



Benchmarking of Competitive Projects

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FY 2005 AOP Task No.: 2.3

**Advanced Power Electronics and Electrical Machines
Quarterly Review
National Transportation Research Center
January 2005**



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Project Summary

- **Background – The project seeks to benchmark and fully characterize competitive automotive hybrid technologies**
- **Expected Outcome #1 – The project will result in a full understanding of operational and thermal performance of known designs**
- **Expected Outcome #2 – The project will answer specific questions pertaining to the likelihood of FreedomCAR reaching design targets.**

Project Summary (continued)

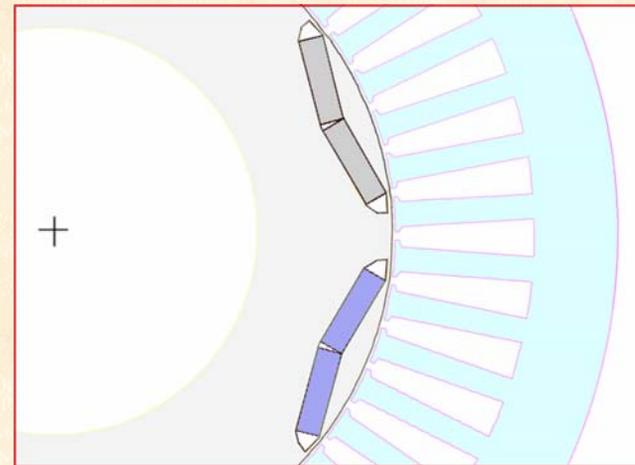
- **Approach – Production hybrid systems are being disassembled, inspected, modeled, and thoroughly tested under controlled conditions.**
- **Timeframe – Testing the hybrid system out of the vehicle requires developing an inverter controller (several-month process).**

Project Summary (continued)

- **Relation to Other Projects:**
 - **Test data benefits ongoing research at ORNL**
 - **Electric Motor R&D**
 - **Field weakening/CPSR enhancement**
 - **Temperature prediction model**
 - **Thermal management studies (Hsu)**
 - **Manufacturing/packaging of inverters**
- **Industry Interactions – Automotive industries benefiting via reports to the EE/TT**
- **Funding – \$473K and spending is on target**

Objectives

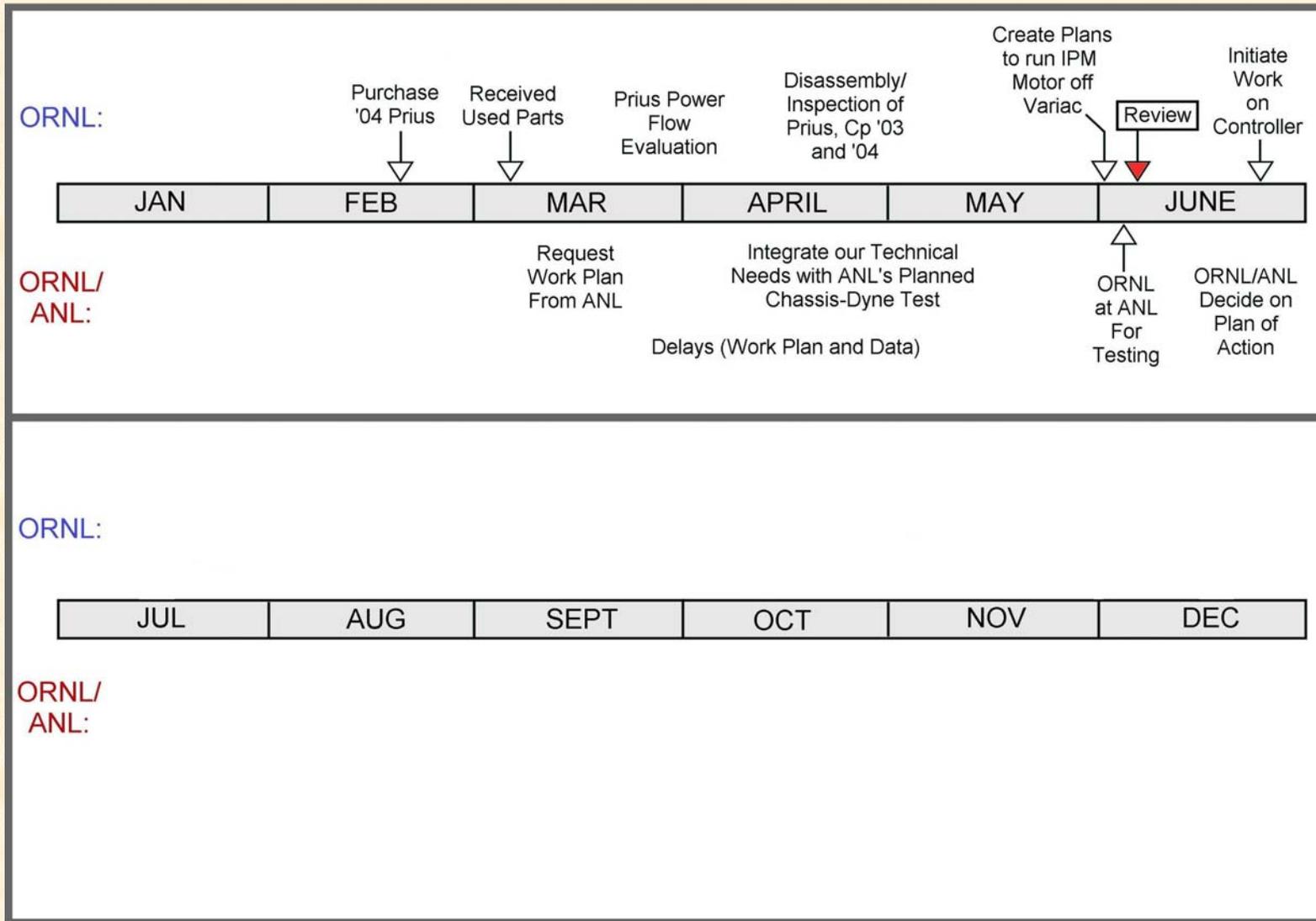
- **Goal – Test and characterize new technological and manufacturing advances of interest to FreedomCAR**
- **Specific Objectives – Conduct electrical and thermal studies**
 - Completion of 2004 Prius
 - Additional hybrid systems now in the market



