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SECA
Solid Oxide Fuel Cell Program

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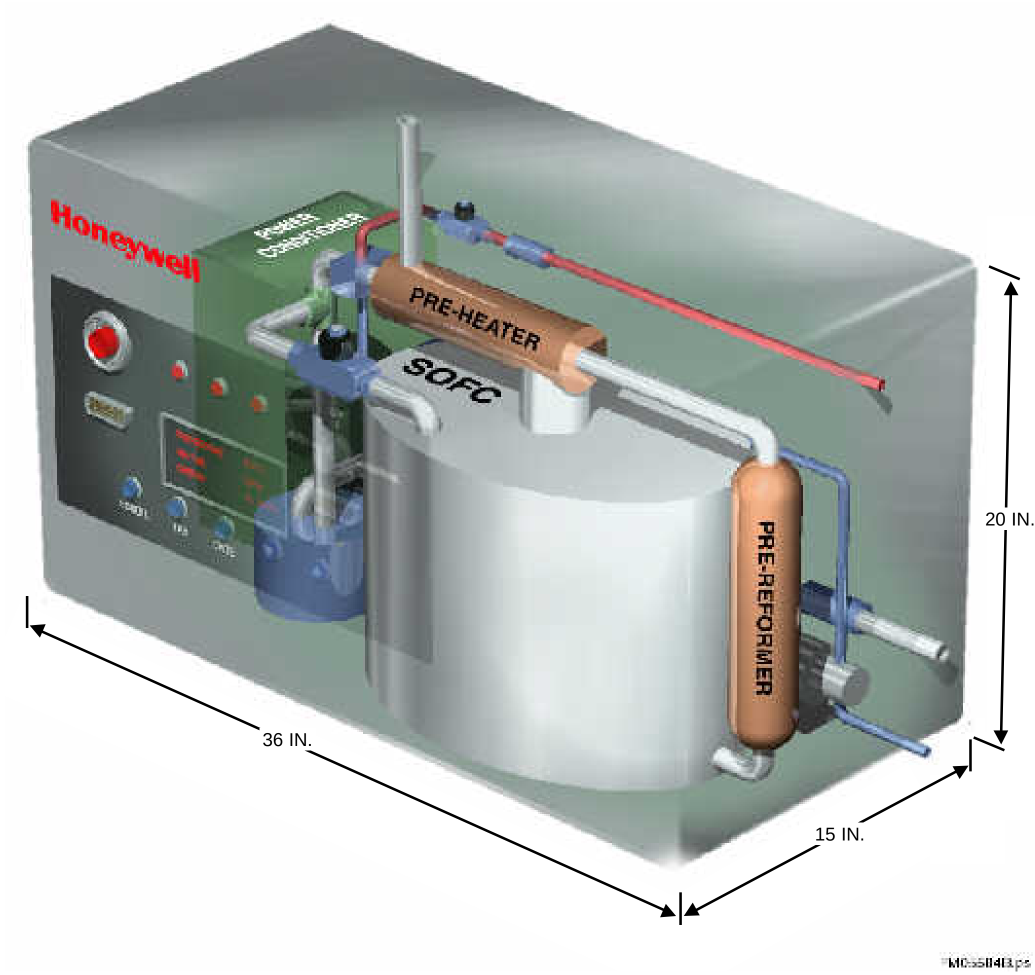
3rd Annual SECA Workshop
Washington, DC
March 21-22, 2002

Program Objective

- **Overall objective**
  - Demonstrate a fuel-flexible, modular 3-to-10-kW solid oxide fuel cell (SOFC) system that can be configured to create highly efficient, cost-competitive, and reliable power plants tailored to specific markets

- **Approach**
  - System approach
  - Development focus
    - High performance
    - Low cost
    - Reliability
    - Modularity
    - Fuel flexibility

SOFC System Concept



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3rd SECA Workshop
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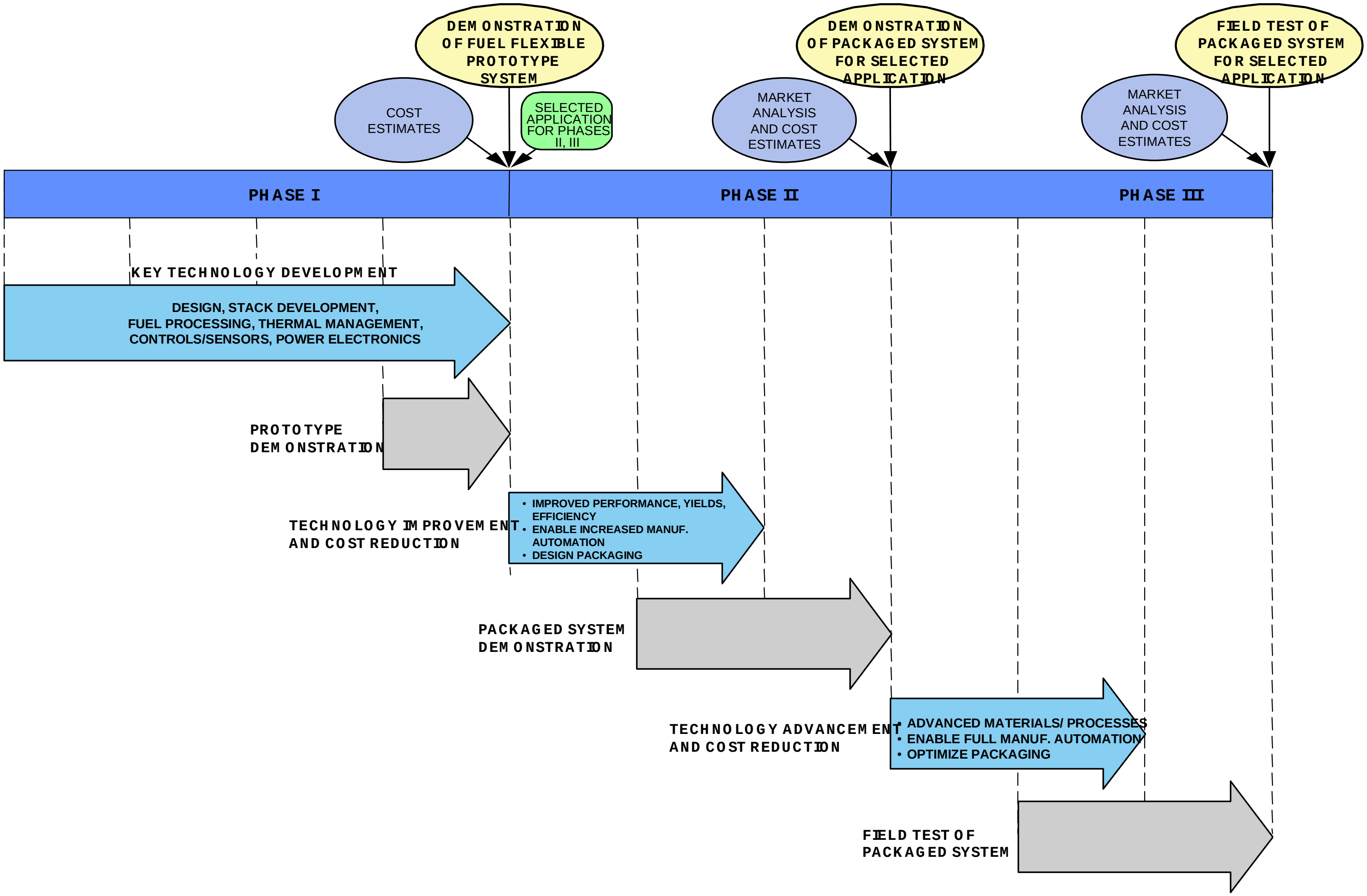
Key System Features

