Electric Drive and Advanced Battery and Components Testbed (EDAB)

PI: Jim Francfort
Presenter: Richard "Barney" Carlson
Energy Storage & Transportation Systems
Idaho National Laboratory
Advanced Vehicle Testing Activity (AVTA)

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Overview

Timeline

- FY10 - Project planning, vehicle design
- FY11 - Vehicle conversion, acquire 1st ESS for testing
- FY12 – Calibrate vehicle control system to battery requirements, on-road testing
- FY13 – Continue on-road testing, report and present on findings, plan next ESS to test

Barriers

- Test advanced technology ESS's in on-road conditions
- Test a wide range of ESS's sizes and capabilities (BEV, EREV, PHEV)
- Test power electronics and components in on-road conditions

Budget

- FY10 – $ 356,000
- FY11 – $ 660,000
- FY12 – $ 300,000
- FY13 – $ 150,000

Partners

- Idaho National Lab - lead
- ECOtality North America - testing
- Oak Ridge National Lab - control system
- AVL North America - vehicle integration

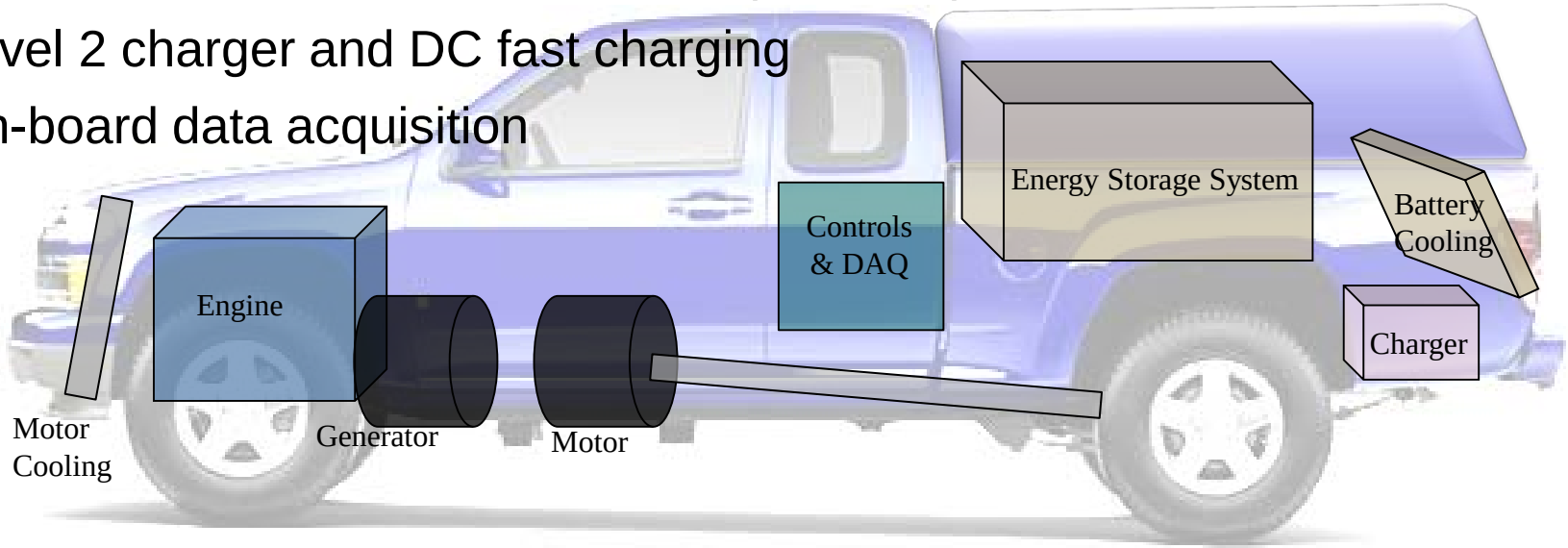
Objective / Relevance

- Provide an on-road and dynamometer capable platform for testing Energy Storage Systems (ESS) developed via DOE ESS supported funding projects
  - Battery Electric Vehicles (BEV)
  - All-Electric Capable Plug-in Hybrid Electric Vehicles (EREV)
  - Blended Plug-in Hybrid Electric Vehicles (PHEV)
- Capture data from ESS performance, capacity fade, and operating condition data during on-road operation
- Capture data from motor and power electronic during on-road operation

