Department of Energy
Transportation Fuel Cell Program

National Laboratory R&D Meeting

JoAnn Milliken

Pacific Northwest National Laboratory
June 7-8, 2000

Office of Advanced Automotive Technologies

Management Team for Fuel Cell R&D

Steve Chalk	**Team Leader: Energy Conversion Technologies (Fuel Cells, CIDI Emission Control, Fuels, Materials, CARAT, GATE)**
Patrick Davis	**Program Manager: Fuel Cell Systems R&D, Fuel Processing R&D, Automotive Propulsion Materials**
Donna Ho	**Program Manager: Fuel Cell Systems R&D, Cooperative Automotive Research for Advanced Technologies (CARAT)**
JoAnn Milliken	**Program Manager: National Lab R&D, Fuel Cell Components R&D, Graduate Automotive Technology Education (GATE)**
Pete Devlin	**Program Manager: Fuels for Fuel Cells (and Diesel Vehicle Emission Control-Fuel Effects)**
Larry Blair	**Program Manager, detailed from Los Alamos National Laboratory**
Nancy Garland	**Program Manager, detailed from Naval Research Laboratory**

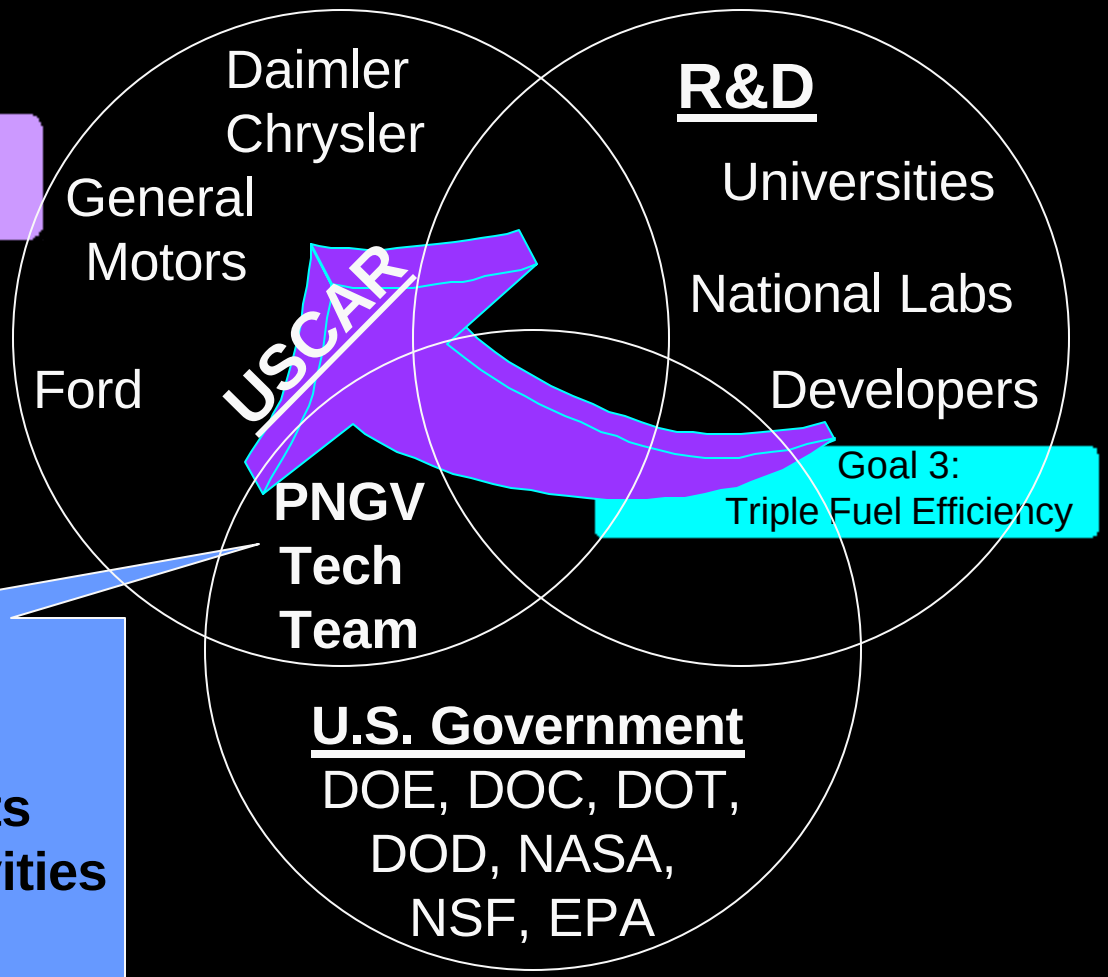
Outline

- Partnership for a New Generation of Vehicles
- Transportation Fuel Cell Program
  - Program Goal/Fuel Strategy
  - Program Status
  - Major Technical Challenges
  - R&D Activities
- Meeting Objectives
- Advisory Panel/Evaluation Criteria
- Future Directions