- **SOFC**
  - High-performance reduced-temperature cells
  - Operation on light hydrocarbons
  - Tape calendering manufacturing process
- **Fuel processor**
  - Low-cost, fuel-flexible fuel processor design
  - Catalytic process
  - Pre-reforming function
- **Other subsystems**
  - Integrated thermal management
  - Flexible control subsystem

Program Features



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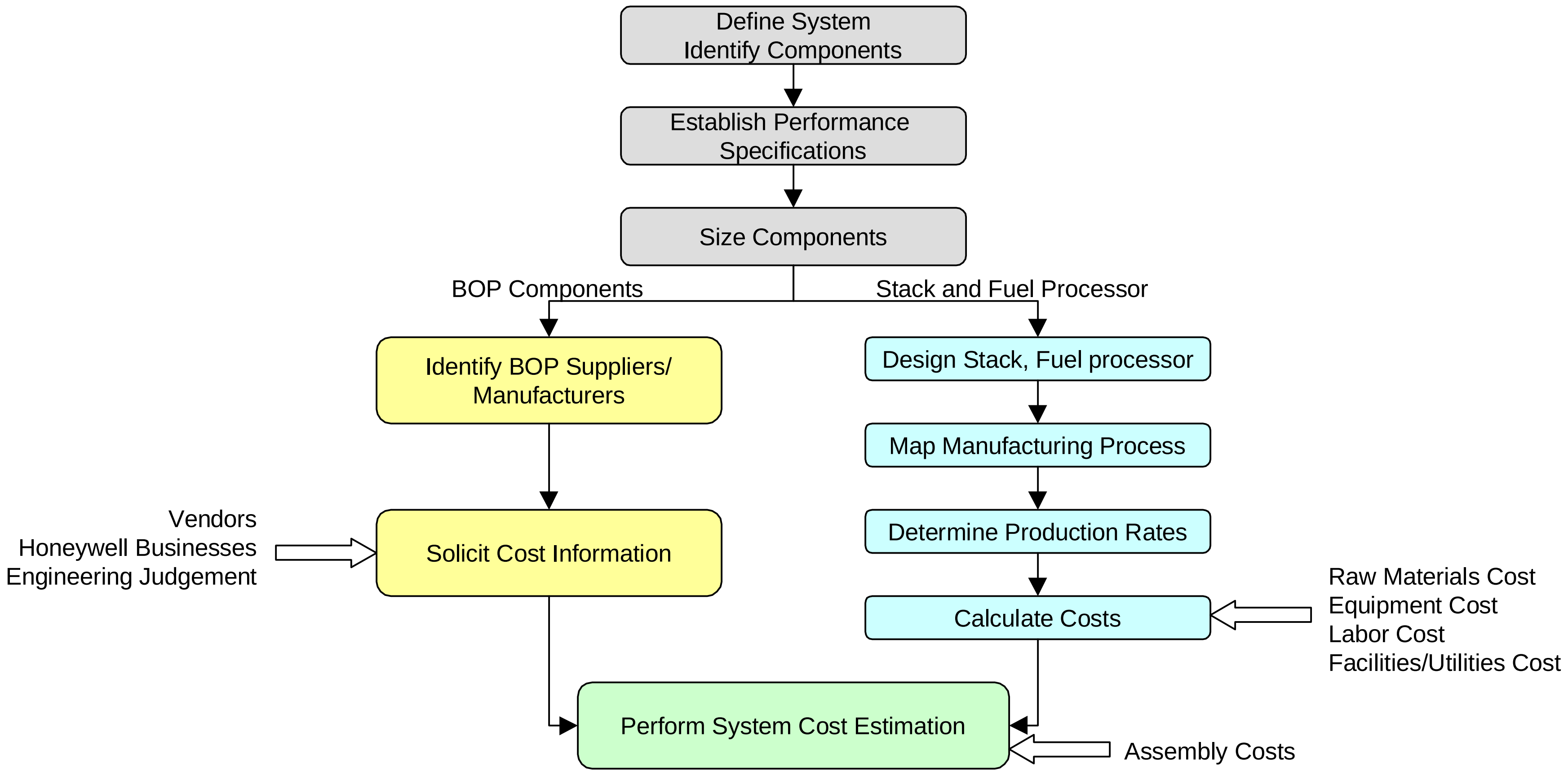
Phase I Work Elements

- System analysis
- Cost estimate
- Stack technology development
- Fuel processing
- Thermal management
- Control and sensor development
- Power electronics
- System prototype demonstration

Schematic of Method for Cost Estimation



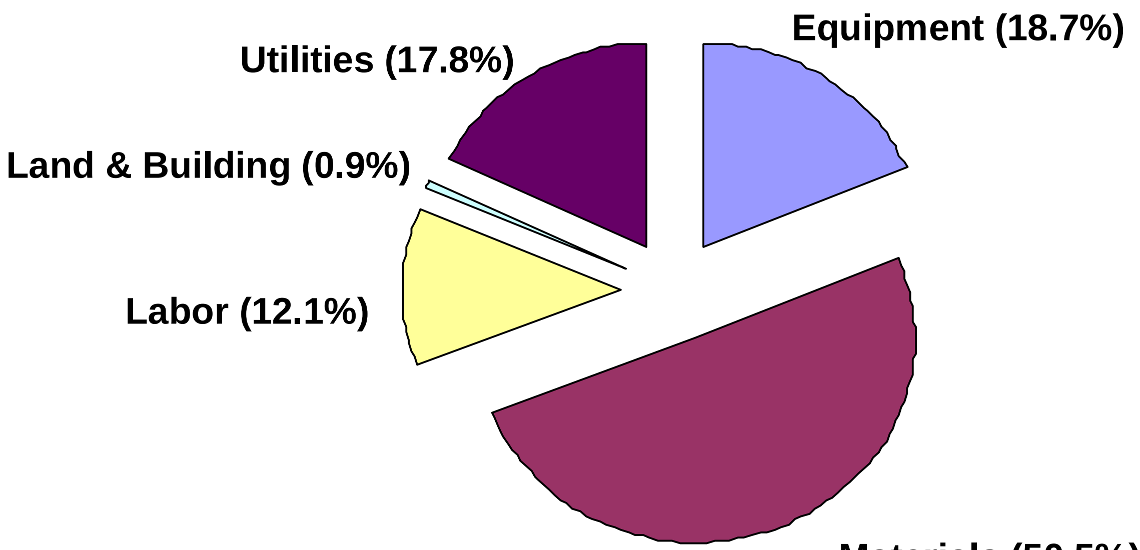
Key Assumptions

- Main system design assumptions
  - **5 kW stationary system operating on natural gas**
  - **Fuel processor as pre-reformer**

