

SECA

Solid Oxide Fuel Cell Program

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Program Objective

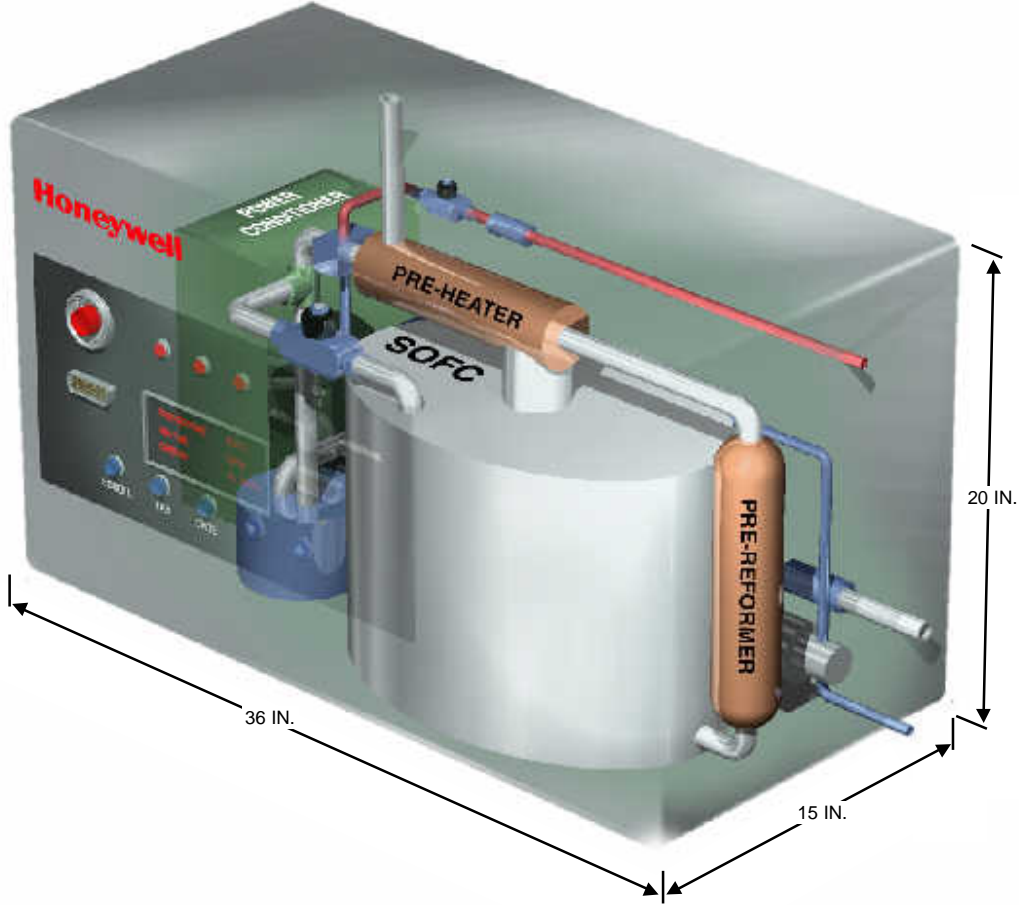
- **Overall objective**

- 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

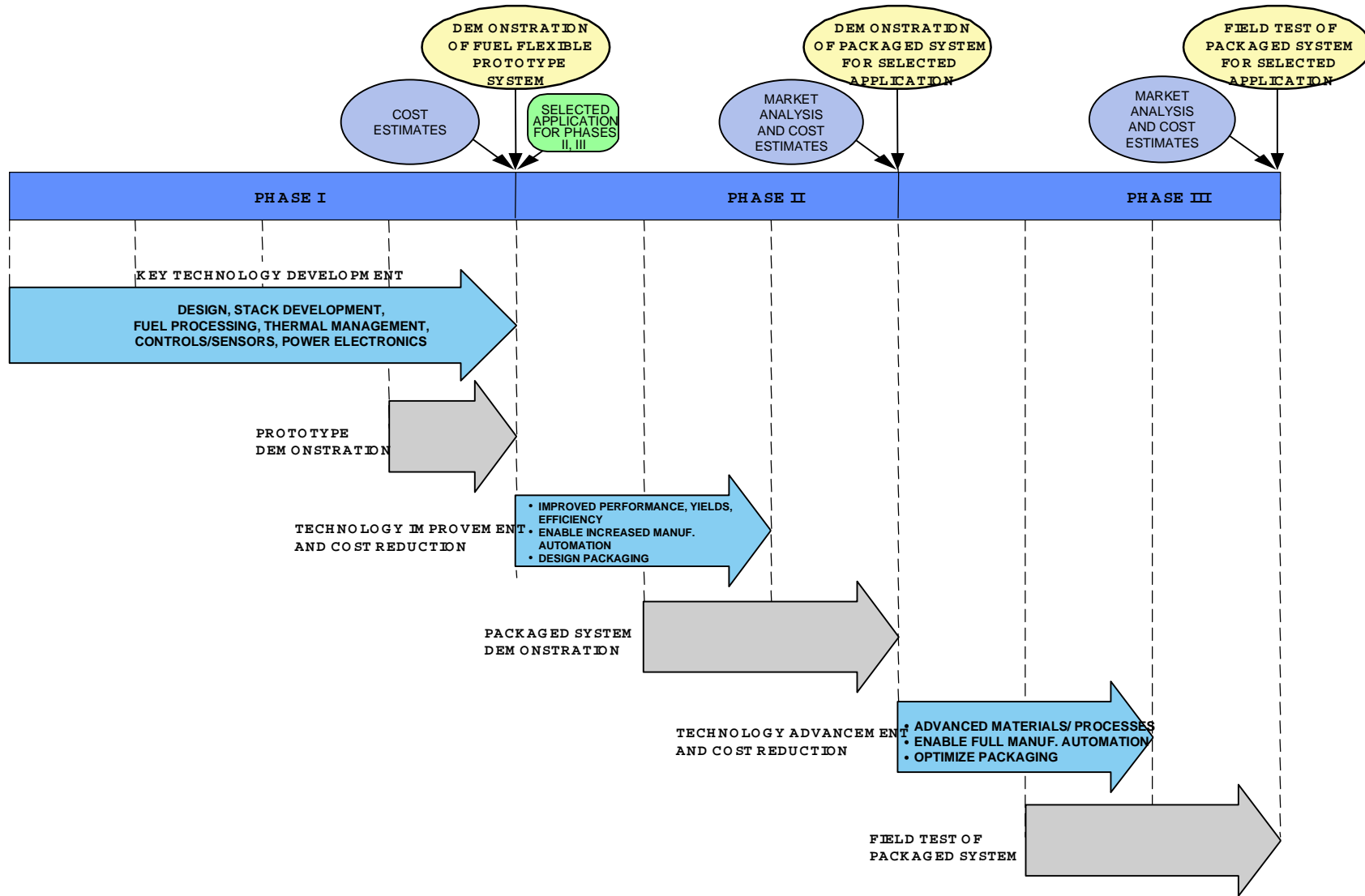


