U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Benchmarking of Competitive Technologies

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Project ID:
apep_03_burress

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Overview

Timeline

- Start: FY04
- Finish: Ongoing

Barriers

- Integrating ORNL developed controller with OEM components
- Adapting novel fixture to test cell

Budget

- Total project funding
  - DOE: 100%
- Funding received in FY08
  - $582K
- Funding received in FY09
  - $472K
- Funding requested in FY10
  - $547K

Partners

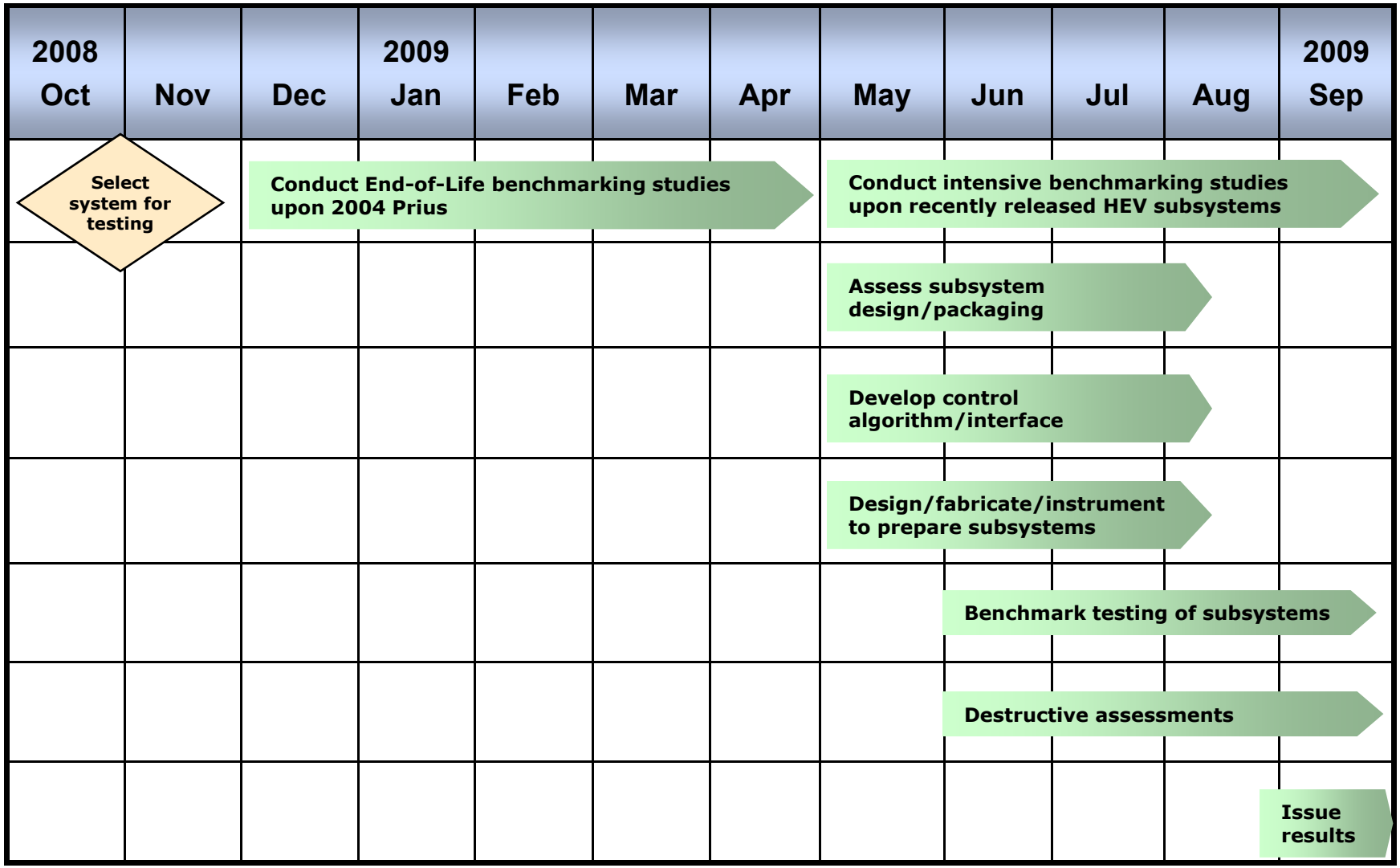
- Argonne National Laboratory

Objectives

- **Conduct End-of-Life studies upon 2004 Prius**
  - Evaluate components from fleet vehicles operated for more that 165,000 miles
  - Observe impacts of extended operation within vehicle