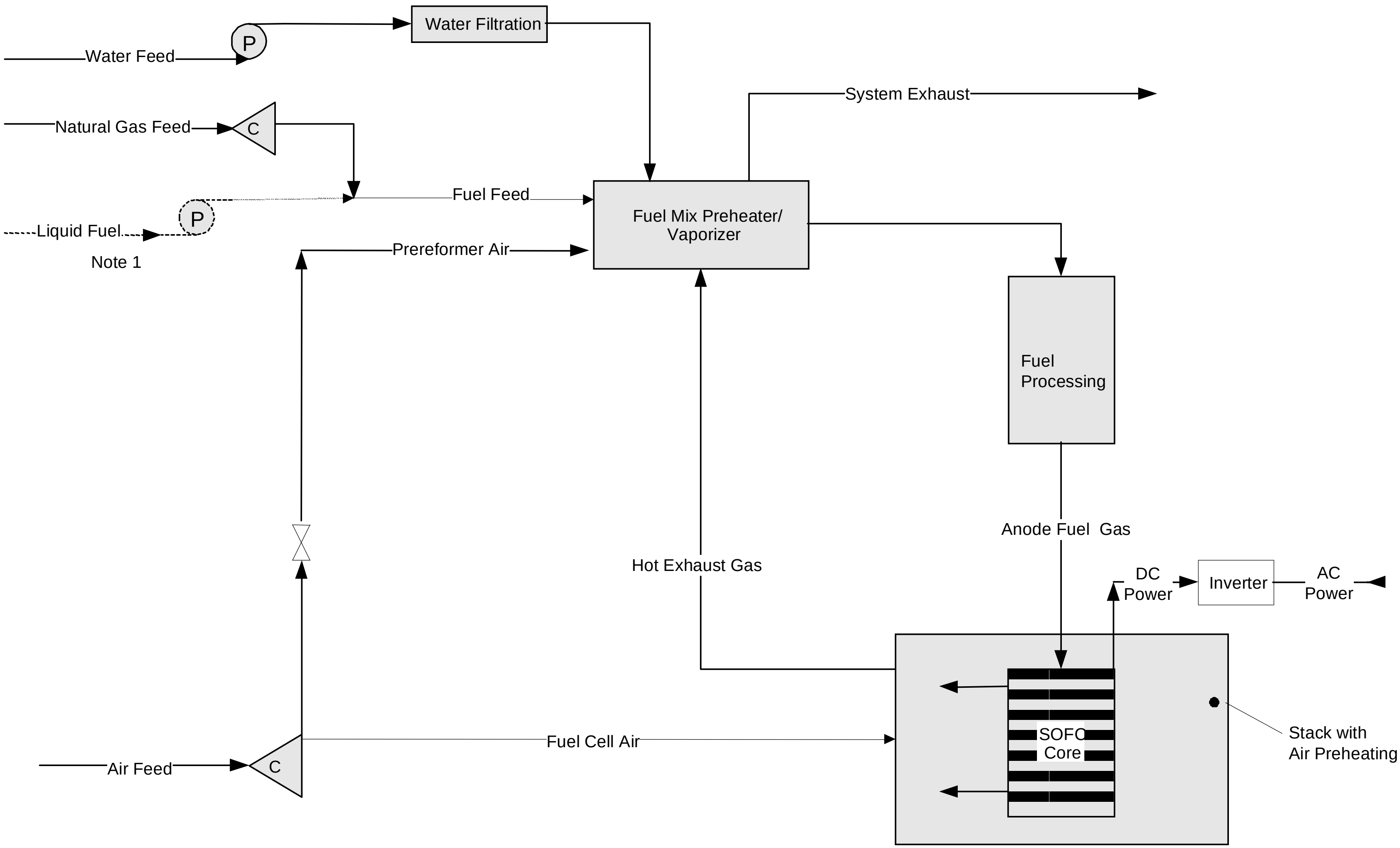
- Key manufacturing assumptions
  - **Production rate of 250 MW/year**
  - **Single plant located in Southwest**