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Key System Features

- **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



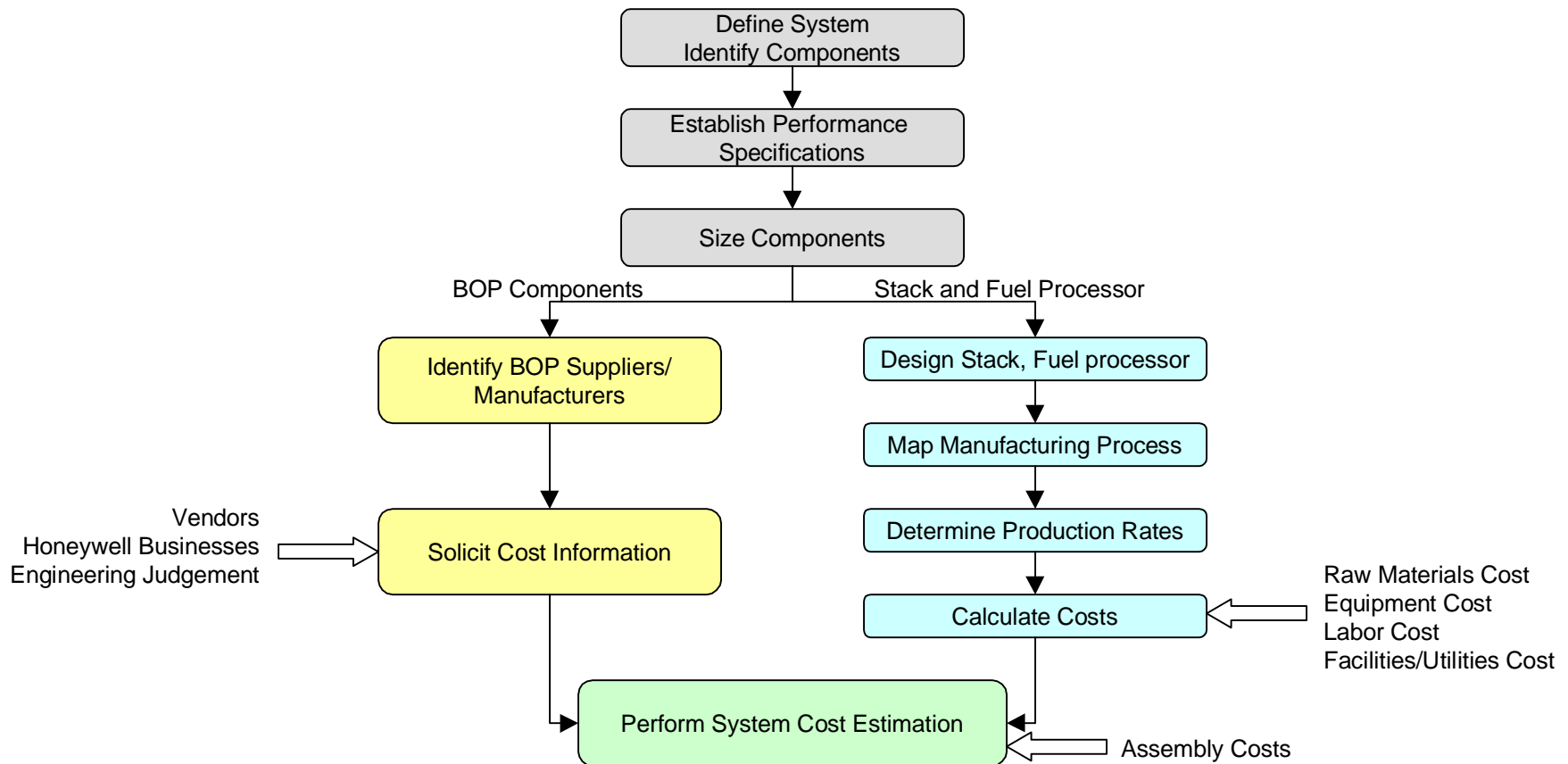
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Phase I Work Elements

