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# **Plug-In HEV Sprinter Van – Battery Considerations and Test Results**

**ZEV Technology Symposium**  
California Air Resources Board  
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# Project Overview

- Objectives
  - Understand battery cycle life durability in PHEV application
  - Acquire specific knowledge of battery durability for PHEV Sprinter Program
- Methodology
  - Conduct sub-pack and pack laboratory tests
  - In-vehicle field tests (three-year duration, not discussed today)
- Participants
  - Southern California Edison (Battery testing and primary project sponsor)
  - EPRI
  - National Renewable Energy Laboratory
  - DaimlerChrysler
  - Battery suppliers (JCI, SAFT)

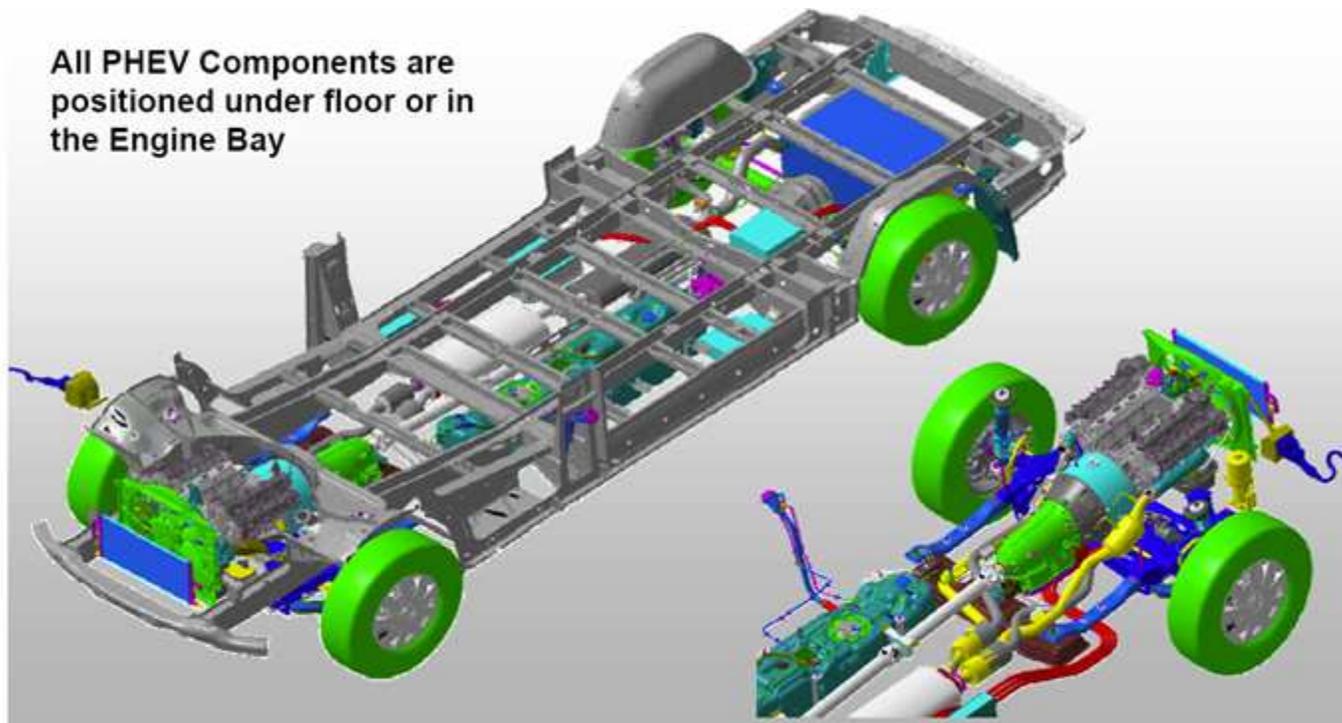
# The Advanced Battery Challenge for Plug-In HEVs

