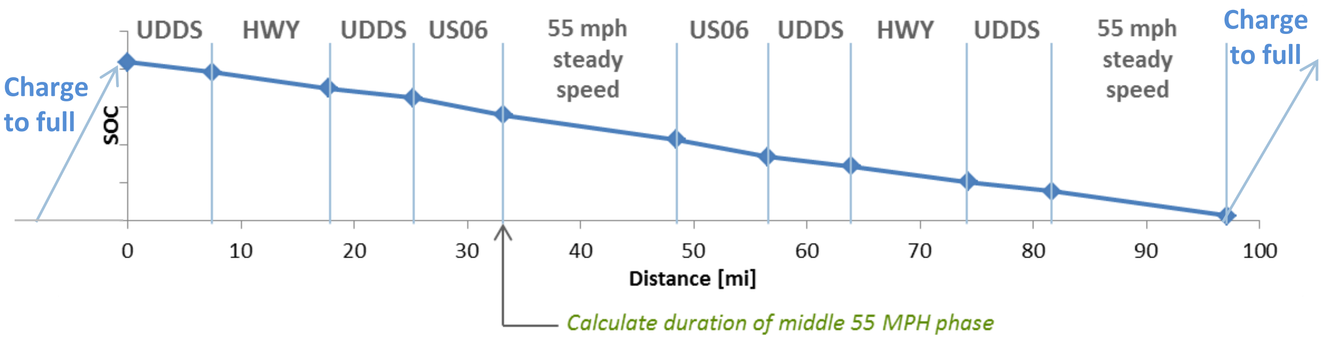
→ "Multi-Cycle Test" – provides both UDDS and HWY data throughout SOC range. Expanded version includes US06 cycle data.



- Cycle data obtained at <u>beginning</u> and <u>end</u> of SOC
- Provides Wh/mi and range for bother UDDS and HWY

Expanded Multi-Cycle Test J1634 Used for Preliminary OEM BEV Testing

→Expanded MCT provides UDDS, HWY and US06



	Whr	Whr/mi
UDDS	1346.8	180.5
HWY	2092.7	203.5
UDDS	1275.2	171.0
US06	2302.1	286.8
SS55	3241.5	
US06	2268.5	282.8
UDDS	1251.0	167.7
HWY	2044.4	199.0
UDDS	1246.9	167.1
SS55	3245.7	
Test Discharge	**20315**	
AC Recharge	**24048**	

Weighting UDDS for "First Cycle Effect"

K1 = 1346.8 / 20315 = 0.06629

K2 = K3 = K4 = (1 – 0.06629)/3 = 0.31123

DC Wh/mi = K1*UDDS1 Wh/mi + K2…

DC Wh/mi = 169.4

Recharge Allocation Factor

RAF = DC $kWh_{total\ test}$ / AC $kWh_{recharge}$

RAF = 20315 / 24048 = 0.8447

* Note that these results are unadjusted and do not reflect expected in-use performance

Charge Recovery

CR = C_c / C_d

CR = 63.69 Ah / 63.49 Ah

CR = 100.3%

(must be greater than 97%)

AC Energy Consumption*

UDDS:

AC Wh/mi = DC Wh/mi / RAF

AC Wh/mi = 169.4 / 0.8447 = 200.5

HWY:

Ave DC Wh/mi = 201.3

AC Wh/mi = 238.2

US06:

Ave DC Wh/mi = 284.8

AC Wh/mi = 337.1

Range Extrapolations*

Usable Battery Energy (UBE)

