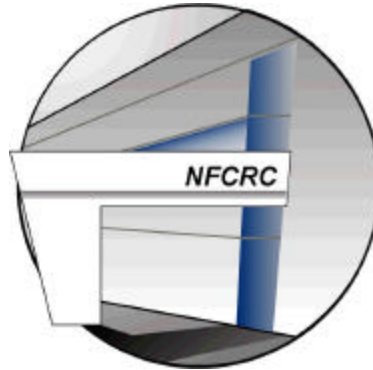


## **NATIONAL FUEL CELL RESEARCH CENTER (NFCRC)**



**UNIVERSITY OF CALIFORNIA  
IRVINE, CA 92697-3550  
<http://www.nfcrc.uci.edu>**

### **OUTLINE**

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- (1) NATIONAL FUEL CELL RESEARCH CENTER**
- (2) FUEL CELL RESEARCH CHALLENGES**

## **NATIONAL FUEL CELL RESEARCH CENTER**

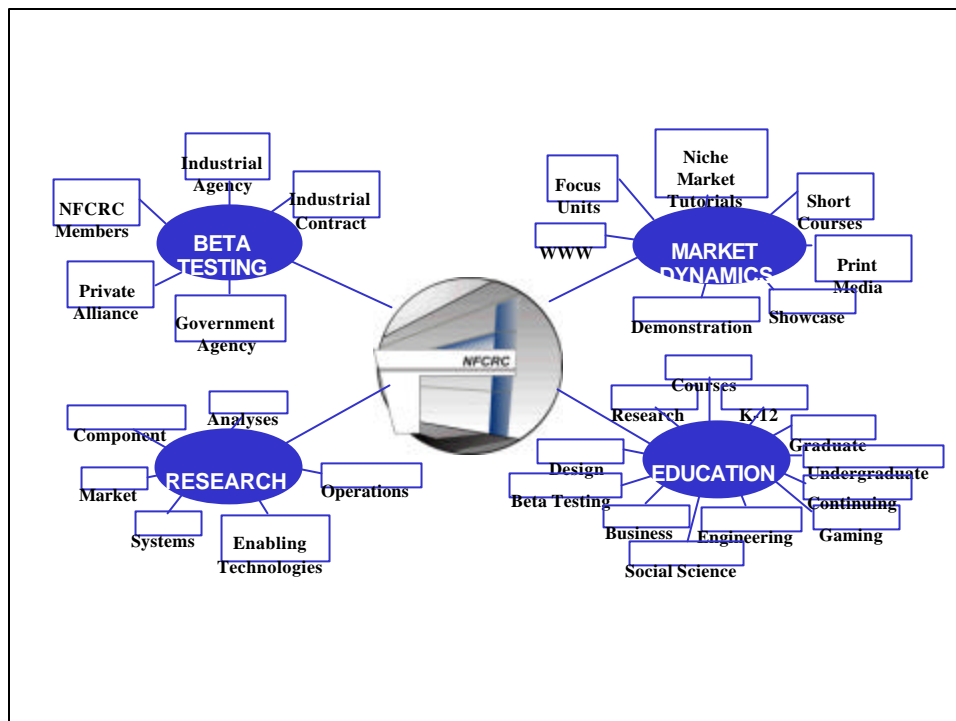
- **FOUNDED IN 1992**
- **RELOCATED (1997) AND DEDICATED (1998) AT UCI**  
DEPARTMENT OF ENERGY  
CALIFORNIA ENERGY COMMISSION
- **MISSION**  
TO FACILITATE AND TO ACCELERATE THE DEVELOPMENT AND DEPLOYMENT OF FUEL CELL TECHNOLOGY AND FUEL CELL SYSTEMS  
  
TO PROMOTE STRATEGIC ALLIANCES THAT ADDRESS THE RESEARCH AND MARKET CHALLENGES ASSOCIATED WITH THE INSTALLATION AND INTEGRATION OF FUEL CELL SYSTEMS INTO THE BUILT ENVIRONMENT
- **MEMBER SUPPORT**
- **FOUR COMPONENTS**

