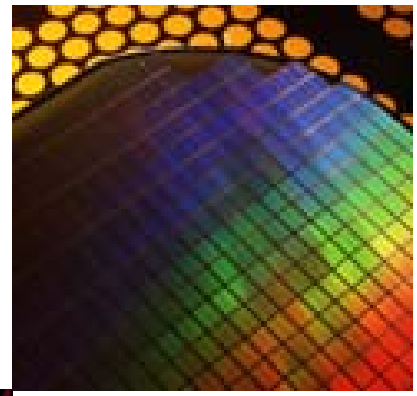
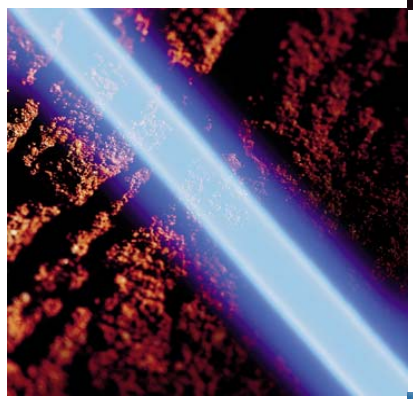
Low Cost Hydrogen Production Platform

Cooperative Agreement: DE-FC36-01GO11004





Timothy M. Aaron

Team

Praxair - Tonawanda, NY
Boothroyd-Dewhurst - Wakefield, RI
Diversified Manufacturing - Lockport, NY