Phase 1	**Project Planning (Vehicle specifications, and test plan)**
Phase 2	**Convert vehicle into Series PHEV to enable on-road testing**
	Safety and Flexibility to accept a wide range of ESS to be tested
	Controls to enable proper operation of each type of ESS
Phase 3	**Test the Energy Storage System**
	Dynamometer (Finalize calibrations and Baseline tests)
	Battery laboratory testing (beginning of life, during, and end of life)
	On-road testing until ESS “end of life” (or 3 yrs max or 100k miles)

Approach - Vehicle Testbed

- Mid sized Pickup truck
  - ESS mounted in truck bed
  - Truck cap will cover / protect ESS
- Series powertrain configuration
- Controls system has three control configurations with a weight / road load emulation algorithm to test ESS for intended operation
  - BEV compact 4 door electric sedan (3000 lbs)
  - EREV mid sized 4 door sedan (3500 lbs)
  - Blended PHEV mid sized SUV (4000 lbs)
- Level 2 charger and DC fast charging
- On-board data acquisition



Approach - Overall Test Plan

- Chassis Dynamometer testing (ORNL)
  - Finalize control system calibrations specific to ESS
  - Vehicle baseline testing for each ESS
- ESS Reference Performance Testing (RPT)
  - Beginning of life (BOL)
  - Periodically during on-road testing
    - every 1,500 miles or 30 days of driving(40 to 60 cycles)
  - End of life (EOL)
- On-Road Testing
  - In Phoenix area
  - Approx. 50% city, 50% highway driving
  - Approx. 100 to 150 miles per day
  - Varying range of driving and charging patterns

Milestones

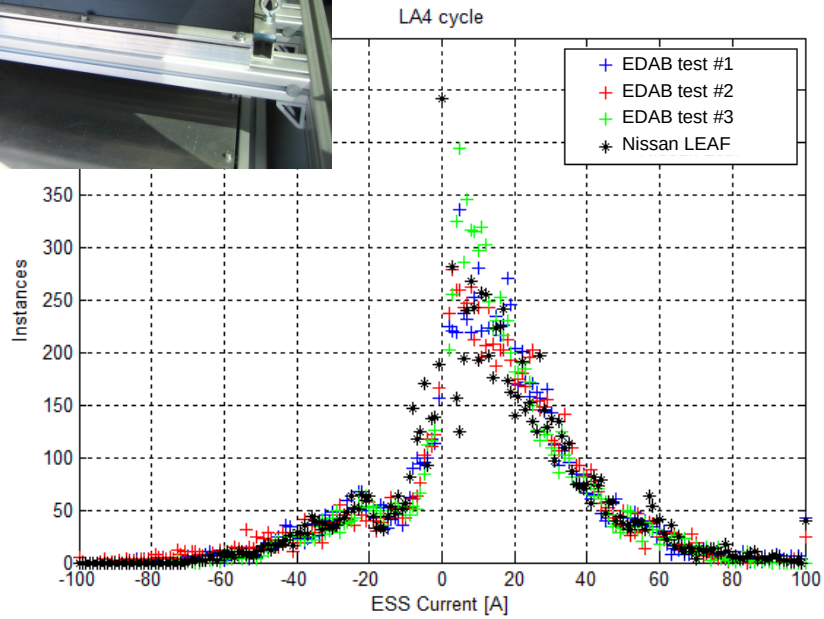
- April 2011 – received 1st ESS (EnerDel Li-ion pack 70 Ah rated)
- Nov 2011 – fully functional ESS integrated into vehicle
- Feb 2012 – control system calibration complete
- Feb 2012 – BOL ESS testing complete
- March 2012 – on-road testing initiated
- March 2013 – 12,600+ miles of on-road testing

