Development of Sensors for Automotive PEM-based Fuel Cells

DOE Agreement DE-FC04-02AL67616

United Technologies Research Center

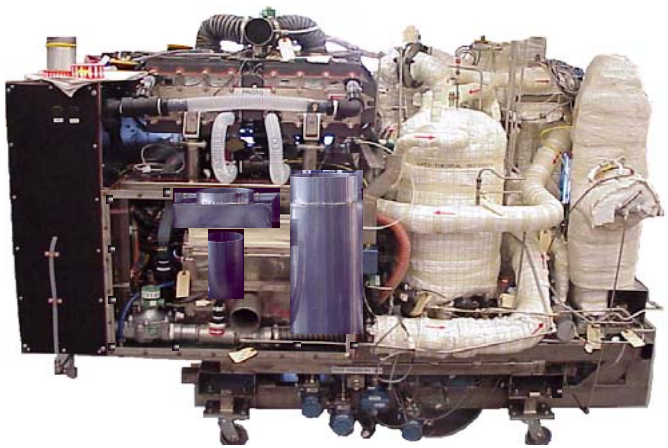
Brian Knight – UTRC

Nancy Garland - DOE

UTC Fuel Cells
A United Technologies Company

DOE Hydrogen and Fuel Cells 2003 Annual Merit Review

May 22, 2003

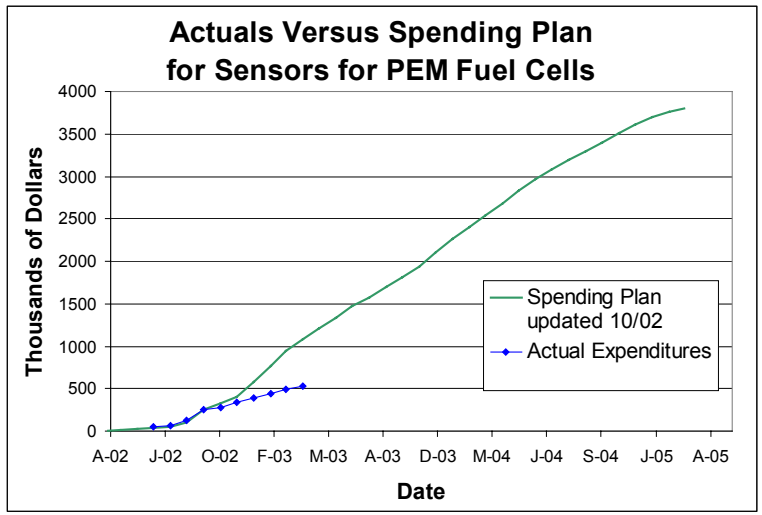


UTC FC Series 200 - 50 kW PEM

Development of Sensors for Automotive PEM-based Fuel Cells – Program Summary

- Project duration: 36 months (Apr 2002 – March 2005)

- Total cost: $3.7MM;
- DOE cost: $3.0MM (80%)
- UTC Cost Share: $0.7MM (20%)
- Total expended to date: $0.51MM



- Project Team
  - UTC Fuel Cells
  - UTRC
  - ATMI
  - Illinois Institute of Technology (IIT)
  - NexTech Materials

- Project Director: Tom Clark UTC FC

Sensors for Automotive PEM-based Fuel Cells Project

Team organization

UTC Fuel Cells
A United Technologies Company

United Technologies
Research Center

DOE program manager and technical advisor:

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Contractor and subcontractor PIs:

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Scott Swartz	NexTech	614-842-6606 x103	swartz@nextechmaterials.com