- **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

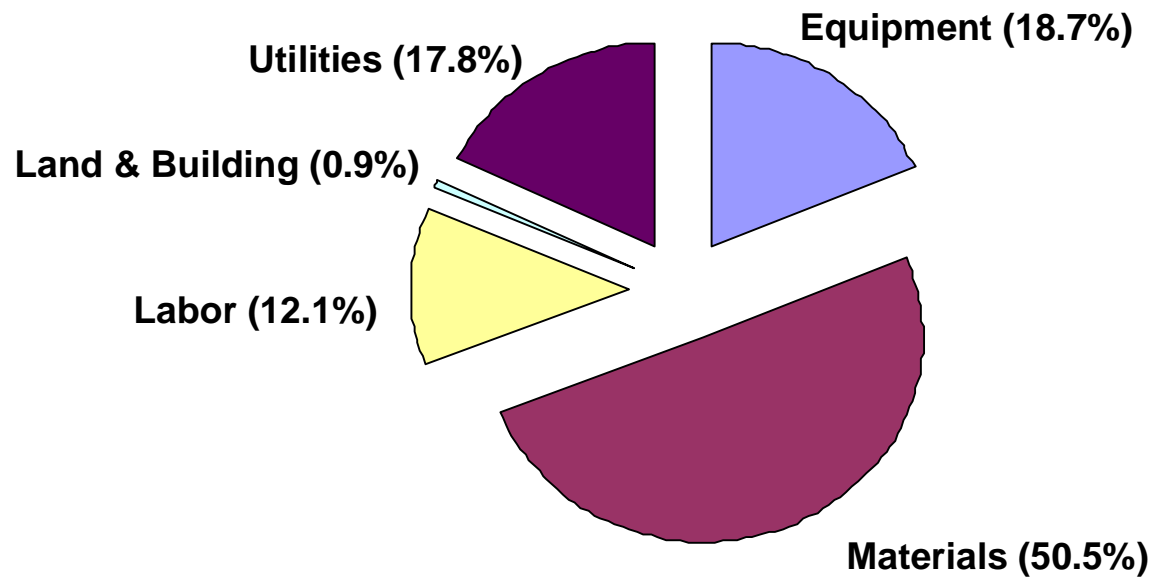


Key Assumptions

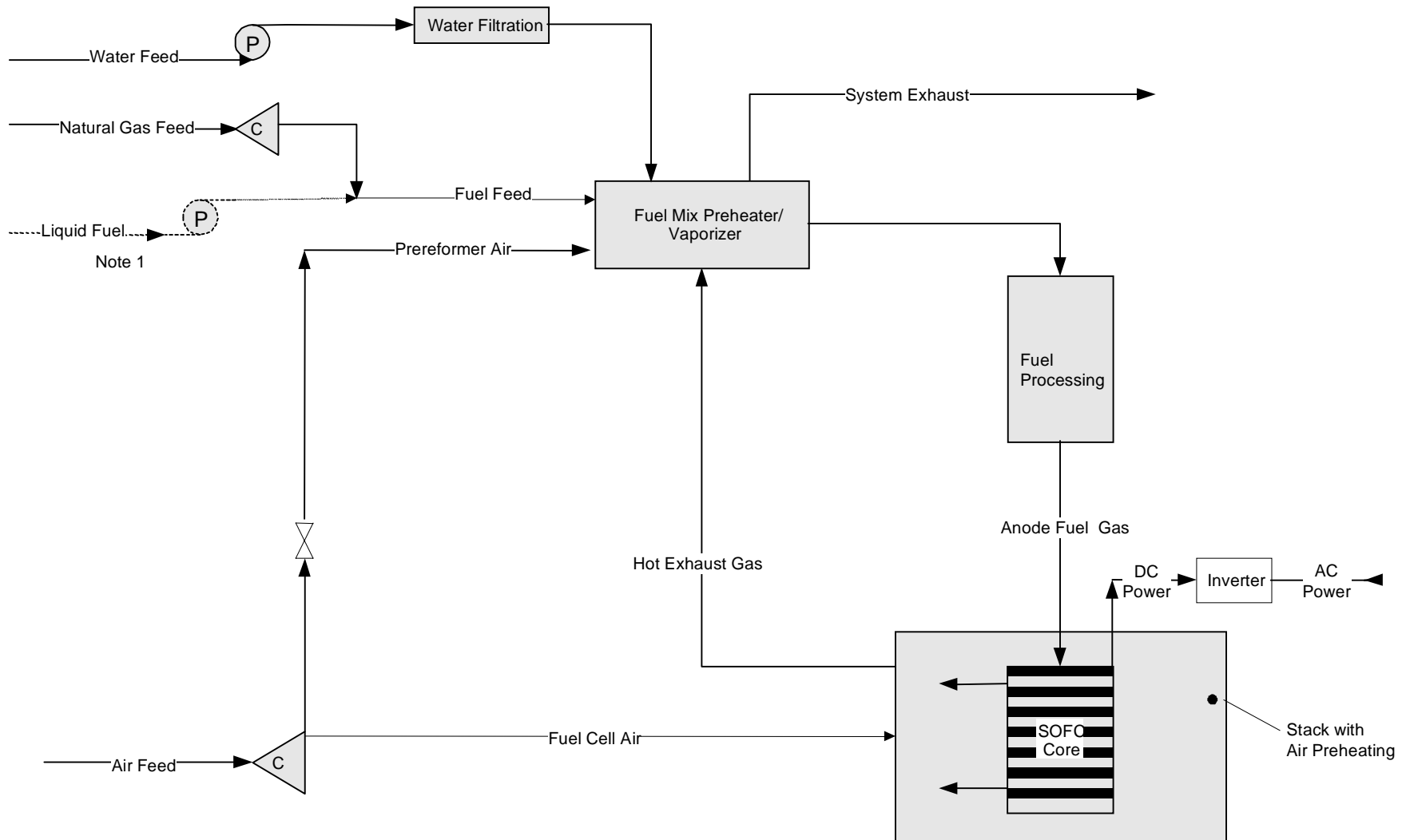
- Main system design assumptions
 - **5 kW stationary system operating on natural gas**
 - **Fuel processor as pre-reformer**
- Key manufacturing assumptions
 - **Production rate of 250 MW/year**
 - **Single plant located in Southwest**