DOE Hydrogen Annual Review Meeting
May 19 - 22, 2003

LCHPP - Program

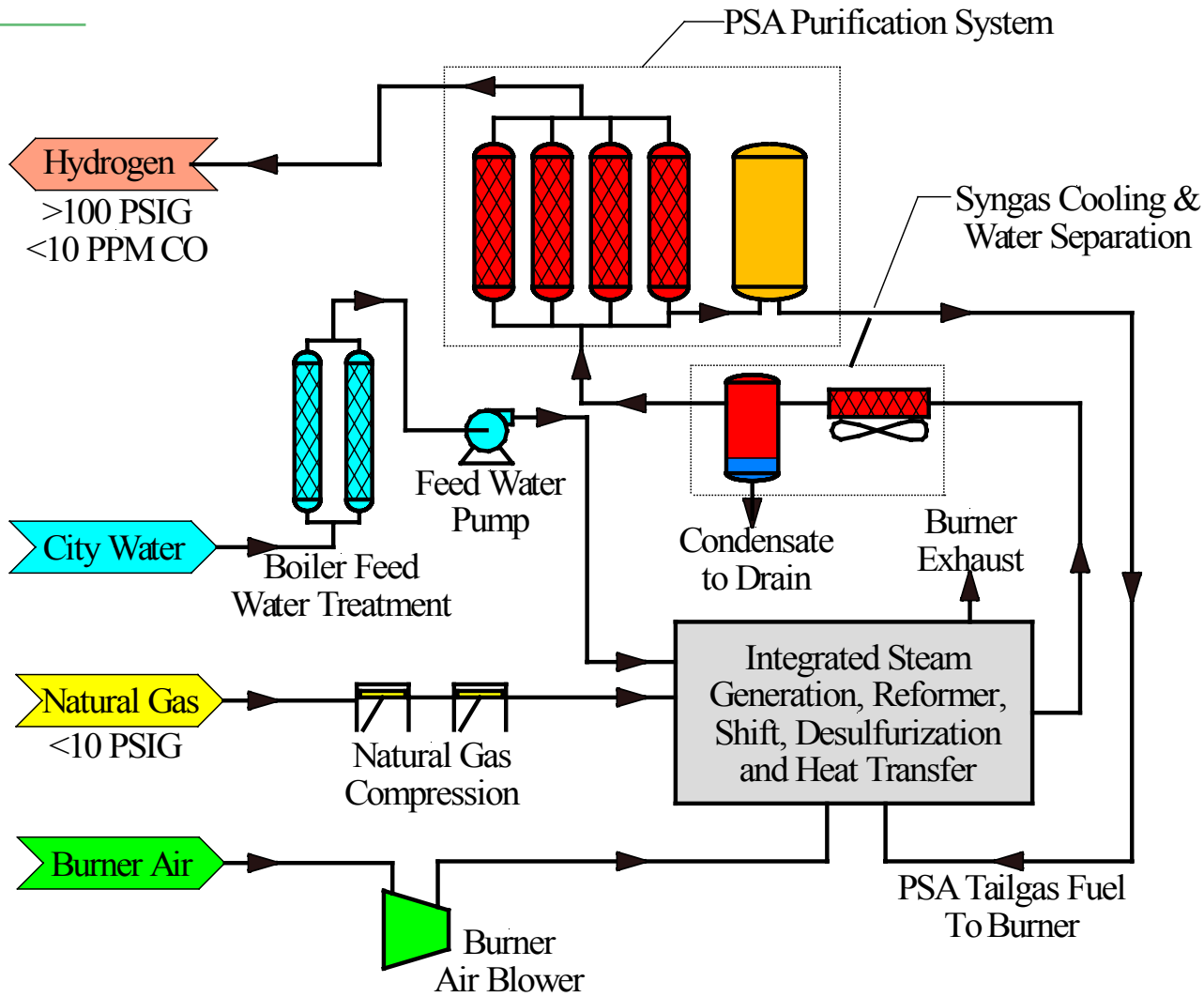
PRAXAIR

- **Goal**
  - Low Cost On-Site H_2 Production
    - Existing Technologies (SMR)
  - Transportation & Industrial (1,000 - 5,000 scfh)
    - Compression / Dispensing Not Included
    - Gas Station Capacity & Size
  - DOE Cost Target $8/MMBtu or $0.26/100 scfh H_2
    - Aggressive Target
    - 75-80% of Target Cost Required for Utilities

LCHPP - DOE Program Plan

- **Phase I** ***(Completed 04/03)***
  - Preliminary Design for Transportation / Industrial
  - Assess Economics Vs. Current Supply Options
  - Business Cases
- **Phase II** ***(06/03 - 12/04)***
  - Detail / Tooling Design
  - Modeling and Simulations
  - Subsystem Prototypes and Testing
  - Update Business Model
- **Phase III** ***(01/05-06/06)***
  - Fabricate Demonstration Unit
  - Verify Performance
  - Develop Tooling Required for Manufacturing