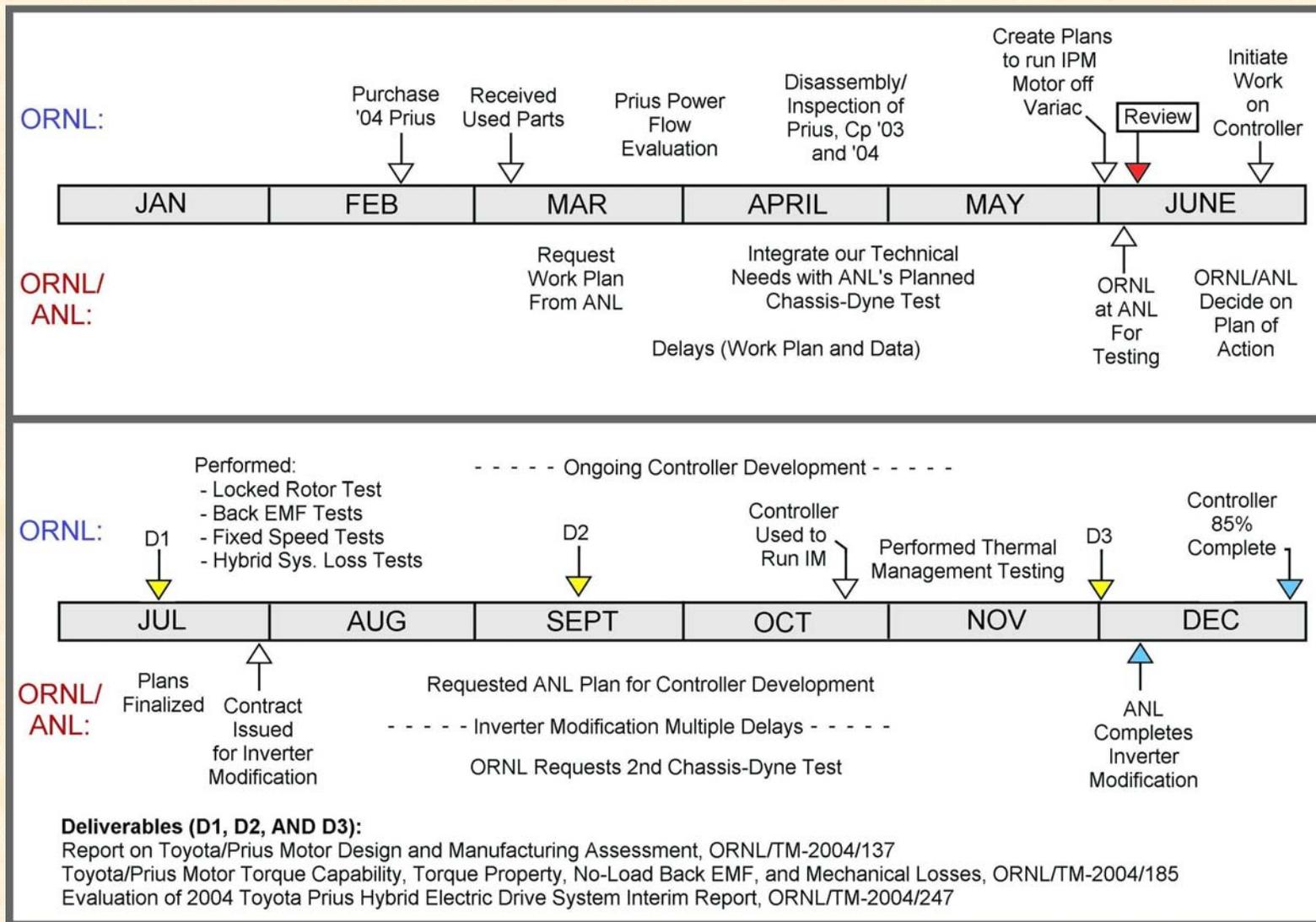
Objectives (cont'd)

