SECA Core Technology Program

Army Fuel Cell Program (CECOM)

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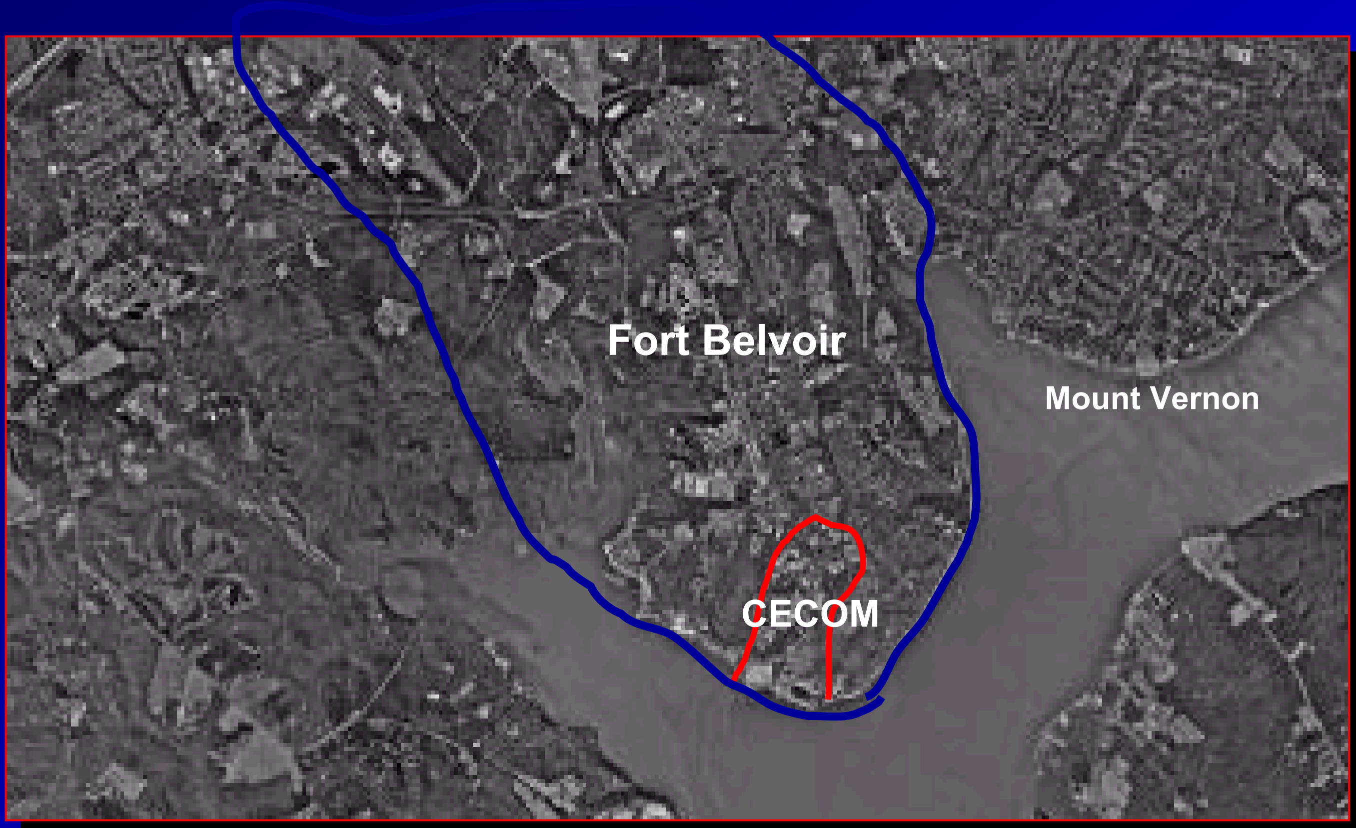
Presentation Outline

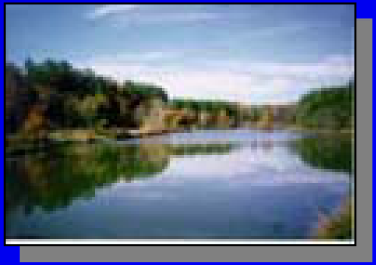
- Who we are
- Army Mobile Power Uses and Needs
- Unique Fuel
- Fuel Reforming
  - Portable Power (~<500 Watts)
  - APU/Generator

Organizational Chart

- Communications and Electronics Research, Development and Engineering Center
  - Army Power Division
    - Battery Branch
    - Environmental Control and Fuel Cell Branch
    - Power Generation Branch

CECOM, Fort Belvoir





Why Fuel Cells?

Fuel Cells Are Quiet,
Low Emissions, Efficient

Need for Power Sources That Exhibit High Power Density and High Energy Density

Fuel Cells Offer the Silence, Simplicity and Reliability of Batteries, with the Ability to Refuel Like an Engine

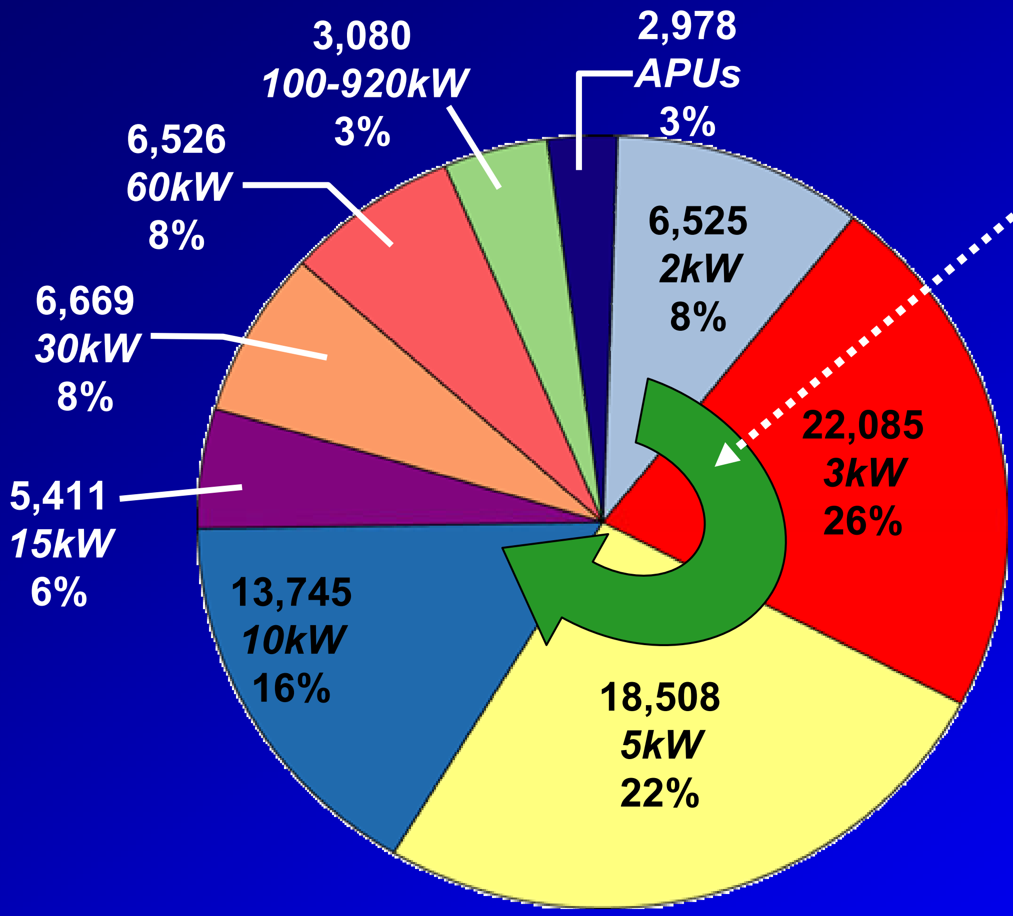
Fuel Efficiency

Army After Next – reduce fuel consumption by 50%.

"Fuel makes up as much as 70% of the volume and weight of the logistics re-supply burden. … and can cost up to $600 per gallon when delivered to a battlefield consumer."