LCHPP - Skid Process Flow



LCHPP - Phase I Accomplishments

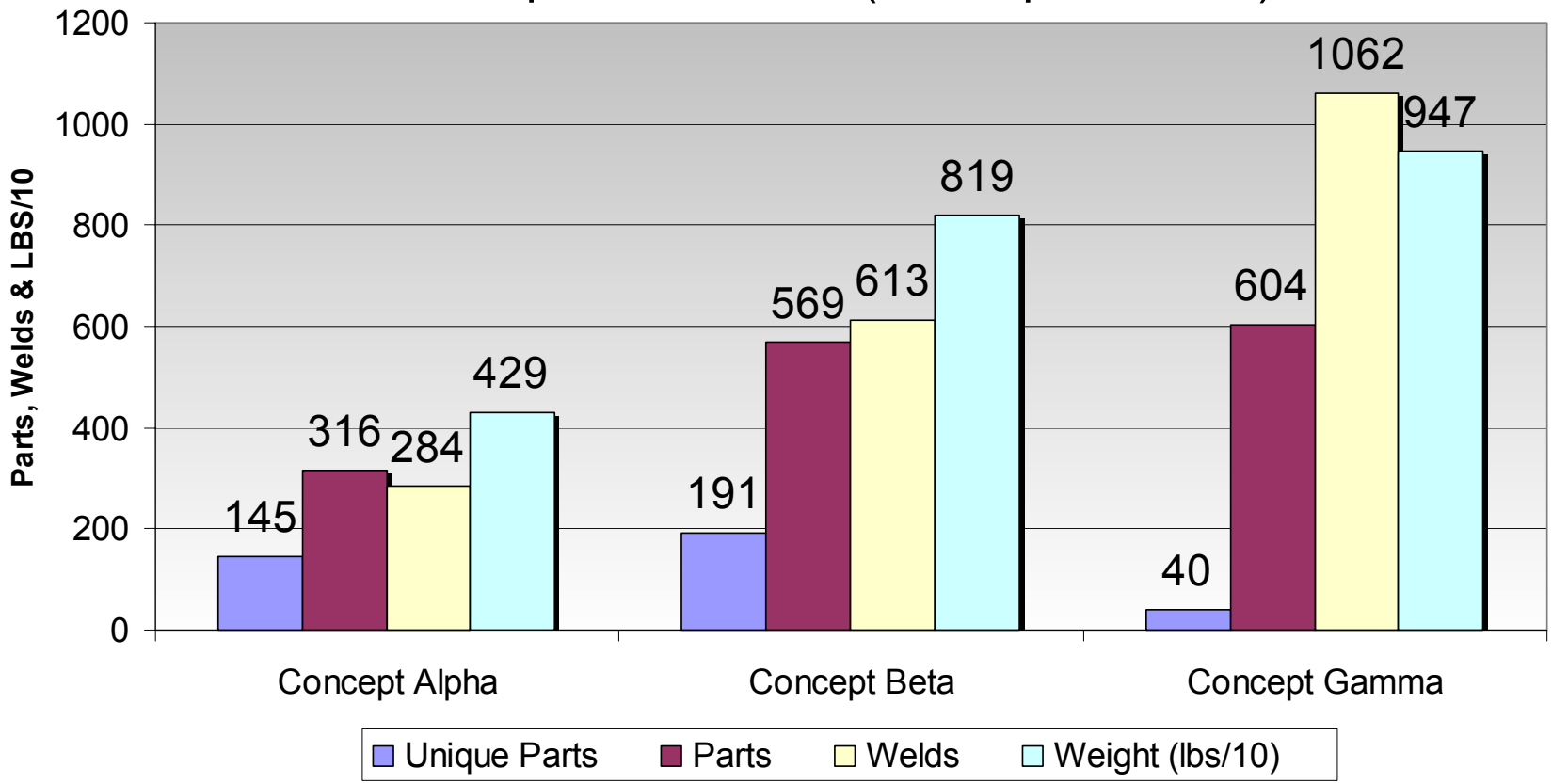
PRAXAIR

- **Sub-System Cost Breakdown**
  - Reformer / Shift / Steam Generation >50% of Capital
- **Reformer Alternatives Evaluation**
  - Reformer Pressure
    - Syngas / Natural Gas Compression
    - Materials of Construction
  - Thermal Integration
- **System Design**
  - 6 Concepts Initially Defined
  - 3 Highest Potential Concept Selected
  - Further Refinement 3D Models / Risk Analysis / DFMA
  - PSA Purification System
  - Auxiliary Systems
  - Skid Design
- **Economic Analysis**

LCHPP - Hot Component Options

PRAXAIR

- **Approaches**
  - Minimize Part Count (Concepts Alpha & Beta)
  - Minimize Unique Part Count (Concept Gamma)