UBE = 20315 Wh

UDDS

R = 20315 / 169.4 = 119.9 miles

HWY

R = 20315 / 201.3 = 100.9 miles

US06

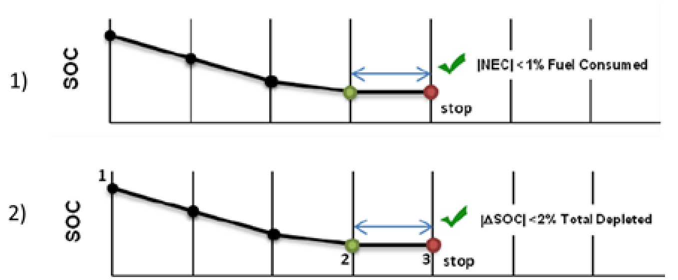
R = 20315 / 284.8 = 71.3 miles

SAE J1711 Concepts Validated on Volt

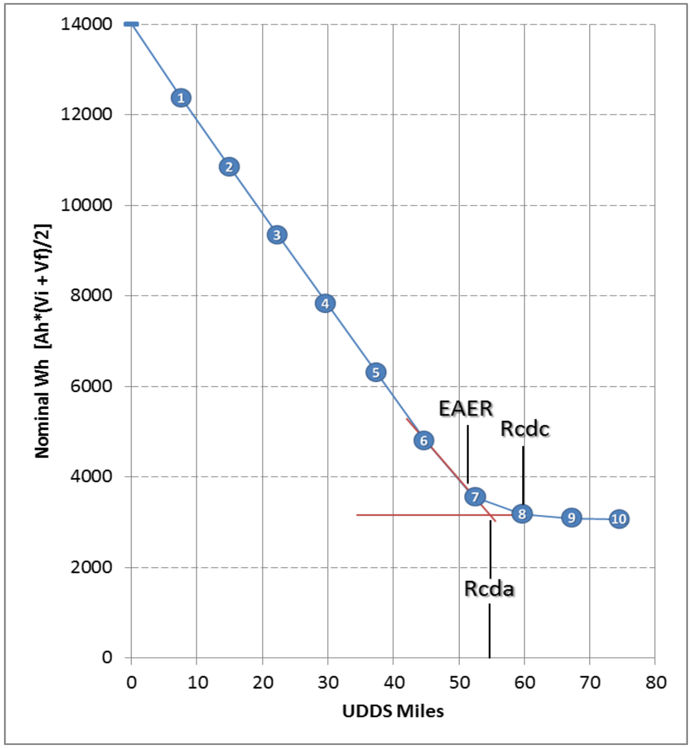
Volt UDDS Full Charge Test Data

				EOT Criteria		AC Wh Calcs	
Cycle	Miles	MPG actual	Ah x (Vi+Vf) /2	(1) Δ% of Fuel	(2) Δ% of Disch	Total % of Disch	AC Wh/mi[1]
1	7.43	inf	1582.9	25.72%	--	14.47%	255.3
2	14.86	inf	1535.7	25.22%	49.24%	14.04%	247.4
3	22.29	inf	1521.0	25.33%	32.78%	13.91%	245.1
4	29.73	inf	1515.2	25.61%	24.62%	13.85%	244.2
5	37.16	inf	1505.6	25.75%	19.65%	13.76%	242.7
6	44.59	inf	1506.1	26.12%	16.43%	13.77%	242.6
7	52.03	232.4	1267.6	22.44%	12.15%	11.59%	204.2
8	59.47	60.6	386.5	6.95%	3.57%	3.53%	62.2
9	66.90	51.0	86.2	1.56%	0.79%	0.79%	13.9
10	74.33	49.0	31.3	0.57%	0.29%	0.29%	5.0

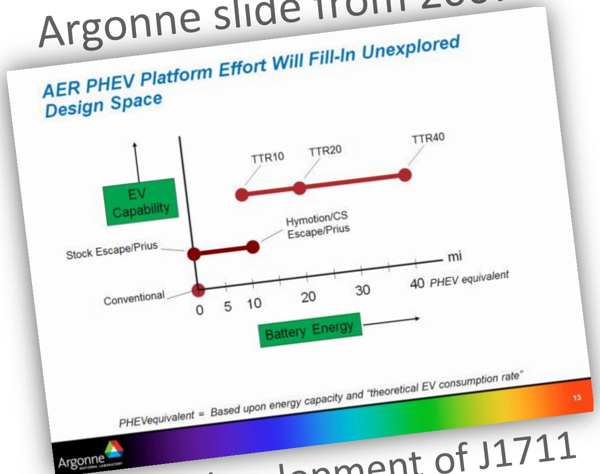
[1] Based upon 13.102 AC kWh recharge to full



- End of Test Criteria checked for robustness. Argonne-prescribed option works best.
- Numerous SAE J1711 range definitions important for calculations of results.
- Same calculations for all PHEVs. PHEV type drives decision of which results are presented.