A Power and Energy Strategy for the United States Army, Final Report (Draft), Logistics Integration Agency

DoD APU/Generator Inventory*



Target Size Range
- Represents 75% of Total

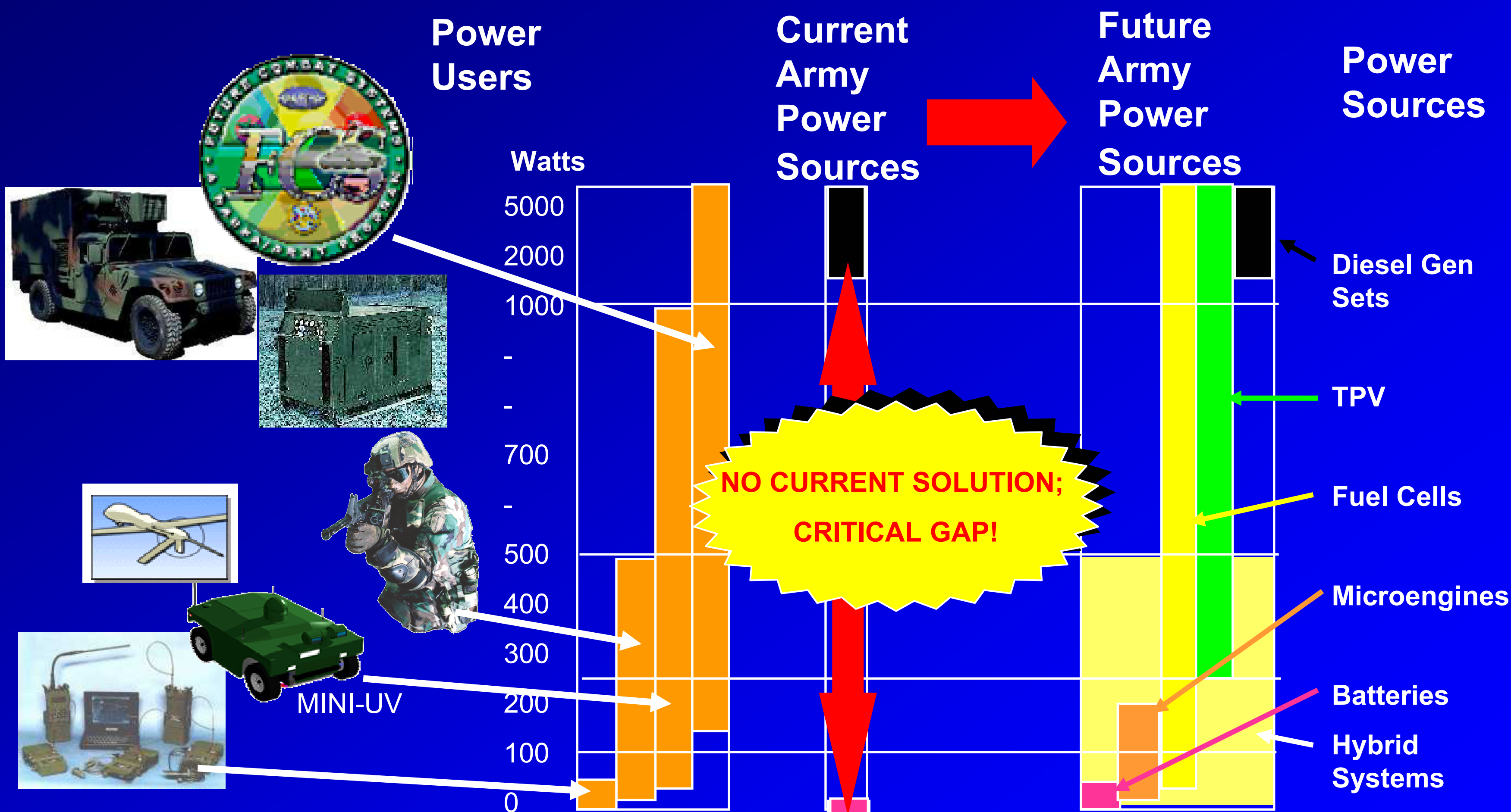
Total DOD Gen Sets and APU Requirements 85,527

Total DOD Value $1.4 B

Source: Program Manager – Mobile Electric Power (as of May 2001)

* Does not include Truck and Combat Vehicle Platform APUs.

Military Power Sources and Uses



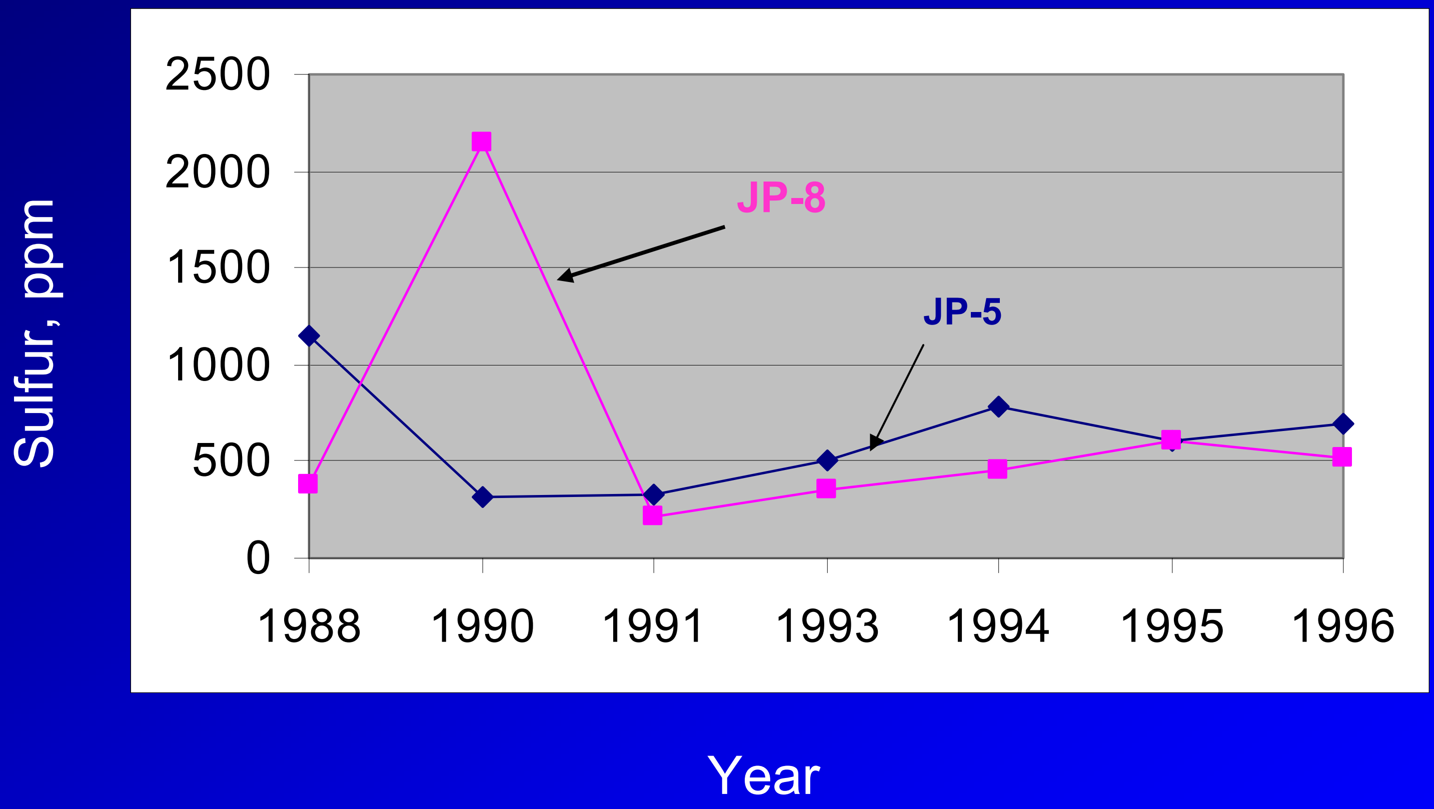
Pacing Technologies

Logistics Fuels

Fuel Property	U.S. 20 Fuels	U.S. ASTM D975 No. 2 Diesel	Fuel Oil, Diesel VV-F-800[3] (Standard)	JP-8, Turbine Fuel MIL-DTL-83133[4]	JP-5, Turbine Fuel MIL-PRF-5624S[5]
Cetane Number	44.9	40 (min.)	40 (min.)	Not Regulated	
Sulfur, wt%	0.027	0.05 (max.) 0.0015 (2006)	0.05 (max.)	0.30 (max.)	0.40 (max.)
Density, g/mL @ 15 ^{o}C	0.846			0.775-0.840	0.788-0.845
Flash Point, ^{o}C		52 (min.)	52 (min.)	38 (min.)	60 (min.)
Boiling Point, ^{o}C	174-344	160[2]-380[2]	160[2]-370	186-330	185-330
Aromatic, vol. %		35	35	25	25