## Consensus conclusion of May 4-5 DOE Meeting on PHEVs

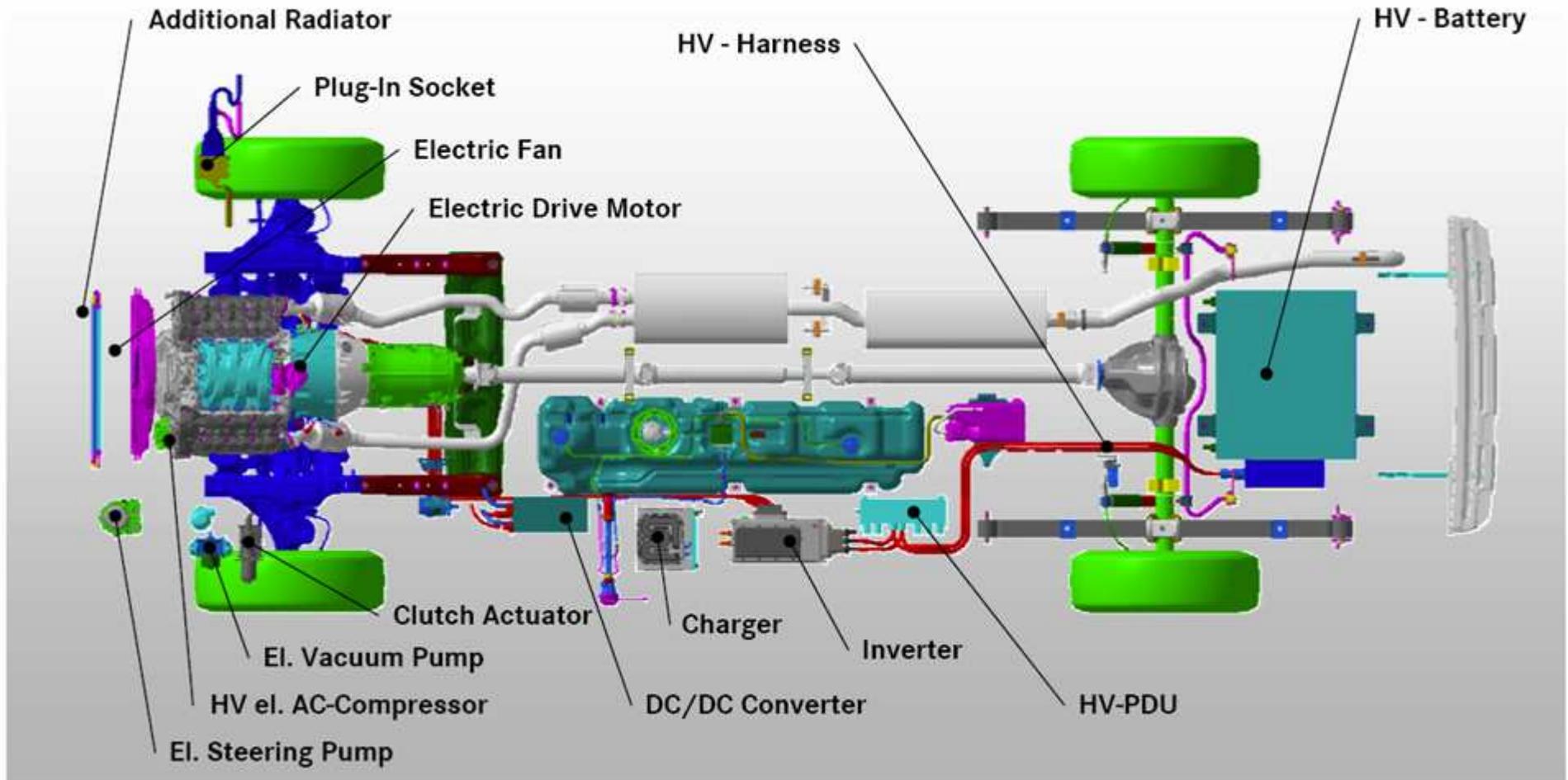
- Key questions are cycle life, and cost/availability of energy batteries for PHEVs
- Current durability test data shows potential for current advanced batteries to meet cycle and calendar life requirements
- Large body of knowledge on battery capabilities for EVs and power assist hybrids (led by USABC)
- **For PHEVs:**
  - Need specific test data for PHEV requirements
  - Must evaluate latest chemistries
  - Continue to evaluate for cycle and calendar life durability, safety

# PHEV Sprinter Overview

- Large commercial van platform—cargo or passenger
- PHEV with up to 20 miles EV range in urban driving
- High power, parallel hybrid system



# Plug-In Hybrid System Schematic



# Battery Technologies

- **VARTA NiMH Vehicle Battery**
  - 280 cells (70 – 4 cell modules)
  - 40 Ah cell capacity
  - 14.4 kWh
  - 70 kW (peak power)
  - 40-cell test pack (50 V nom.)
- **SAFT Li-Ion Vehicle Battery**
  - 102 cells (17 – 6 cell modules)
  - 39 Ah per module
  - 15.5 kWh
  - 87 kW (peak power)
  - 18-cell test pack (65 V nom.)



# **Test Profile Development**

# PHEV Test Profile Development

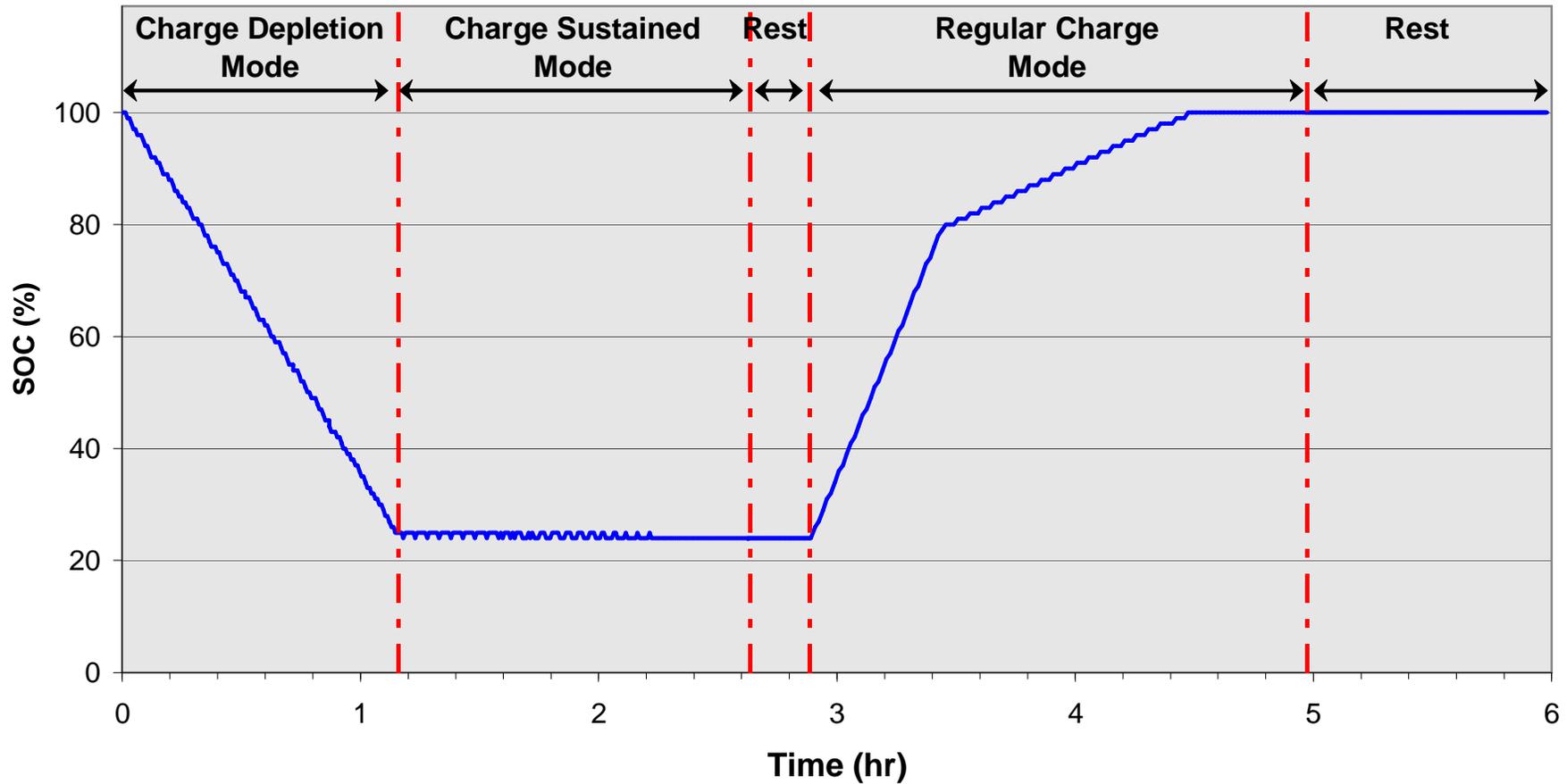
- Derived from a dynamic vehicle-level simulation
- Based on the final portion of the INRETS URB1 vehicle test cycle
- Replicates the urban driving conditions likely to be the most demanding to the battery (low speed, high acceleration and charge-sustained HEV mode at low battery SOC)
- Uses a combination of both HEV and EV driving modes to represent greater than 50% of statistical daily trips

