

HEV, PHEV, BEV Test Standard Validation

**2011 DOE Hydrogen Program and Vehicle Technologies
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Sponsored by Lee Slezak



U.S. Department of Energy

Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Project ID # VSS052

Standards Overview

Timeline

- Continuing effort since 2006
- Focus on EV Testing (SAE J1634)
 - J1634 begun in 2009
 - J1634 completion in 2011 YE
 - J1634: 90% Complete
- Aid in SAE 2711 MD/HD Procedure
 - Revision process started

Budget

- \$400k in FY11
- Effort leverages Advanced Powertrain Research Facility staff and test vehicles

Barriers

- Barriers addressed
 - Address codes and standards needed to enable wide-spread adoption of electric-drive transportation technologies

Partners

- ANL staff is Co-Chair of J1634
 - Task Force includes experts from EPA, Toyota, Honda, Ford, Chrysler, GM, Nissan, JARI, Mitsubishi, CARB
- AVTA, OEMs and Suppliers, Customers, X-Prize, Tesla, BMW

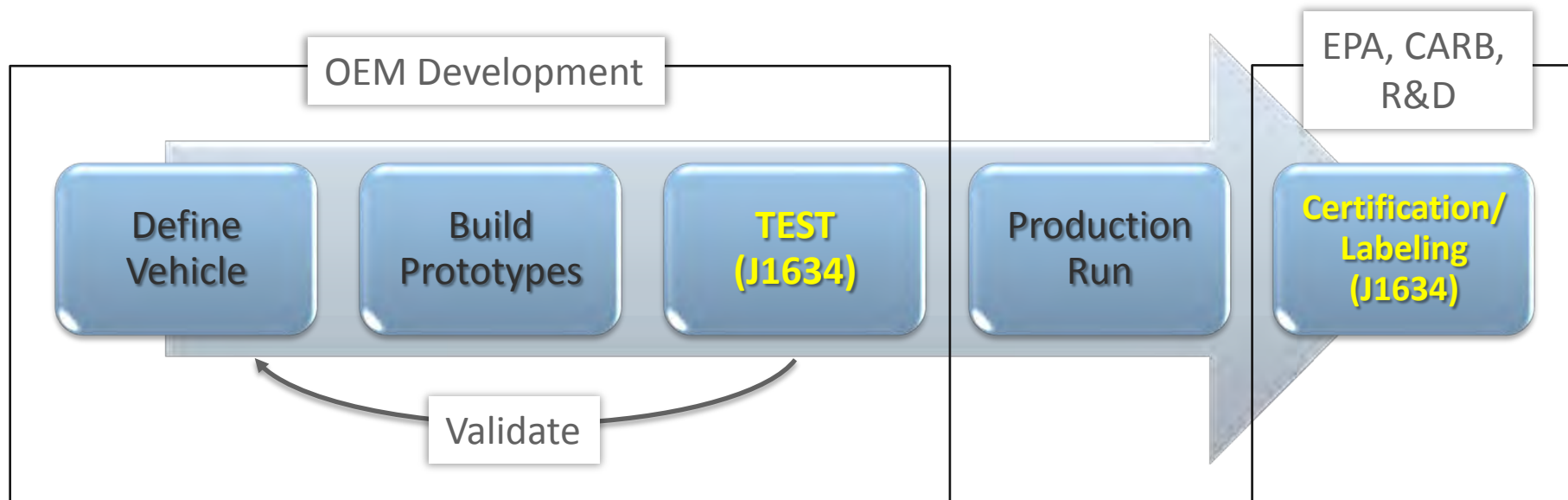
Standards Development Activities in FY11