## **INTERNATIONAL BASED MEMBERSHIP**

- **AGENCIES**
  - U.S. DEPARTMENT OF ENERGY
  - U.S. DEPARTMENT OF DEFENSE
  - CALIFORNIA ENERGY COMMISSION
  - CALIFORNIA AIR RESOURCES BOARD
  - SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
- **INSTITUTES**
  - ELECTRIC POWER RESEARCH INSTITUTE
  - CALIFORNIA INSTITUTE FOR ENERGY AND EFFICIENCY
- **INDUSTRY**
  - SOUTHERN CALIFORNIA EDISON
  - SOUTHERN CALIFORNIA GAS COMPANY
  - TOYOTA
  - PARKER-HANNIFIN
  - CHEVRON-TEXACO
  - SIEMENS WESTINGHOUSE POWER CORPORATION
  - FUEL CELL ENERGY INCORPORATED
  - HORIBA LIMITED
  - CAPSTONE TURBINE CORPORATION
  - LOS ANGELES DEPARTMENT OF WATER AND POWER
  - PLUG POWER
  - AIR PRODUCTS

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- (1) NATIONAL FUEL CELL RESEARCH CENTER
- (2) FUEL CELL RESEARCH CHALLENGES
  - ⇒ UNIVERSITIES FOR FUEL CELLS
  - FUEL CELL ANALYSES TOOLS
  - HYBRID TECHNOLOGY
  - HYDROGEN INFRASTRUCTURE

## UNIVERSITIES FOR FUEL CELLS

- **NFCRC OUTREACH INITIATIVE**

DEPARTMENT OF ENERGY  
DEPARTMENT OF DEFENSE

- **MISSION**

- INITIATE UNIVERSITY AWARENESS AND PROGRAMS IN BOTH RESEARCH AND CURRICULA
- ADDRESS FUNDAMENTAL FUEL CELL ENGINEERING AND SCIENCE CHALLENGES
- DEVELOP WORK FORCE FOR NATION'S INDUSTRY

- **SIX RESEARCH FOCI**

◊ MATERIALS	SYSTEMS & ANALYSES
◊ POWER ELECTRONICS	INFORMATION TECHNOLOGY
◊ CONTROLS	FUEL PROCESSING

- **Results at: <http://www.nfcrc.uci.edu/UfFC>**

## RESEARCH CHALLENGES: MATERIALS

- **General materials issues**
  - E.g., Nano-scale materials, composites, ionic and electronic conductivity, thermal expansion
- **Materials processing**
  - E.g., thin films, chemical synthesis, ceramic processing, tape casting, screen printing, heat treatment
- **Fundamental understanding**
  - E.g., point defect chemistry, interdiffusion, oxidation, demixing, grain boundary transport, polarizations
- **Materials features and performance**
  - E.g., materials stability, interface stability, differential thermal expansion, adhesion, sulfur tolerance, direct hydrocarbon oxidation
- **New materials**
  - E.g., solid acids, mixed conductors, ionically conducting oxides, lower temperature operation, low activation energy materials, proton conducting perovskites
- **Modeling and simulation**
  - E.g., combinatorial approaches, thermal-mechanical effects, finite element stress analyses, fracture mechanical properties, computational chemistry

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## RESEARCH CHALLENGES: POWER ELECTRONICS

- **Fundamental understanding of FC/PEL interactions**
- **Real-time protocol for fuel cell interfaces**
- **Dynamic modeling of fuel cell systems & components**
- **Fuel cell specific PEL topology & device design**
- **Identification of degree to which resolution should/can be integrated into the FC interface design**
- **Modeling and architecture of multiple and hybrid systems, micro-grids, storage, other components, ...**
- **Understanding of fuel cell characteristics germane to PEL (e.g., Ripple,...)**
- **Systems integration (stability, reliability, economics, ...)**
- **Parasitic effects of FCs and relation to PEL, EMC**
- **Management of Interconnect with utility grid**
- **Mass customization**

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- **Developing models that aid in control design and analysis**
- **Interfaces between models at different scales / resolution**
- **Capabilities for model validation (experiments)**
- **Sensing and actuation technologies**
- **Understanding, insight, interoperability and control of three (3) main parts of a Fuel Cell Power Plant**
- **Diagnostics and Failure Prognosis**
- **Cost (design for manufacturing) and Complexity (design for control) issues**
- **Identification of system, hybrid components or additional controls required to apply fuel cells to actual duty cycles and applications**
- **Integration issues: Not just the components, but, integration and composite performance**

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### Control / Sensors / Actuators / Models