# PHEV Test Profile Overview

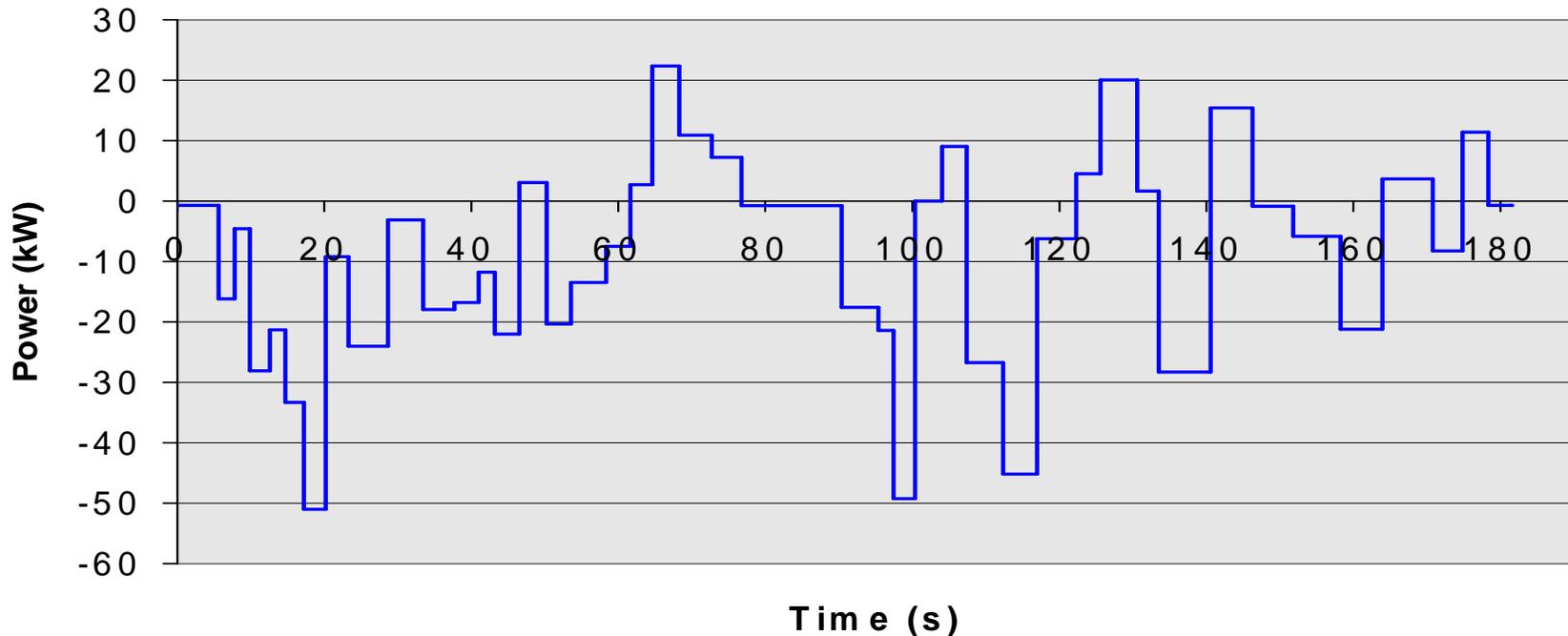
- Test profile composed of three main modes
  - Charge depletion mode, simulating the EV operation
  - Charge sustained mode, simulating the hybrid operation (HEV mode)
  - Regular charge mode, simulating the vehicle being recharged from an outlet

(Equivalent to a 2.6 hours / 50 miles drive)