- **J1634**: BEV dynamometer test standards (consumption and range)
 - Rewrite for modern BEVs
- **J1715**: HEV Terminology (“to EREV or not to EREV”)
 - Updated from version several years ago
- **J2951**: Drive Quality Evaluation for Chassis Dynamometer Testing
 - New standard to explain fuel economy variations
- **ISO 23274-2**: PHEV dyno testing in depleting mode
 - 23274-1 is testing in the sustaining mode
- **J2711**: Dyno testing of MD/HD vehicles including HEV
 - Committee just formed. Lead roles still being considered



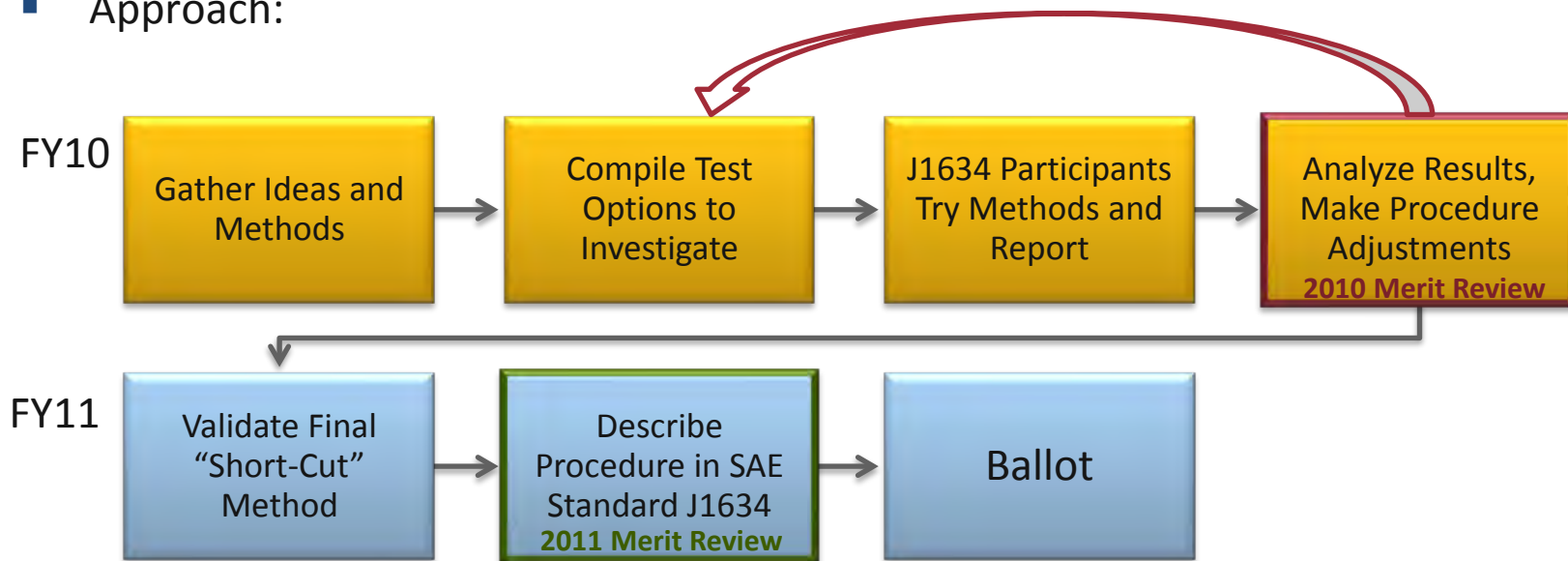
J1634 Relevance: Industry and Regulatory Agencies will Incorporate this Updated BEV Test Procedure

- Vehicle economy / range is defined according to test procedures
- OEMs recognized immediately existing J1634 is not suitable for >100mi EVs
- **Relevance: Mass produced BEVs will use the J1634 Task Force methods**
- **Relevance: MD and HD BEVs can also use same general technique**