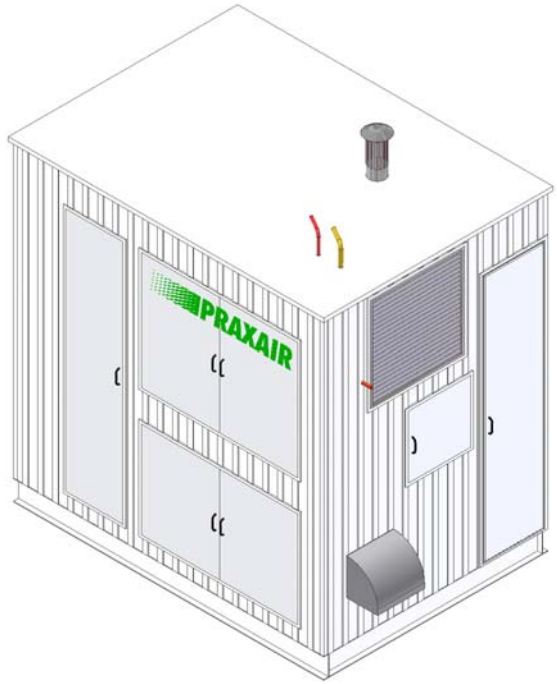
LCHPP - Hot Components DFMA Analysis

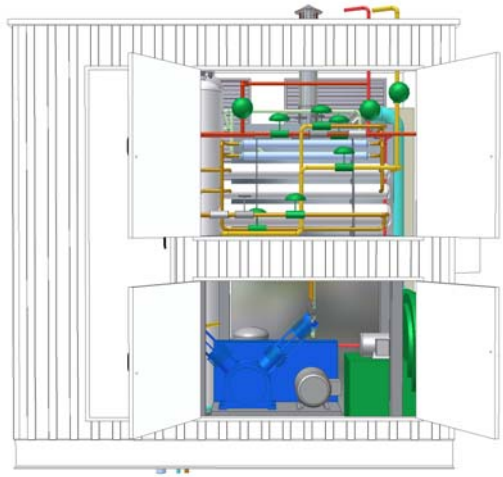
PRAXAIR

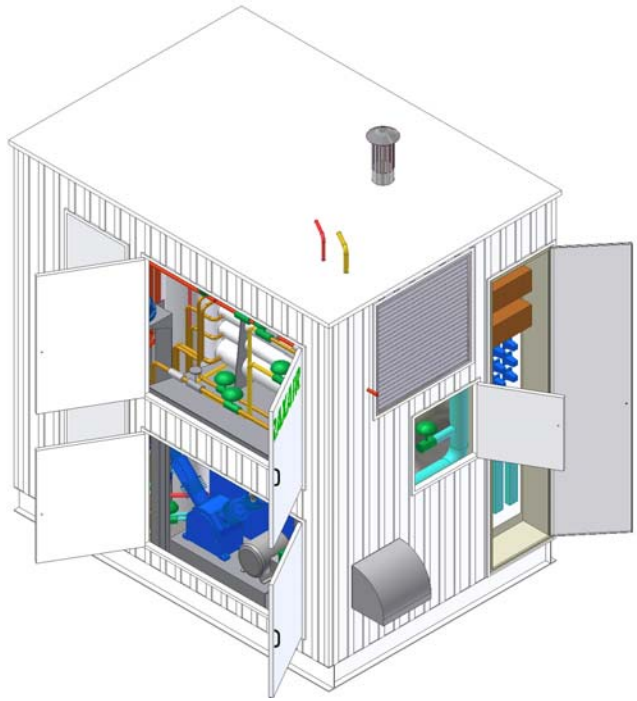
- **DFMA Summary**
  - Lower Part Count = Lower Cost
    - Integrated Concepts Chosen
  - Highest Integration = Lowest Cost Potential
    - Initial Cost Vs. Overall Cost
    - Phase II Testing
  - Material Costs Not Insignificant
    - Cost Reductions / Units Produced

LCHPP - Skid Assembly

- Safety
- Compact, Single Skid
- Easily Installed
- Welded Construction
- Highly Integrated