# Simulating a Plug-In HEV Duty Cycle

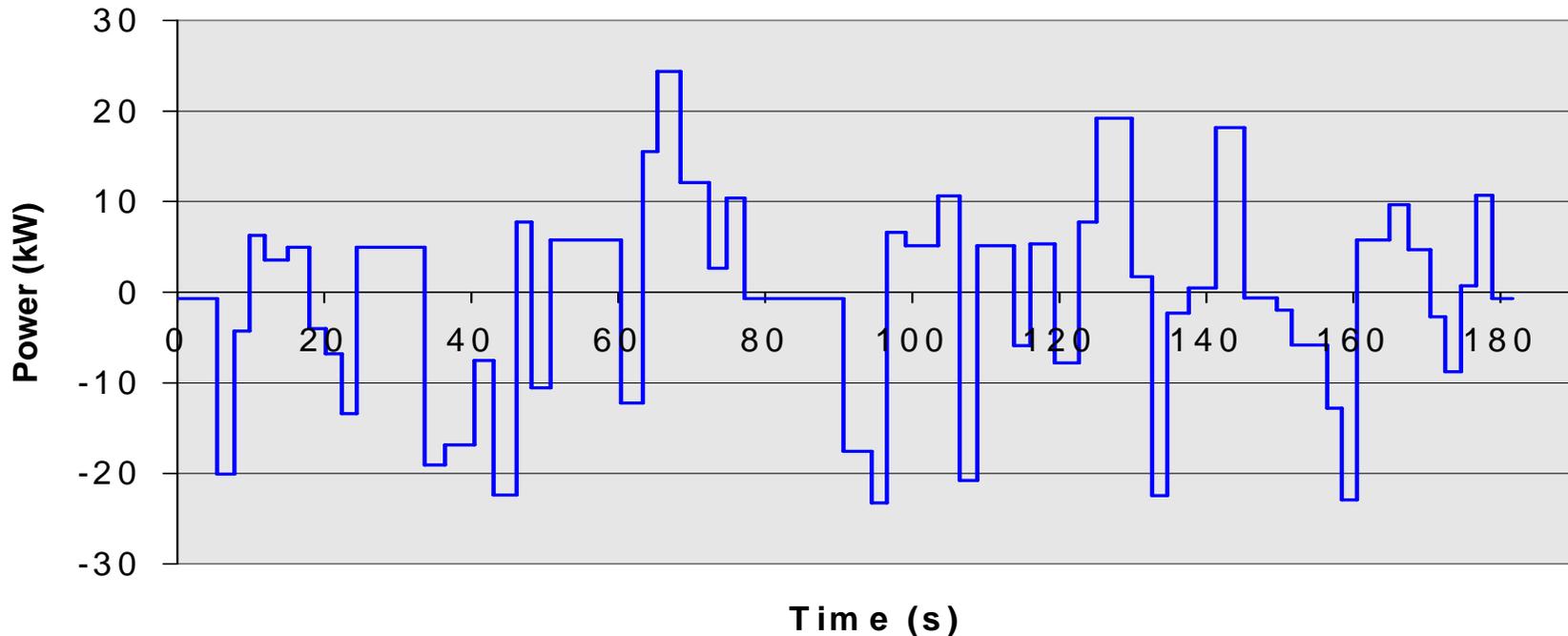


# Charge Depletion Mode



- 180 sec test cycle
- Run from 100% SOC down to approximately 25% SOC
- Mode ends when the battery voltage stays below a pre-defined threshold for more than 10 sec