Cost Estimates

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



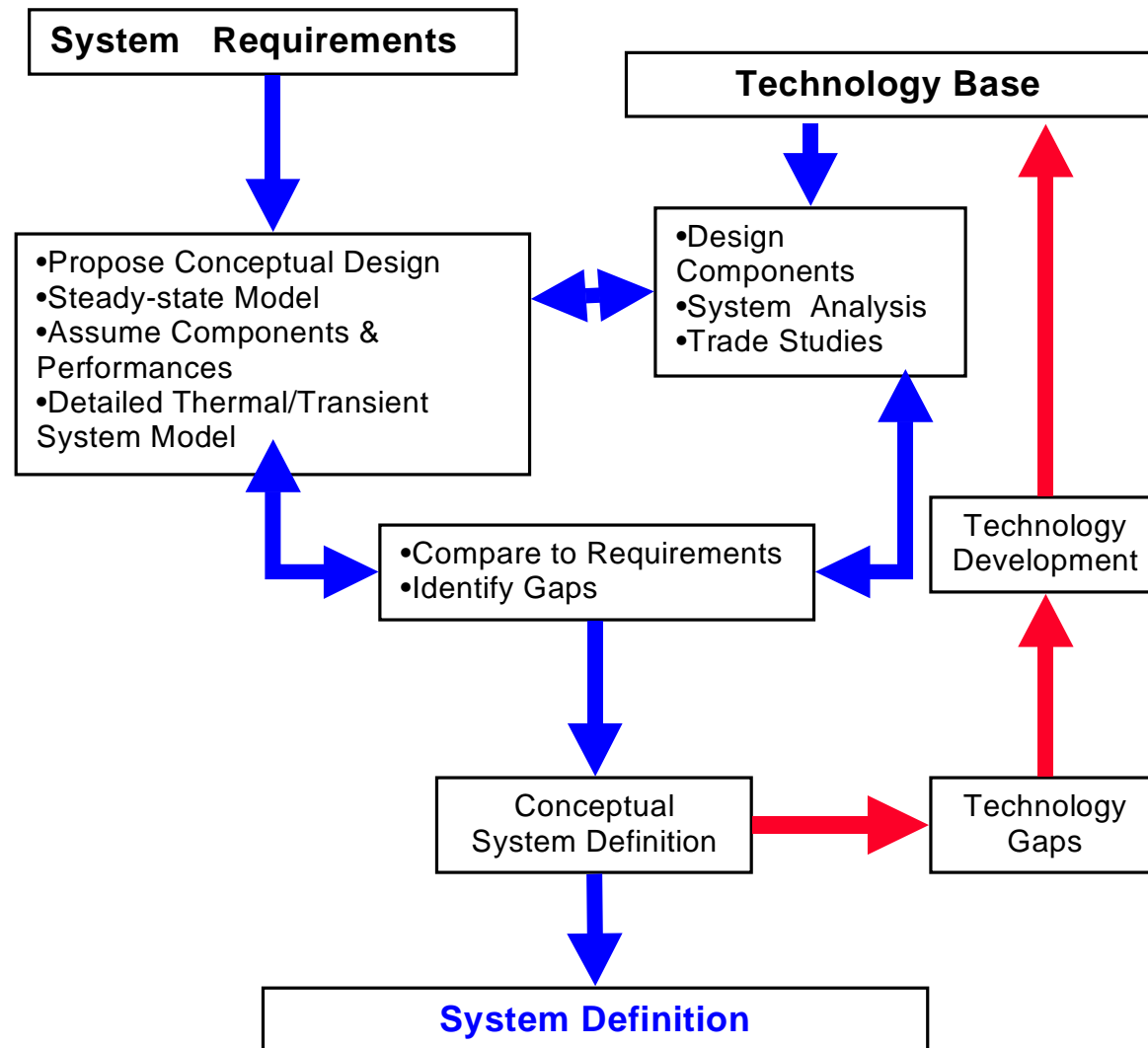
System Concept



NOTES:

1. Optional liquid fuel feed for non-stationary applications

System Design and Analysis Approach



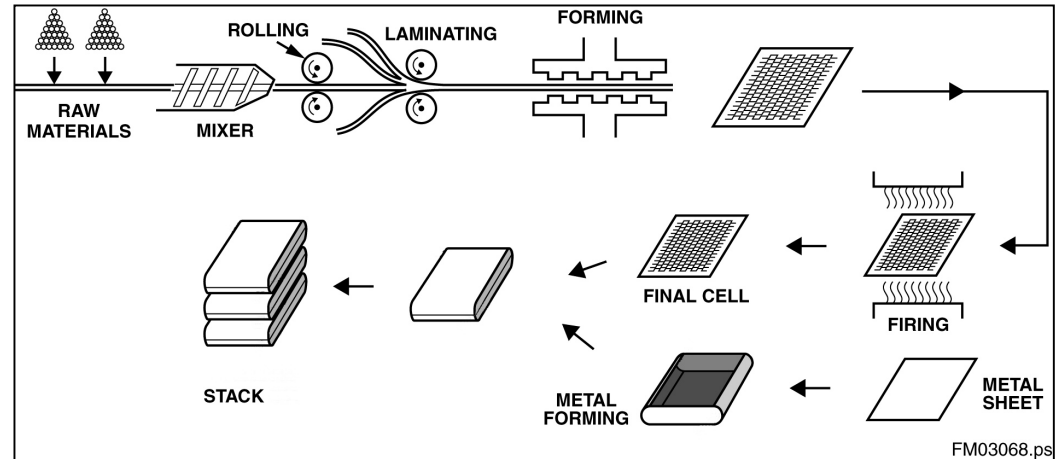
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Performance Estimates

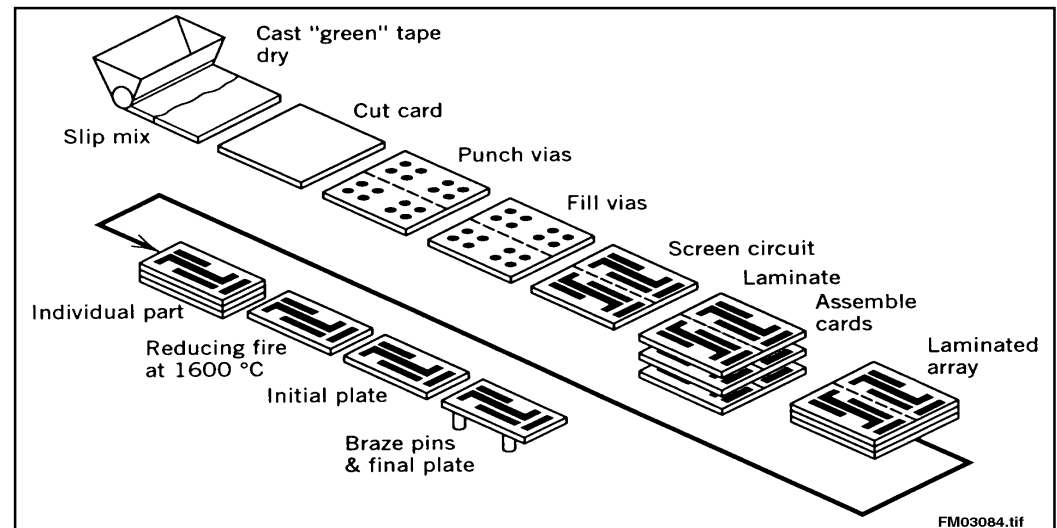
	Stationary	Mobile	Military
Fuel	Natural Gas	Gasoline	Diesel
Stack			
Voltage, V	0.75	0.75	0.75
Utilization	0.80	0.80	0.80
Power			
Fuel cell, kW	5.7	5.9	6.1
Net, kW	5.0	5.0	5.0
Efficiency			
Net, %	40	33	30