Model scale	Control	Control functions	Sensing and diagnostics needs	Actuation needs	Model type	Modeling tools
Vehicle	Active and passive	Driveability, performance, energy use	?	?	Quasi-static, Low-order lumped	Matlab Simulink
Power-plant	Active and passive	Meet demand, energy conversion efficiency,	Voltage, Power, Temperature, Humidity, flow, other	Valves, Regulators, temperature, voltage, power, motor controllers, etc.	Low-order lumped	Matlab Simulink
Fuel cell	Active and passive	Voltage and current (AC, DC), fuel supply	Gas composition Humidity	Valves, Regulators, Temp.	Low-order lumped	Matlab Simulink, ...
Stack						... nent
Cell						... nt, al
Characterization	passive	mole fraction (bulk flow), pressure	Humidity Temperature Detailed diagnostics		3-D PDEs	Finite Element,
Micro	Passive	Thermal and molecular transport processes, gas diffusion layer, 2-phase flow resistance	Gas composition Humidity Temperature Detailed diagnostics	MEMS	3-D PDEs	?
Nano	Passive	Nanostructure and materials properties (e.g.: surface reactivity, catalysis, catalyst transport processes)	Gas composition Humidity Temperature Detailed diagnostics	?	?	?

• Results at: <http://www.nfcr.uci.edu/UfFC>

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⇒ FUEL CELL ANALYSES TOOLS

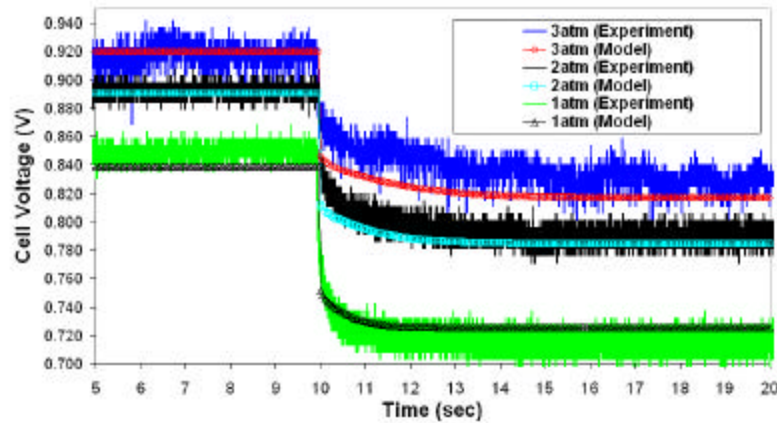
– HYBRID TECHNOLOGY

– HYDROGEN INFRASTRUCTURE

## FUEL CELL ANALYSES TOOLS

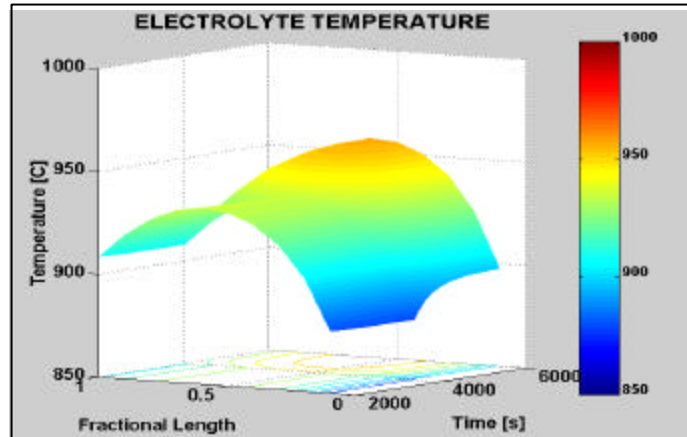
- Planar MCFC Dynamic Data
- Dynamic MCFC Model (Simulink®)
- Electrochemical Transient Reponse – 3 Pressures

Cell Voltage vs. Time Following a Resistance Load Change  
From 0.1533 to 0.0692 Ohms at 650 C