# Charge Sustained Mode

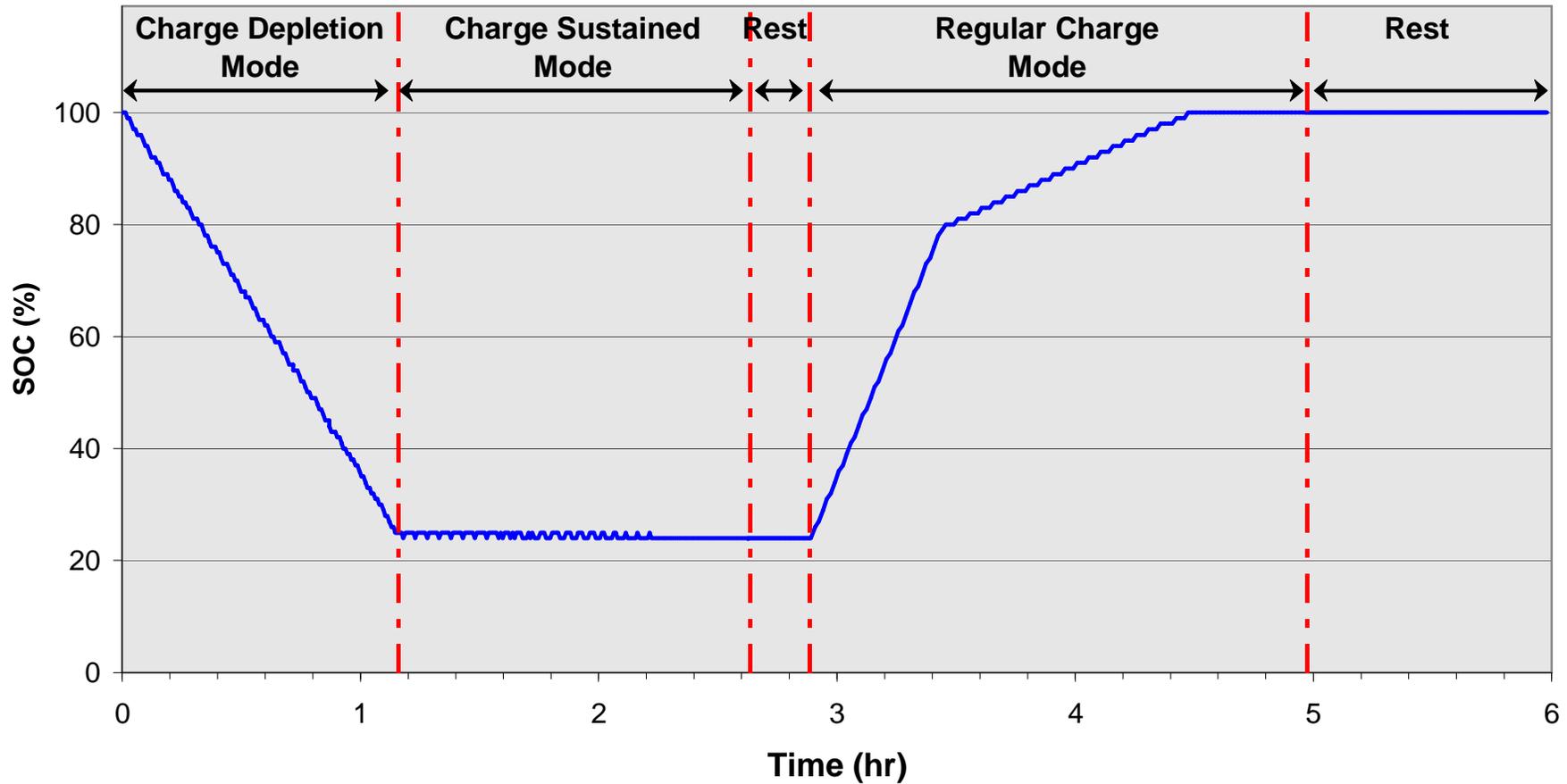


- 180 sec test cycle
- Run at approximately 25% SOC
- Mode ends when the duration of the charge depletion mode plus the duration of the charge sustained mode reaches 2.6 hours

## Regular Charge Mode

- A regular charge, following the manufacturer recommendation, is applied to the battery
  - Charge rate is C/1 for the VARTA NiMH battery
  - Charge rate is C/2 for the SAFT Li-Ion battery