ATMI

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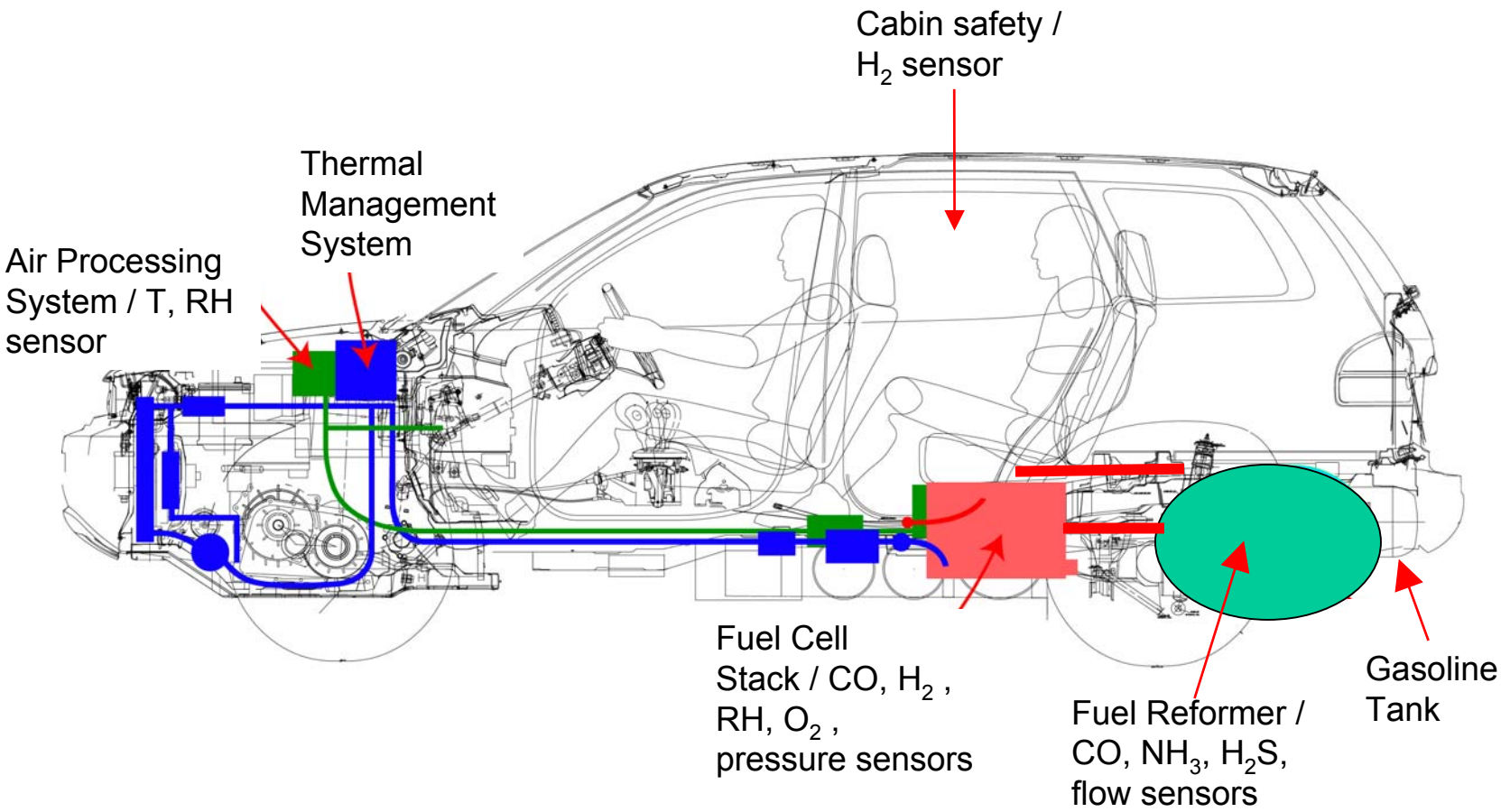
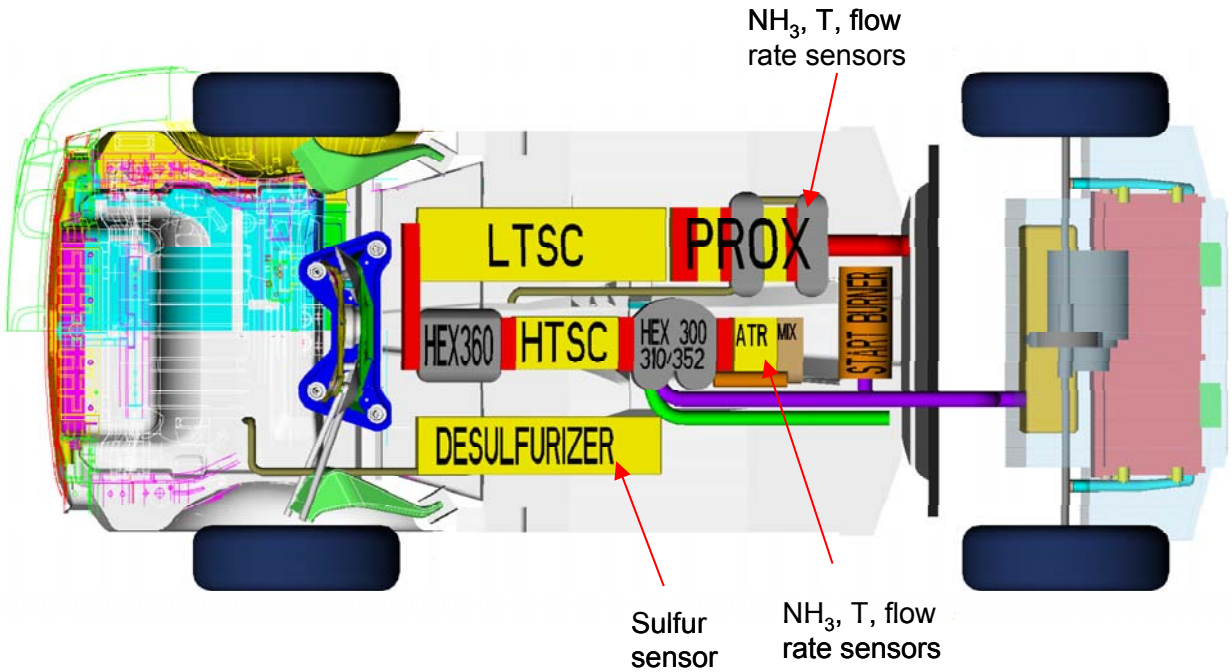
NEXTECH MATERIALS

