Office of FreedomCAR and Vehicle Technologies Advanced Power Electronics Overview

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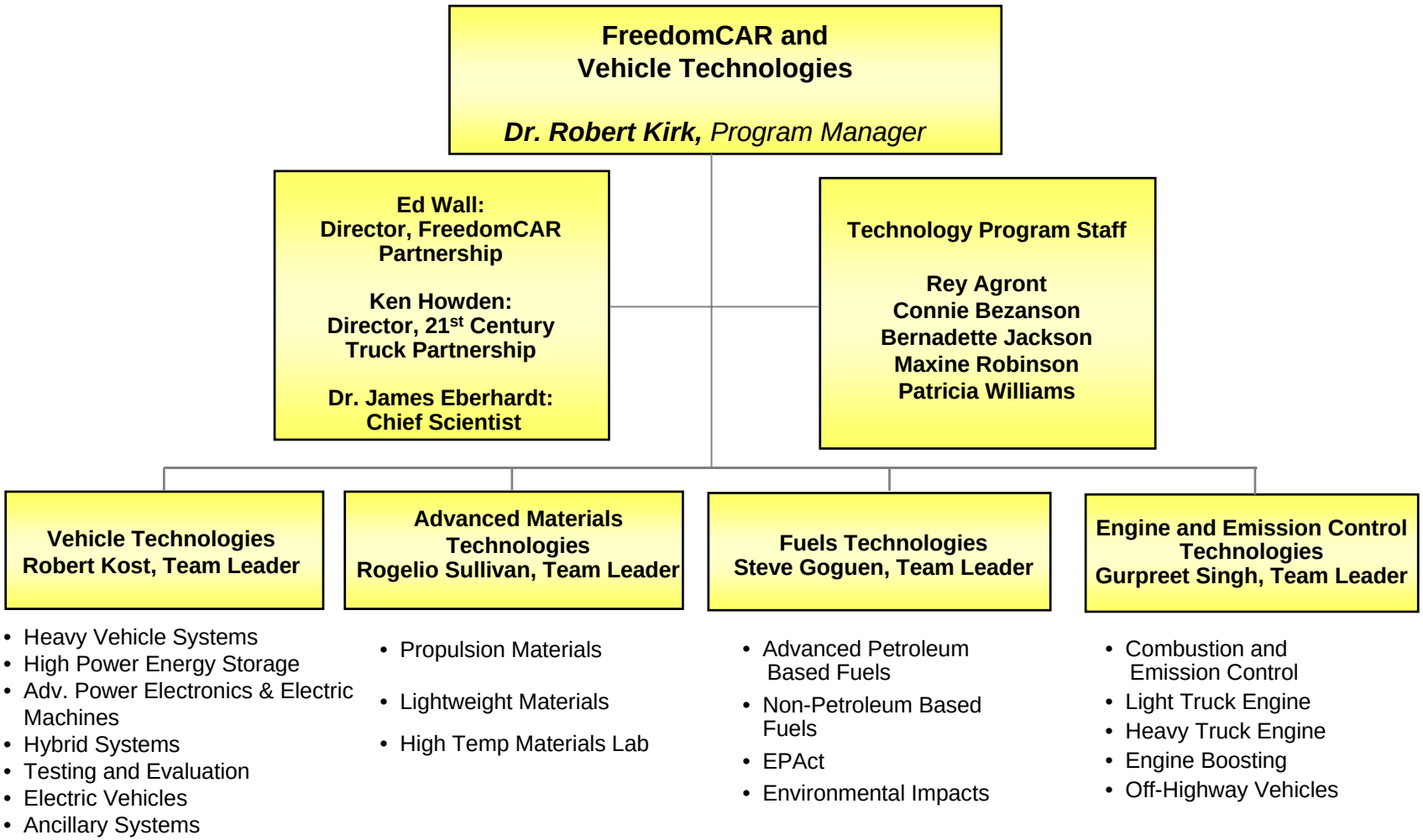
Energy Efficiency and Renewable Energy
U.S. Department of Energy

FreedomCAR & Vehicle Technologies Program Focus

Enable America to use less petroleum by researching and developing technologies to improve the energy efficiency of cars and trucks.