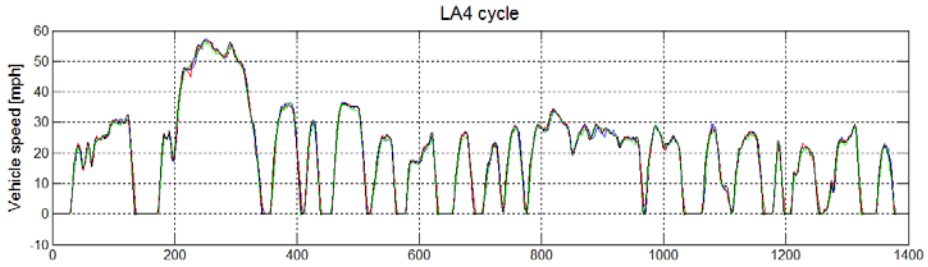
Technical Accomplishments

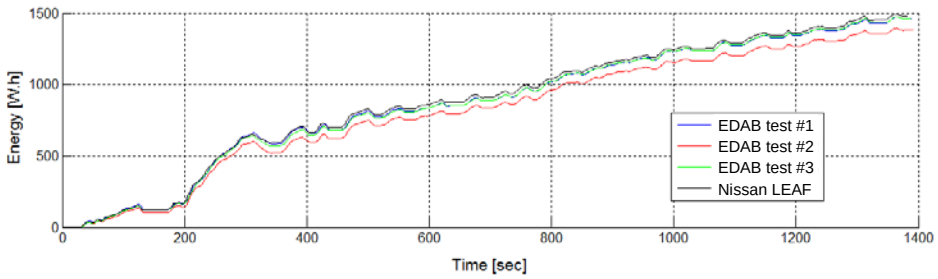
- Control system calibration complete (ORNL)
  - ESS power and energy demand representative of baseline BEV (Nissan Leaf)
- On-road testing initiated
  - On-road driving daily of 2 cycles (drive, charge, drive, charge)
  - initial results show ESS operating consistent with small BEV
- After 12,600 miles of real world driving and charging
  - Measured capacity fade of 14.5% (63.2 to 54.0) since BOT
  - ESS discharge resistance (at 50% SOC) increased 26% since BOT

Technical Accomplishments (continued)

- Control system calibrated to utilize the ESS within the operating range of a Nissan Leaf (BEV)
- Energy throughput over standard drive cycles differs less than 6% from Nissan Leaf
- Current profiles are very similar



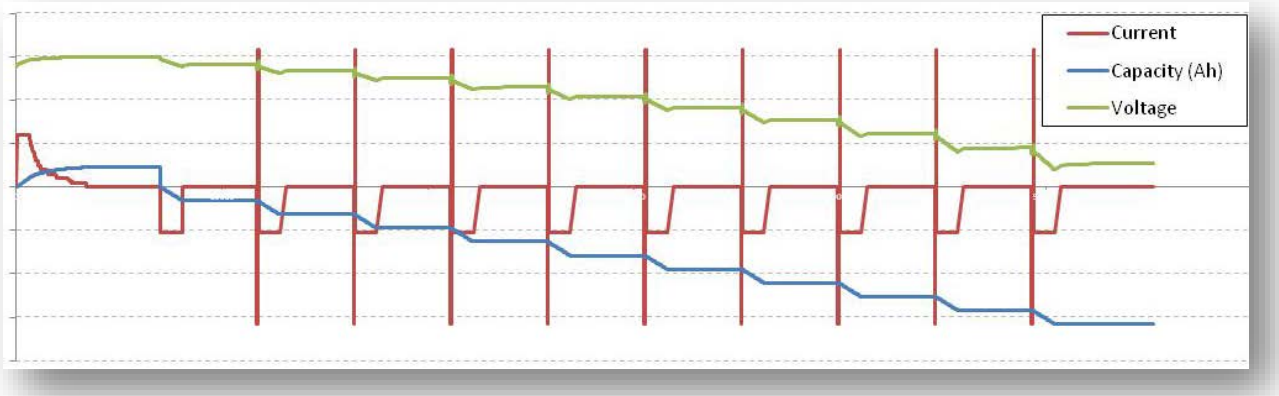




Technical Accomplishments (continued)