1. Average values for 20 or more diesel fuels used in the winter (eastern U.S.) in 1994. Source: Chemistry of Diesel Fuels, Song, C., 2000.
2. Typical value(s). No actual value regulated.
3. Fuel Oil, Diesel, VV-F-800
4. Turbine Fuels, Aviation, Kerosene Types, NATO F-34 (JP-8) and NATO F-35, MIL-DTL-83133
5. Turbine Fuel, Aviation, Grades JP-4, JP-5, and JP-5/JP-8 ST, MIL-PRF-5624S

Turbine Fuel Sulfur Content



Hydrocarbon Fuel Reforming

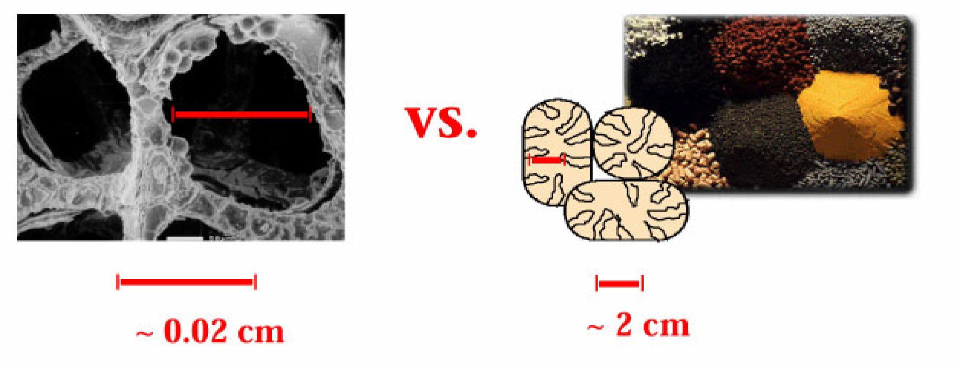
Hydrocarbon Fuel Reforming

- Funding two microchannel hydrocarbon reforming projects. Reformate stream to be used with a PEM fuel cell.

- Both projects are approximately twenty-four months into a four year development effort. All information is preliminary.
    1) Targeted at a man worn applications (~15W);
       Fuel = non-sulfur fuel
    2) Targeted at larger (~kW) applications;
       Fuel = Diesel/JP-8

Microchannel Fuel Processing

- Enhanced Heat Transfer
- Enhanced Mass Transfer
- High Surface Area to Volume Ratio
- Low pressure Drop Through Channels



Mass transport distance reduced by several orders of Magnitude. Thus reforming system size reduced by order of magnitude.

Man-Worn/ Portable Fuel Reformer

Battelle
. . . Putting Technology To Work

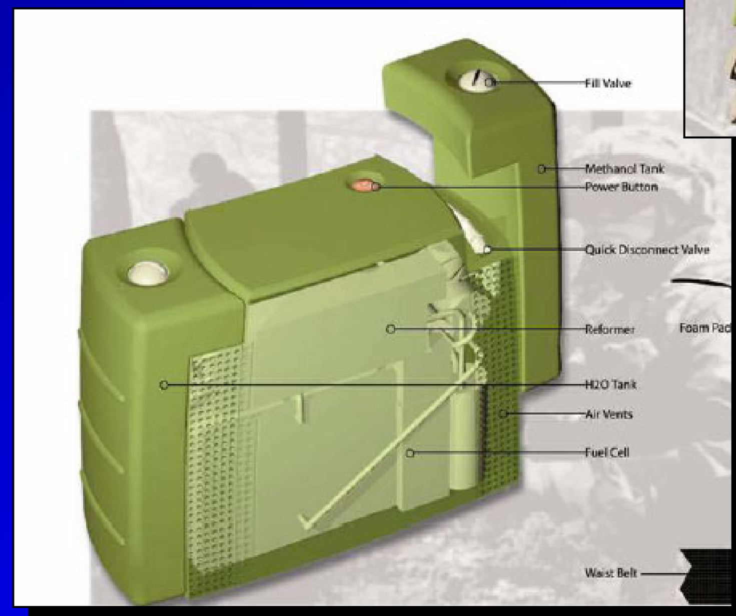
Microchannel Fuel Reformer

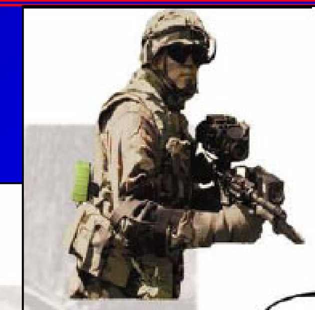
Battelle
. . . Putting Technology To Work

Design Goals:

- 15 We nominal; 30 We peak
- Weight < 1 kg (dry); Volume < 1 liter
- Fuel: Syn-Diesel, Methanol