FreedomCAR & Vehicle Technologies

Organization



Advanced Power Electronics Goals

To develop power electronics and electronic machinery technologies that enable improvements in performance and dramatic decreases in vehicle system costs.

Barriers

- **Cost**
- **Volume and thermal management**
- **Weight**
- **Motor and inverter integration**
- **Reliability and ruggedness**

Technical Targets

Parameter	2004	2006	2010
Power electronics (inverter/controller)[1]			
Specific power at peak load (kW/kg)	5	5	See Note 4
Volumetric power density (kW/l)	12	12	
Cost ($/kW)[3]	7	6	
Efficiency (10 to 100% speed FTP drive cycle)	97-98	97-98	
Electric motor/generator (traction)[1,3]			
Specific power at peak load (kW/kg)	1.6	1.7	
Volumetric power density (kW/l)	5	5	
Cost ($/kW)	8	7	
Efficiency (10 to 100% speed, 20% rated torque)	93	93	
Integrated motor/inverter (traction)[2,3]			
Specific power at peak load (kW/kg)			Tbd[5]
Volumetric power density (kW/l)			Tbd[5]
Cost ($/kW)			12
Efficiency (10 to 100% speed, 20% rated torque)			95
Lifetime (yr)			15

Task 1 Power Electronics

•Develop improved inverter/converter architectures and topologies, including special bus-bar designs, to allow faster switching and less expensive transistors.

•Develop improved packaging concepts, focusing on integration of power switches, gate drives, control logic, and filter capacitors to allow higher power density, higher reliability, and lower cost.

•Develop improved low-cost dielectric materials that increase capacitance; improved capacitors with high-temperature, high-current capabilities and low equivalent-series resistance; and improved high-current sensors with high-temperature capabilities.

•Develop efficient control algorithms and sensor-less control techniques.

•Develop a semiconductor controller suitable for automotive use.

Motor/Inverter Integration

The focus of this effort is to develop an integrated motor/controller comprised of the motor and inverter in a single package. The goals for the system include an integrated power electronics system capable of 15 years lifetime and capable of delivering at least 55 kW of power for 18 sec and 30 kW continuous power.

Power Electronics

The focus of this effort is to reduce power electronics cost, and improve performance and reliability through R&D. This effort will also provide for further integration and volume reduction of the inverter.

Capacitors

The focus of this effort is to develop low volume, high reliability capacitors that will reduce power inverter volume and weight. High temperature polymer dielectric materials and high volume manufacturing processes will be developed. Research includes high energy thin film capacitors.

Task 2. Electric-Machine Technology

- Develop advanced materials and manufacturing processes to reduce costs.
- Develop improved high-flux, low-cost magnet materials.
- Develop low-cost laminations and magnet wire
- Develop improved technologies for permanent-magnet, synchronous, and switched-reluctance motors.

Electric Traction Motors

The focus of this effort is to reduce motor cost, and to improve performance and reliability through R&D. This effort will also address improved materials and manufacturing processes.

Permanent Magnets

The focus of this effort is to reduce the cost of permanent magnet materials and to increase the maximum operating temperature of electric drive motors. Research includes bonded magnets, materials, and advanced manufacturing techniques for high-volume manufacturing.

Task 3. Power Management and Integration

- Develop and fabricate integrated motor/inverter drive systems with emphasis on cost, density, reliability, and efficiency.
- Develop advanced thermal-management techniques for the inverter, motor, and integrated system.
- Develop steady-state and dynamic electric-drive-system computer models, including the capability to determine performance/cost tradeoffs for drive systems.
- Develop a DC/DC converter suitable for automotive applications.

DC-DC Converter

The focus of this effort is to provide a high voltage (400V) to 12V output, with an option to provide a 42V output, DC-to-DC converter module for hybrid and fuel cell vehicles.

Motor Controller on a Chip

The focus of this effort is to provide a traction motor controller system on a chip. The proposed architecture will achieve cost reduction by integration of functions and inclusion of necessary external circuitry within a single semiconductor device.