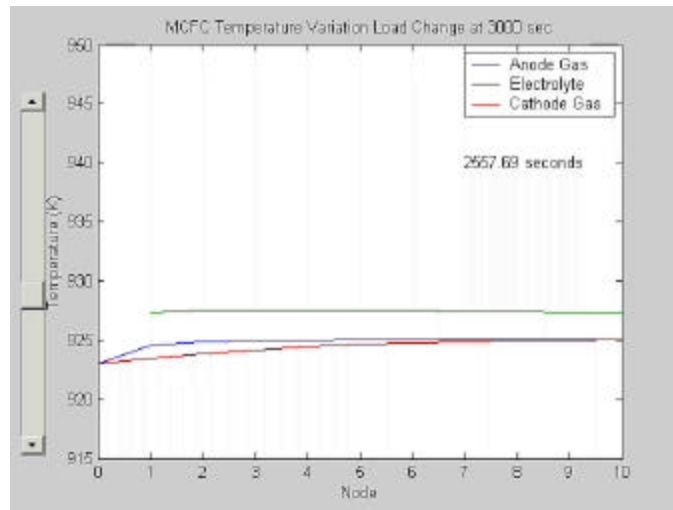
## FUEL CELL ANALYSES TOOLS

- Dynamic Tubular SOFC Model (Simulink®)
- FC Stack Thermal Transient Reponse
  - uncontrolled current demand increase at 4000 seconds



## FUEL CELL ANALYSES TOOLS

- Dynamic planar MCFC Model (Simulink®)
- FC Stack Thermal Transient Reponse
  - uncontrolled current demand increase at 3000 seconds



## RESEARCH CHALLENGES: ANALYSES

- **Fundamental understanding**
  - E.g., pore diffusion, polarizations, coupled electrochemistry, reformation, heat and mass transfer, flooding, drying
- **Materials level modeling and simulation**
  - E.g., thermal-mechanical modeling, finite element stress analyses, fracture mechanical properties
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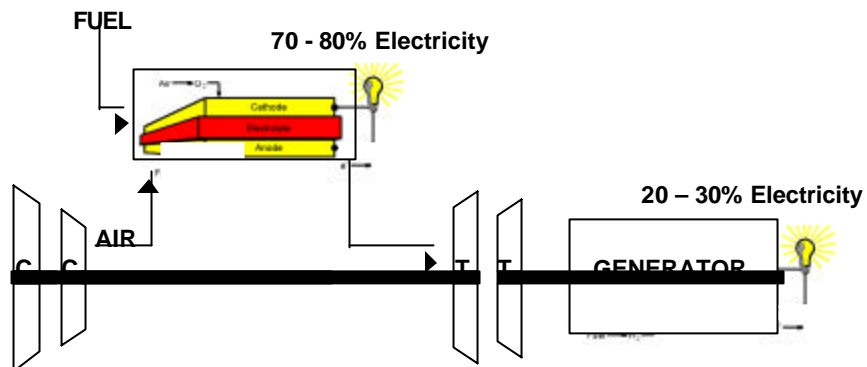
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- - HYBRID TECHNOLOGY
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### HYBRID

- High Fuel-to- Electricity Efficiency
  - Theory: 75 - 80%
- NFCRC Roles:
  - First (only) SOFC-GT Proof-of-concept
  - Integration & Demonstration
  - Simulation and Analyses



## DISTRIBUTED GENERATION

### 220 kW

Partners: Siemens Westinghouse, Southern California Edison  
World Record Proof-of-Concept: 53% (fuel-to-AC electricity)



## CENTRAL PLANT

- MAJOR DOE PROGRAM: *"VISION 21"*

DESIGN

300 MW

PLANT

- PRODUCTION EFFICIENCY
  - NATURAL GAS
  - COAL
- CO-PRODUCTION
  - FISH
  - HYDRO
- MINIMIZE ENVIRONMENTAL IMPACT



## CENTRAL PLANT

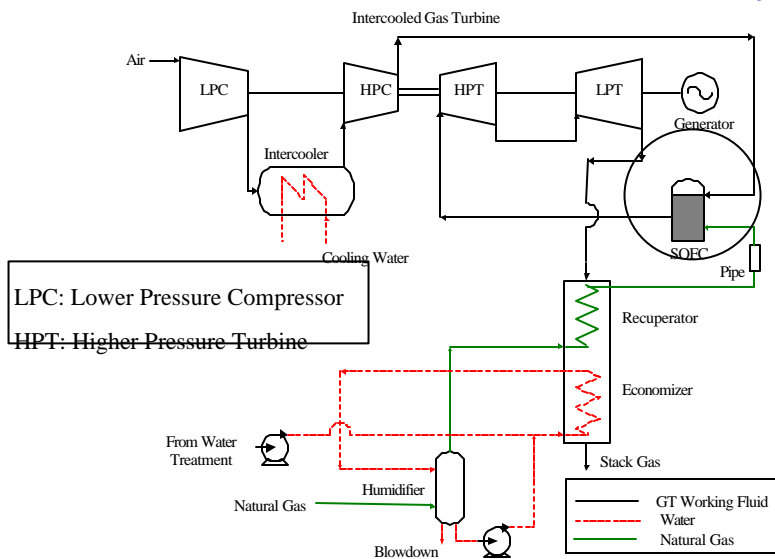
- MAJOR DOE PROGRAM : “VISION 21”