Cost Estimates

- Projected system cost when fully developed:
  $388/kW
- Stack Costs

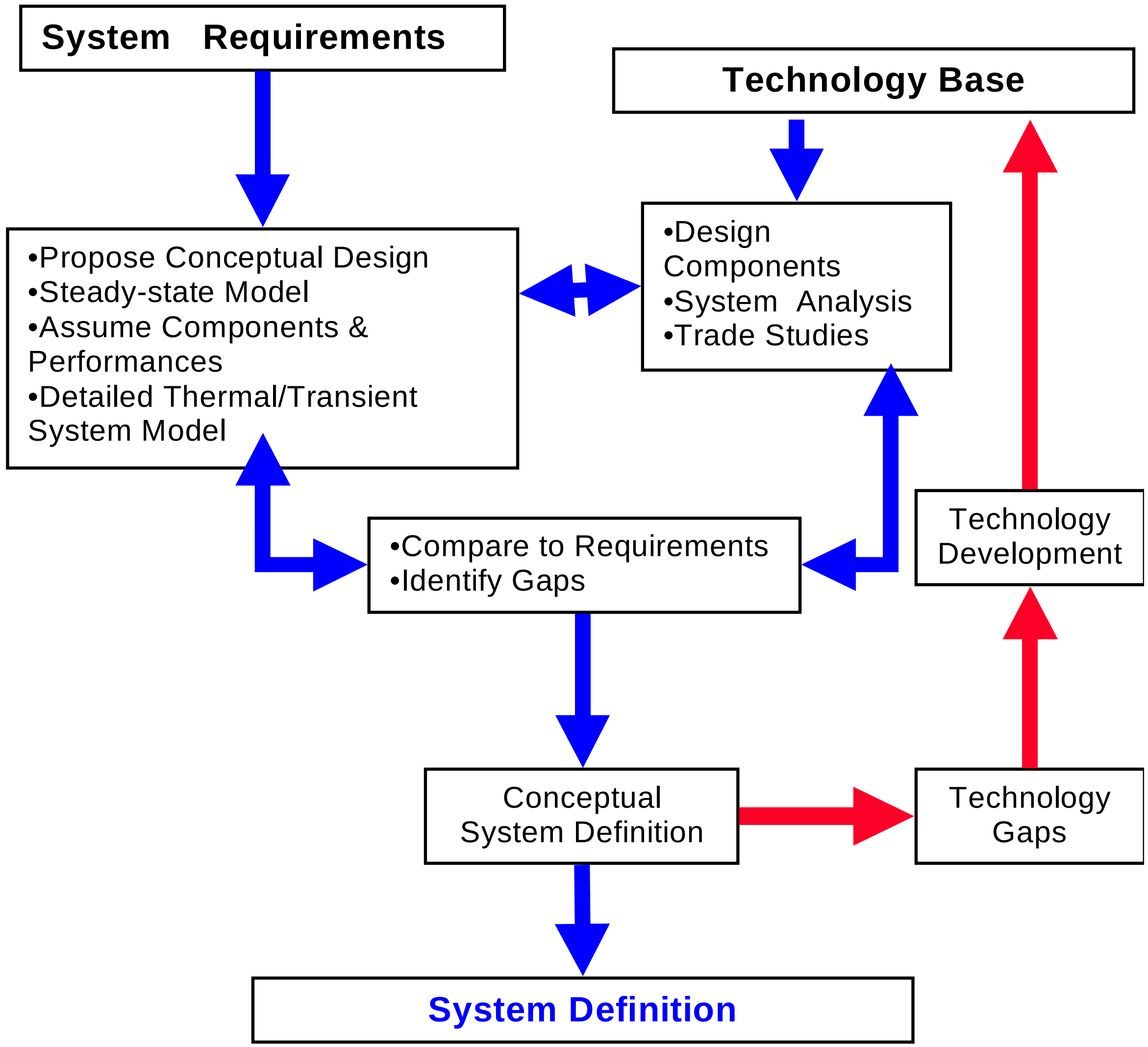


System Concept



NOTES:
1. Optional liquid fuel feed for non-stationary applications

System Design and Analysis Approach

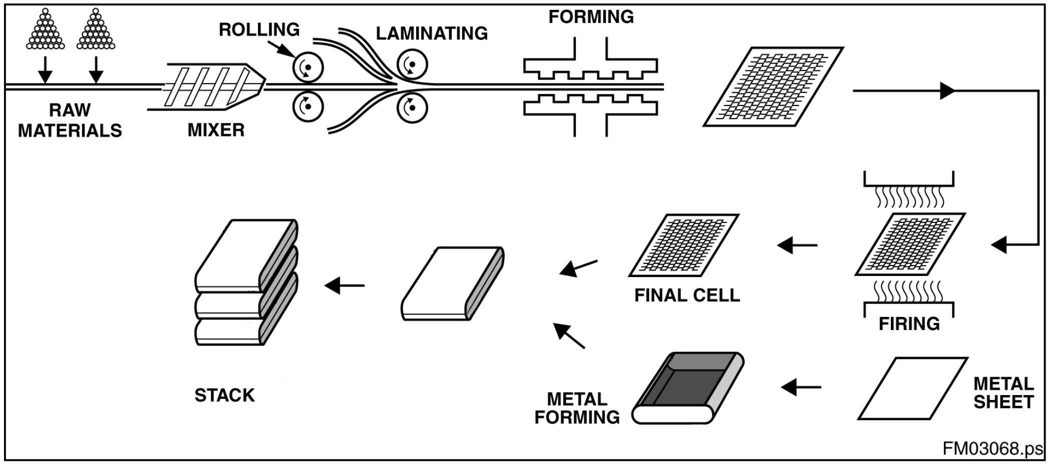


Performance Estimates

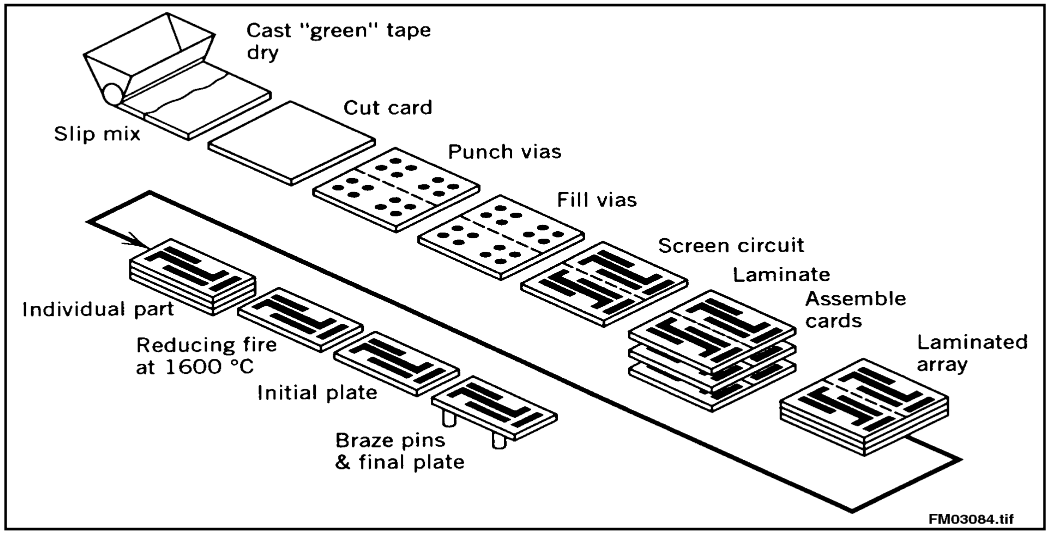
	Stationary	Mobile	Military
Fuel	Natural Gas	Gasoline	Diesel
Stack			
Voltage, V	0.75	0.75	0.75
Utilization	0.80	0.80	0.80
Power			
Fuel cell, kW	5.7	5.9	6.1
Net, kW	5.0	5.0	5.0
Efficiency			
Net, %	40	33	30

Low Cost Manufacturing Process

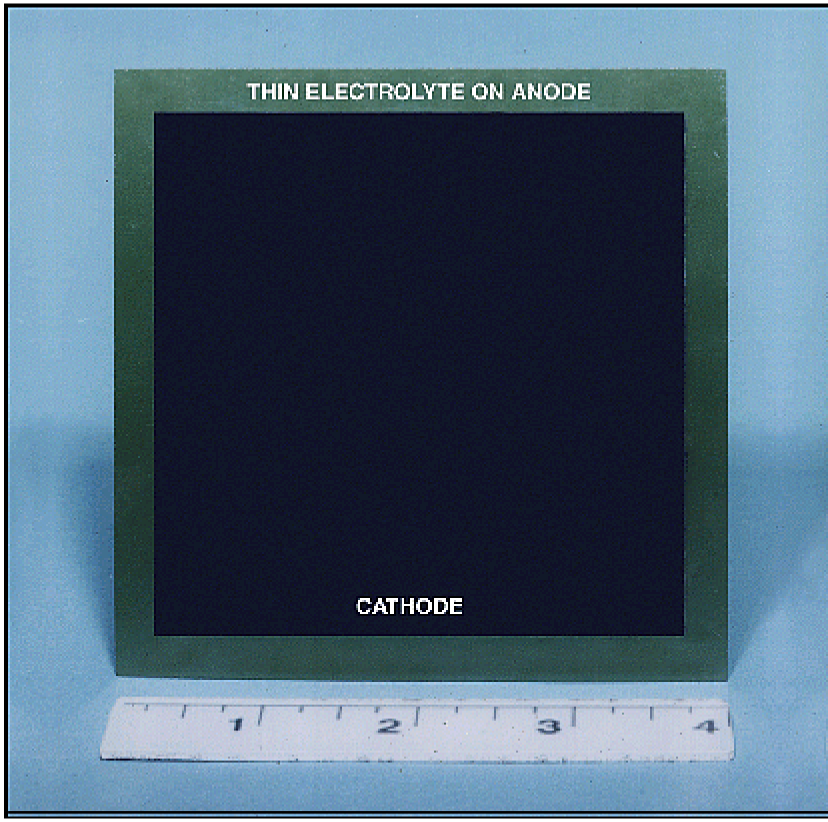
- **Fabrication process with tape calendering**