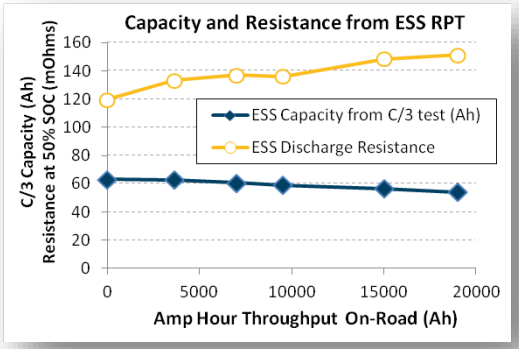
- Beginning of Life ESS testing is complete
  - C/3 capacity testing
  - EVPC power pulse testing

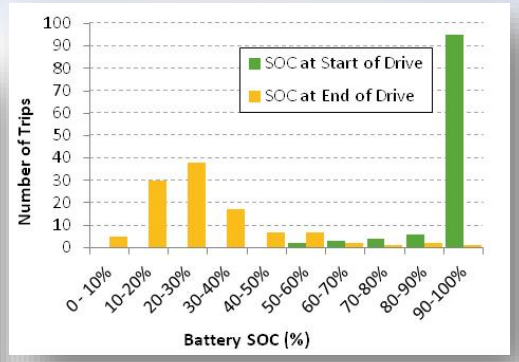
- Beginning of Life testing results
  - Capacity (C/3)
    - 63.2 Ah
  - EVPC Discharge Resistance (@ 50% DOD)
    - 120 mOhms
  - EVPC Charge Resistance (@ 50% DOD)
    - 96 mOhms



Technical Accomplishments (continued)

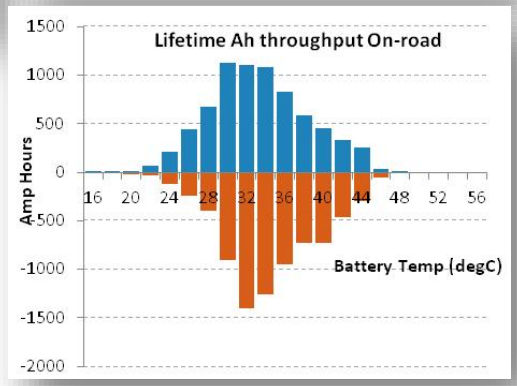
- Real-world driving & charging
  - EnerDel 70Ah pack

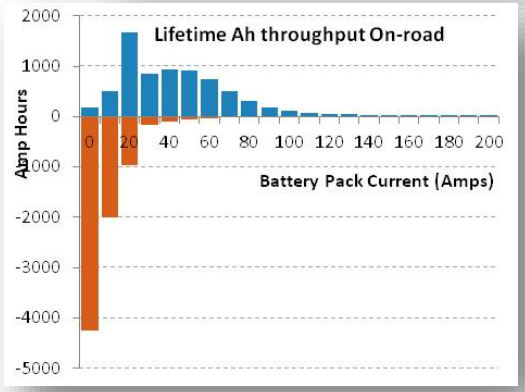




<u>On-road results through 2/25/13</u>

- 14.5% ESS capacity fade
- 26% increase in discharge resistance
- 19,000 Ah total throughput (~150 full cycles)
- 12,600 miles driven
- 232 DC Wh/mi
  - Very similar to Nissan Leaf operation
- 52% City / 48% Hwy
- On-road ESS temperature operating between 20°C and 48°C (typically 30°C to 36°C)
- Most on-road ESS operation below 70 A (i.e. below C_1 rate)