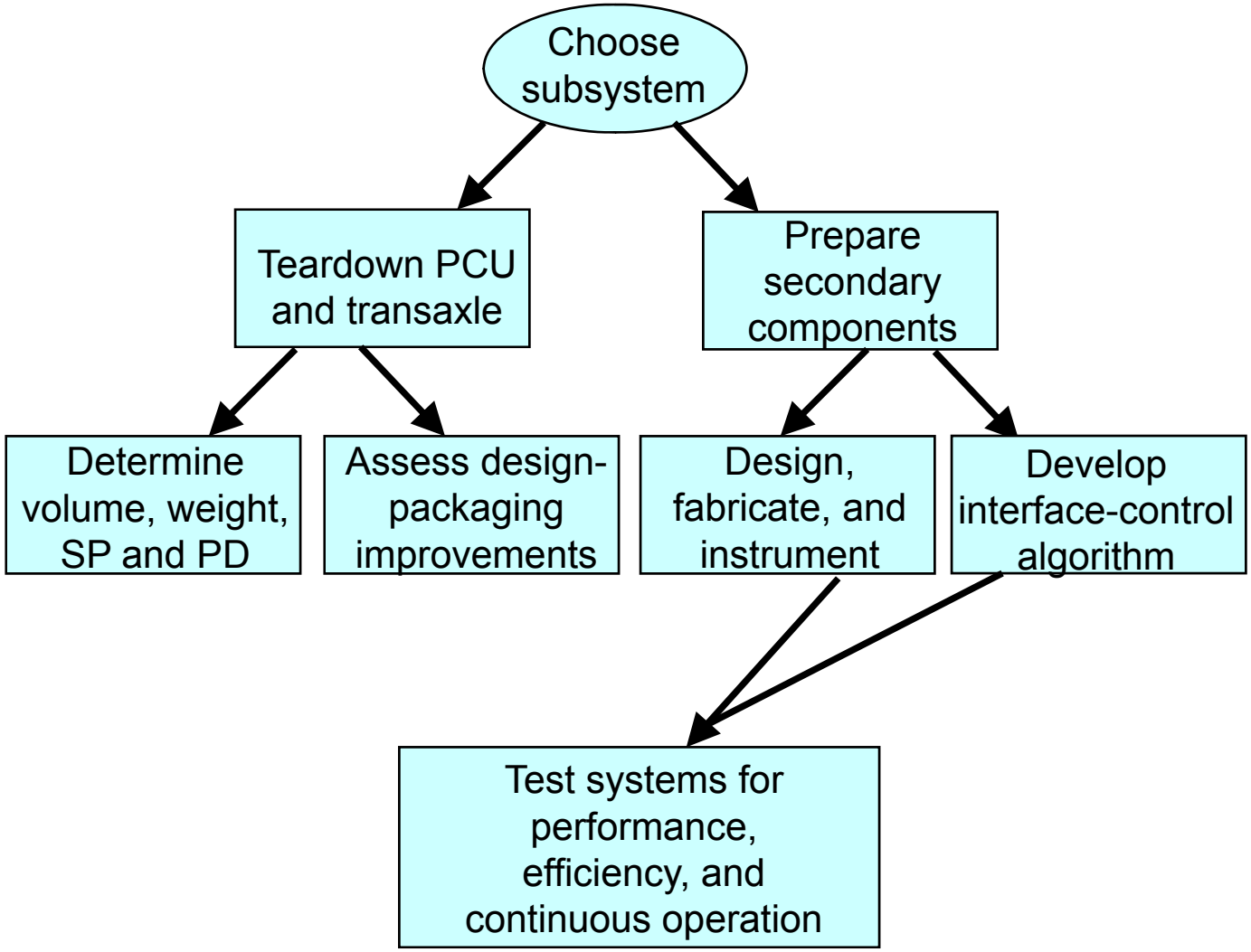
- **Benchmark 2010 Prius (or other state-of-the art HEV technology, if unavailable)**
  - Assess design, packaging, and fabrication characteristics from intensive disassembly of subsystems
    - Determine techniques used to improve specific power and/or power density
    - Reveal compositions and characteristics of key components
      - Trade-offs (magnet strength vs coercivity)
      - General cost analysis
  - Examine performance and operational characteristics during comprehensive test-cell evaluations
    - Establish realistic power rating (18 seconds)
    - Provide detailed information regarding time-dependent and condition-dependent operation
  - Develop conclusions from evaluations and assessments
    - Compare results with other HEV technologies
    - Identify new areas of interest
    - Evaluate advantages and disadvantages of design changes
      - Example: Complexity of LS 600h double sided cooling system