Partnership for a New Generation of Vehicles

Goal 1:
Advanced Manufacturing

Goal 2:
Near-Term Vehicle Improvements



Goal 3:
Triple Fuel Efficiency

PNGV Fuel Cell
Technical Team

- **Sets technical targets**
- **Prioritizes R&D activities**
- **Reviews progress**

PNGV Timeline

1993 1997 1998 2000 2004

Technology Candidates:

- Hybrid-Electric
- Fuel Cells
- CIDI Engines, Turbines
- Stirling
- Low Emissions Technologies
- New Materials
- Advanced Design Simulations
- Efficient Electronics/ Electrical Devices
- Advanced Batteries
- Ultra-Capacitors/ Flywheels

Technology Downselect

- **Hybrid-Electric Vehicle Drive**
- **Direct- Injection Engines**
- **Fuel Cells**
- **Lightweight Mat'ls**

Concept Vehicles

Production Prototypes

DaimlerChrysler Jeep Commander

Ford P2000

GM Precept

DOE Goals for Transportation Fuel Cells

DOE Fuel Cell Program Objective

By 2004, develop and validate fuel-flexible fuel cell power system technologies that are:

- **cost-competitive with internal combustion engines, and**
- **equivalent in performance, range, safety, and reliability**

Simultaneously pursue parallel strategies

On-Board: **Fuel flexible fuel processor (current fuel infrastructure)**

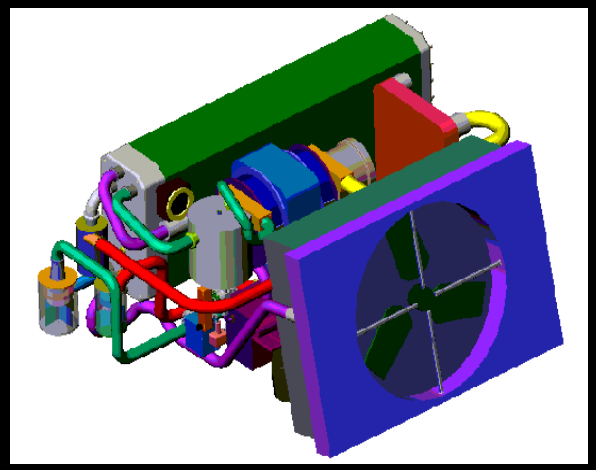
Primary Focus: Advanced petroleum-based fuel

Off Board: **Hydrogen generation (new fuel infrastructure leading to renewable, sustainable energy)**

- **On-board H_2 storage**
- **Off-board H_2 generation and refueling systems**

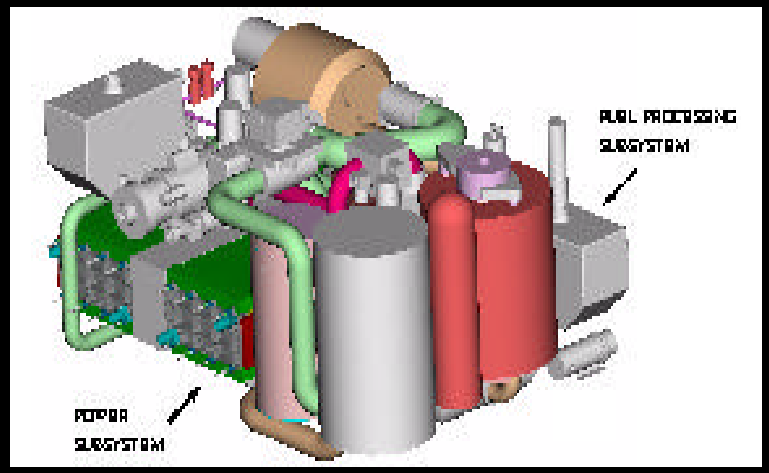
CY 2000 Hardware Deliverables

Two 50 kW Stack Systems
Honeywell Engines and Systems
Energy Partners



EP 50 kW_{net} Automotive System

Two 50 kW Integrated Systems
Plug Power (pressurized)
International Fuel Cells (ambient)