- **Technical Support to FreedomCAR:**
 - Attainability of efficiency targets by specific HEV designs
 - Peak/continuous power levels of specific designs
 - Testing for thermal effects, especially at 105°C
 - Peak power to wt and vol data available
- **Broad-based thermal management testing of liquid-cooled and passive HEV systems**

FY 2004 Progress/Results



FY 2004 Progress/Results (cont.d)



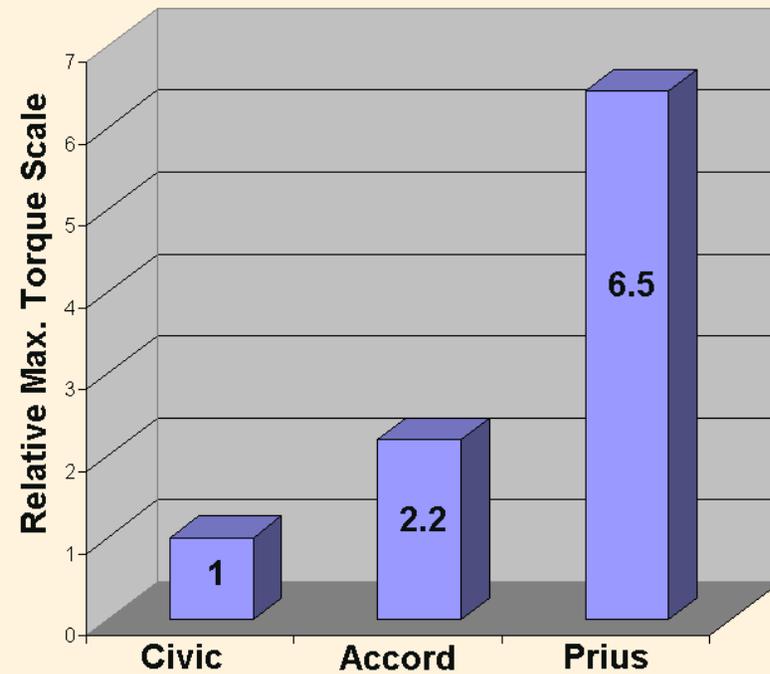
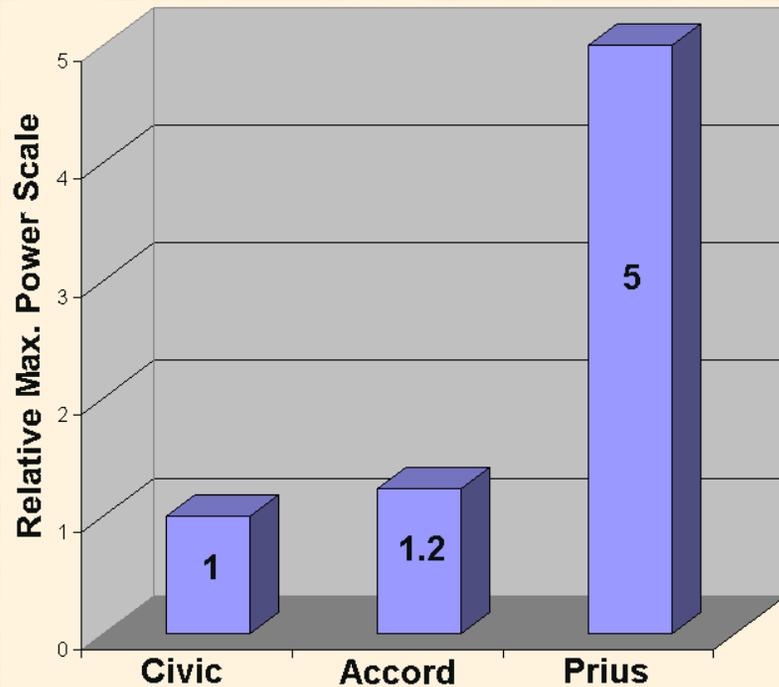
FY 2004 Progress/Results (cont'd)