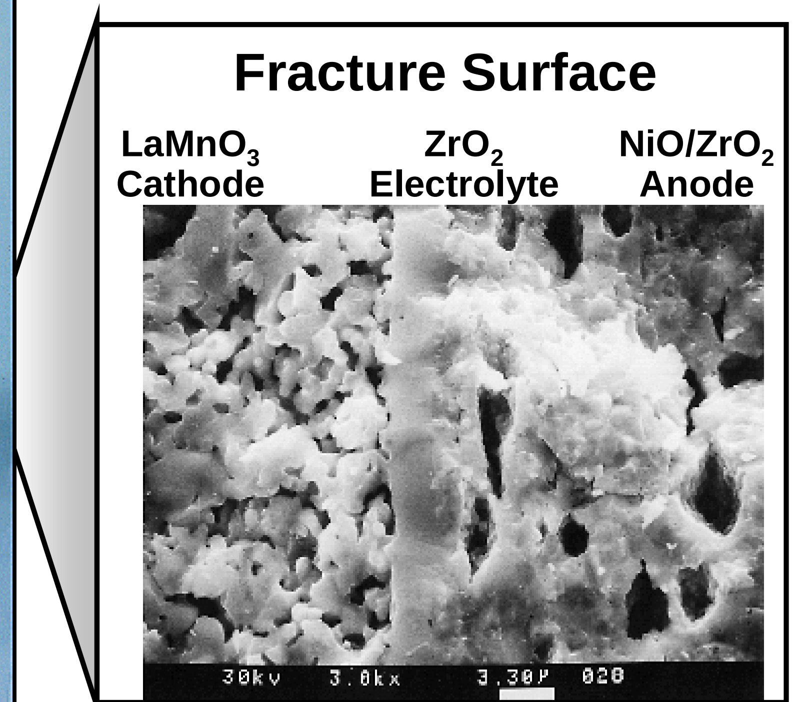


- **Multilayer electronics fabrication process**



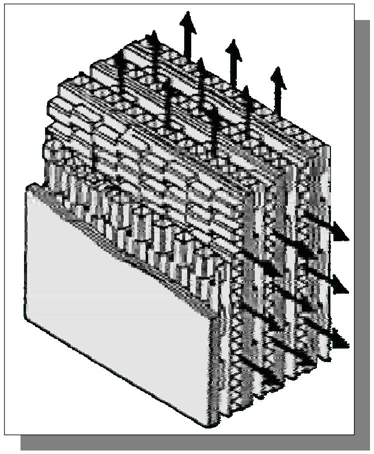
Thin Electrolyte Cell



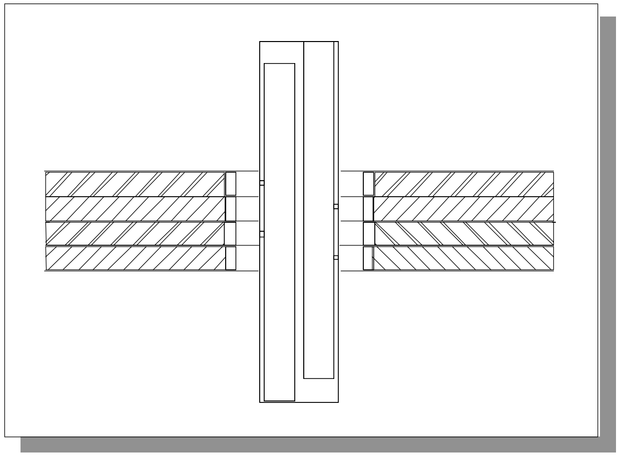


Stack Configurations

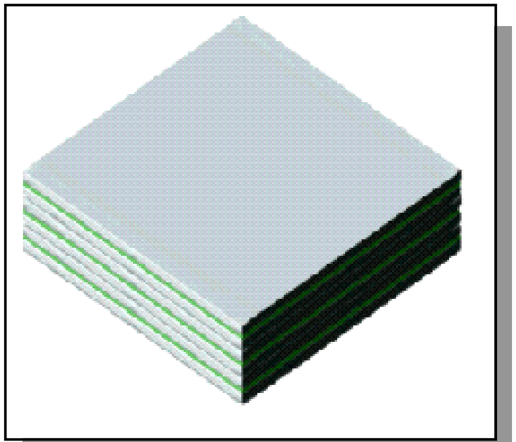
- Thin film electrolytes
- Thin foil metallic interconnects
- Gas manifold options
- Gas flow configuration flexibility



Crossflow Design

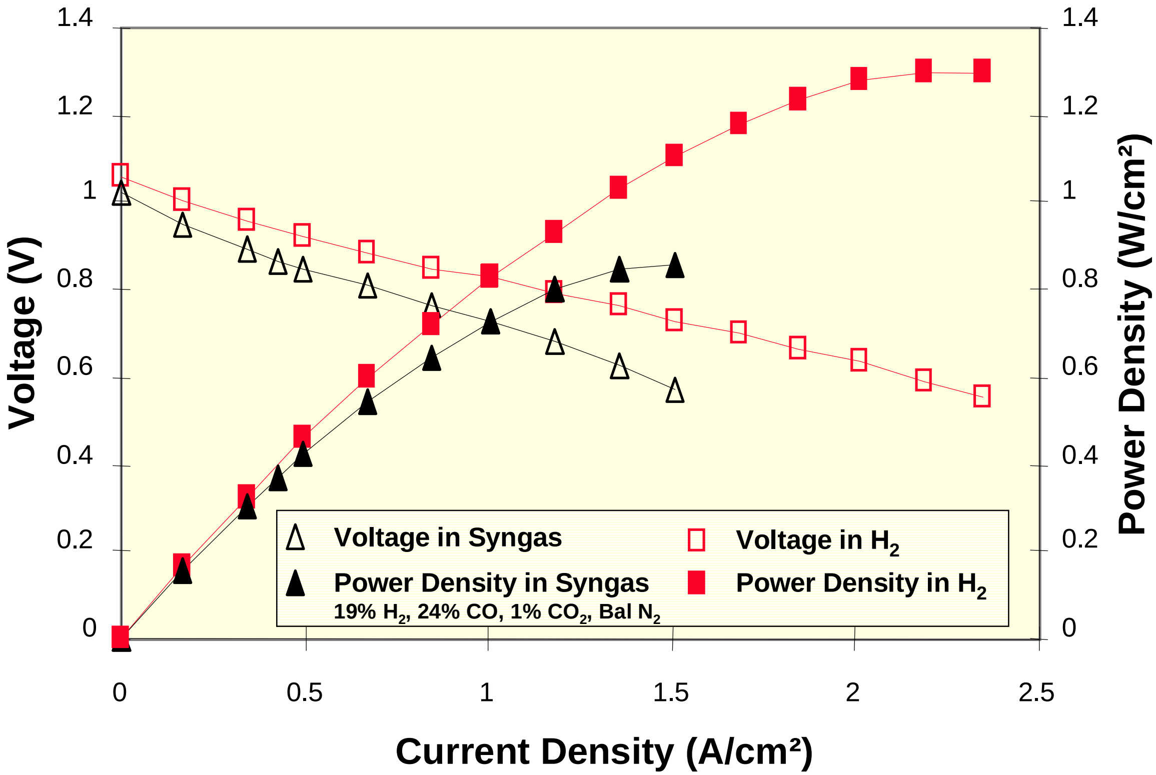


Radial Flow Design



Unitized Cell Design

SOFC Performance



- 800°C operation
- Open circuit voltages in agreement with theoretical values
- Peak power density:
  - 1.3 W/cm² in hydrogen
  - 0.85 W/cm² in JP-8 syngas