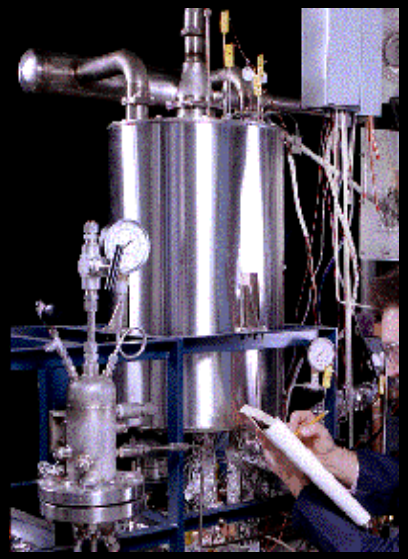


IFC Conceptual 50 kW Powerplant

Progress achieved to be measured against PNGV Year 2000 Targets

Fuel-Flexible Fuel Processors under Development

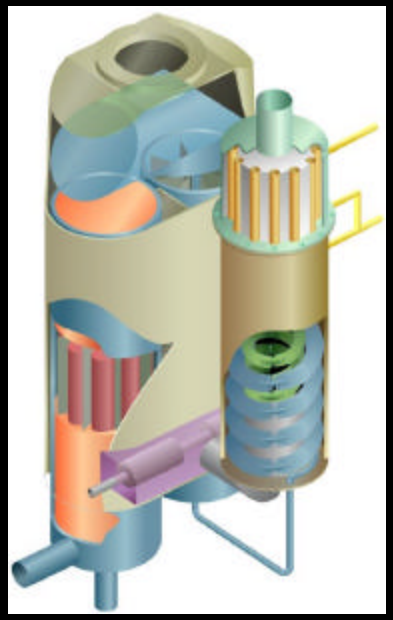
Epyx



ANL

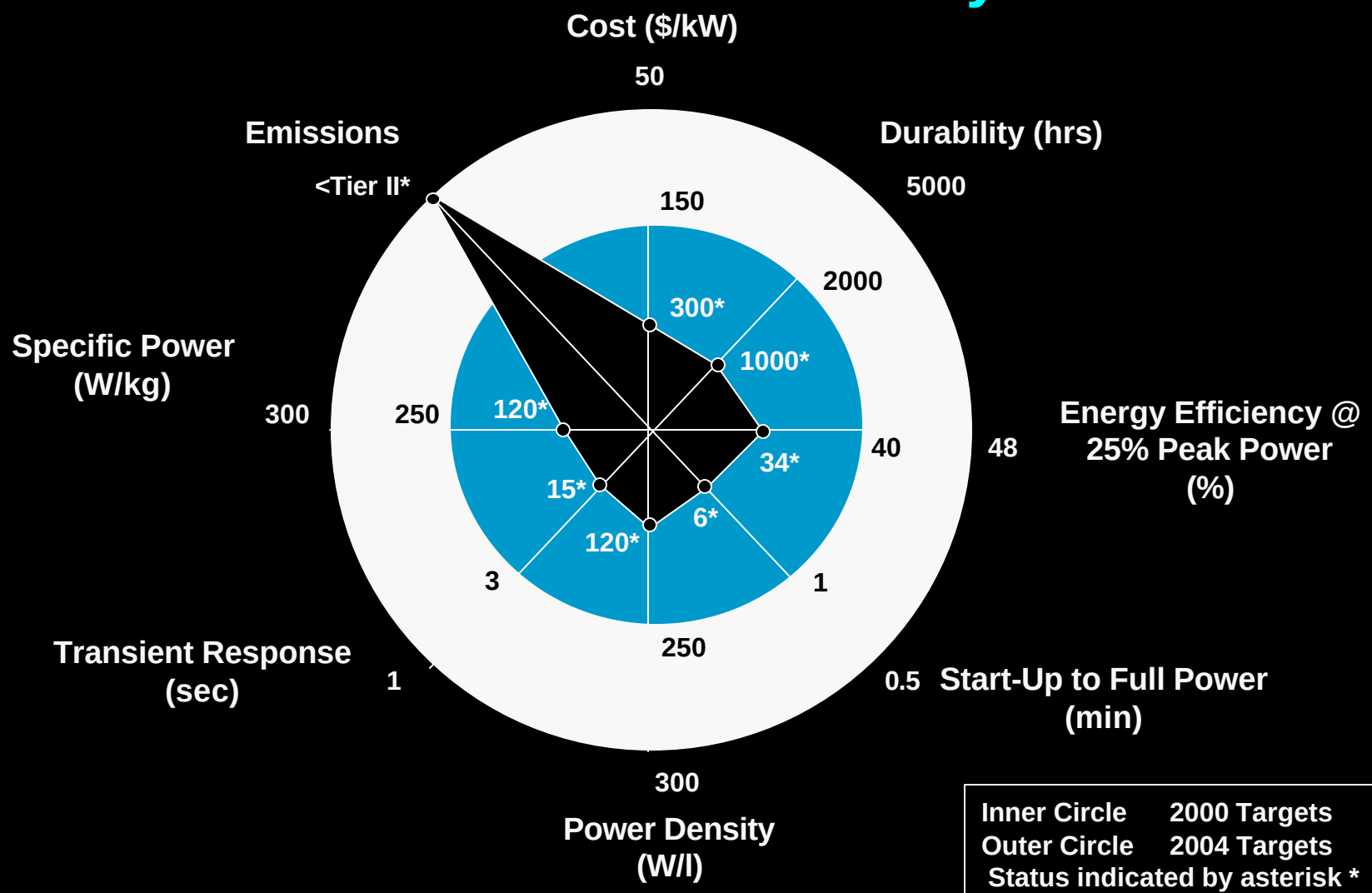
HBT

McDermott



Status vs Technical Targets

50-kW Gasoline-Fueled Fuel Cell System



Inner Circle	2000 Targets
Outer Circle	2004 Targets
Status indicated by asterisk *	

Key Technical Challenges

Efficiency
- higher cell voltage
- cathode activity
- fuel processor start-up
- compressor parasitic power

Thermal/Air/Water Management
- heat rejection
- compressor size, weight, turndown

PEMFCs

On-Board Fuel Processing
- size/weight
- start-up/transients
- catalyst durability
- fuel issues
- CO clean-up

Cost
- precious metal loading
- WGS catalyst activity
- high-volume fabrication

R&D Activities Address Key Technical Challenges

On-Board Fuel Processing

Autothermal Reforming (ANL)

- Fuel Composition Effects (LANL/ANL)
- CO Clean-Up Technology (LANL)
- Alternative Shift Catalysts (ANL)
- Sulfur Removal (ANL)
- Microchannel Fuel Processing (PNNL)

Thermal/Air/Water Management

- Carbon Foam (ORNL)

System Analysis (ANL)

Efficiency

- Optimized Electrodes (LANL)
- New Alloy Electrocatalysts (LBNL)