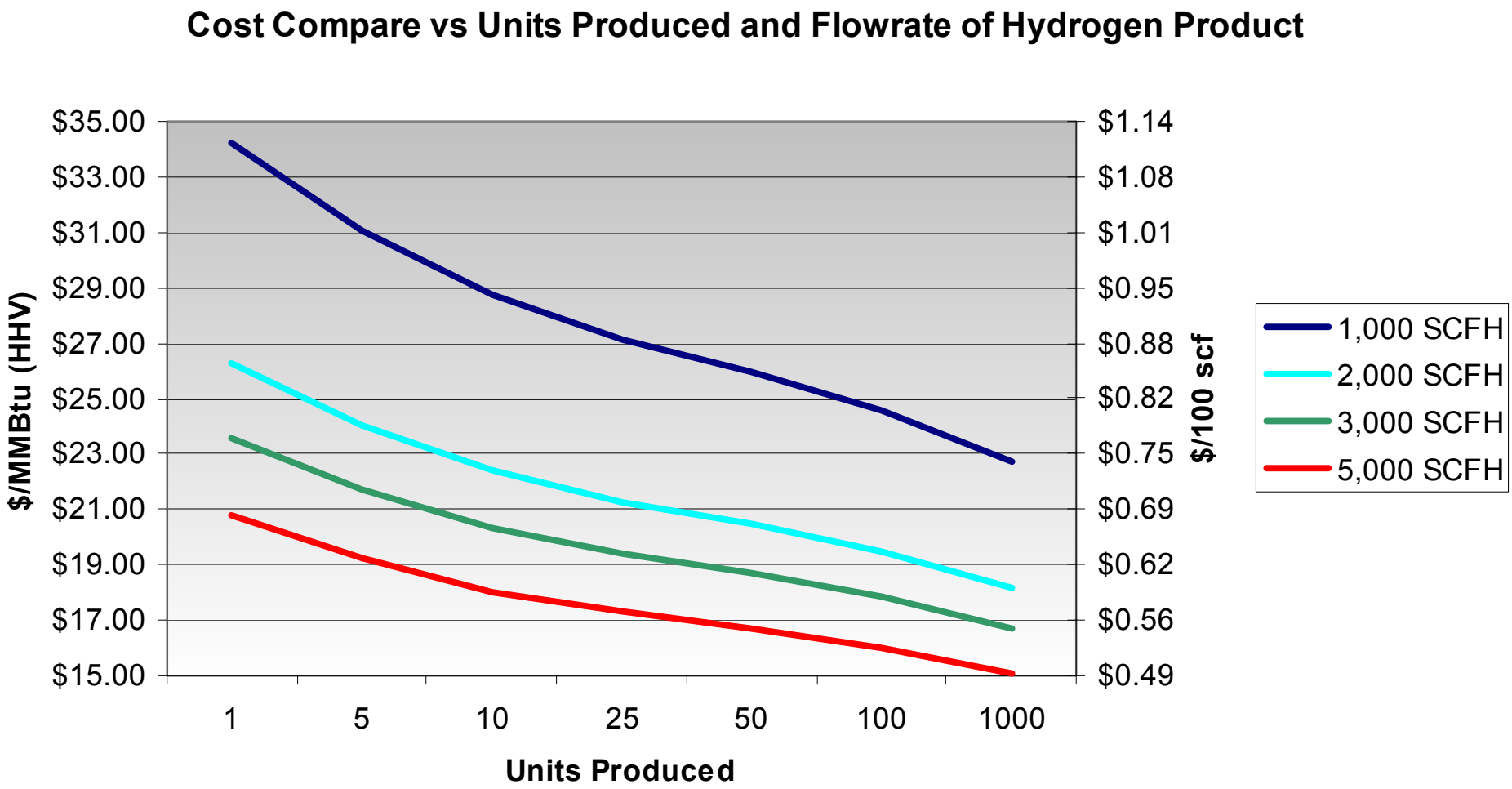


LCHPP - System Cost Summary

PRAXAIR

- **Cost Model Assumptions**
  - Power - $0.05 $/kWh
  - Natural Gas - $4.00 $/MMBtu, HHV
  - Water - $2.31 per 1,000 Gallon
  - Capital Recovery Factor - 15% Return, 15 Yr Life
  - On-Stream Factor - 80%
  - Contingency - 10%
  - M&R - 3% of Capital
  - Site Labor

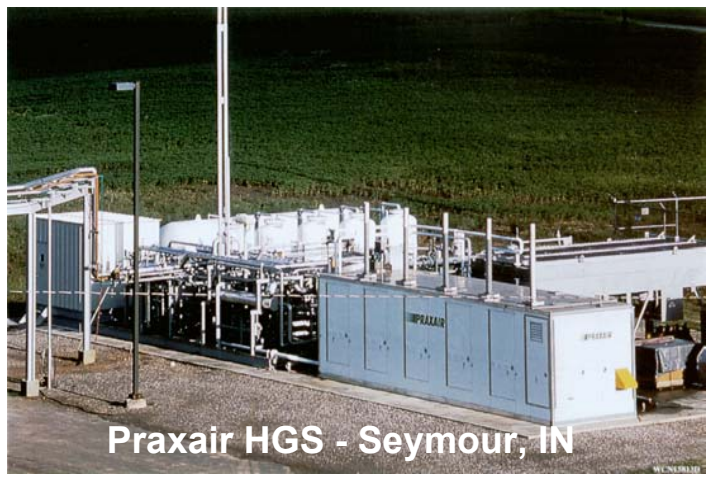
LCHPP - System Cost Summary



LCHPP Phase I Conclusions

PRAXAIR

- **Results / Learnings**
  - Potential for Cost Competitive System
  - System Design
  - Cost / Market Analysis
  - Risk Analysis
  - Economic Study
  - DFMA Analysis (Hot Components Only)
  - Praxair HGS Comparison
    - 1/4 Capacity
    - 1/6 Physical Plant Size
    - Lower H_2 Cost
  - Recommendations
    - Phase II Development