Collaboration

- Results from ESS testing will be provide to U.S. DOE, Tech Teams, and other National Labs for use with modeling tools, energy storage development, and improved understanding of operating conditions of ESS's during driving and charging
- After ESS has reached End of Life (EOL), the ESS will be transferred to 2nd Use ESS projects

Future Work

- At the completion of testing of the EnerDel ESS, transfer ESS to 2nd Use experiment
- Next ESS to be tested
  - Quotes were received from several companies
    - Various ESS capacities and applications (PHEV40 and BEV)
- ESS chosen as next test subject
  - Toshiba 20Ah SCiB (Lithium-Titanate) ESS
  - Liquid cooled
  - PHEV pack configuration (13.2kWh)

Summary

- The project is in Phase 3 (On-road ESS testing)
  - Baseline dynamometer testing and controls calibration is complete
  - Beginning of Life ESS testing is complete
  - On-road ESS testing is being conducted

- Provide data/results from on-road operation of advanced technology ESS
  - Power and Capacity Fade results
  - Impact of driving / charging patterns on ESS
  - Temperature operation effects
  - Cell balancing impact and interaction by on-road operation
  - Power and energy utilization impact
- Provide data / results from on-road operation of motor and power electronics
- Provide EOL ESS to "2nd Use ESS" Experiments

Acknowledgement

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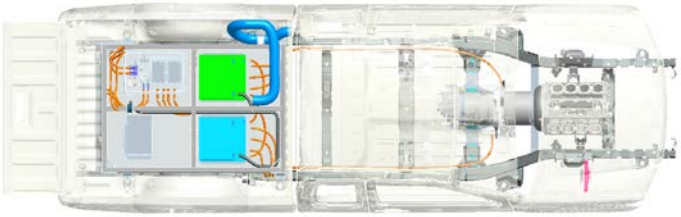
More Information

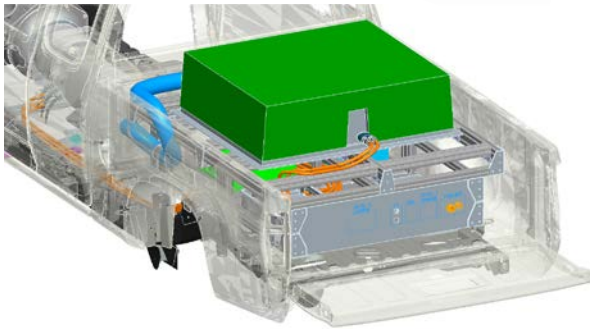
http://avt.inl.gov

Reviewer-Only Slides

Vehicle Testbed

- Flexibility to test a wide range of ESS
- Up to 48” W x 68” L x 30” H
  - “T” portion of a “t - pack” can be up to 52”
- Load capacity up to 1000 lbs.
- Modular mounting system
- Liquid cooling and air cooling systems for ESS are integrated into the testbed
- Power capability up to 145 kW (propulsion and regenerative braking)
- Testbed is compatible with 340 to 420 VDC (down to 240 VDC with decreased power)
- Controls communications (CAN), safety interlock, charging flexibility (Level 1 up to 50+ kW)





EDAB Synergies with other DOE Activities (PHEV R&D plan)

- Energy Storage
  - Testing mechanism for testing battery pack deliverables from ARRA program
  - Preparation of “end of life” battery packs for use in “2nd use” battery experiments
  - Ability for fast charging (demonstration, communication, impact on battery life)
  - Ability for testing and demonstration of advanced battery system combinations
    - Batteries and ultra capacitors combinations
    - Energy battery and Power battery combinations
- Electric Drive Systems
  - Provide on-road benchmark data to Power Electronics community from one advanced traction drive DC Brushless motor system (others in future with additional vehicle test platforms)
  - System interactions during on-road driving
    - Noise on high voltage bus; temperature limitations / cooling requirements validation; communications challenges (traction drive, battery system, APU)
- Vehicle Efficiency Technologies
  - Provide battery in-use data to modeling community
  - Provide motor and power electronics operation data to modeling community
  - EREV and PHEV controls systems and calibrations utilized