- Efficient Fuel Cell System (LANL)
- Direct-Methanol Fuel Cells (LANL)
- Composite Bipolar Plates (ORNL)

Cost

R&D Activities are Focused on PNGV Technical Targets

2004 Technical Targets

System

- System Analysis

48% efficiency
300 W/l, 300 W/kg

Fuel Processing

- Autothermal Reforming
- Fuel Composition Effects
- CO Clean-Up Technology
- Alternative Shift Catalysts
- Sulfur Removal
- Microchannel Fuel Processing

80% efficiency
750 W/l, 750 W/kg
<0.5 min start-up
10 ppm CO, 0 sulfur
>5000 hr life
$10/kW

Stack Subsystem

- Optimized Electrodes
- New Alloy Electrocatalysts
- Direct-Methanol Fuel Cells
- Composite Bipolar Plates
- Efficient Fuel Cell System
- Carbon Foam

MEA: $10/kW

Plate : $10/kW

100 ppm CO tol.
0.2 g/kW Pt
60% efficiency
>5000 hr life
$40/kW
500 W/l, 500 W/kg

R&D Activities Are Focused on PNGV Technical Targets

Posters

- Hollow Fiber Fuel Cells (LANL)
- MEA Characterization (ORNL)
- MEA Backing Layers (ORNL)
- Bipolar Plate Surface Modification (ORNL)
- Nanofluids for Thermal Management (ANL)
- Coatings for Air Compressors (ORNL)

2004 Stack Subsystem Technical Targets

100 ppm CO tol.
0.2 g/kW Pt
60% efficiency
>5000 hr life
$40/kW
500 W/l, 500 W/kg

Non-Lab Posters

High Temperature Membranes (Cape Cod Research)
DMFC Membranes (Penn State University)