# Simulating a Plug-In HEV Duty Cycle

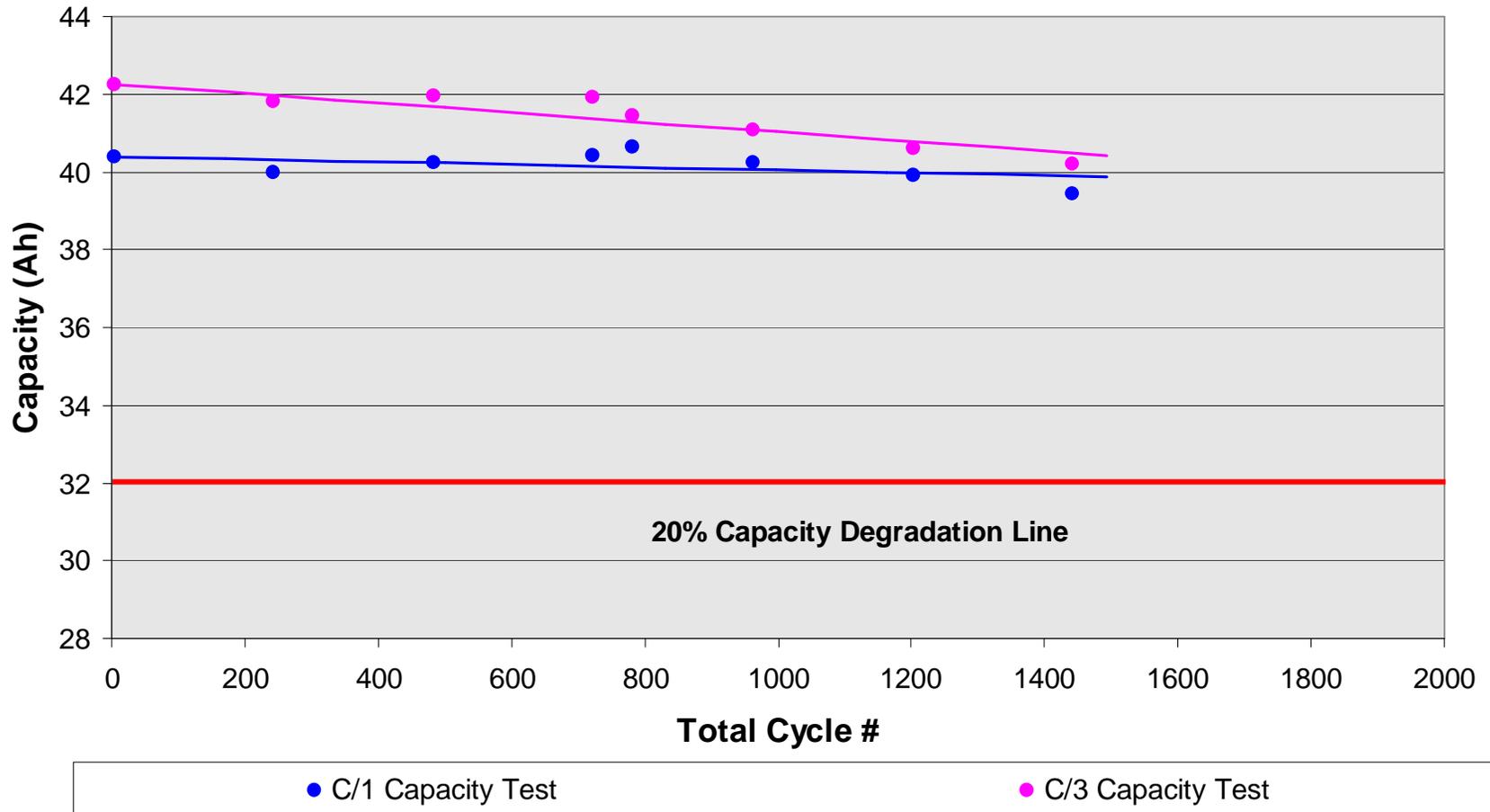


# **Current Status of Test Results**

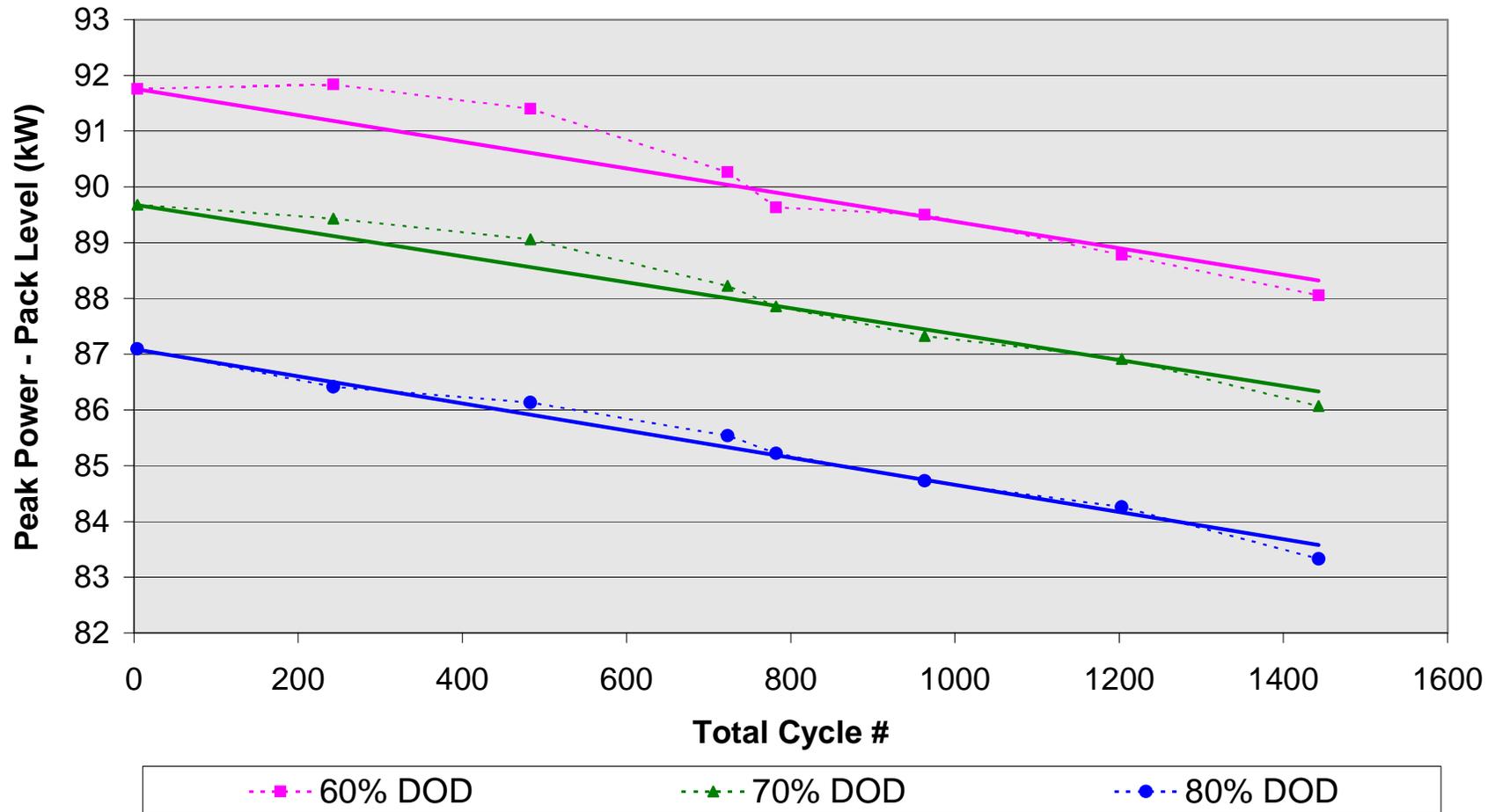
# Reference Performance Test

- RPTs are performed every 200 cycles (approximately 50 days) and includes:
  - A C/1 Capacity Test
  - A C/3 Capacity Test
  - A Peak Power Test (USABC Test Manual)
  - An HPPC Test (Hybrid Pulse Power Characterization – PNGV Test Manual)

