J1634 SAE BEV Test Procedures

2010 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

June 09, 2010

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Sponsored by Lee Slezak

U.S. Department of Energy

Energy Efficiency and Renewable Energy

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Project ID # VSS027

Overview

Timeline

- Start: March 2009
- End: Calendar year 2010?
- 50% Complete

Barriers

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

Budget

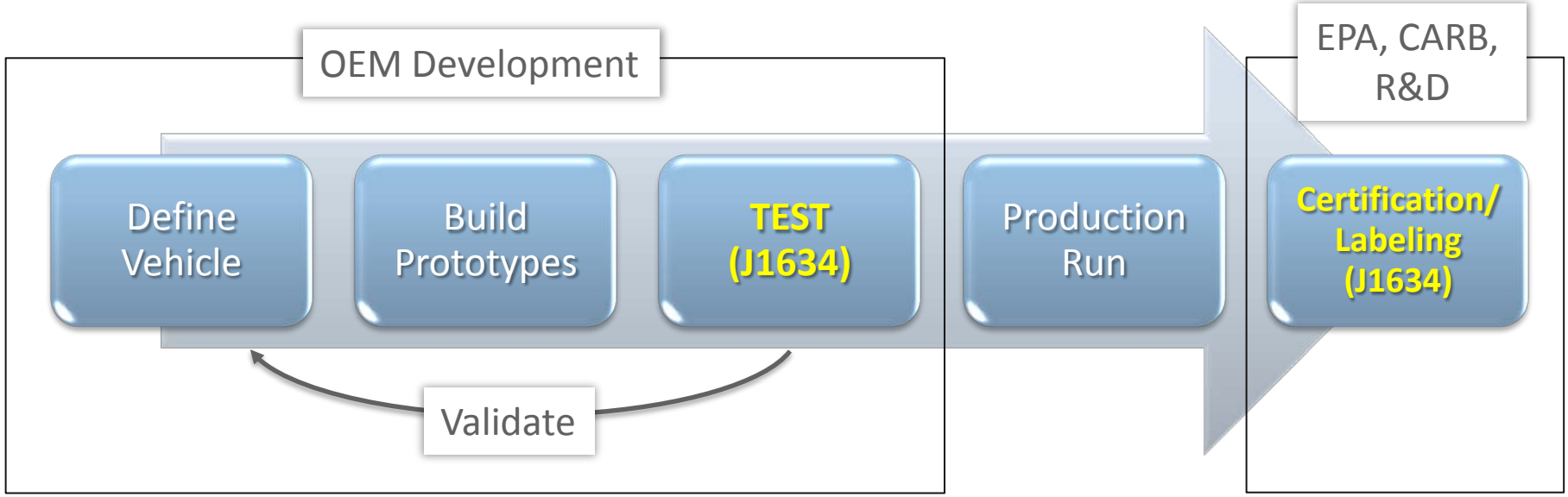
- $0 in FY09
- $150k in FY10
- (not possible without Benchmarking program at ANL)

Partners

- ANL staff is Co-Chair of J1634
- Task Force includes experts from EPA, Toyota, Honda, Ford, Chrysler, GM, Nissan, JARI, Mitsubishi, CARB, Tesla, BMW

Relevance: Industry and Regulatory Agencies Will Use This Updated BEV Test Procedure

- Vehicle economy / range is defined according to test procedures
- Over-burdensome procedures worked for low volume, one-off EVs
- In 2008, it became clear that production EVs will be in large-scale production
- OEMs knew immediately that the current J1634 is not suitable for >100mi EVs
- Vehicle development process requires repeated tests according to procedures
- **Relevance: Mass produced BEVs will use the J1634 Task Force methods!**