Laboratories Work Closely With Industry

Fuel Processing

LANL - Epyx, HBT
LANL- McDermott
LANL - Energy Partners
ANL - Plug Power, UCI

System Modeling

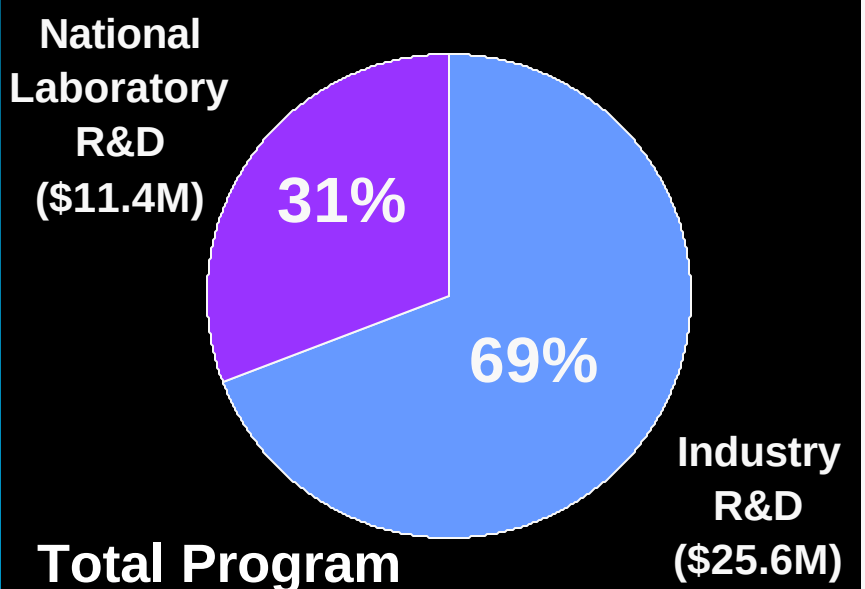
ANL - Plug Power,
International Fuel Cells,
Energy Partners, Honeywell

Stack Components

LANL - Plug Power
ORNL - Plug Power
LBNL - E-TEK
LANL - Motorola

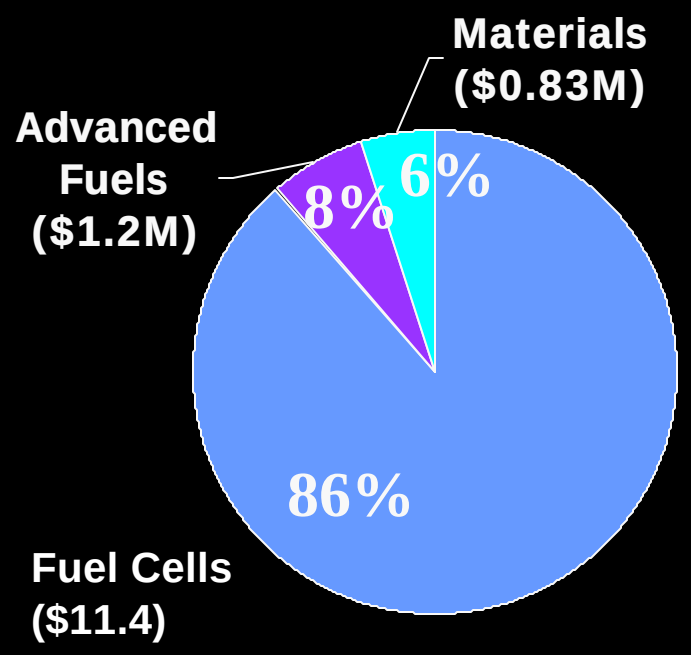
Transportation Fuel Cell R&D FY 2000 Funding

Fuel Cell Program Funding Laboratory - Industry



Total Program Funding: $37.0M

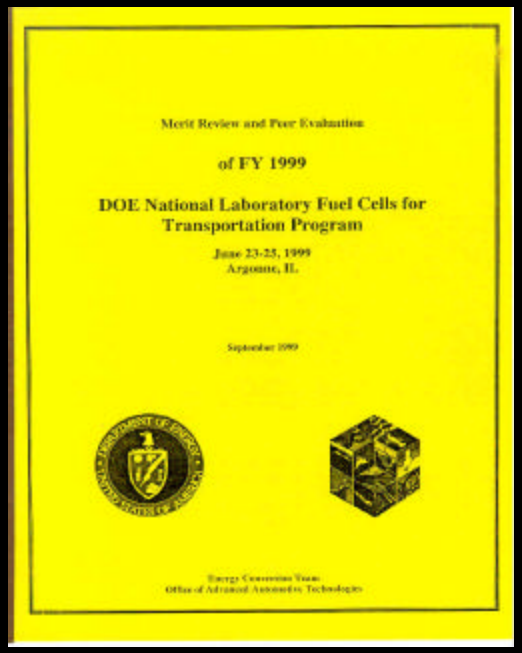
Funding from All OAAT Programs



Total Laboratory Funding: $13.4M

Meeting Objectives

- **Review progress/plans**
- **Foster industry/laboratory interactions, technology transfer**
- **Enhance National laboratory interactions**
- **Guide R&D priorities**



Merit Review and Peer Evaluation

of FY 1999

DOE National Laboratory Fuel Cells for Transportation Program

June 23-25, 1999
Argonne, IL

September 1999

Energy Conversion Team
Office of Advanced Automotive Technologies

Advisory Panel

Fuel Processor Developers, Fuel Providers

Fred Cornforth (Phillips)
James Cross (Nuvera)
Rob Privette (McDermott)