Milestones



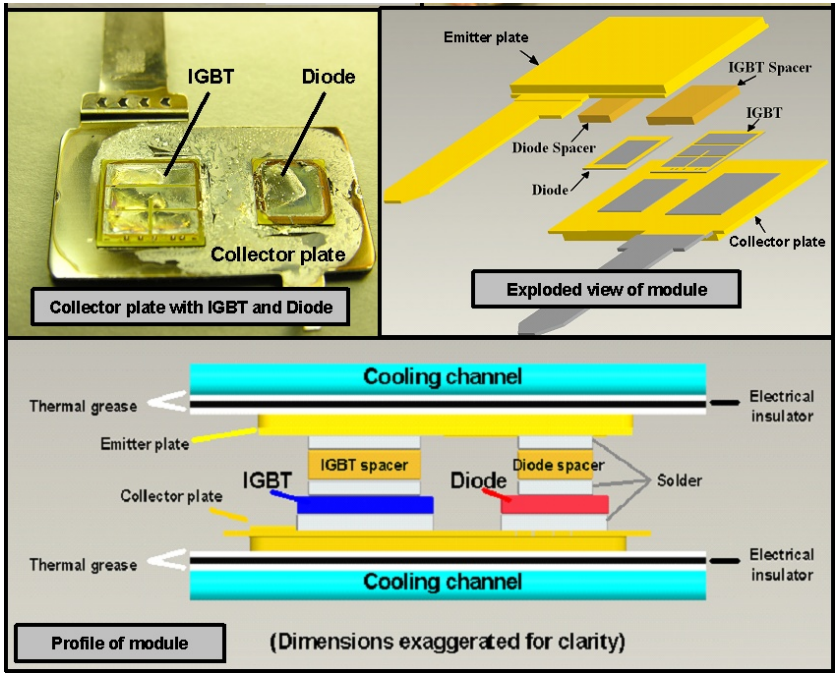
Decision Point: Selection of subsystems to be evaluated in FY09 based upon input from DOE and EETT