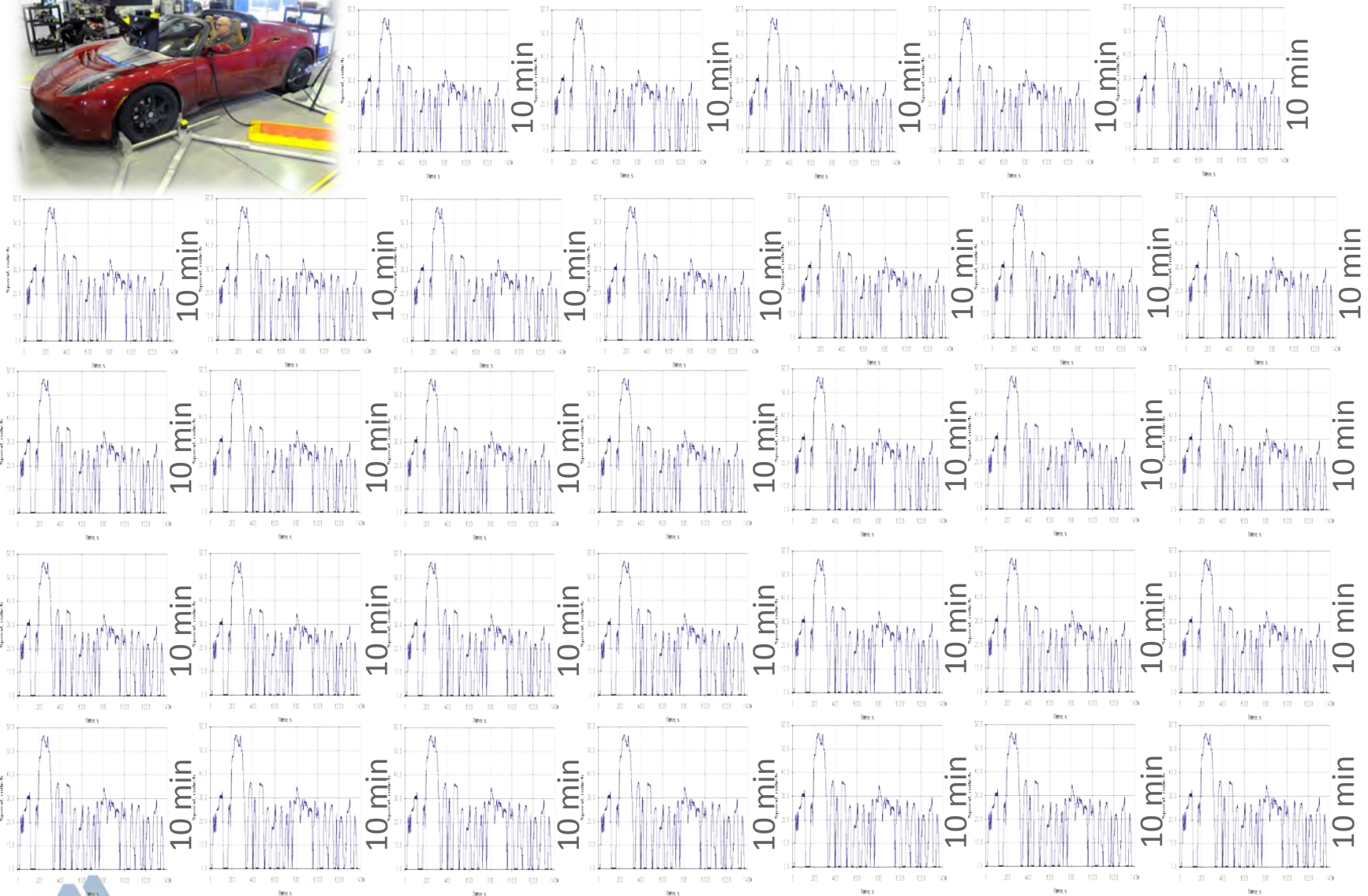
J1634 Approach: Provide Data, Direction, Validation, Document Development