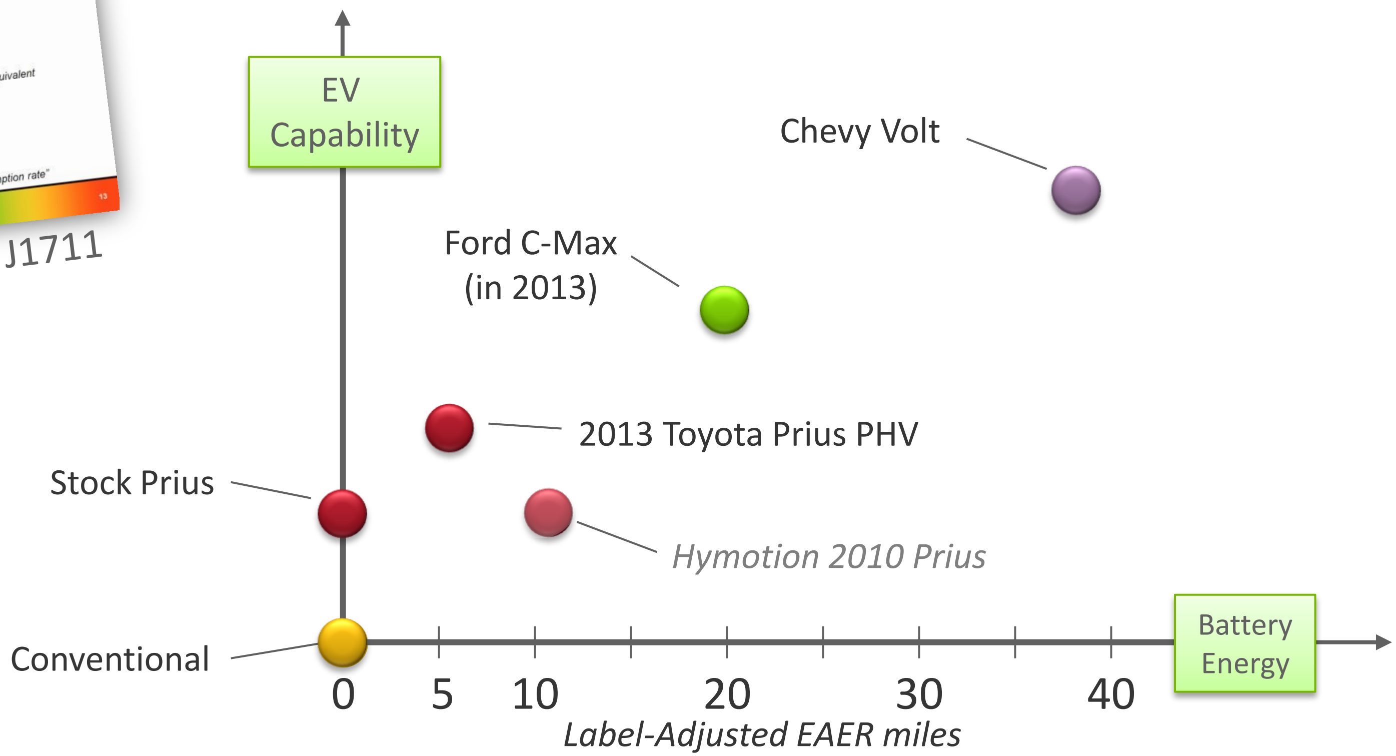


Argonne slide from 2007:



During development of J1711

Future Work: SAE J1711 Validation Over Entire PHEV Design Space



- J1711 developed using only prototypes
- However, no validation performed with OEM vehicles
- By end of 2013, most of PHEV design space can be tested with OEM PHEVs

Future Work: New Standards and Continued Validation / Improvement of Existing Procedures

Argonne's Mike Duoba briefing President Obama on Testing Standards March 15, 2013

Refinement:

- HEV and PHEV procedures (**J1711**) will be evaluated with diverse set of OEM PHEVs (Prius and C-Max PHEVs)
- More BEV and 5-Cycle evaluations
  - Current "**70% Rule**" should eventually be replaced with procedures that reflect and reward advances in BEV thermal management, efficient auxiliaries and improved thermal insulation

New or Revised Standards:

- Newly formed SAE task addressing Powertrain Power in HEVs
  - Specifications in engine net power and torque currently follow SAE J1349
  - However, "specmanship" in hybrid vehicle power and electric motor power do not currently conform to a uniform standard
  - The new task force will address standard methods to define, measure, and report Vehicle Power, Motor Power, and Battery Power (among other parameters)
- Finish SAE **J2711-1** (Chassis dynamometer test procedures)