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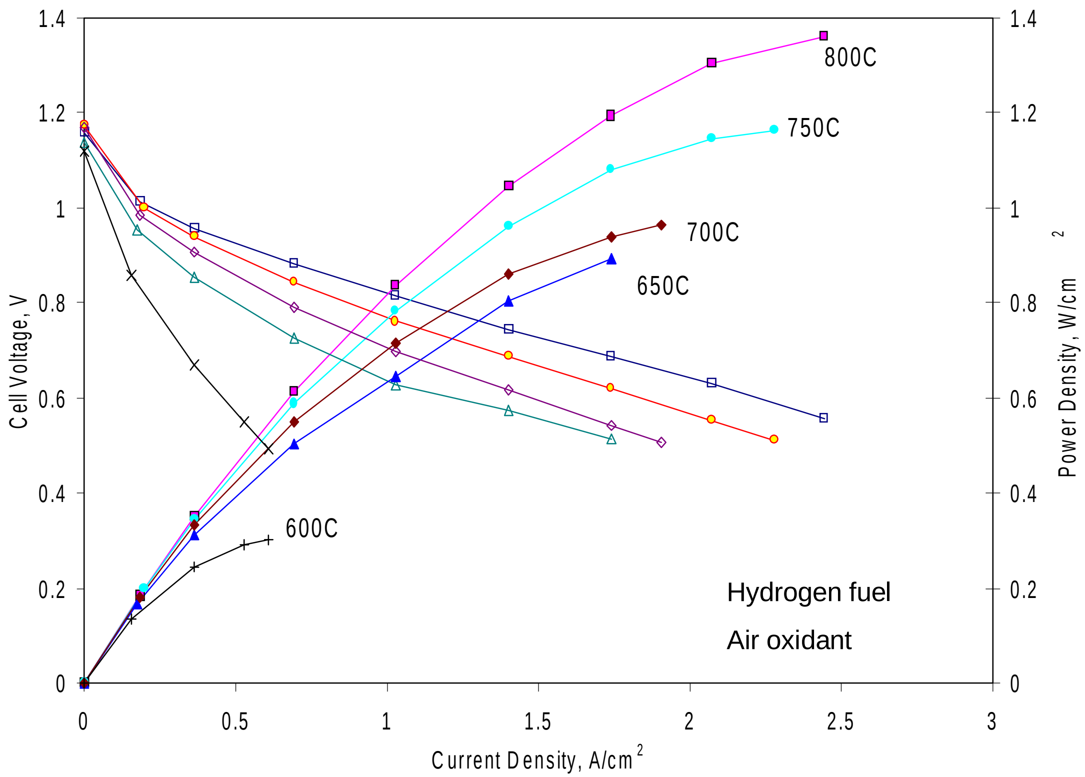
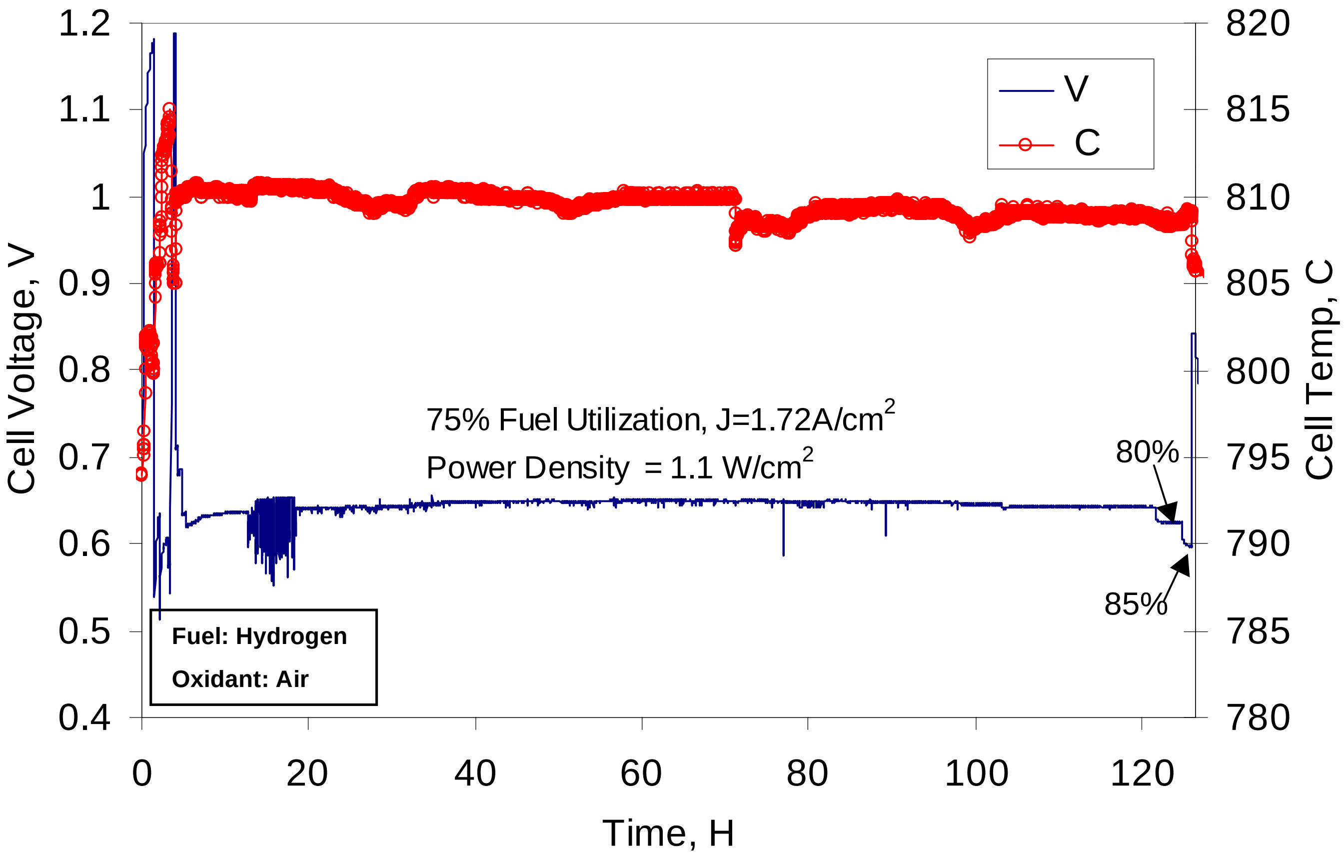
SOFC Cell Performance at Reduced Temperatures



High power densities (e.g., 0.9 W/cm² at 650°C) achieved at reduced temperatures (<800°C) with anode-supported thin-electrolyte cells