- Jeff Glodich (Ford) and Mike Duoba co-chair J1634 task force
- Objective:
 - Develop new, shorter test methods that accomplish the same objectives as existing J1634 procedure
 - Validate methods with actual BEV dynamometer testing
 - Leverage on-going/previous testing at ANL
- Approach:



J1634 Problem Statement: "Death by Urban"

250mi = 17+ hours of testing, no interruptions allowed



J1634 Approach: ANL Procedure Development

- Test Product: Find **Efficiency** (AC Wh/mi) and **Range** (mi) for any given cycle
- Constraint: Short-cut must provide repeatable results consistent with the long J1634 method
- Short-Cut Method in General:
 1. Find battery capacity (on-dyno)
 2. Run test cycles (UDDS, HWY, US06) to find Efficiency
 3. Use consumption and capacity data to find Range
- ANL tools and vehicles
 - FY10: EV-optimized 2WD dyno facility
 - FY10: OEM BEVs from companies and private owners
 - FY10: ANL-built “TTR” prototype PHEV platform run in EV mode
 - FY10: Battery HIL testing isolating battery to validate repeatability, response of battery, charger, and BMS
 - FY11: Several X-Prize BEVs
 - FY11: Tier 1 Supplier BEV

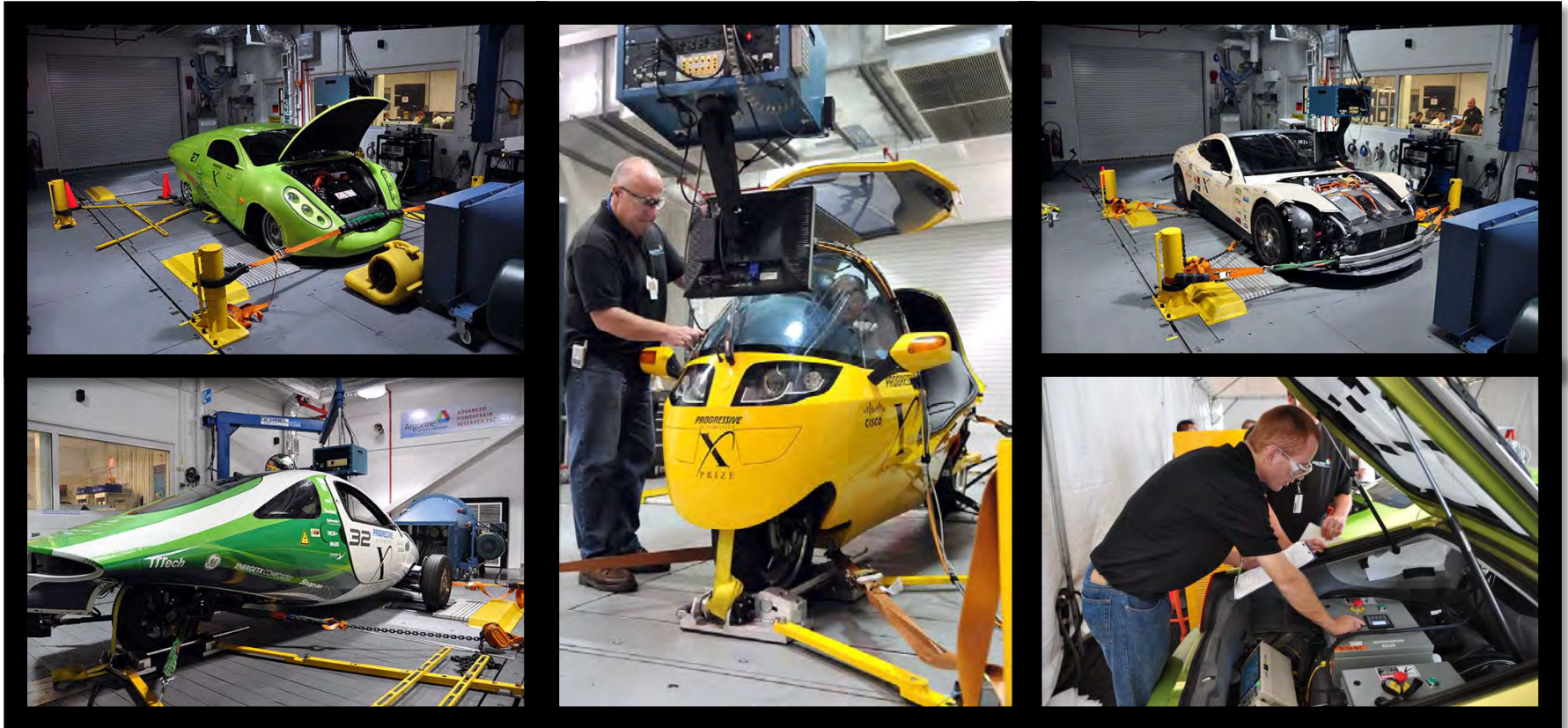


J1634 Technical Accomplishment: ANL Staff Provided Key Inputs to Test Concept

- Committee decided to adopt ANL concept (internally called “Super Short Cut”) for most time-efficient test procedure
 - Run UDDS, HWY, US06 as if it were a conventional vehicle, then recharge
 - Use method similar to J1711 method to calculate AC energy based upon DC dyno measurements
- Helped define equations and terminology
- Definitions made to be compatible with J1711 and ISO standards



J1634 Technical Accomplishment: Argonne Tested X-Prize Electric Vehicles



- ANL developed test procedure - some concepts compared with the draft J1634 at that time
- ANL had to validate “full charge” to avoid errors in AC kWh/mi data (and possible gaming)
- Collecting data from a diverse set of advanced batteries and BMS systems provided guidance for J1634 charge validation rule



BEV Test Procedure (J1634) Project Summary

- **Objective:** Develop test procedure methods that are practical for today's >100mi range battery electric vehicles
- **Relevance:** Direction of J1634 will likely be used throughout industry and government agencies for quantifying BEV performance on a dynamometer
- **Accomplishments:**
 - Using experience from ANL's successful benchmarking program and J1711 leadership, many key features of the new test concepts were ANL contributions
 - Numerous testing projects supported development and validation of new test concepts for wide-spread collaboration
- **Next Steps:** Document revisions underway for modifications related to new testing methods
- **Conclusion:** Many contributions of committee members make this program a truly group effort to develop a suitable test procedure for the next generation of electric vehicles