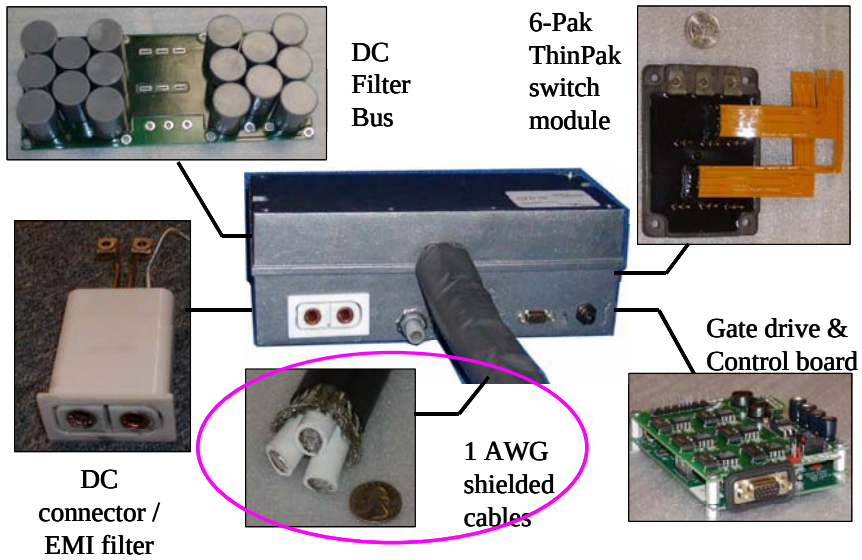
Thermal Management

The focus of this effort is to improve the thermal characteristics of the power electronics and motors. Combinations of high temperature materials and advanced cooling strategies that can extract heat quickly will be investigated. The objective is to find solutions that lower the cost, increase power density, and increase reliability. Innovative packaging, advanced phase-change coolants, materials, and new cooling techniques will be investigated.