- **Actual progress compared well to planned progress**
- **Usual delays in working with an outside lab and in complex system development**
- **We are accomplishing everything we set out to do**
- **(No specific milestone dates were set in June)**

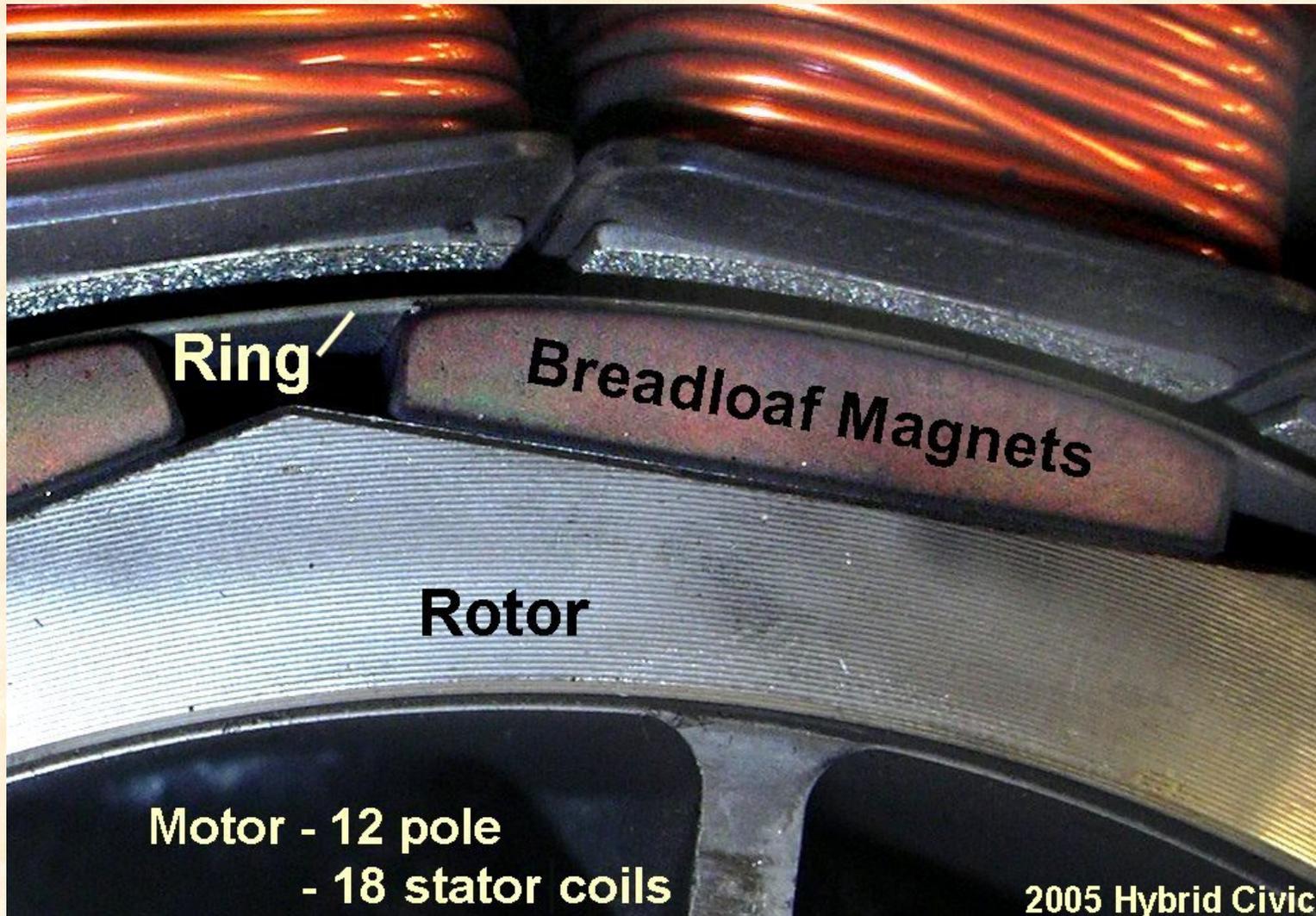
Comparison of HEV PMMs

Model	Voltage	Rotor Design	Cooling	Torque	Power
Prius	200-500	8-Pole IPM "V" config.	Liquid	400 Nm @0-1200 rpm	50 kW @1200- 1540 rpm
Civic	144	12-Pole Surface	Passive	62 Nm @1000 rpm	10 kW @3000 rpm
Accord	144	12-Pole Surface (?)	Passive (?)	136 Nm @840 rpm	12.3 kW @840 rpm