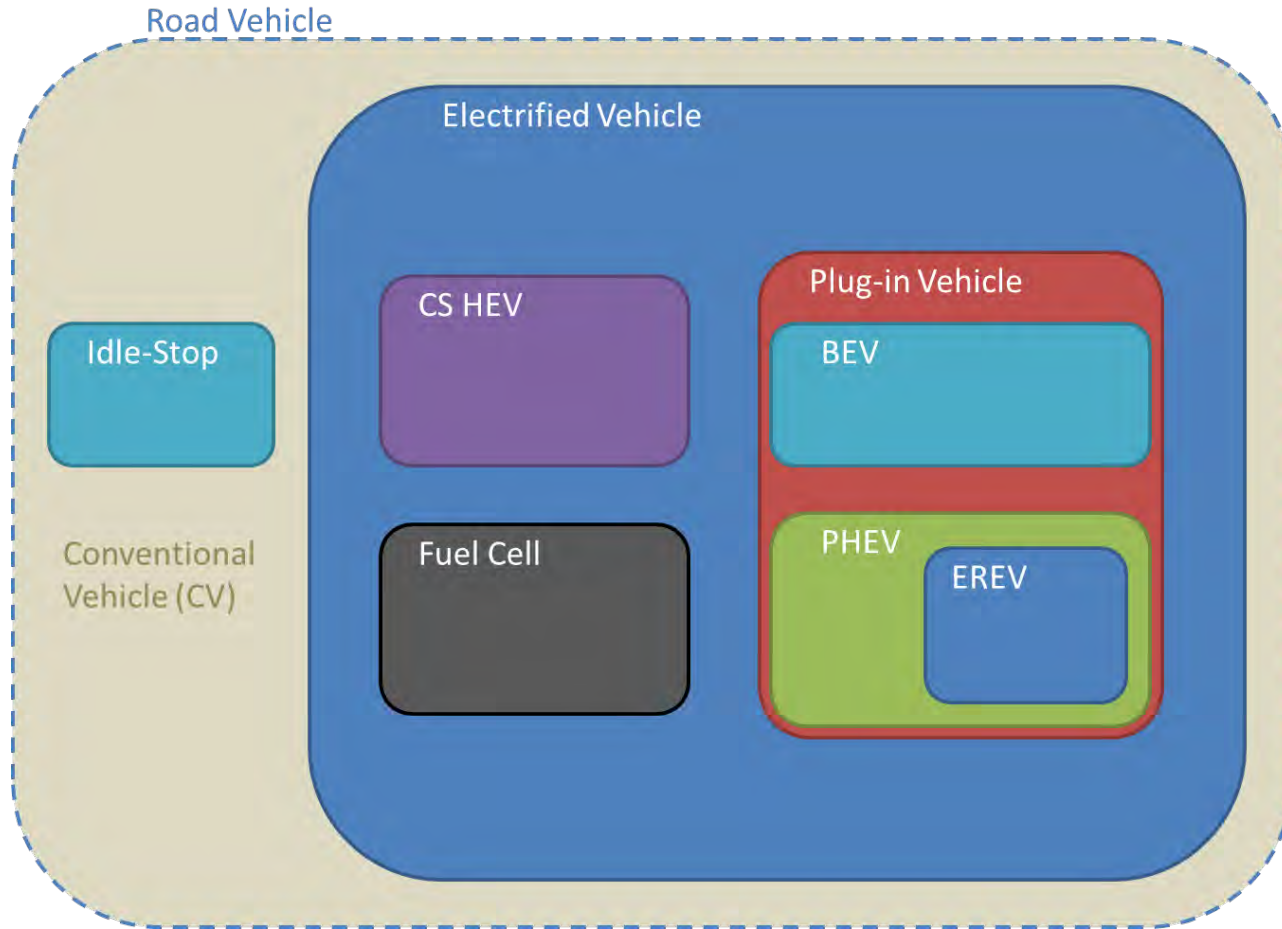


Challenges for J1715: New Technology Needs New, Consensus Terminology

- SAE Technical Information Report J1715 “Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology” was first published in 2008
- Discussions in media, advertising jargon and in technical papers offered confusing and sometimes conflicting terminology
 - Micro-hybrid
 - Strong hybrid
 - Plug-in hybrid
 - Extended-Range Electric Vehicle (E-REV)
 - Range-Extended Electric Vehicle (ReEV)
- Decided early on that “strong, full, mild” terms would not be part of SAE hybrid terminology
- Much discussion on whether “EREV” would be an SAE term
 - Is an EREV a PHEV?

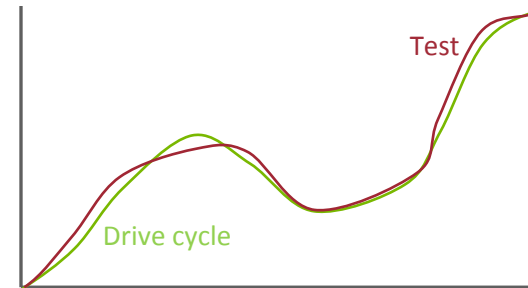
J1715 Accomplishment: Fine-Tuning Terminology

ANL proposed vehicle terminology map



J2951: Develop Metrics to Help Explain Test-to-Test Variation Due to Driver Variability

- **Started:** Aug 2010. **Finish:** Summer 2011?
- Prescribed certification tolerances leave room for significant fuel economy variation
- Existing speed tolerance is not enough information to explain varied results
- Data has shown that higher fuel consumption results correlate with higher driven dyno energy
- Results from hybrids are notoriously “noisy”
- ANL has been using enhanced driver performance metrics for 10 years
- ANL is providing conceptual input and data to committee
- **Accomplishments:** Equations at right are represented in 80% finished draft.