Process: Steam Reforming

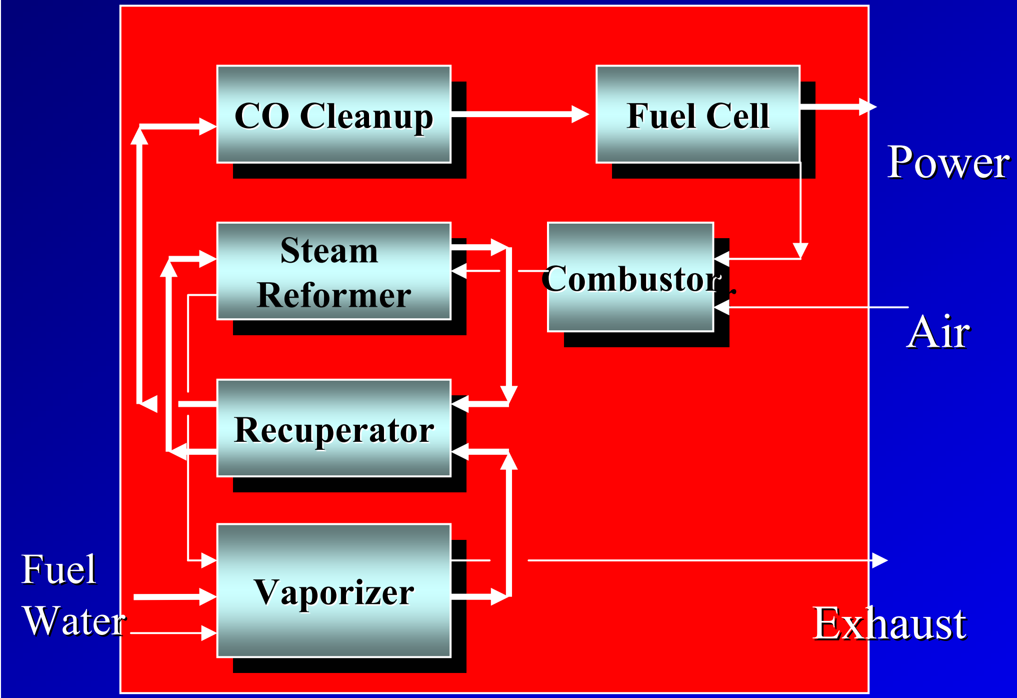


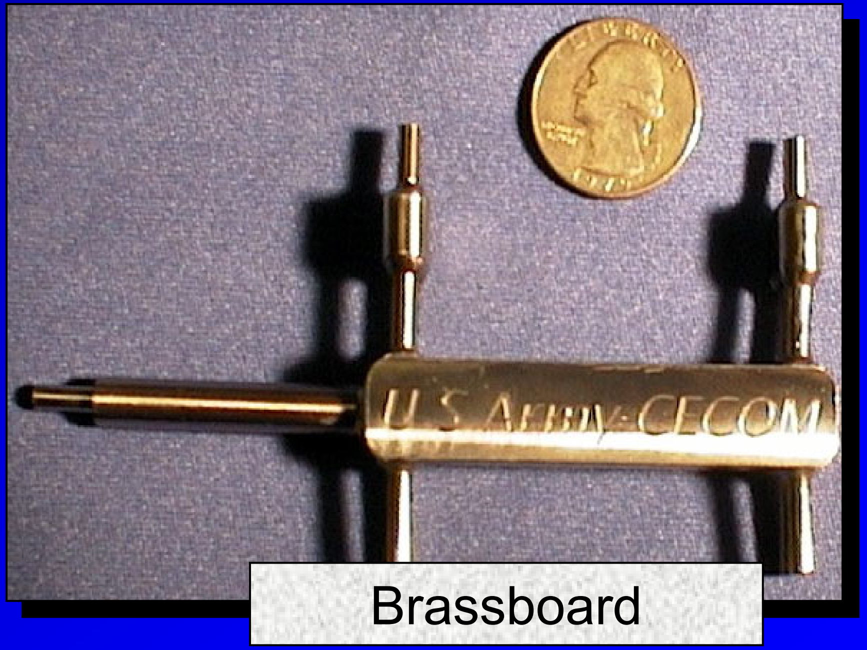


Status/Schedule:

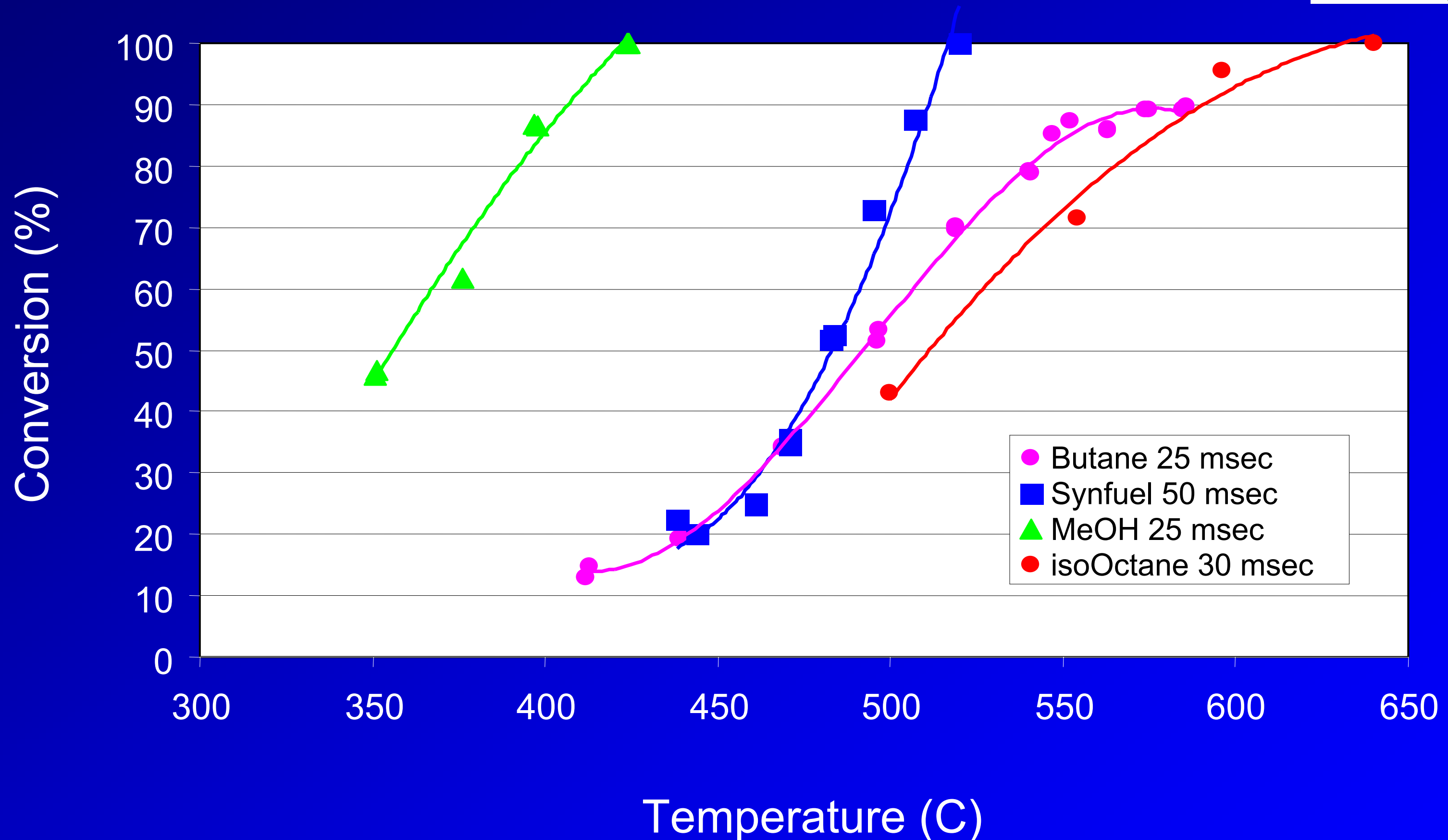
- Catalyst Testing Showed no loss of activity with non sulfur fuels (Butane, iso-octane, methanol, synthetic diesel)
- CO Clean Up – Underway
- Demonstration of Integrated Fuel Processor – Fall 2002

Process Flow Diagram





Multi-Fuel Catalysts Evaluation



GHSV = 72,000 Hr^{-1}

Preliminary Results

	Brassboard
Operating Conditions	
Pressure	1 atm
Temperature	350 °C
Contact time	140 ms
Steam/Carbon	1.8
Reformate Composition	
H_2	~75%
CO_2	~24%
CO	~0.8%
Fuel Processor Efficiency (LHV)	45%
Overall System Efficiency (LHV)	22%

Battelle
. . . Putting Technology To Work

Assumptions: Fuel Cell Operation @ 0.75 V/cell and H_2 utilization @ 80%

System Results

Fuel Cell System Results (14 day Mission):

• Fuel Cell System dry weight	1kg
• Fuel Water Volume	6.1L
• System Weight	6.1 kg
• Energy Density	720 W-hr/kg