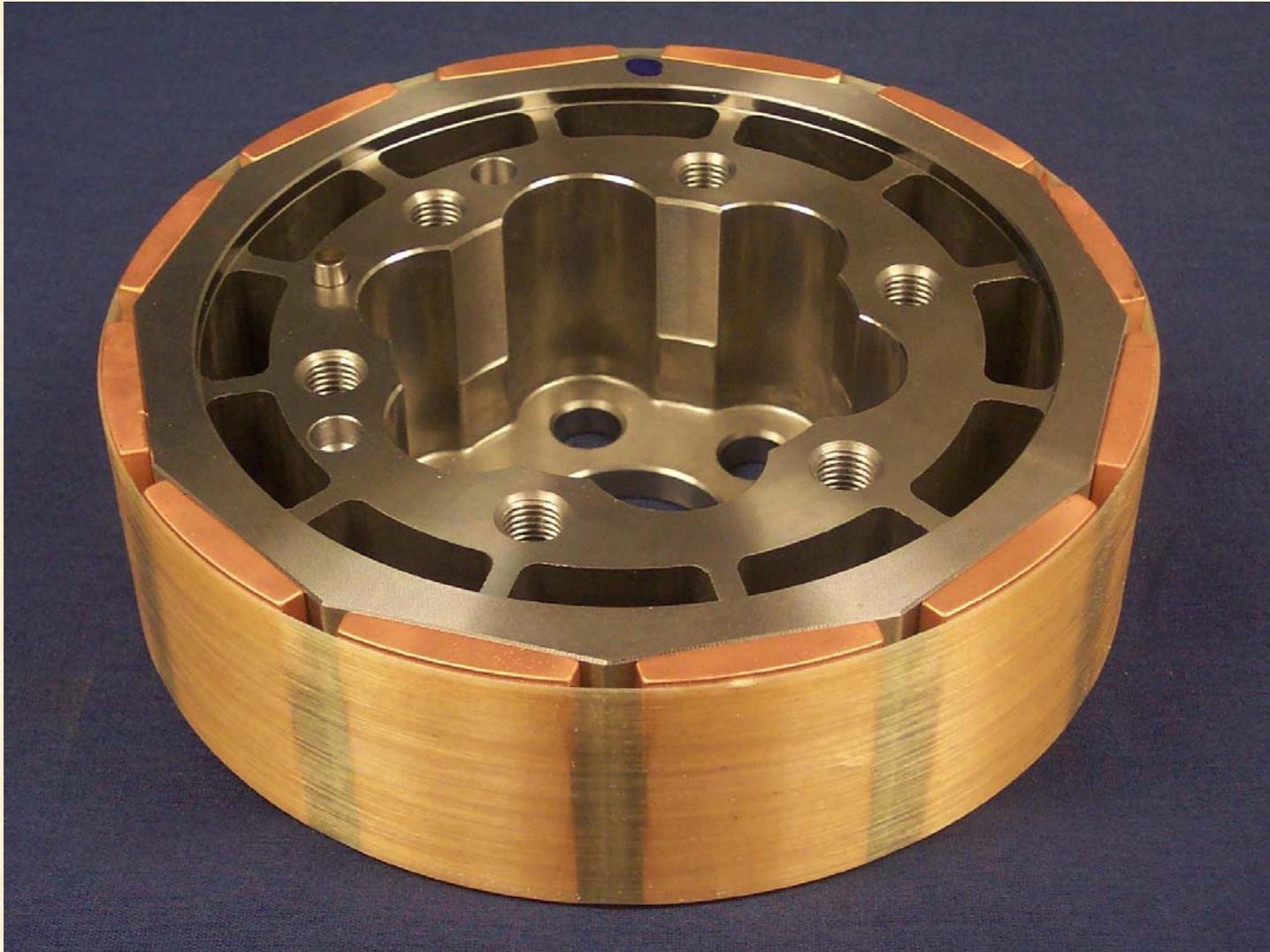
Comparison of HEVs in the Market



Civic



Civic

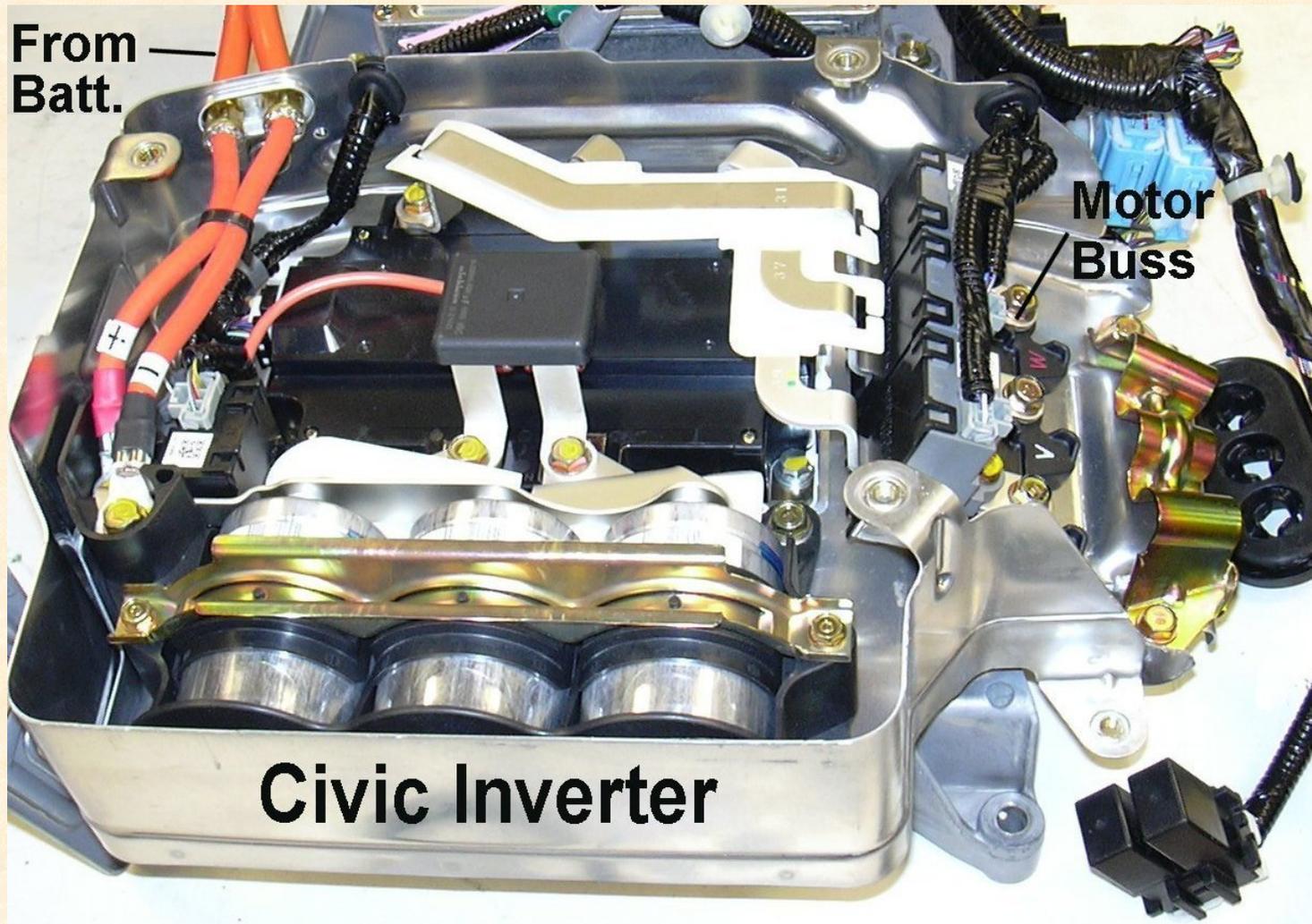


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Quarterly APEEM Update – January 2005


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Civic Inverter



FY 2005 Plan

- **Execution Plan**

- **Electrical and thermal studies into hybrid systems:**
 - **Continue studies of 2004 Prius inverter, motor, and overall thermal system**
 - **Procure and evaluate 2005 Honda and other drive systems**

- **Ready to leverage on Prius work by testing other hybrid systems (Civic and Accord)**

- **Optional: Second chassis-dyne test at ANL**

FY 2005 Plan (cont'd)

Milestones and Schedule

- Complete Prius by May 2005**
- Complete Civic by July 2005**
- Complete Accord by September 2005**