Driven Energy vs Cycle Energy

$$\text{Cycle Energy (CE)} = \sum_0^N \text{Work}_i^+ = \sum_{i=0}^{i=N} \left[1.015 \cdot \text{ETW} \cdot a_i + F_0 + F_1 v_i + F_2 v_i^2 \right]^+ \times d_i$$

Excessive Transients

$$\text{ASC} = \frac{\left[\sum_{\text{ABS}} \left[\frac{V_{i+1} - V_{i-1}}{2\Delta t} \right] \right]_{\text{Driven}} - \left[\sum_{\text{ABS}} \left[\frac{V_{i+1} - V_{i-1}}{2\Delta t} \right] \right]_{\text{Target}}}{\left[\sum_{\text{ABS}} \left[\frac{V_{i+1} - V_{i-1}}{2\Delta t} \right] \right]_{\text{Target}}} \times 100$$

Number of peak accels

Still under development

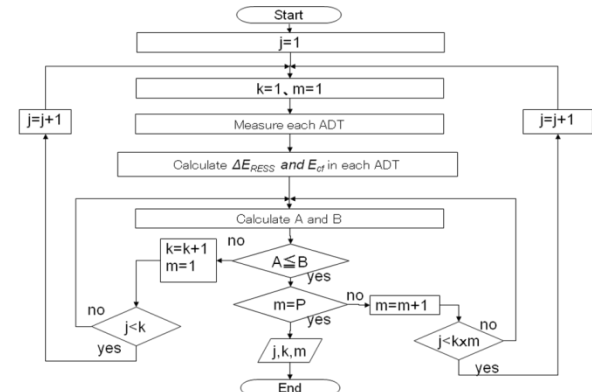
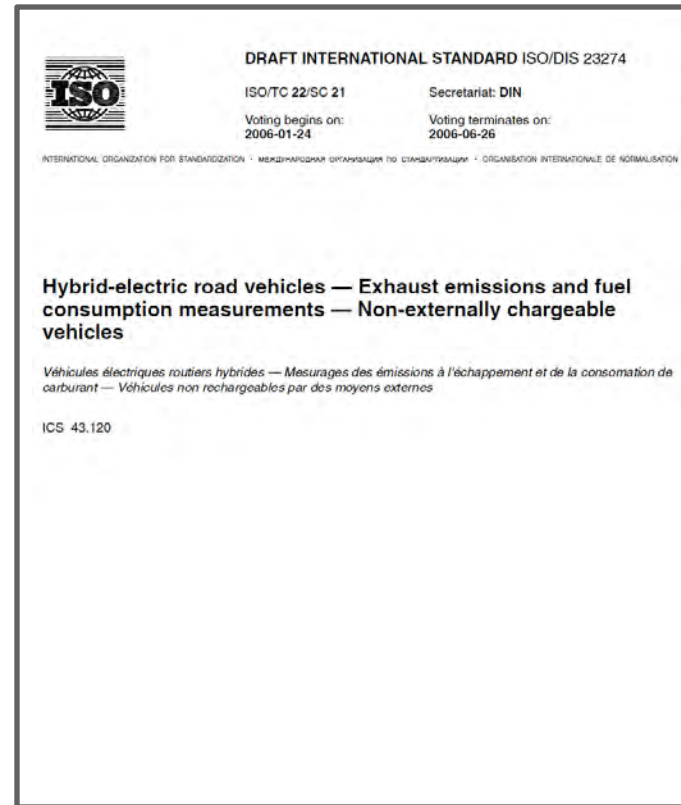
ISO 23274-2 Support