### DESIGN NEXT GENERATION CENTRAL POWER PLANT

- PRODUCE ELECTRICITY AT ULTRA HIGH EFFICIENCY
  - NATURAL GAS - 75% (LHV)
  - COAL - 60% (HHV)
- CO-PRODUCE TRANSPORTATION FUELS
  - FISHER-TROPSCH LIQUIDS
  - HYDROGEN
- MINIMIZE ENVIRONMENTAL IMPACT

## 300MW “HYBRID” VISION 21 PLANT

76% fuel-to-electricity efficiency



## RESEARCH CHALLENGES: HYBRIDS

- **HIGH**
  - Turbine compatibility
  - Hybrid behavior
    - Load loss
    - Load following
    - Thermal management
    - System optimization
  - High temperature fuel cell behavior
  - Safety, training
- **“MODEST”**
  - Combustors
- **STRONG**
  - Sensors and controls
  - Fuel flexibility, reformation
  - Invertors and power electronics
  - Analyses
    - Steady-state models
    - Dynamic models
    - Market

SOURCE: SECOND ANNUAL DOE/UN HYBRID CONFERENCE, APRIL 2002, CHARLOTTE

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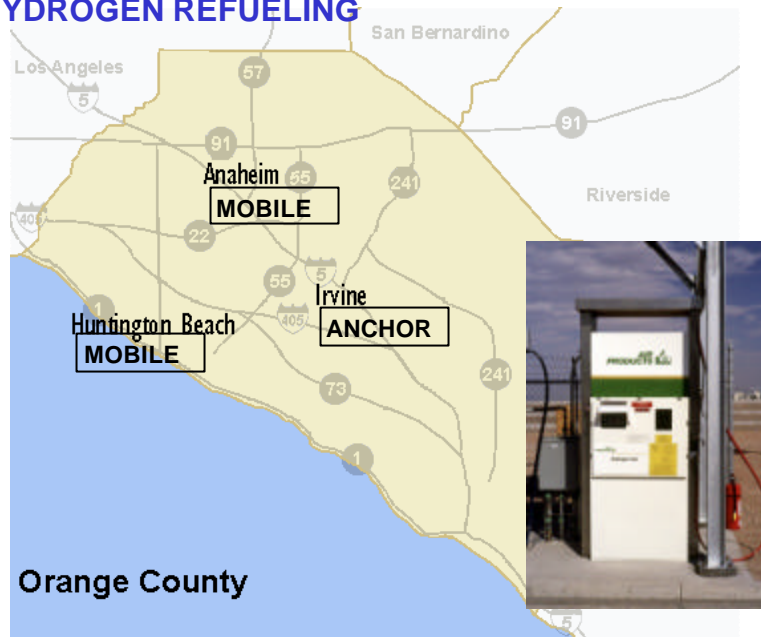
⇒ HYDROGEN INFRASTRUCTURE

• DECEMBER 24, 2002



• **MR. GREGG KELLY**  
PRESIDENT AND CEO  
ORTHODYNE ELECTRONICS

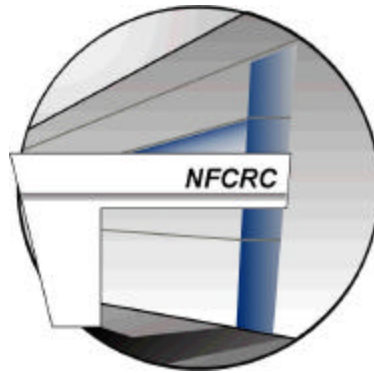
- **HYDROGEN REFUELING**



- **JANUARY 7, 2003**



**THANK YOU!**



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