Schedule assumes greatly reduced time for controller development

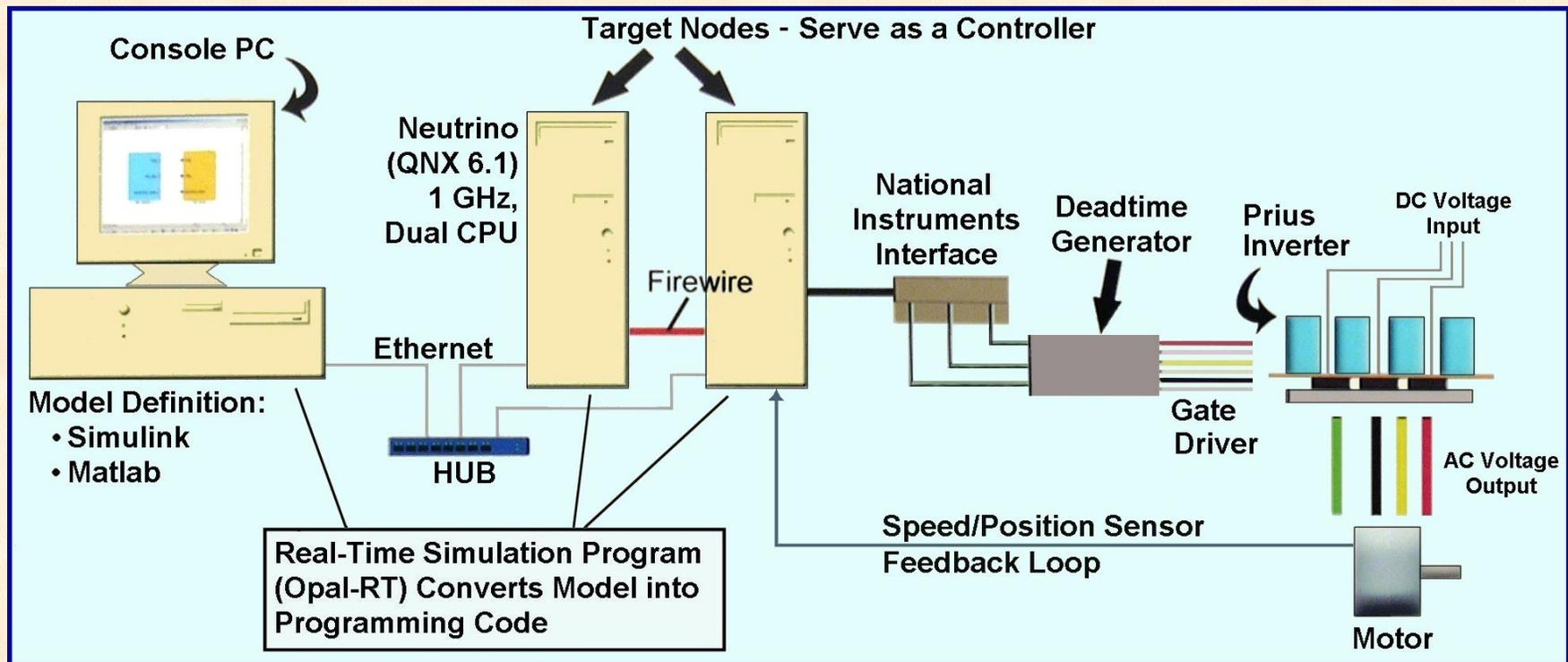
FY 2005 Plan (cont'd)

- **For Each HEV System**
 - **Perform initial fixed-speed, component testing of the motor**
 - **Prepare the inverter controller**
 - **Instrument inverter**
 - **Perform component-level test on dynamometer**
 - **Document the results**