Low Cost Manufacturing Process

- **Fabrication process with tape calendaring**

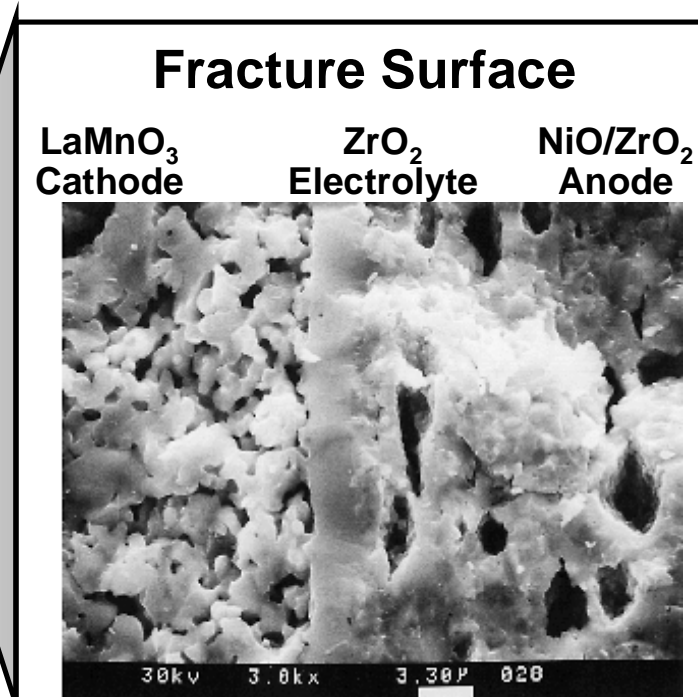
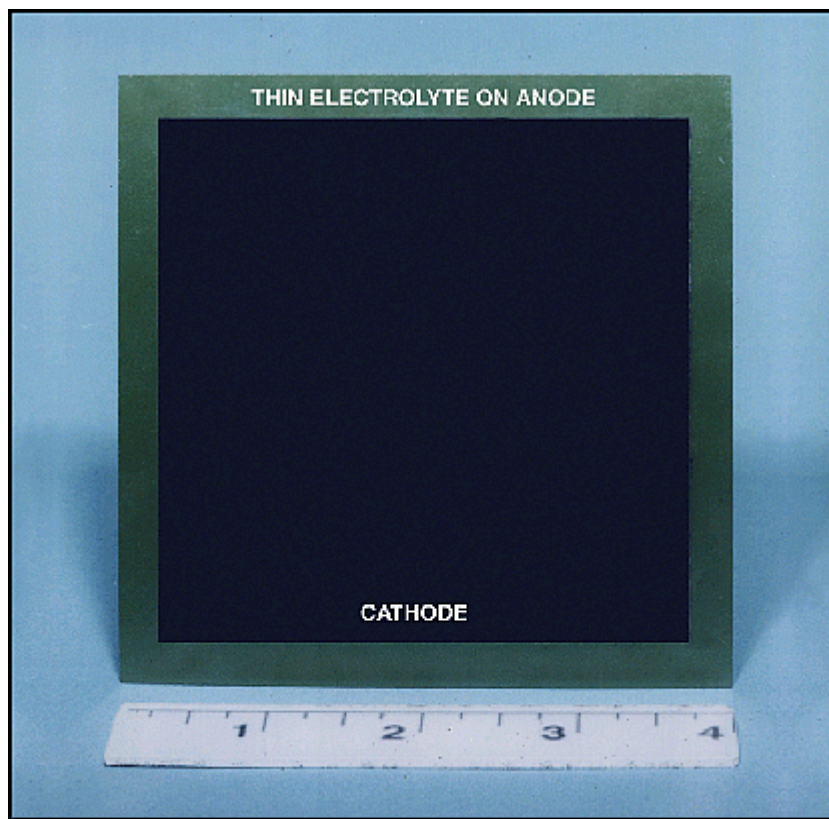


- **Multilayer electronics fabrication process**



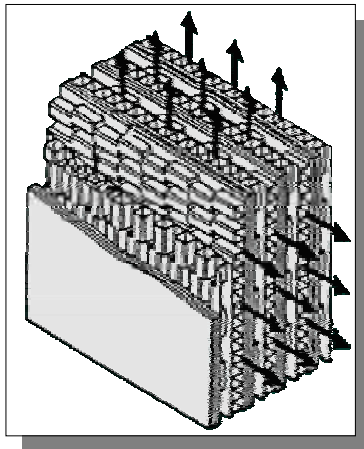
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Thin Electrolyte Cell

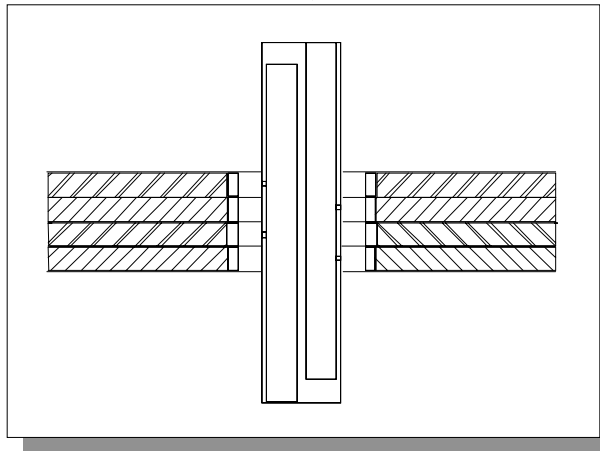


Stack Configurations

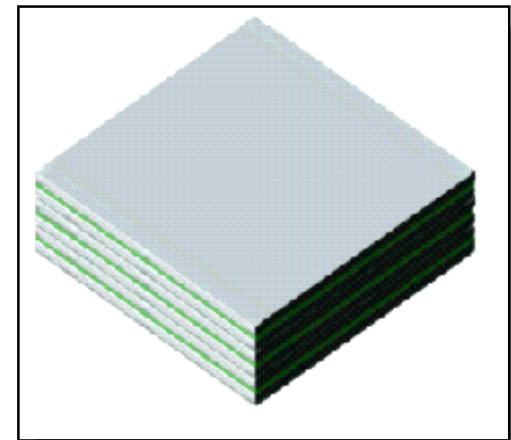
- Thin film electrolytes
- Thin foil metallic interconnects
- Gas manifold options
- Gas flow configuration flexibility