Phase II Objectives

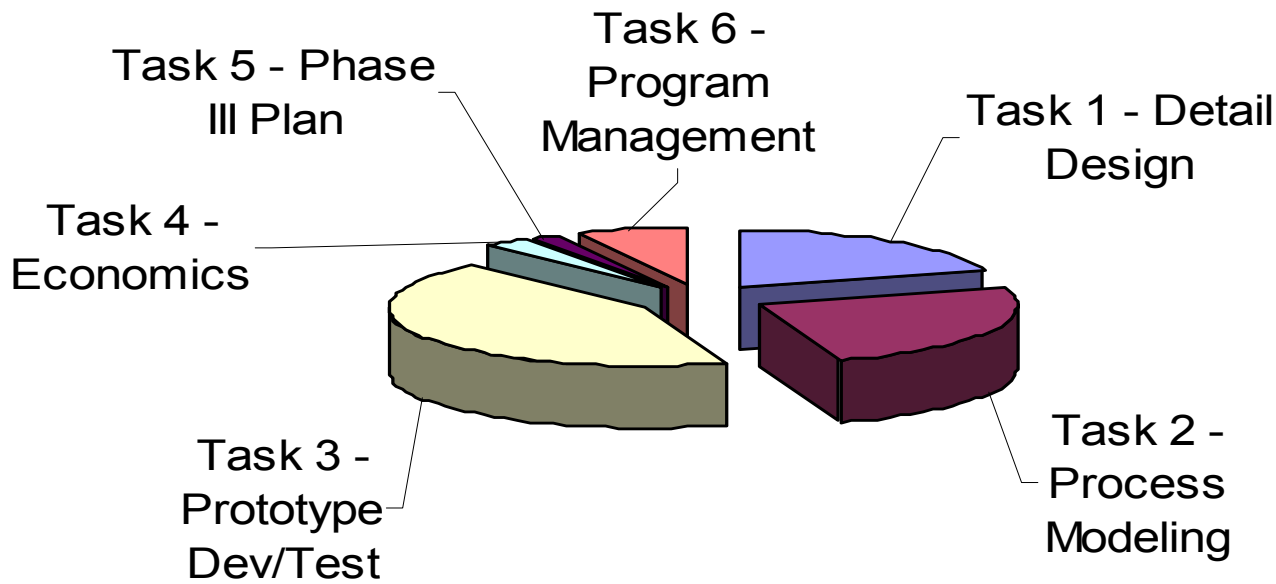
PRAXAIR

- **Detail Design**
- **Tooling Design**
- **DFMA Analysis - System & Components**
- **Prototype Development & Testing**
  - Computer Modeling
    - Heat Transfer
    - Fluid Dynamics
    - Reaction Kinetics
  - Mitigate Risks
- **Economics / Business Case**
- **Phase III Plan**

Phase II Program Tasks & Estimated Allocation

PRAXAIR

2002	2003	2004	2005	2006
	Phase I	Phase II	Phase III	



- Task 1 - Detail Design
- Task 2 - Process Modeling
- Task 3 - Prototype Dev/Test
- Task 4 - Economics
- Task 5 - Phase III Plan
- Task 6 - Program Management

Phase II Cooperative Efforts

- **Praxair**
  - Overall Lead
- **Boothroyd-Dewhurst**
  - System Optimization
  - Cost Reduction / Estimating
- **Diversified Manufacturing**
  - Manufacturing
  - Prototype Development
- **Computer Modeling**
  - Reformer / Shift Design
  - Burner Design
  - Heat Transfer
- **Catalyst Supplier**

Low Cost Hydrogen Production Platform

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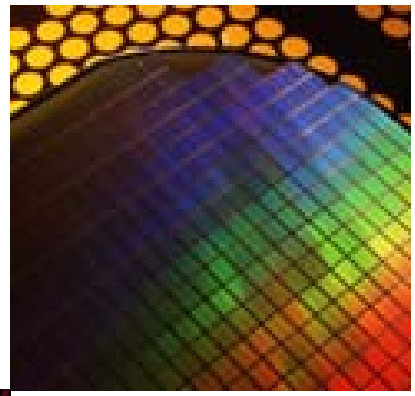

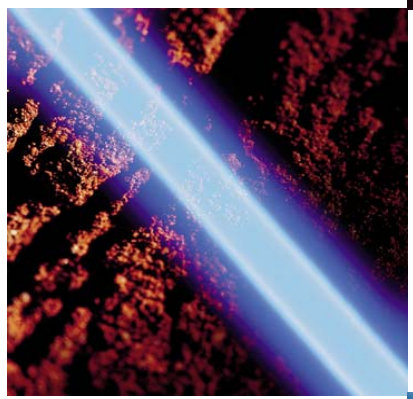

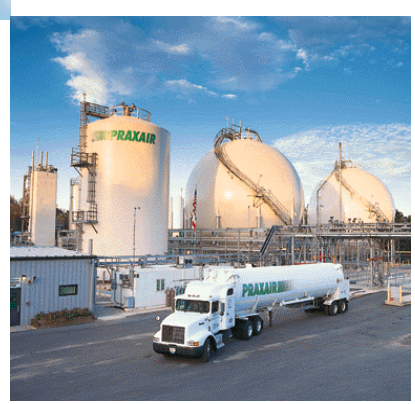

Questions?

Praxair Internal Review Meeting
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