Fuel Cell Component/ Stack/System Developers

James Braun (Energy Partners)
Mark Debe (3M)
Bill Ernst (Plug Power)
David Lane (W .L. Gore)
Gerry Merten (XCELLSiS)
Stan Simpson (Honeywell)
Doug Wheeler (IFC)

Evaluation Criteria

- ***Relevance*** to technical barriers and DOE/PNGV objectives
- ***Effectiveness of the Approach*** to overcoming technical barriers
- ***Progress*** toward DOE/PNGV goals
- ***Collaborations*** and Tech Transfer
- ***Plans*** for future research

USCAR

Doanh Tran (DaimlerChrysler)
Jim Adams/Ron Sims (Ford)
Swathy Swathirajan/Fred Wagner (General Motors)

Universities Other Gov't

Vernon Roan (U. Florida)
Richard Carlin (ONR)

1999 Merit Review of National Lab R&D

Project Title	Comments	Action
On-Board Hydrogen Generation	Objectives not clear; focus should be redefined	Funding reduced; focus redefined via workshop w/industry
Electrocatalysts using Rapid Throughput Approach	Brute force approach; looking for a home run without basic understanding	Terminated; cathode projects focused on more scientific approaches

Research Focus

Less system integration and full-scale stack development; more materials, components and enabling technologies

Fuel cell critical R&D
- high-temp. membranes
- higher activity cathodes
- low-Pt MEAs
- bipolar plates
- high volume fabrication

Fuel processor components
- water-gas shift catalysts
- microchannel reactors, heat exchangers

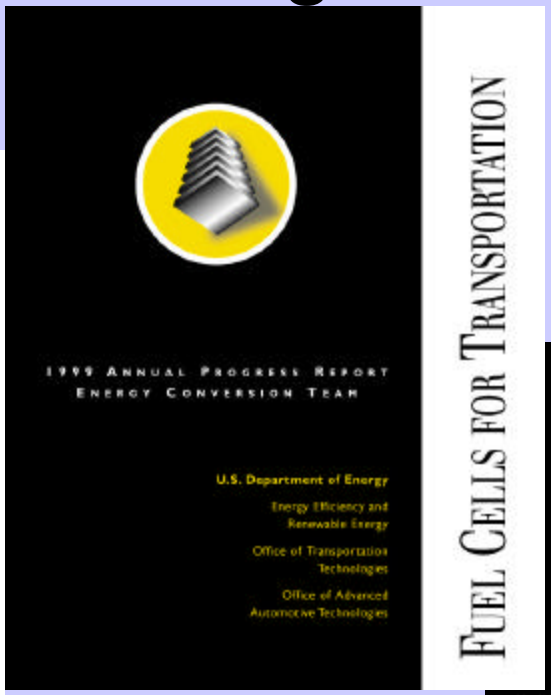
System Validation/ Analysis

Balance of Plant
- sensors/actuators
- compressors
- humidifiers, heat exchangers