Crossflow Design



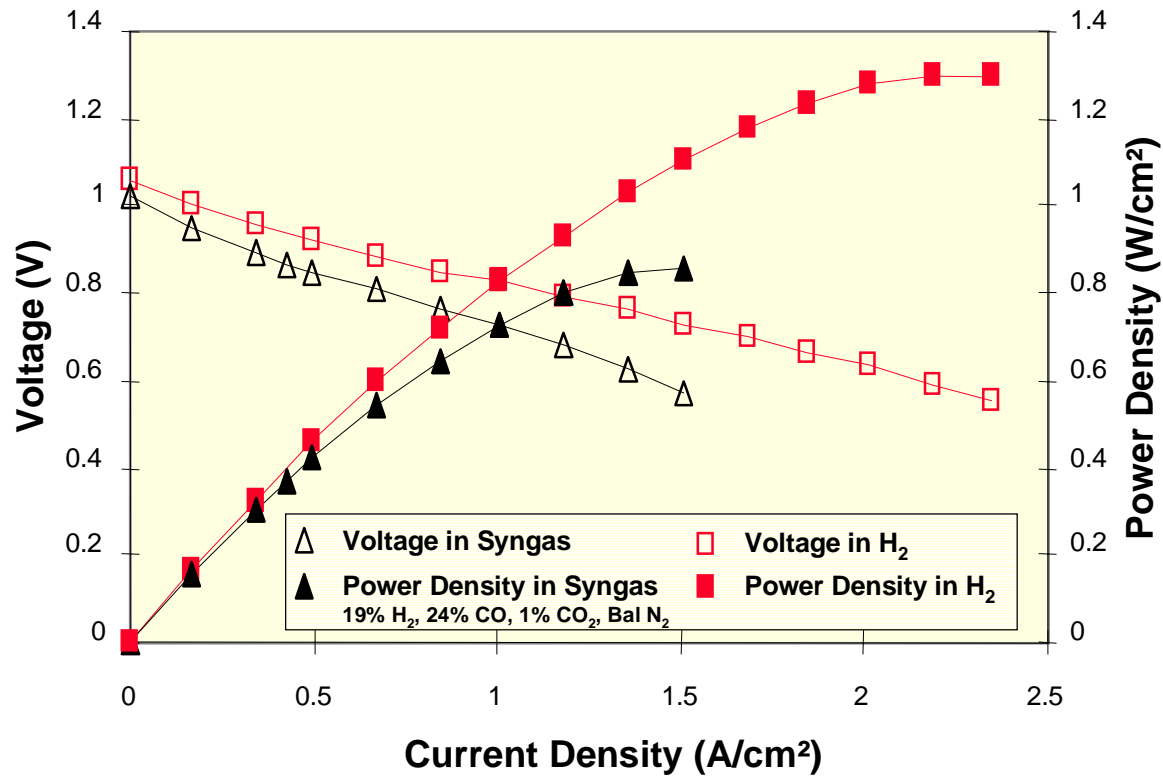
Radial Flow Design



Unitized Cell Design

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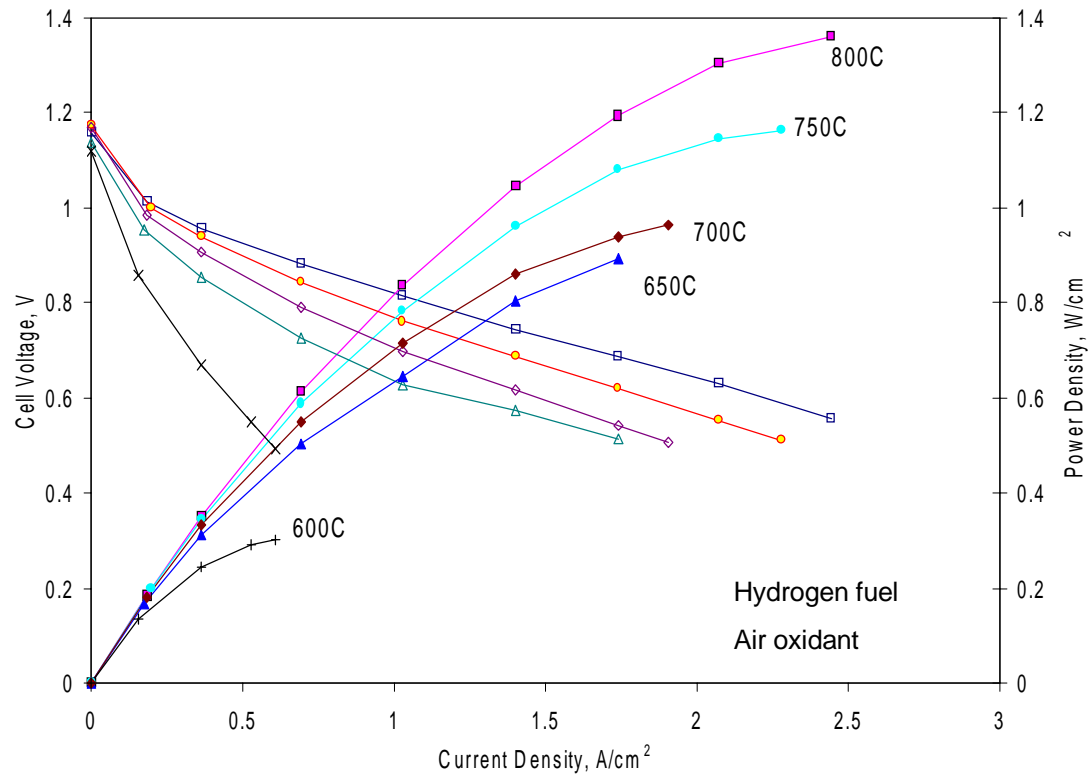
SOFC Performance