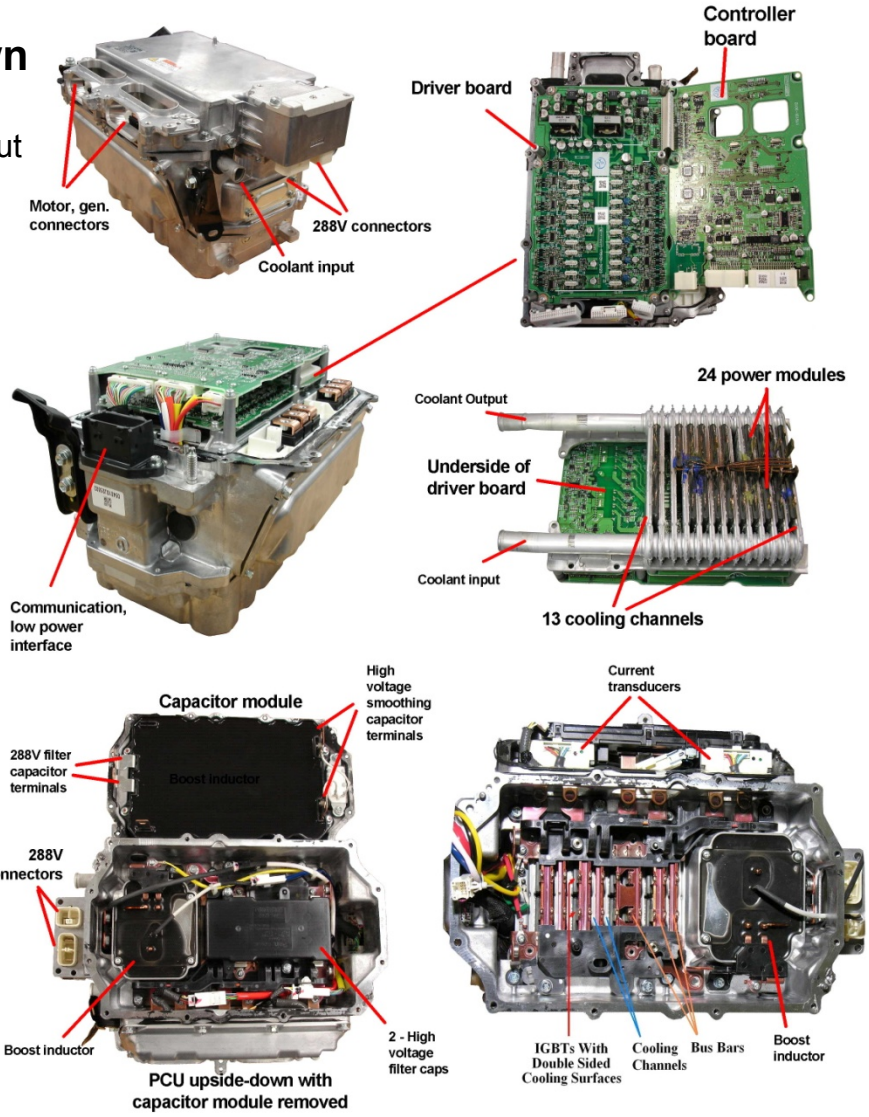
Approach


Choose subsystem
Teardown PCU and transaxle
Prepare secondary components
Determine volume, weight, SP and PD
Assess design-packaging improvements
Design, fabricate, and instrument
Develop interface-control algorithm
Test systems for performance, efficiency, and continuous operation

Technical Accomplishments (1)

- **LS 600h Power Converter Unit teardown**
  - Comparison of size and power capability