On-Board Hydrogen Storage
- physical storage
- chemical storage

Feed Stream Enhancement
- oxygen concentration
- hydrogen concentration

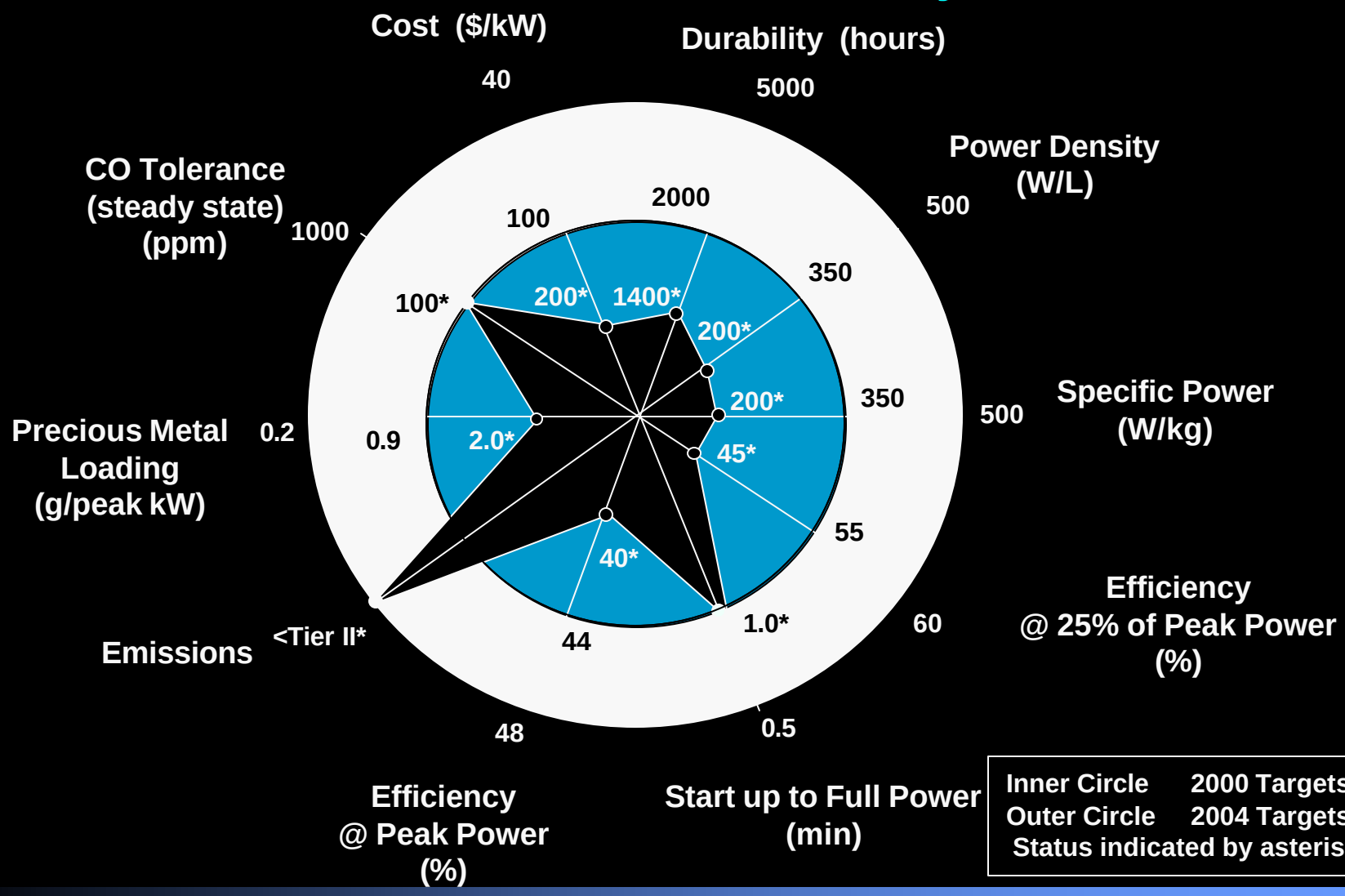
Additional Program Information: www.ott.doe.gov/oaat