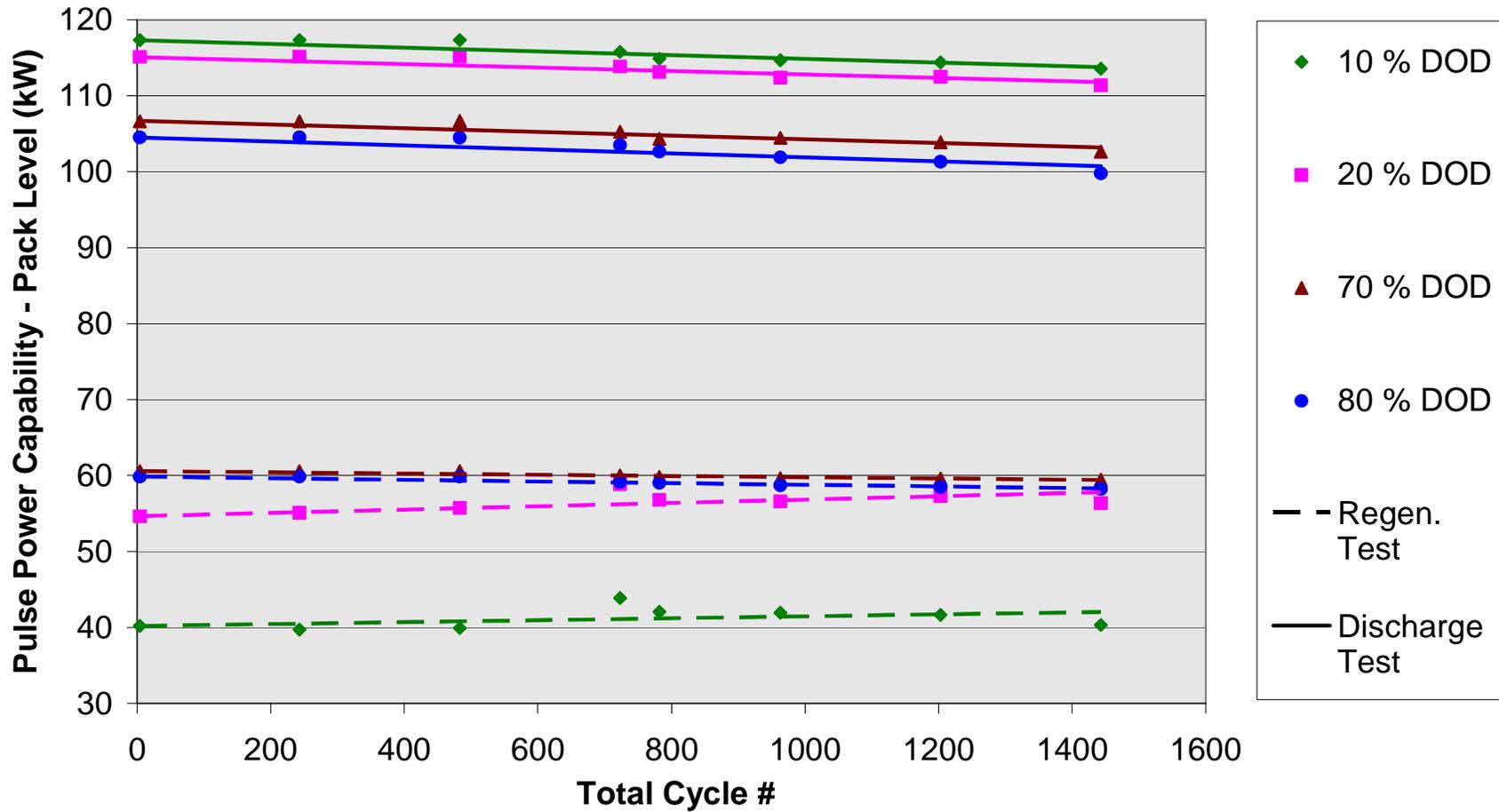
# SAFT – Capacity Test Results



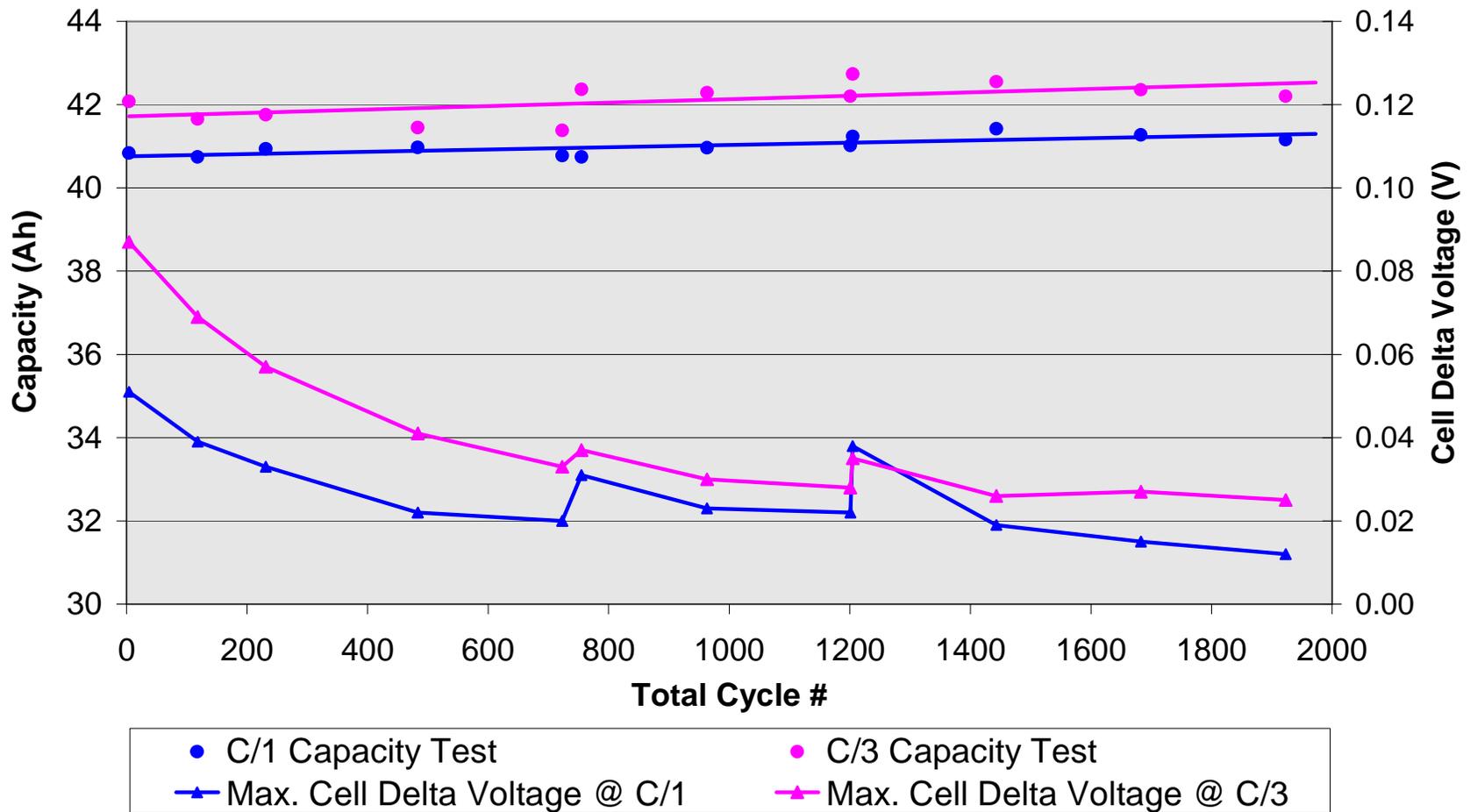
# SAFT – Peak Power Test Results



# SAFT – HPPC Results



# VARTA – Capacity Test Results



# Project Status

- VARTA NiMH Battery (DNP2)
  - Battery went through **1950** cycles – 18.5 Months
  - No significant capacity degradation
  - ~ 6% of power degradation
- SAFT Li-Ion Battery
  - Battery went through **1450** cycles – 15.5 Months
  - ~ 5% of capacity degradation
  - ~ 4% of power degradation