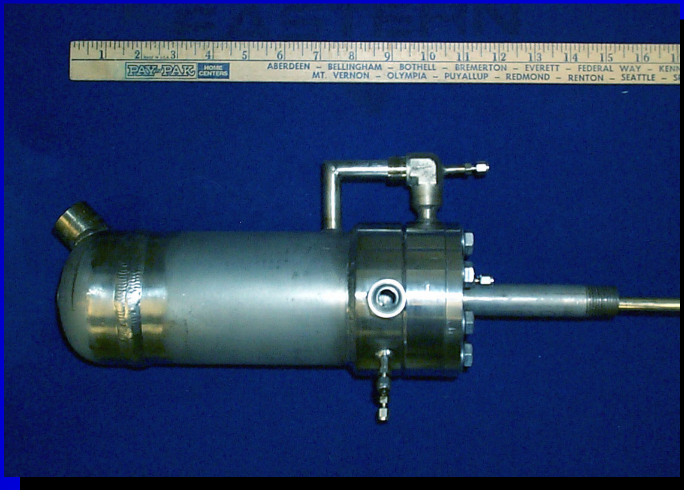
Multi-kW Logistics Fuel Reformer

INNOVATEK

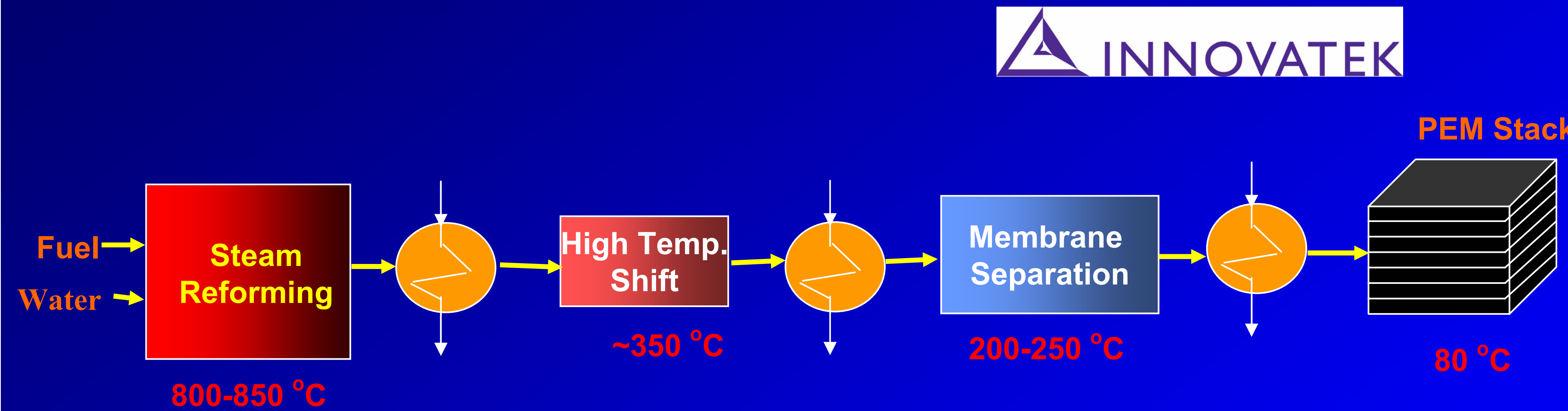
Diesel/JP-8 Microchannel Fuel Reforming

INNOVATEK

- Scope:
  Design, develop and test a multi-kW fuel cell reformer that will produce H_2 from diesel compatible with PEM fuel cell.
- Schedule:
  48 months (April 2000 – March 2004)
- Process: Steam Reforming
- Fuels: Diesel/JP-8



Process and Enabling Technologies



- S-Tolerant Reforming Catalyst
- S-Tolerant H-Separation Membrane
- Fuel Injector Micro-Nozzle to prevent Coking
- Micro-channel reactor & heat exchanger system design