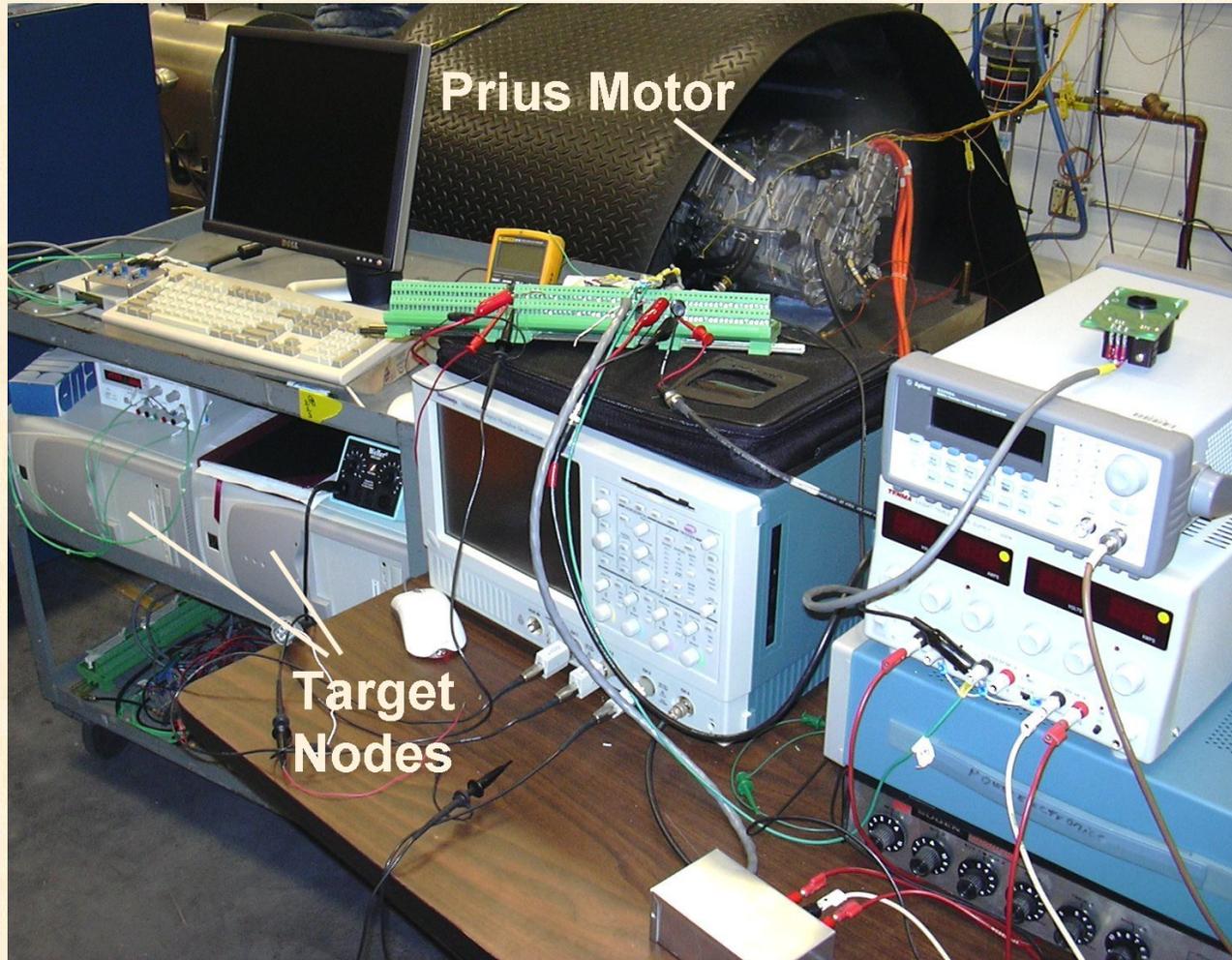
FY 2005 Progress to Date

- **Initial test of controller using an IM**
- **Performed thermal management tests on Prius at elevated temperatures of interest to the EE/TT (35°C, 50°C, 75°C, and 105°C)**
- **Issued interim report, *Evaluation of 2004 Toyota Prius Hybrid Electric Drive System Interim Report* (ORNL/TM-2004/247)**
- **ANL completed modifications to 2004 inverter**
- **Moved controller system to test cell to integrate it to the system in preparation of full-range testing of Prius motor**

FY 2005 Progress to Date (cont'd)



FY 2005 Progress to Date (cont'd)



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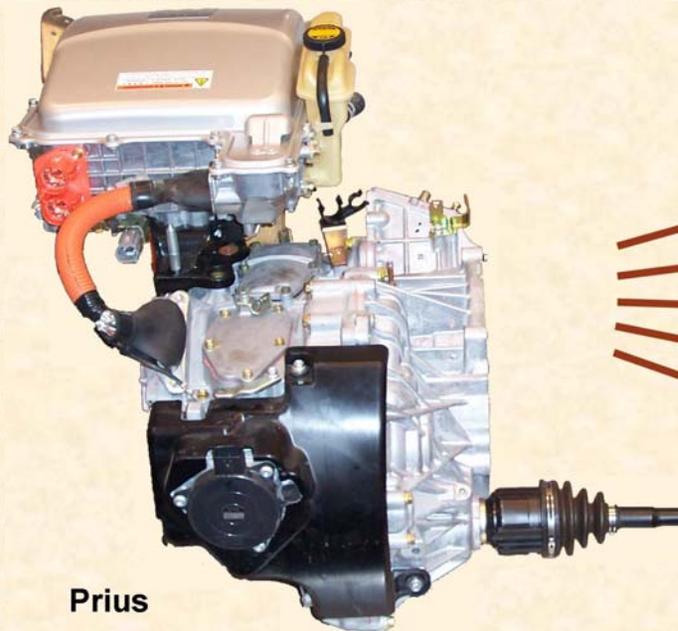

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FY 2005 Progress to Date (cont'd)

- **No delays or changes to the execution plan**
- **The most notable technical accomplishment is the near-completion of the ORNL controller system**
- **Interim Report:** Contains hybrid system description; results from performance, thermal, and loss tests (ANL/ORNL); and technical findings

Important Distinction

The benchmarking project is not reverse engineering, but an important opportunity for researchers to acquire data from successful HEV systems and learn from them.



Motor R&D

Field Weakening

Thermal Studies

Manufacturing

Packaging

Future Plans and Expectations

- **Prius represents commercialized HEV technology with technical innovations**
- **Must consider other marketed designs**
 - Fundamental differences in thermal design
 - Differences in rotor design
 - Highly conventional PMMs are used in HEVs
 - Leverage off of progress made in controller development
 - Time will also be saved in in-house modifications of other inverter systems

Plans Beyond FY 2005

- **Diversify technology evaluations**
- **PMM/Inverter designs are changing rapidly**
- **ORNL can rapidly respond to the new issues of interest to FreedomCAR**
- **Continued testing of HEV systems – both marketed and promising new designs**