Harmonization of PHEV Procedures

- ISO Standards require many years to develop
- Attended meetings since 2007
 - Tokyo, Paris, Berlin, Chicago, Paris
- Most difficult problem is defining end of charge-depleting operation
- ISO committee looking to a very precise method, but perhaps not always practical for routine testing
- Settled on a method that is not in conflict with J1711

$$A = \left| \sum_{i=1+(j-k \times m)}^{j-k \times (m-1)} \Delta E_{RESS}(i) \right|$$

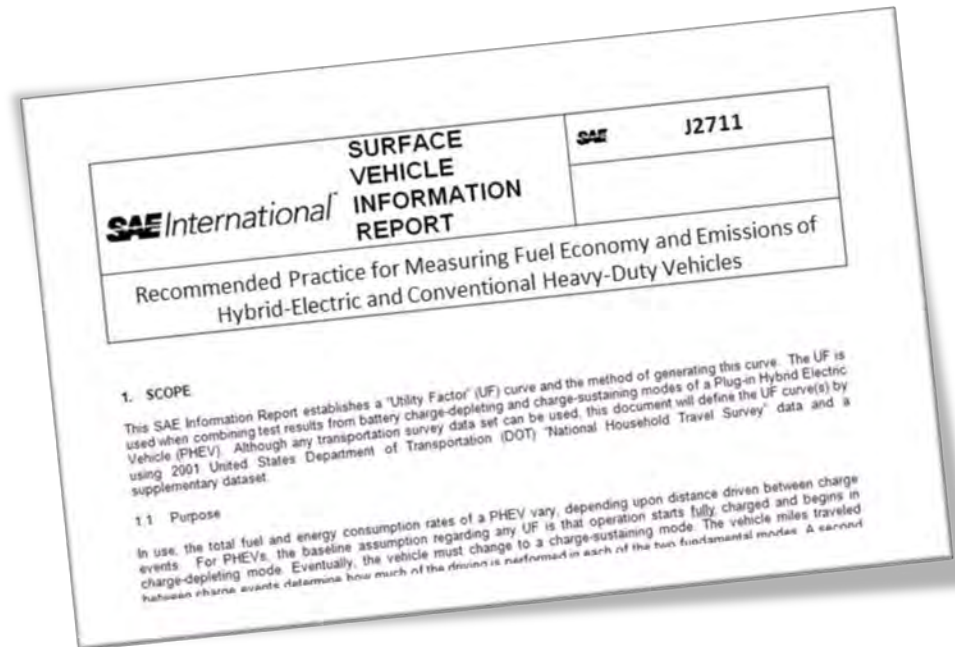
$$B = 0.01 \times \sum_{i=1+(j-k \times m)}^{j-k \times (m-1)} E_{CF}(i)$$



J2711: Now Underway

MD/HD Vehicle Testing

- Standard is just beginning revision process (Revision of 2002 document)
- ANL is taking a leadership role to ensure best-practices from light-duty testing are implemented when appropriate
- Very challenging, it likely covers:
 - Hardware-in-the-loop methods
 - Dynamometer methods
 - On-road methods
- Properly dealing with charge-balance, SOC issues will take some development and validation



Collaborations and Coordination with Other Institutions

AVTA (Advanced Vehicle Testing activities)

Baseline dynamometer testing of vehicles



SAE Task Force Membership

- OEMs
- Suppliers
- Regulators
- National Labs

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DOE Evaluation Activities

- National lab analysis
- Technology evaluation



Summary of FY11 Standards Development Activities

ANL is continuing to leverage many years of vehicle testing success to help develop procedures that are robust, practical, and unbiased

On-going standards for 2011

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