Feed Stock For Steam Reforming

INNOVATEK

Test Series

Diesel

Retail Gasoline

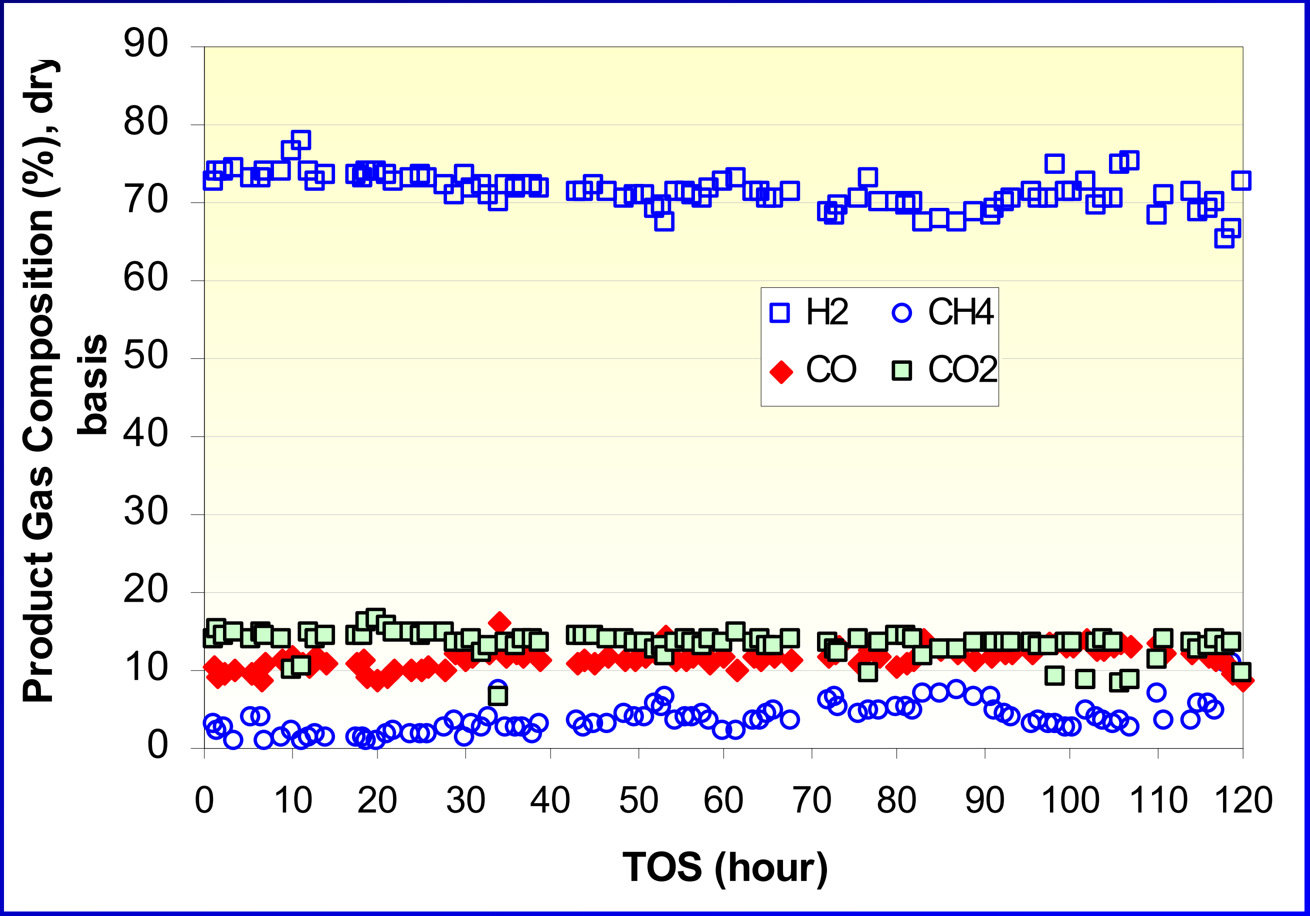
Iso-octane
Toluene
Dodecane + S

Iso-octane
Toluene
Dodecane

Iso-octane

High Sulfur Content Iso-Octane Testing

INNOVATEK



1000 ppm S

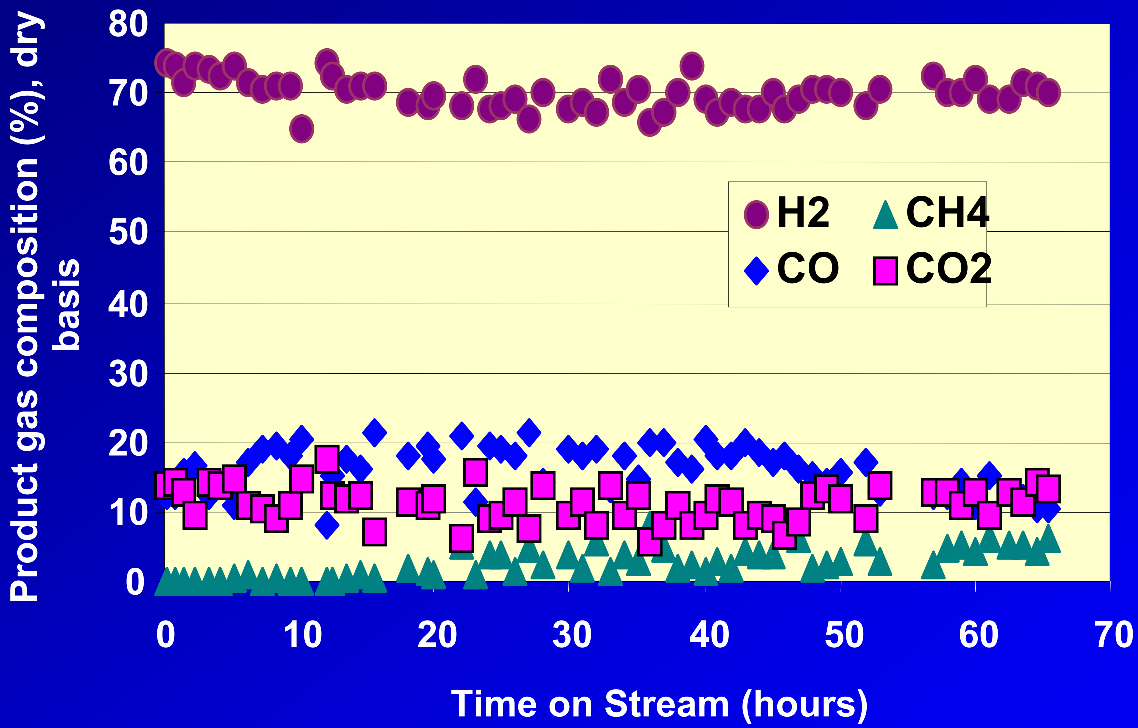
0.3 gram ITC-3

Steam/C = 4

800º C

Catalyst Evaluation

InnovaTek Proprietary Catalyst ITC-2



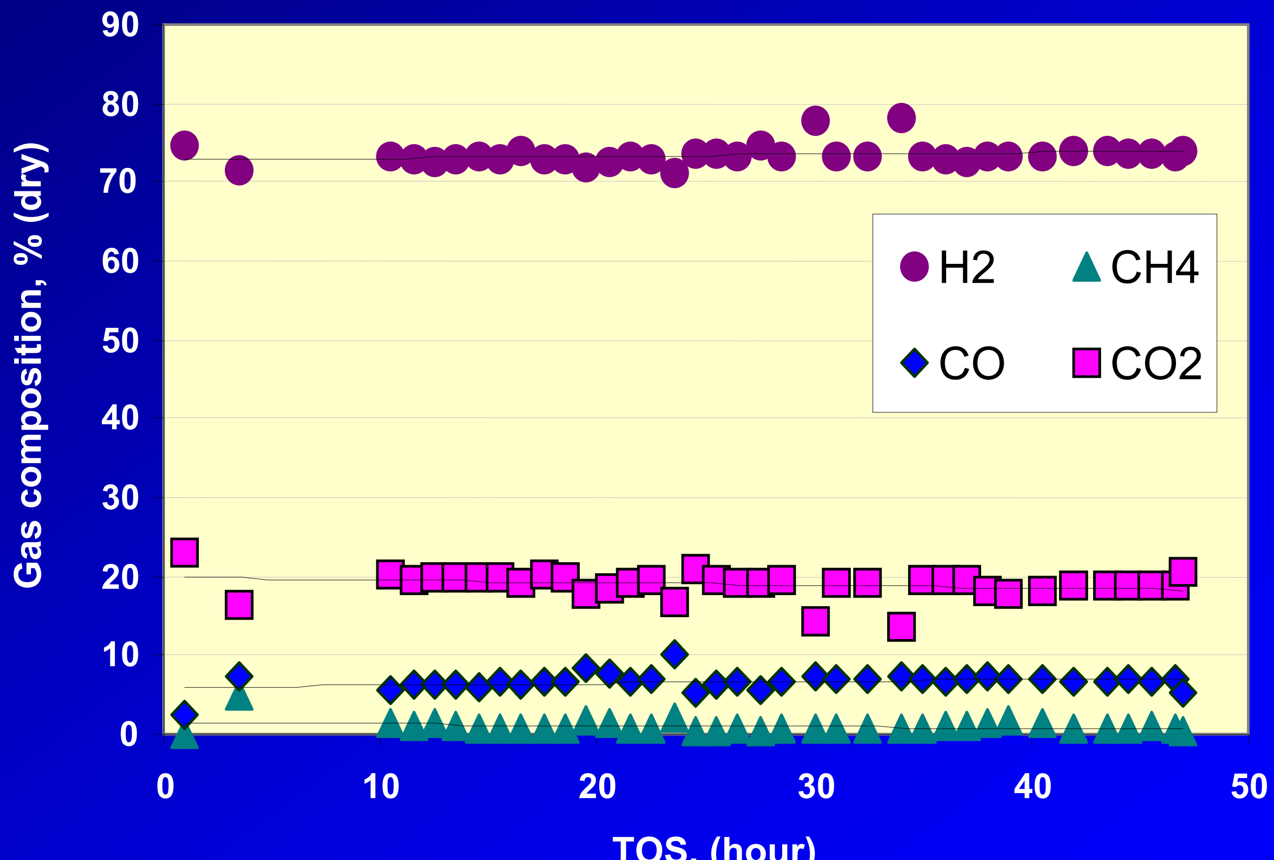
Catalyst Amount:
3.75g
LHSV: 27hr $^{-1}$
Feed: 0.3g min $^{-1}$
Temp: 800ºC
Steam/C: 4