Additional Information

Status vs Technical Targets

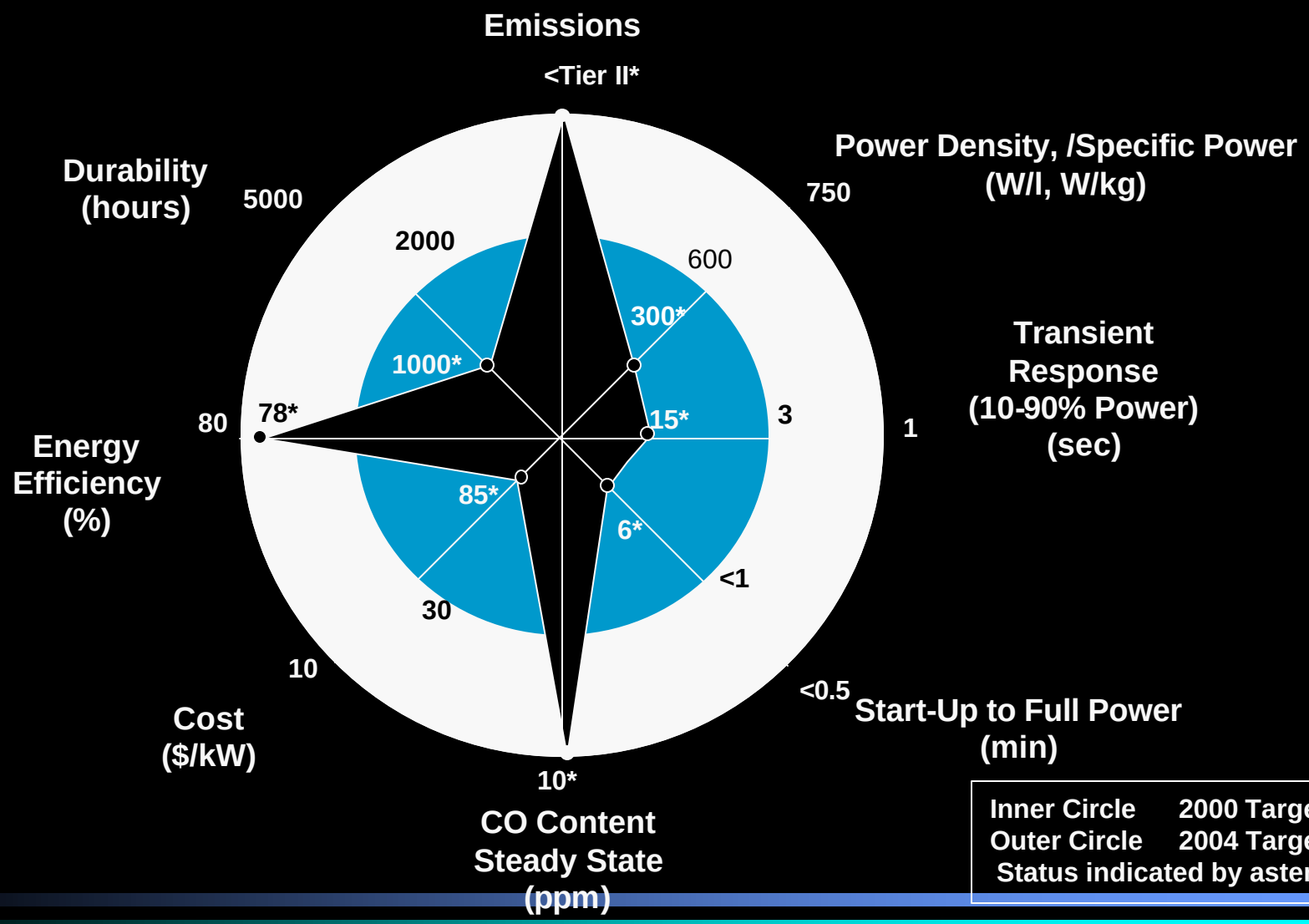
50-kW Reformate Fuel Cell Stack SubSystem



Inner Circle	2000 Targets
Outer Circle	2004 Targets
Status indicated by asterisk *	

Status vs Technical Targets

50-kW Gasoline Fuel Processor



Inner Circle	2000 Targets
Outer Circle	2004 Targets
Status indicated by asterisk *	

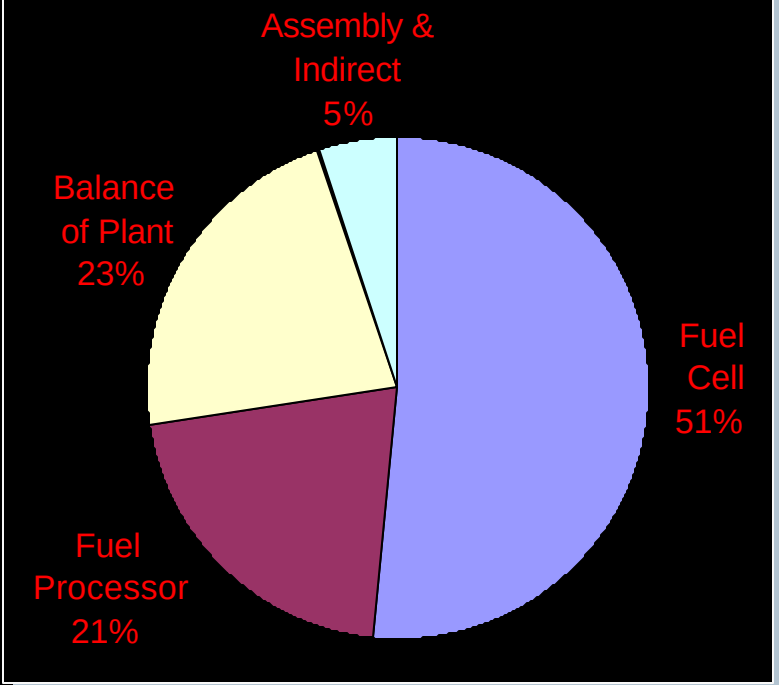
Current Cost Projected to High Volume

Based on Current Performance of Gasoline-Powered Fuel Cell System

	Cost ($/kW)			
	Unit Cost ($)	ADL Yr 2000	PNGV Goals Yr 2000	PNGV Goals Yr 2004
Fuel Cell Stack	7,500	150	100	40
Fuel Processor	3,070	61	30	10
BOP	3,310	66	Included in Stack Cost Target	
Assembly	720	14		
Total	**14,600**	**292**	130	50

Basis: 50 kWe net, 500,000 units/yr

Cost Breakdown by Sub-System



Source: A.D. Little