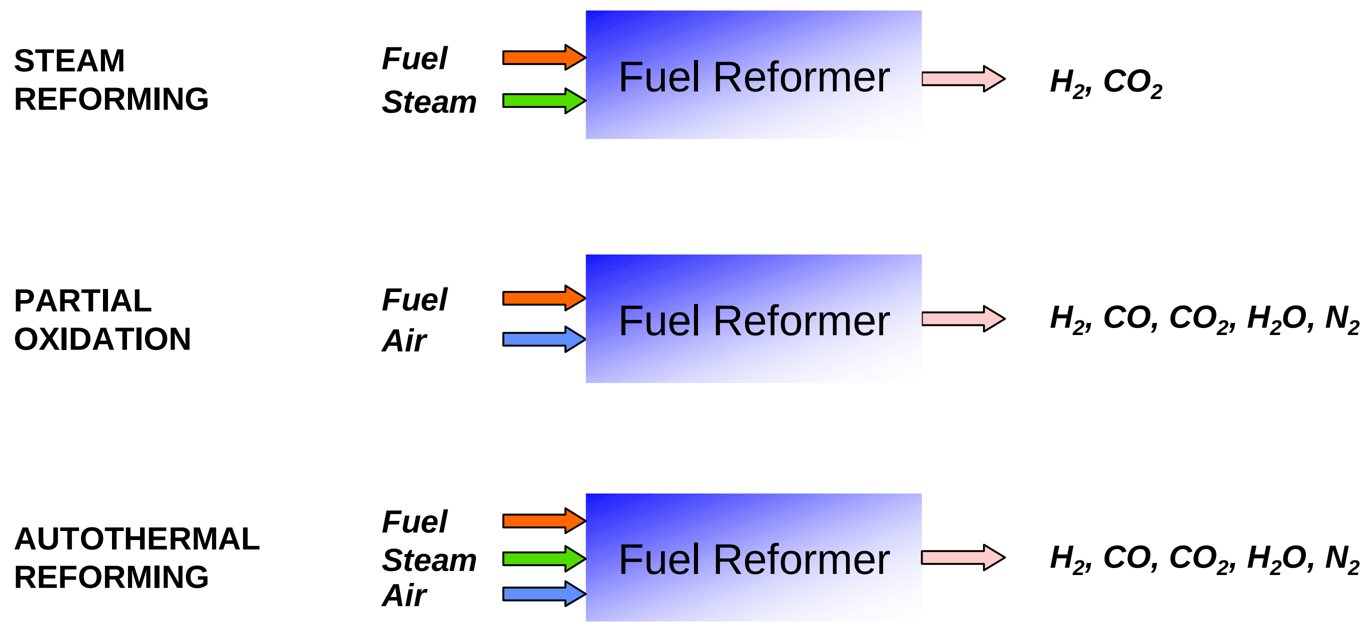
Cell Fuel Utilization



Other Cell/Stack Accomplishments

- Demonstration of high cell performance (1.8 W/cm^2 at 800˚C) with high utilization (50%)
- Operation of a stack module for more than 3000 hours
  - Identification and modeling of degradation rate
- Fabrication scaleup and improvement

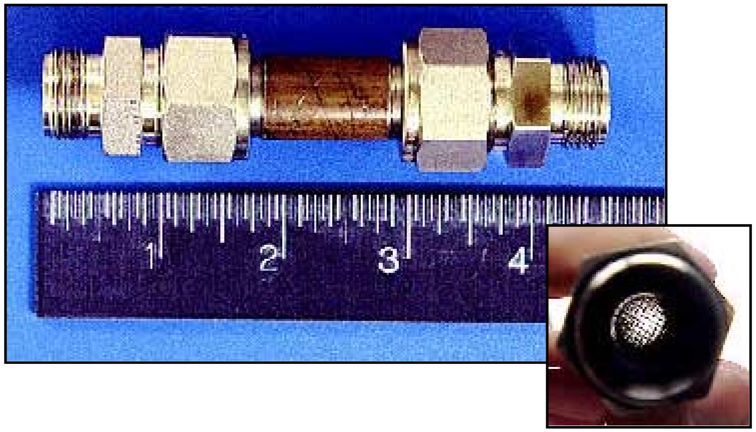
Reforming Options

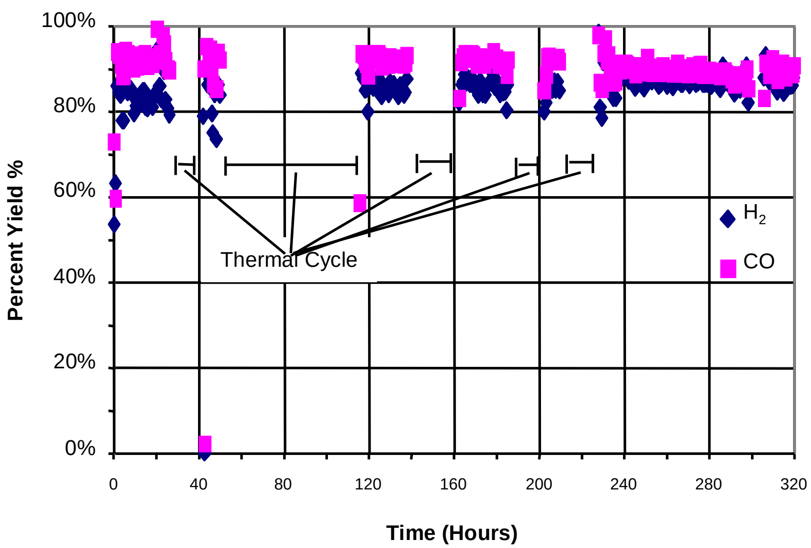


Fuel Processing Approach

- Fuel processor as a pre-reformer for hydrocarbon fuels
- Approach: Catalytic partial oxidation (CPOX) as baseline and process modifications as required for different types of fuels

CPOX for Processing Hydrocarbon Fuels





- Fuels: propane, butane, octane, JP-8, and diesel
- Duration: 700 hours to date
- Thermal cycles: 10
- Sulfur tolerance: 1000 ppm dibenzothiophene in JP-8
- Yield: 70-80% of LHV in JP-8