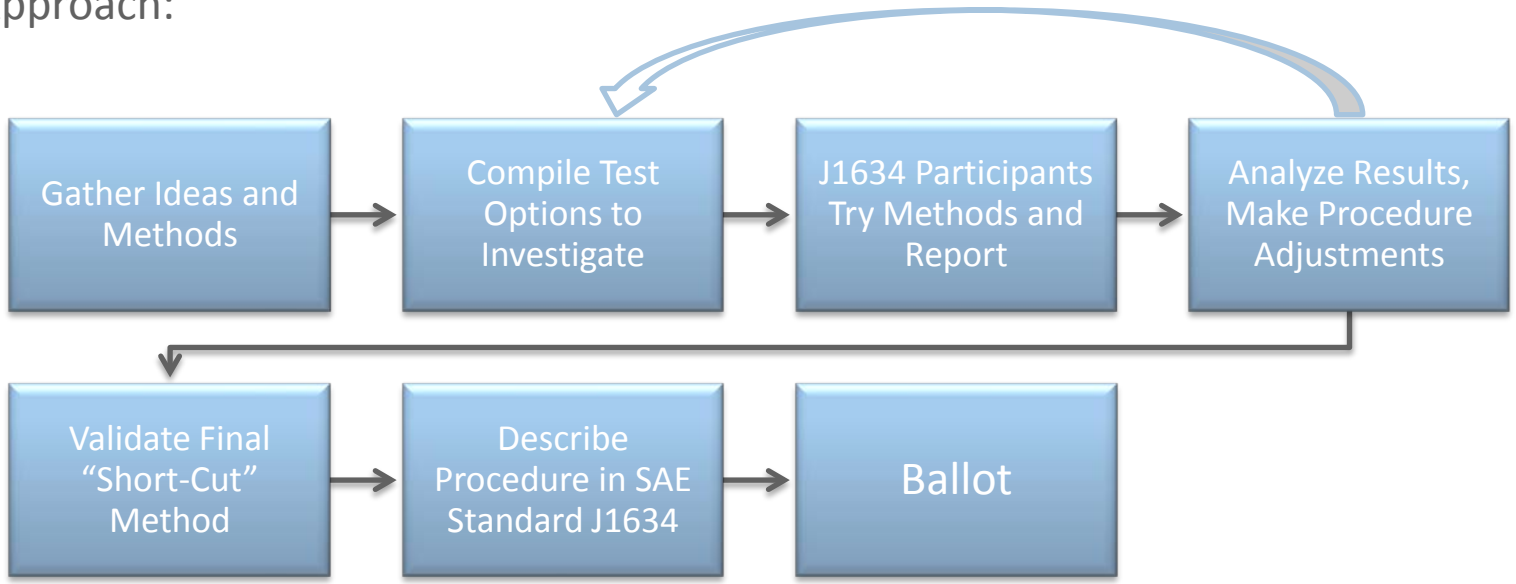
Problem Statement: Current J1634

"Death by Urban"

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

Approach: Co-Chair J1634, Use Concepts Developed in J1711

- Jeff Glodich (Ford) and Mike Duoba co-chair new J1634 task force
- Objective:
  - Develop new, shorter test methods that accomplish the same objectives as existing J1634 procedure
  - Try to solve known weaknesses of “long-form” J1634 test
- Approach:



Approach: J1634 Short-Cut Methods

- Test Product: Find AC Wh/mi and total range for any given cycle
- Constraint: Short-cut must provide repeatable results consistent with the long J1634 method
- Short-Cut Method in General:
  1. Find in-situ battery capacity (an on-dyno test)
  2. Run a representative number of cycles from a full charge
  3. Charge back to full, recording AC Wh
  4. Process data to predict range from consumption rate and capacity
- The above generic approach requires several variables be tested to achieve best accuracy while maintaining manageable total test time.
- ANL tools and vehicles
  - EV-optimized 2WD dyno facility
  - OEM BEVs from AVTA program and private owners
  - ANL-built “TTR” prototype PHEV platform run in EV mode
  - Battery HIL testing isolating battery to validate repeatability, response of battery, charger, and BMS