Fuel Composition:
60% iso-octane
20% toluene
20% dodecane
476 ppm S

Preliminary Catalyst Evaluation

INNOVATEK

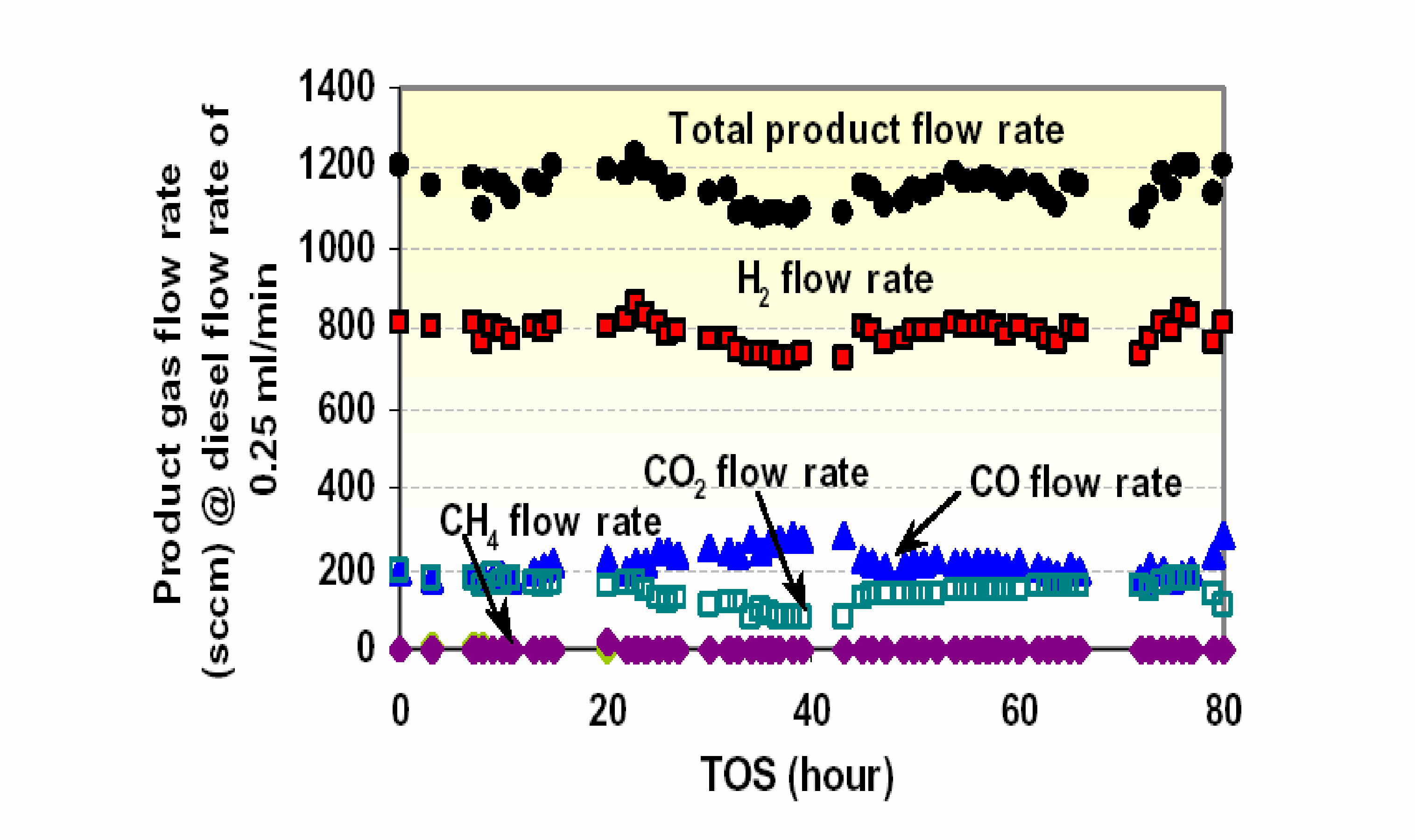
InnovaTek Proprietary Catalyst ITC-3



Temp: 800ºC
Catalyst Amt: 3 g
LHSV: 22 hr^{-1}
Fuel: Gasoline (commercial)

Low Sulfur Diesel Fuel Reforming

INNOVATEK



Status

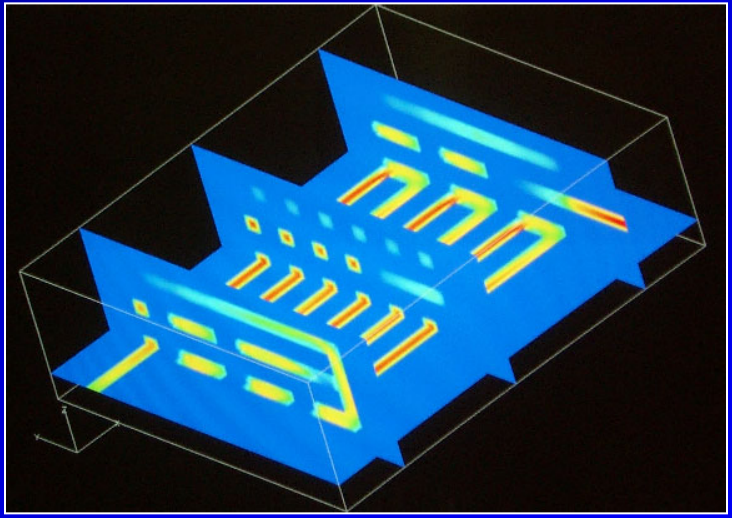
INNOVATEK

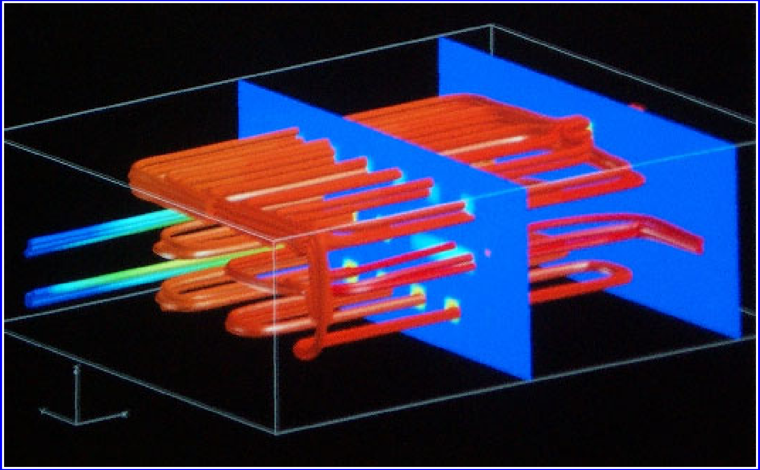
- Catalysts Testing
  - Identified and Tested 5 catalysts/support media combinations.
  - Focusing on Catalyst Loading Reduction
- Subcomponents
  - Membrane Separator
    - Initial results show lowered hydrogen flux when sulfur is present.
  - Diesel Fuel Injector
  - Heat Exchangers
- Demonstration of integrated fuel reformer scheduled for Fall of 2002.

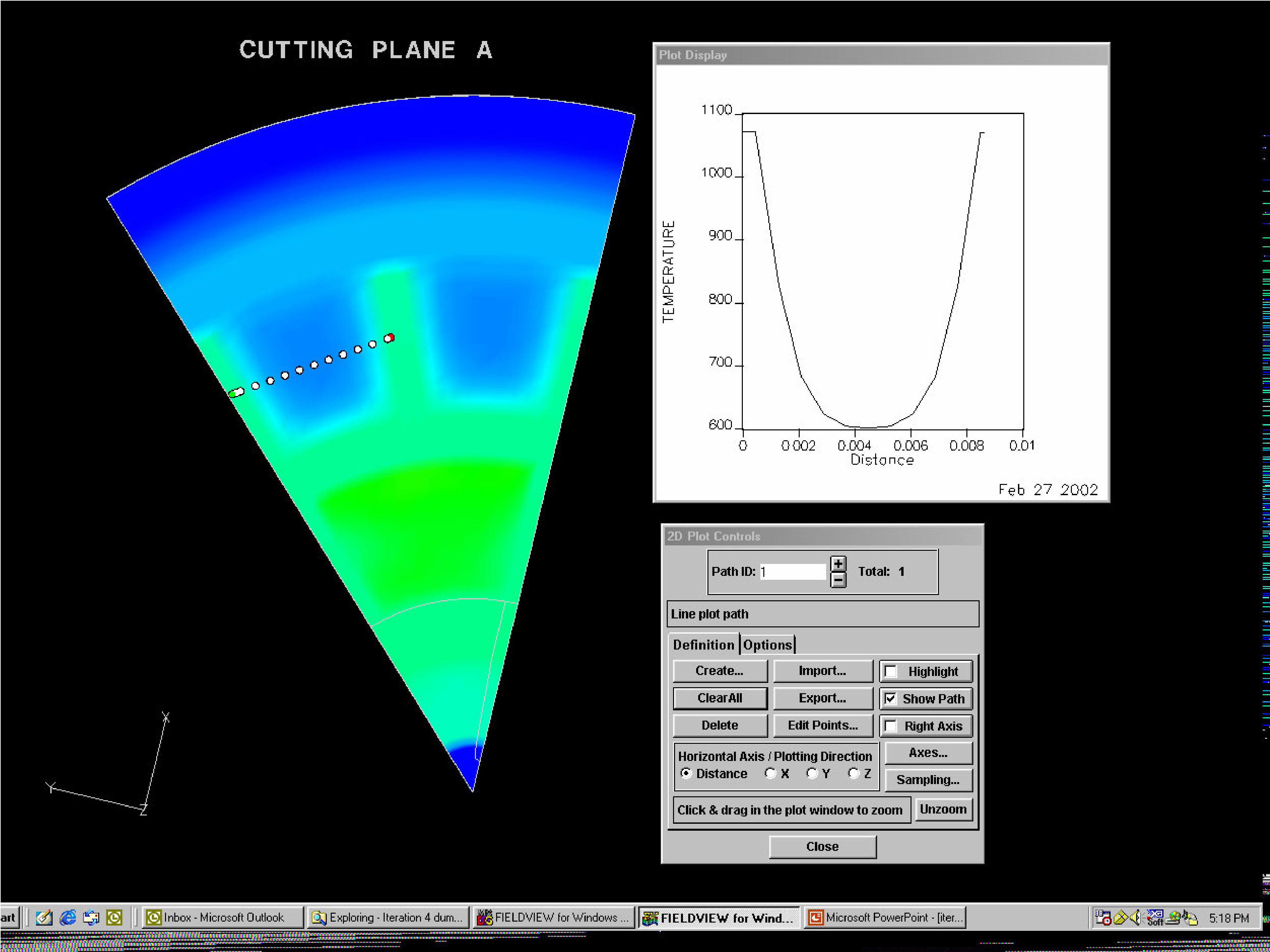
Computational Fluid Dynamics

CFD Analysis

- CFD analysis is being used to optimize reactor geometries.
- Current efforts are focused on heat transfer/fluids with broad assumptions used for combustion.
- Future efforts will include incorporation of combustion algorithms.