- 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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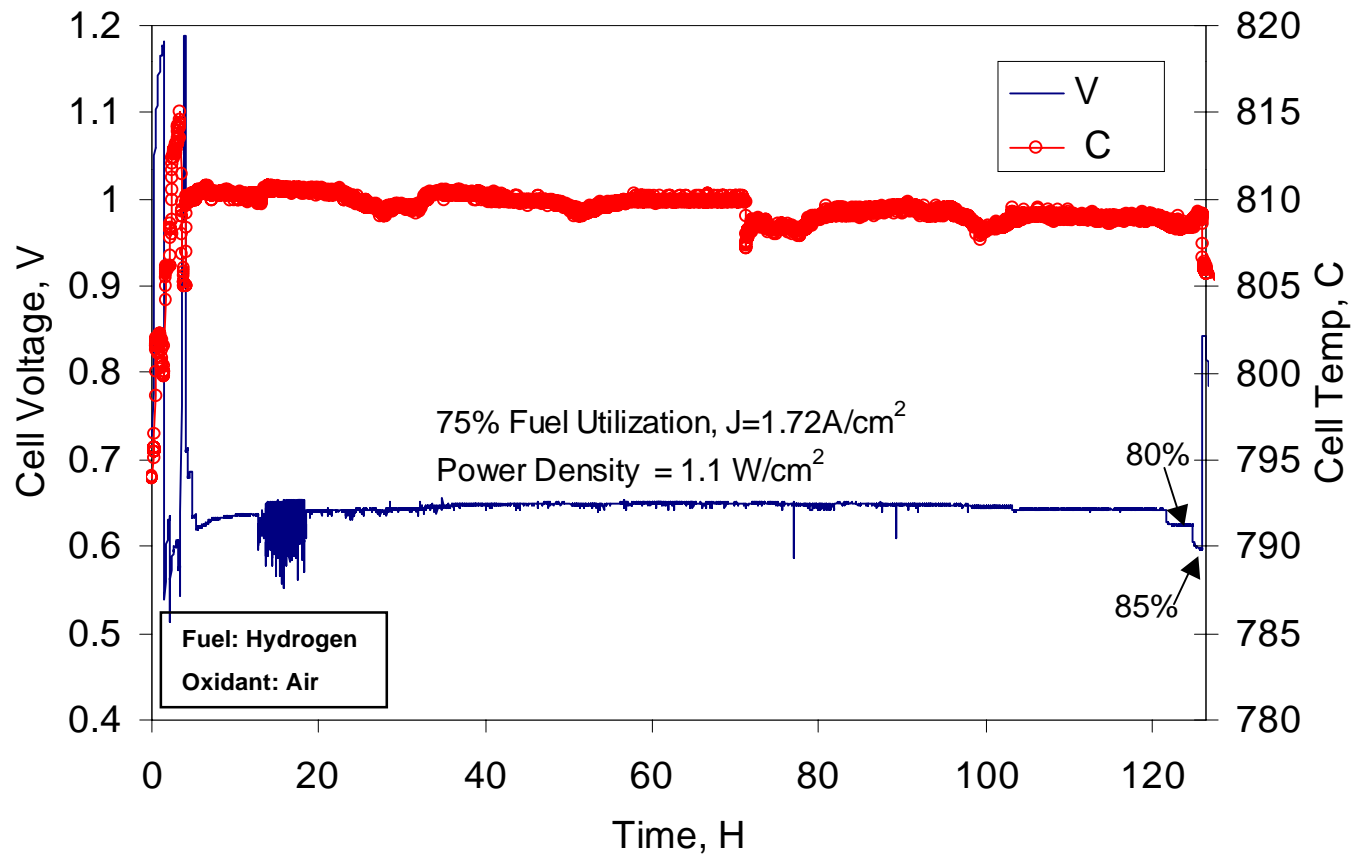
SOFC Cell Performance at Reduced Temperatures



High power densities (e.g., 0.9 W/cm^2 at 650°C) achieved at reduced temperatures (<800°C) with anode-supported thin-electrolyte cells

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Cell Fuel Utilization



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Other Cell/Stack Accomplishments

- **Demonstration of high cell performance (1.8 W/cm² 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

STEAM
REFORMING



PARTIAL
OXIDATION



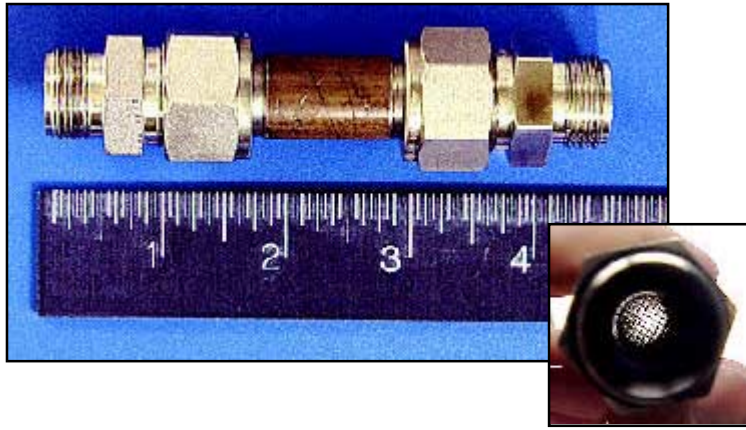
AUTOTHERMAL
REFORMING



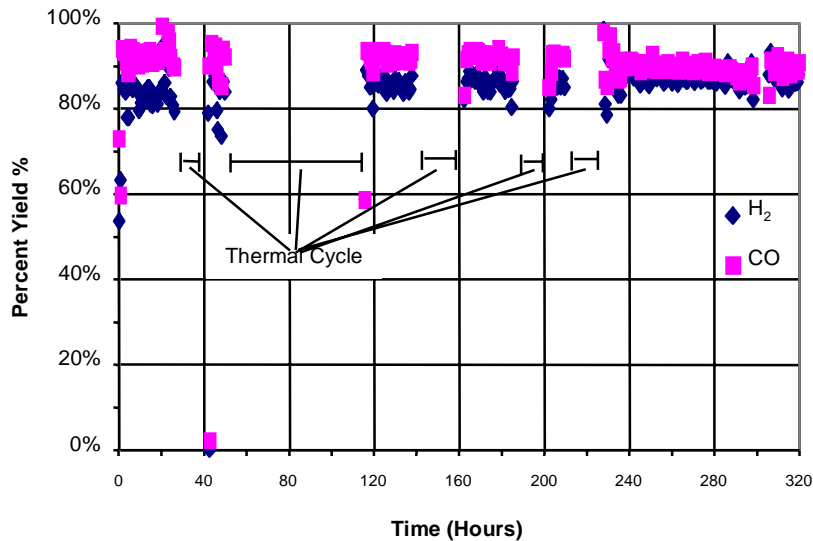
Fuel Processing Approach

- **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



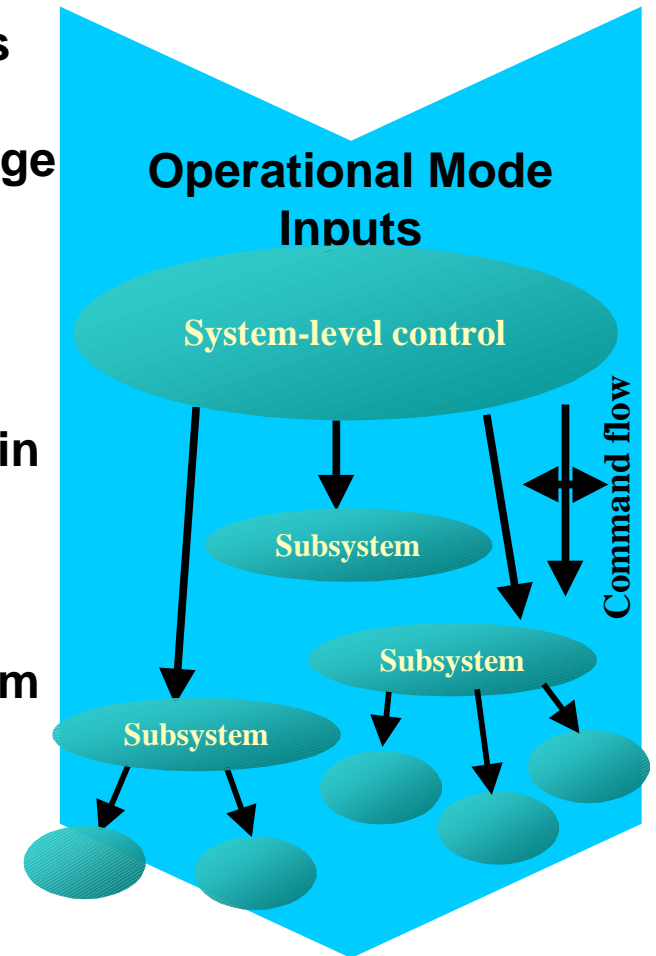
- **Fuels:** propane, butane, octane, JP-8, and diesel
- **Duration:** 700 hours to date
- **Thermal cycles:** 10
- **Sulfur tolerance:** 1000 ppm dibenzothiophene in JP-8
- **Yield:** 70-80% of LHV in JP-8