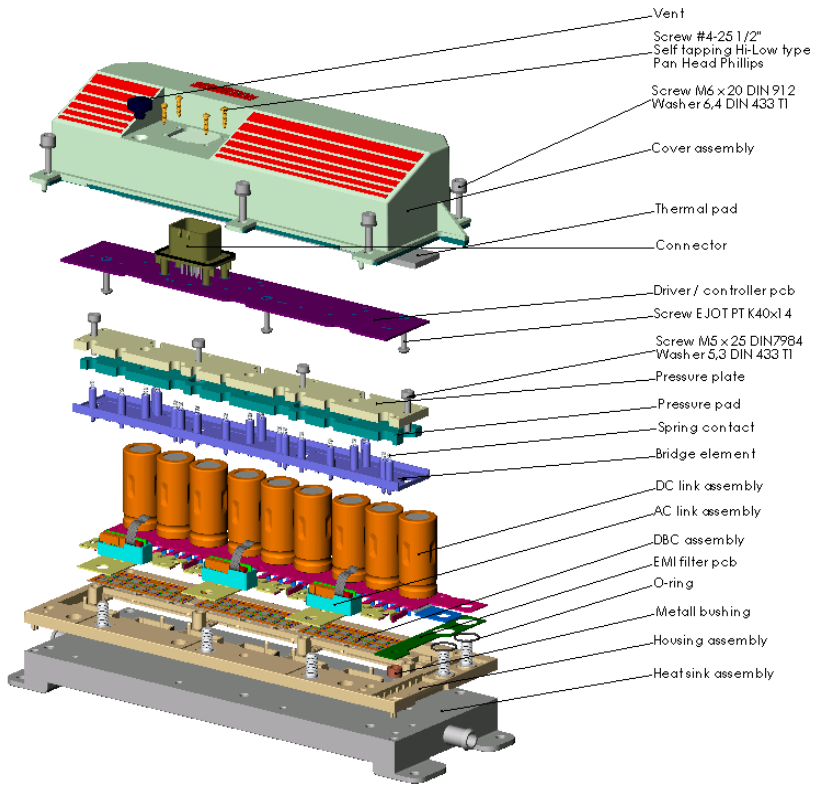
DOE Inverter Prototypes

- Semikron
- Satcon
- Silicon Power

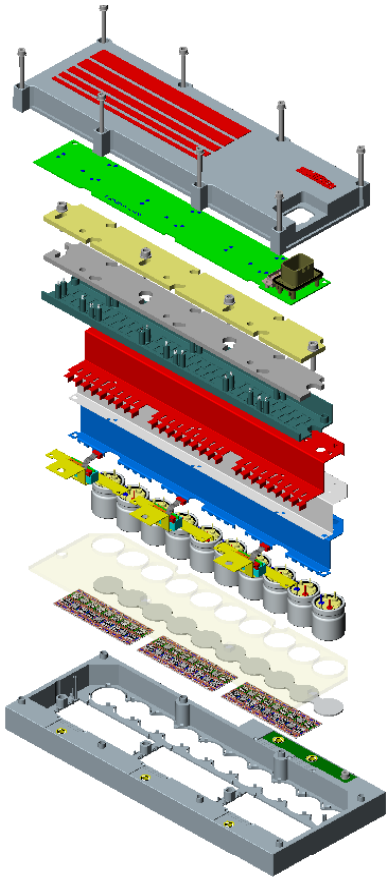
Silicon Power Inverter
600 V 55kW



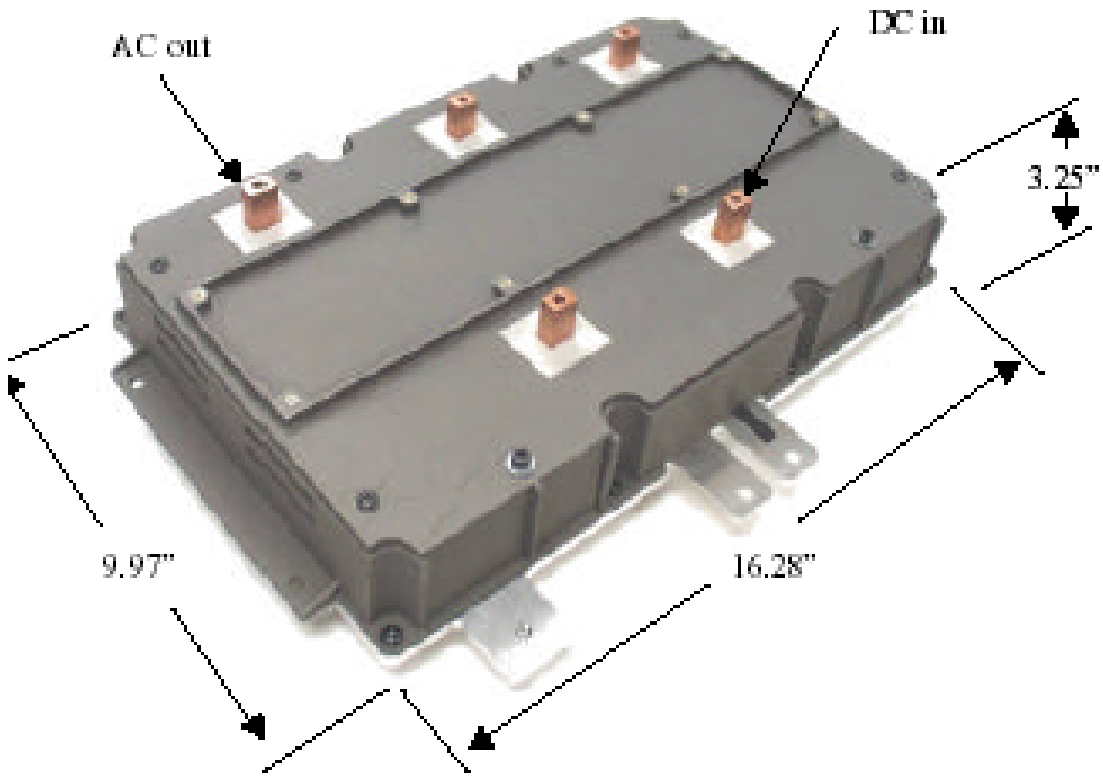
Semikron Inverter
42 V 15kW



Semikron
450 V 55kW



Satcon Inverter
360 V 80kW



Major Milestones Inverter Technologies

- SiC Inverter 2Q 2005
- 42V/12V DC/DC Converter 4Q 2006
- Inverter Packaging 3Q 2007
- Advanced Capacitors 2Q 2008
- Advanced Thermal Mnmt 3Q 2008
- Integrated Motor/Controller 2Q 2010