  - Comparison of power electronics design and layout
- **LS 600h power module much more advanced**
  - Double sided power module and cooling infrastructure

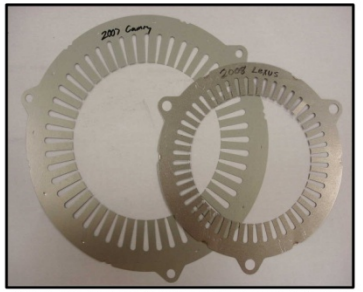




Technical Accomplishments (2)

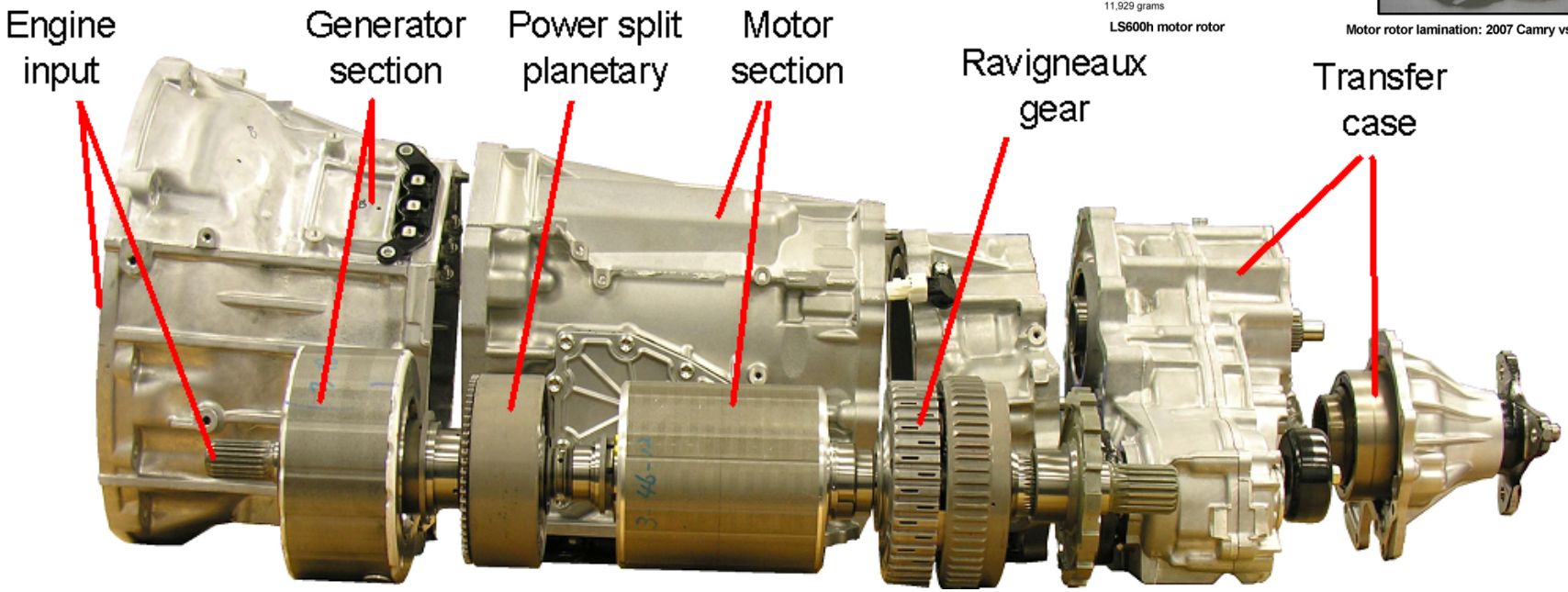
- Lexus LS 600h transaxle teardown
  - Evaluation of drive characteristics
    - Planetary/drive gears, motor volume, etc
  - Assessment of cooling system functionality
    - Oil flow and heat exchange