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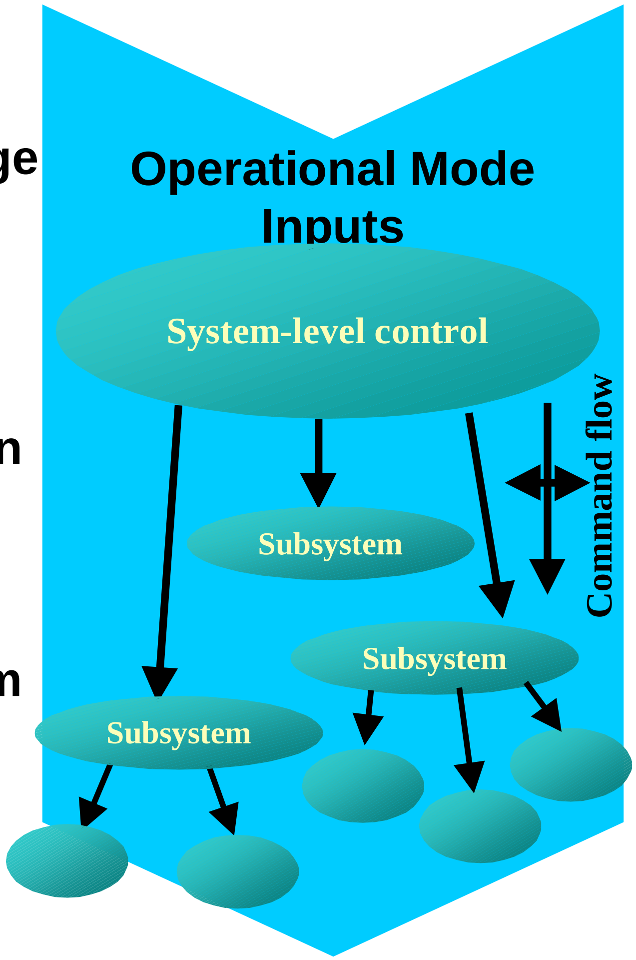
Control System Functions

– **Control system functionality drives integration**
– **Coordinate subsystems for shared resources and efficient operation**
– **Efficiently regulate over a wide operating range**
  - Flow / Composition
  - Temperature
  - Pressure
  - Power
– **Provide safe system operation through built-in test**
– **Perform process and component health monitoring for improved life cycle**
– **Provides user interface and automated system operation**
  - Startup/ Shutdown
  - Scheduled operation
  - Status indicators/alarms
  - Emergency Shutdown



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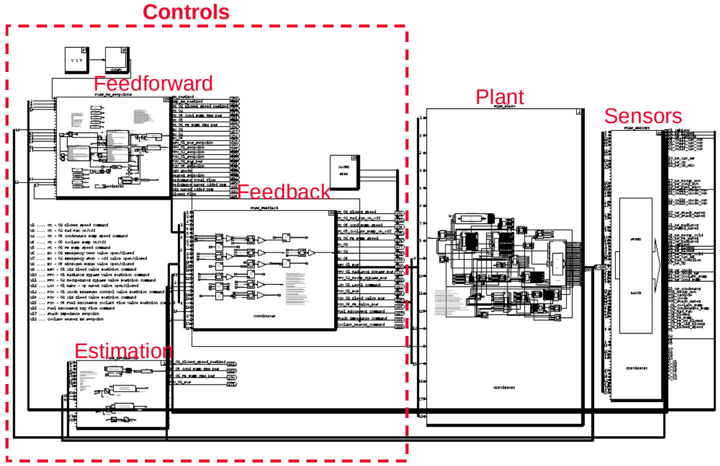
Control & Sensing Approach

– Honeywell's proprietary ***Fuel Cell Dynamic Component Library*** **allows for rapid development of dynamic system models and prototyping of control systems through simulation.**

– **Rapid prototyping capabilities allow for direct transfer of controls designed in simulation to control of fuel cell system.**

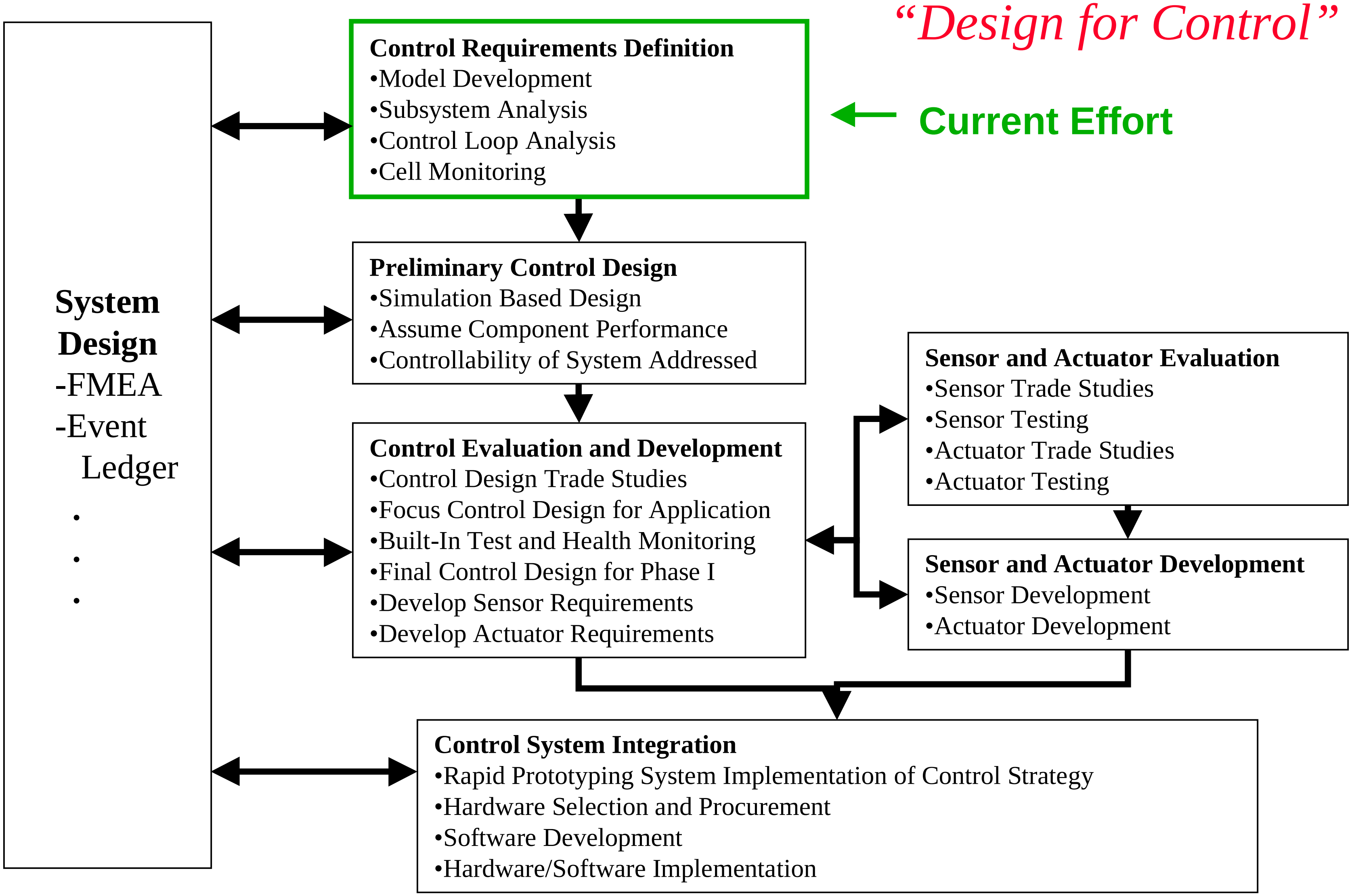
– **Advanced control and sensing techniques can investigated through simulation trade studies and then the most promising approaches easily implemented in hardware system.**



Rapid Prototyping

Controls Analysis and Design Process

"Design for Control"



Concluding Remarks

- SECA SOFC system concept
- System features
  - High performance
  - Low cost
  - Flexibility
- Various activities to support system development

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