Technical Accomplishments: ANL Defined The Following Test Methodology Concepts

Committee Looking at the Following Test Components

- **On-Dyno Battery Capacity Test**: Extrapolation based upon dyno test, not from standard battery test data
  - 55 MPH steady-state speed, in 50min segments with 10 min rests.
  - Accel and decel specifications defined
- **"Short Cut":** Run each required cycle 4 times, recharge after
  - AC recharge energy used for consumption result
  - Range is extrapolated using one of several methods still under consideration
- **"Super Short Cut":** Run BEV like a conventional vehicle
  - Run UDDS, HWY, US06, etc as if it were a conventional vehicle, then recharge
  - Use J1711-developed method of assigning AC charger energy based upon DC used in each cycle

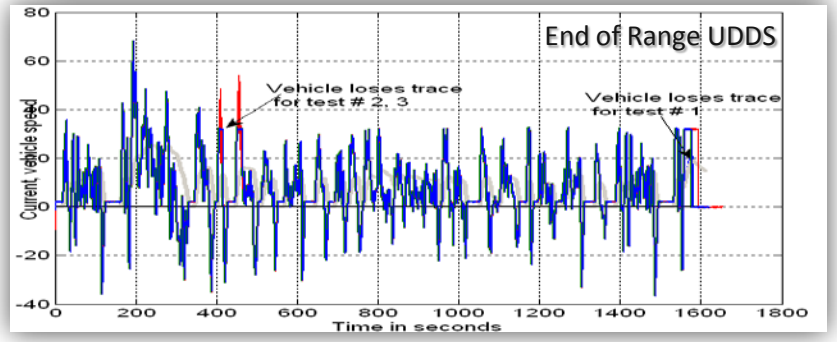
Accomplishments: Used Battery HIL to Test Initial Viability of Short Cut Concepts

- Virtual: Vehicle, powertrain, cycle driving
- Real hardware: Battery, charger, BMS
- Model of vehicle ensured consistent behavior during test options, focusing on battery response
- Conclusions
  - Short-cut methods provide similar and repeatable results
  - Short-cut range determination is in fact more repeatable than long methods because variability in end-of-range power limits during transient cycles

Results Summary

	Shortcut Test # 1	J1634 Test # 1	Shortcut Test # 2	J1634 Test # 2	Shortcut Test # 3	J1634 Test # 3
Range (mi)	123.4	127.31	124.48	122.17	124.48	122.18
Discharge Wh/mile	161.71	165.9	161.51	166.55	161.49	166.86

Observations:
1. The range calculated by the short-cut matches well with the actual range.
2. Discharge Wh/mi by short-cut is ~ 3% higher than the actual discharge range.



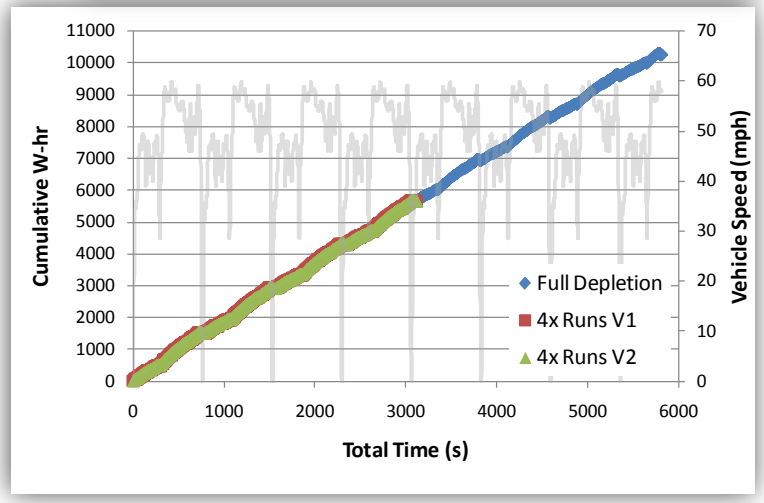
Accomplishments: ANL Testing of OEM Vehicles