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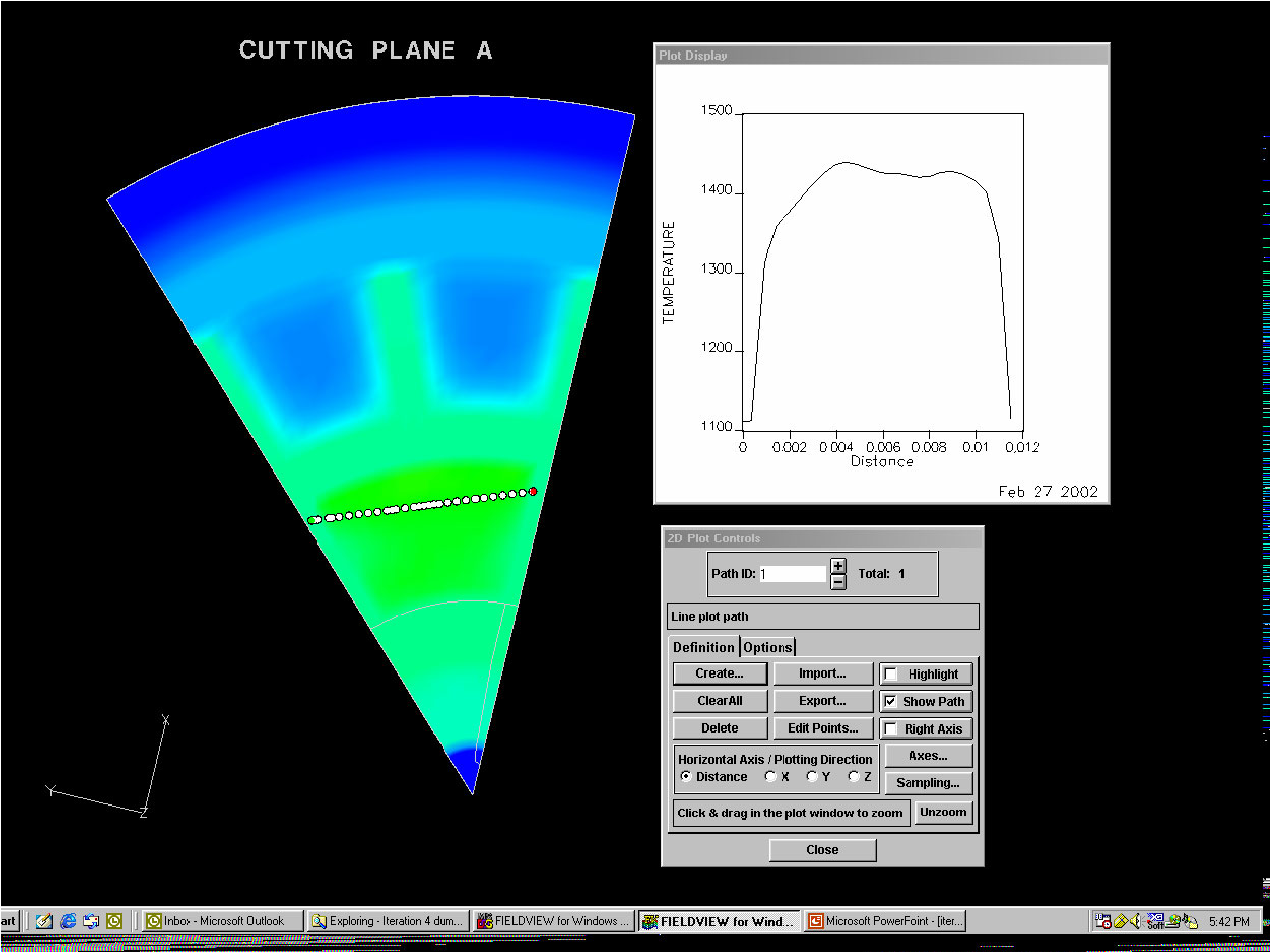

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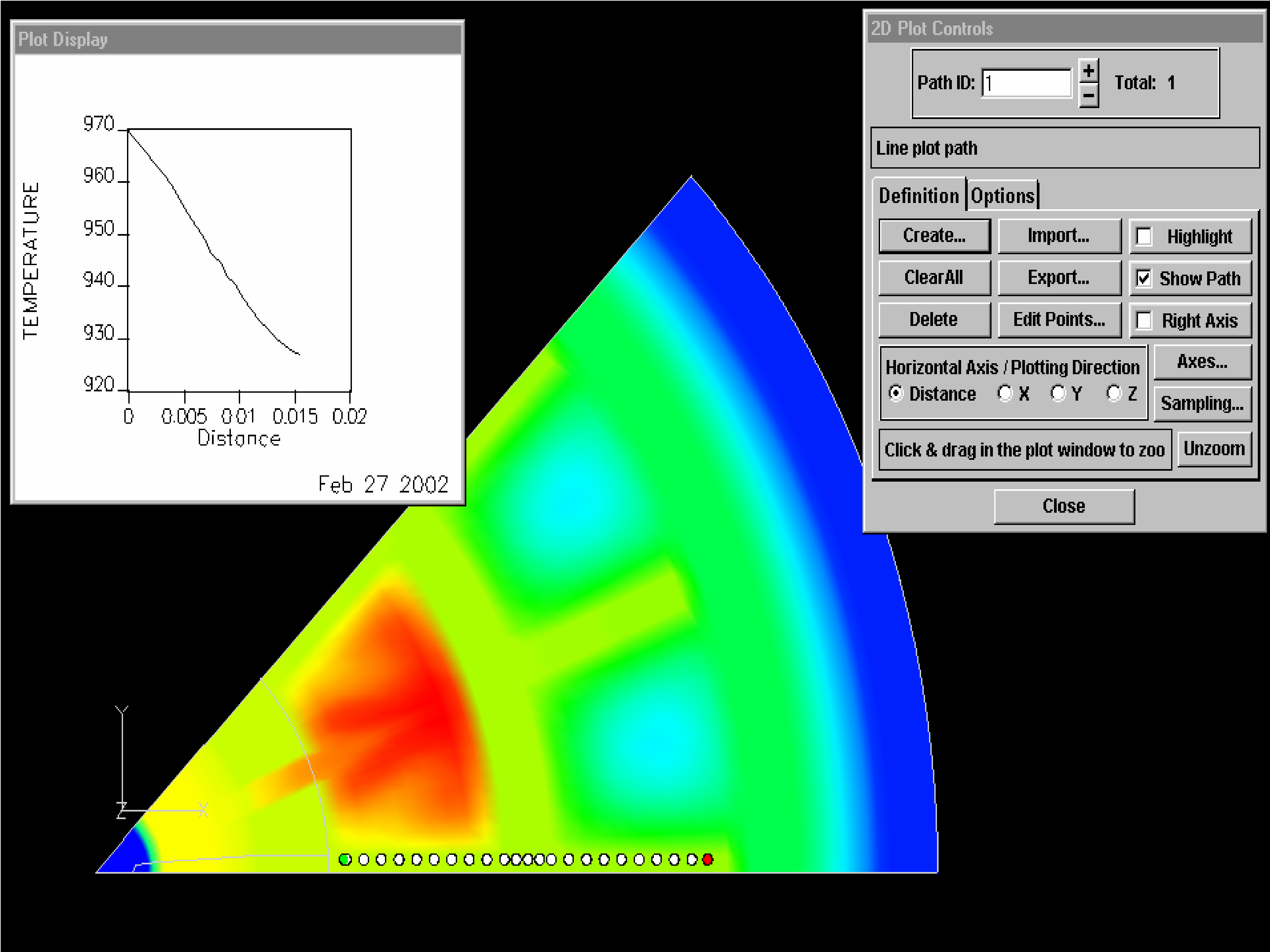

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Acknowledgements

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