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Control System Functions

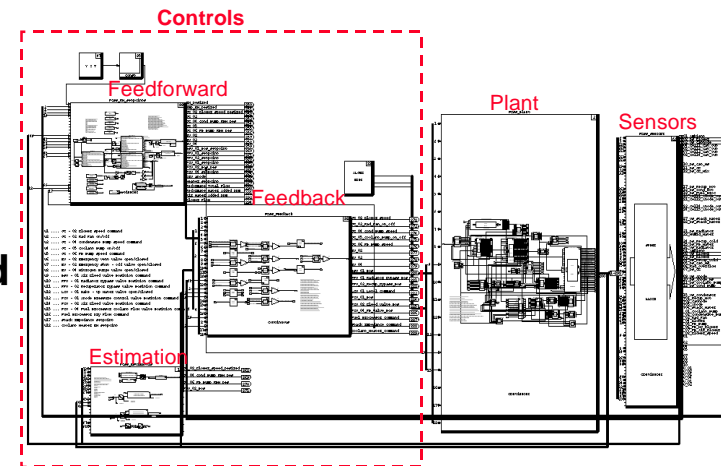
- **Control system functionality drives integration**
- **Coordinate subsystems for shared resources and efficient operation**
- **Efficiently regulate over a wide operating range**
 - ◆ Flow / Composition
 - ◆ Temperature
 - ◆ Pressure
 - ◆ Power
- **Provide safe system operation through built-in test**
- **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 be investigated through simulation trade studies and then the most promising approaches easily implemented in hardware system.

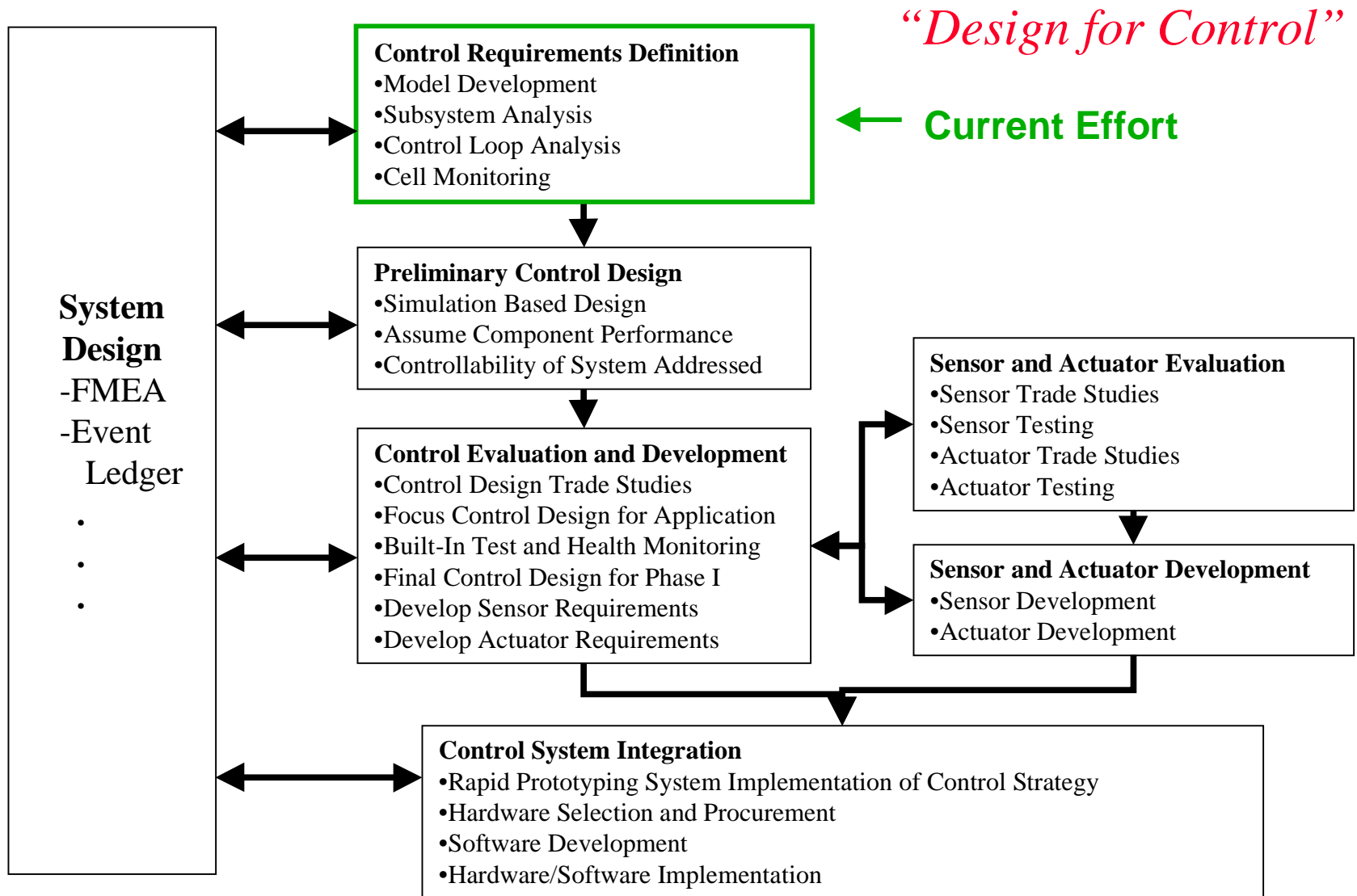


↓ Rapid Prototyping



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Controls Analysis and Design Process



Concluding Remarks

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