- Magna Focus BEV
  - Predating short-cut development
  - More experience conducting J1634
- BMW Mini E
  - Vehicle owned by BMW
  - Testing performed at BMWs California facility, using ANL instrumentation and test plan
  - Differences in methods were small but noticeable
  - Natural test-to-test variability of vehicle made it difficult to find procedure-based biases
- Tesla
  - Private owner donated Roaster Sport for one month of testing
  - Very repeatable results
  - Interesting finds related to intermittent thermal management
  - Still processing data…

Accomplishments: Use ANL Vehicle Platform Tools, "Through-the-road" (TTR) PHEV

- PHEV configured to run in pure EV mode
- Vehicle highly downsized in order to boost actual range
- Experimented to find on-dyno capacity test protocol
- Results of range estimation were encouraging
- Helped quantify important consumption characteristics differentiating warmed-up results versus initial drive cycles

Actual Hwy Range (mi)	77.4
Estimated Hwy Range (mi)	77.0



Collaborations: Standards Development Are Collaborative By Nature. Consensus Must Be Built

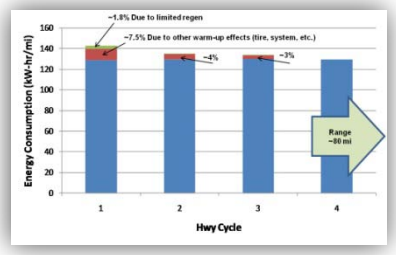
- Ran Mini E with ANL instrumentation hardware at BMW facilities in Oxnard, CA
- Working with Tesla to make dyno test successful (spare parts, traction control assistance)
- Mitsubishi contributed data to committee
- Magna brought early Focus BEV prototype for early ANL testing experience
- Committee participants:

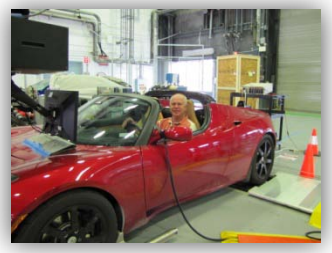
California Environmental Protection Agency AIR RESOURCES BOARD
TOYOTA
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
MITSUBISHI MOTORS
GM
JARI 財団法人日本自動車研究所 Japan Automobile Research Institute
Ford
BMW
CHRYSLER
HONDA
TESLA
NISSAN

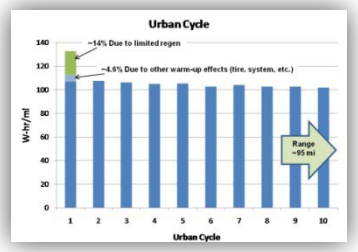
Future Work: New J1634 Test Concept and Still Under Development

- Need more data to have confidence in new methods
- Range estimation methods are very repeatable and comparable to existing long J1634 methods
  - Still need to find best approach
- Short-cut has higher consumption due to warm-up conditions during short-cut
- “Super Short-Cut” eliminated this problem, but has another limitation in intermittent thermal management
- More development needed!

Future Work: Development, Analysis, Validation







- More test data required to validate new procedure concepts
  - Several BEVs planned in AVTA test program
- Current concepts may need adjustments, development
- Complete analysis of various short-cut methods on Tesla results
- Investigate applicability of “super short-cut” method and its compatibility with unpredictable A/C usage invoked by battery thermal management
- Try method on “old” Lead-Acid BEV technology (must work for all BEVs, even old ones)
- More complete and appropriate description of required instrumentation specifications (accuracy, drift, resolution…)

BEV Test Procedure (J1634) Project Summary

- **Objective**: Find 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 tasked with quantifying BEV performance on an dynamometer
- **Accomplishments**:
  - Using experience from ANL's successful benchmarking program, many key features of the new test concepts were ANL contributions
  - Mini E, Tesla, TTR, Battery HIL, and Magna Focus EV prototype testing in support of validating new ideas about test concepts
- **Progress**: Procedures are being honed through testing varied BEV designs, expectations are to finish by end of calendar year
- **In Conclusion**: Many contributions of committee members make this program a truly group effort to providing a solution the critically relevant need of a suitable test procedure for the next generation of electric vehicles