LS600h motor stator


Motor stator lamination: 2007 Camry vs 2008 LS600h

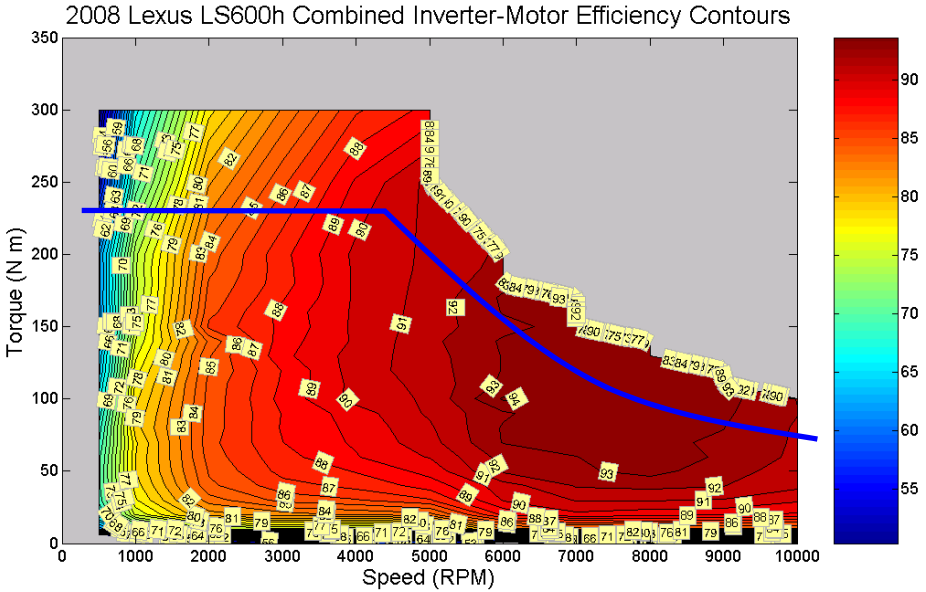
LS600h motor rotor

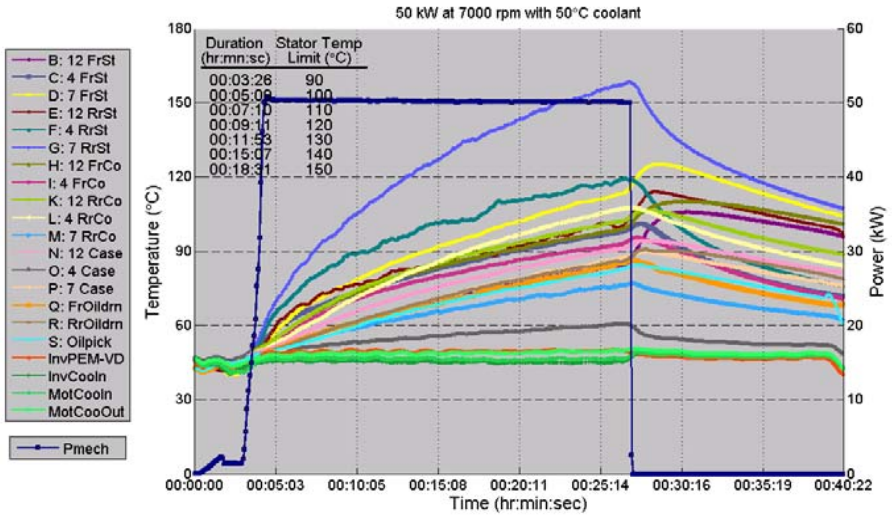

Motor rotor lamination: 2007 Camry vs 2008 LS600h

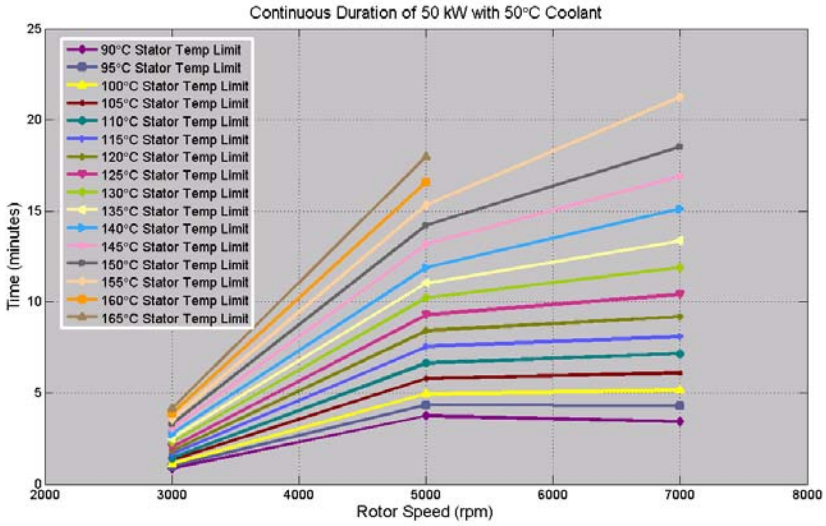


Technical Accomplishments (3)

- **LS 600h efficiency and continuous test results**
  - Steady state efficiency map
  - Continuous duration
    - Dependent upon speed, coolant temperature, and stator temperature limitations
    - Camry much higher than Prius
    - Similarities between LS 600h and Camry







Future Work

- **Benchmarking efforts will focus on technologies of interest to DOE, the Electrical and Electronics Technical Team, and Vehicle Systems Analysis Technical Team**
- **Comprehensive analyses of subject technologies**
  - Assess design, packaging, and fabrication characteristics from intensive disassembly of subsystems
    - Determine techniques used to improve specific power and/or power density
    - Reveal compositions and characteristics of key components
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Summary

- Various drive systems sub-assemblies fully assessed (Prius, Accord, Camry, LS 600h)
  - Power density and specific power determined
  - Design specifications validated

Component & Parameter	Lexus (110 kW)	Camry (70 kW)	Prius (50 kW)
Motor			
Peak power density, kW/L	**6.6**	**5.9**	**3.3**
Peak specific power, kW/kg	**2.5**	**1.7**	**1.11**
Inverter (excluding generator inverter)			
Peak power density, kW/L	**10.6**	**7.4**	**3.6**
Peak specific power, kW/kg	**7.7**	**5.0**	**3.7**

Design Feature	2008 LS 600h	2007 Camry	2006 Accord	2004 Prius
Motor-related Technology				
Motor peak power rating	110 kW	70kW	12.4 kW	50 kW
Motor peak torque rating	300 Newton meters (Nm)	270 Nm	136 Nm	400 Nm
Rotational speed rating	10,230 rpm	14,000 rpm	6,000 rpm	6,000 rpm
Power electronics-related Technology				
IPM Cooling	Double-sided infrastructure, water/glycol loop	Heat sink with water/glycol loop	Air-cooled heat sink	Same as Camry
Bi-directional DC-DC converter output voltage	~288-650 Vdc	250–650 Vdc	N/A	200–500 Vdc
Bi-directional DC-DC converter power rating	36.5 kW	30 kW	N/A	20 kW
High-voltage (HV) Ni-MH battery	288 V, 6.5 Ah,	244.8 V, 6.5 Ah,	144V, 6.5 Ah	201.6 V, 6.5 Ah,
	36.5 kW	30 kW	13.8 kW	20 kW