## Next Steps

- Continue battery modules testing for up to 3,000 cycles
  - Expected completion dates:
    - August 2007 for the VARTA battery pack
    - February 2008 for the SAFT battery pack
- Introduce full battery pack testing to validate sub-packs test results
- Three-year field evaluation of PHEV Sprinter battery systems (Phase 1 & 2 vehicles)

**Extra Slides**



# Acknowledgements

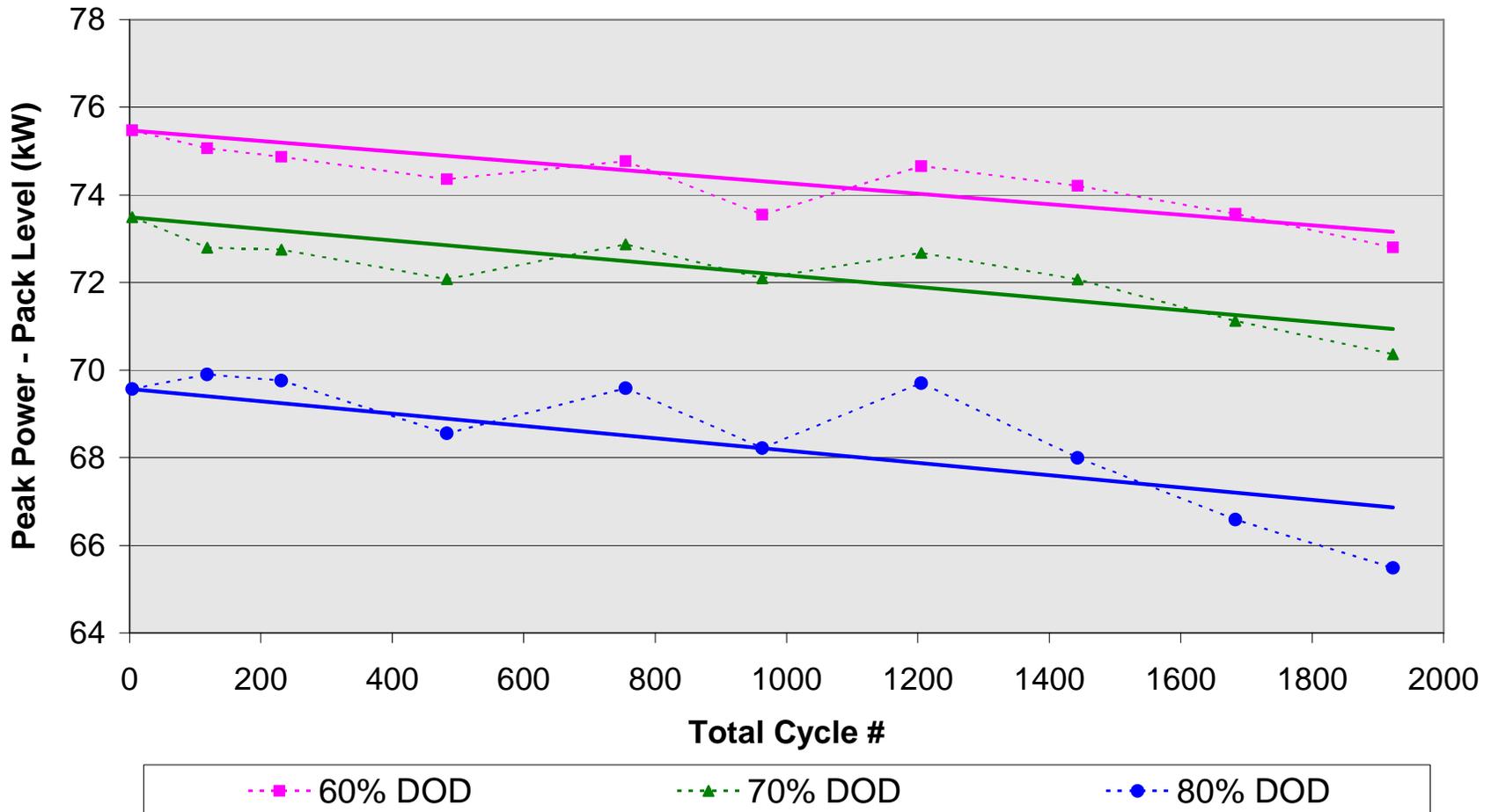
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# VARTA – Peak Power Test Results



# VARTA –HPPC Results