Sensors for Automotive PEM Fuel Cells - Motivation

Sensor Performance and Cost Improvements Needed



Gasoline Fuel Reformer – Sensor Needs



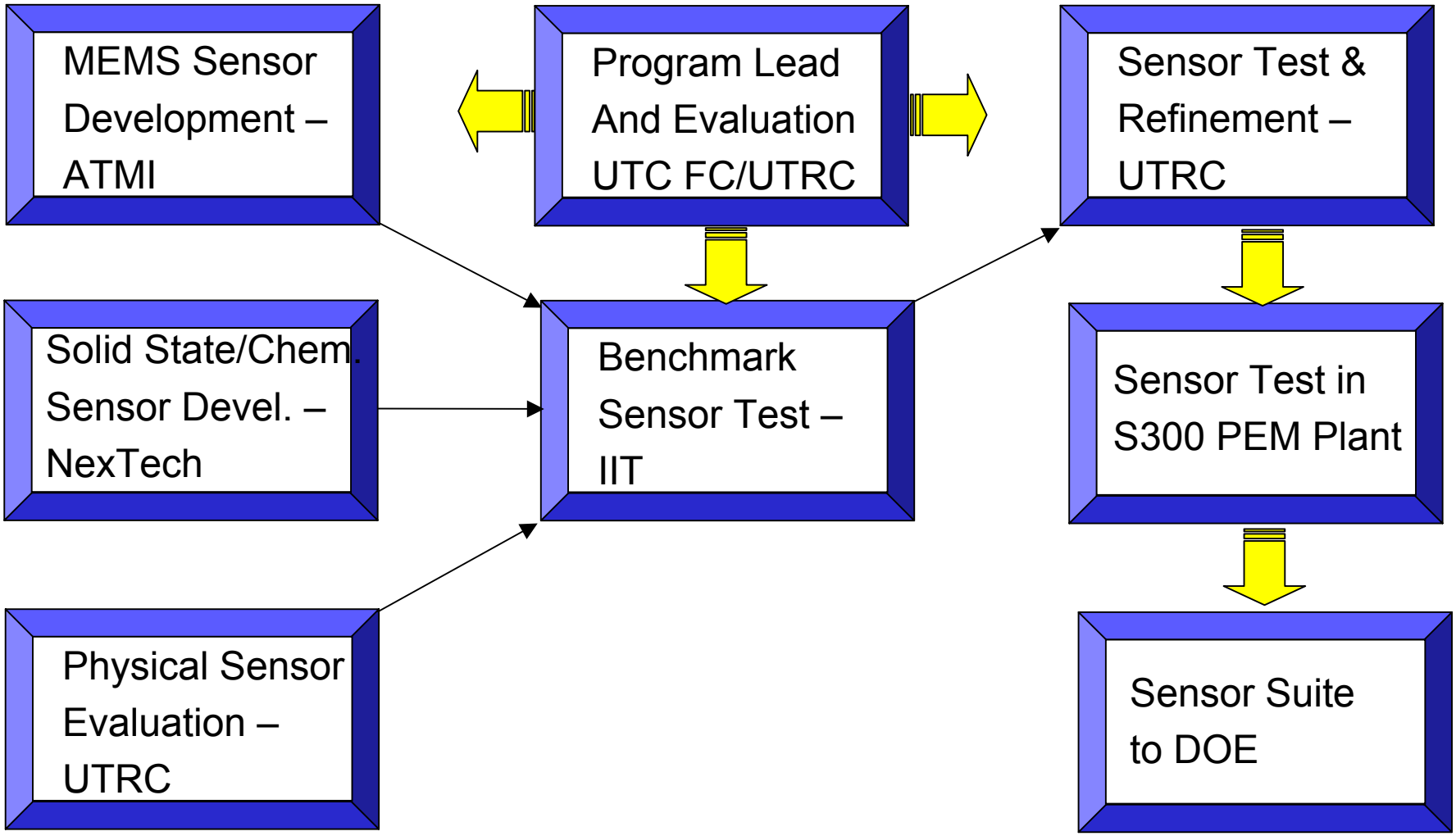
- Chemical sensors
  - –Process streams: before, in, and after reformer, before and in fuel cell stack: CO, H_2, O_2, H_2S, NH_3.
  - –Safety [H_2].
  - –Response times compatible with function being monitored.

Sensor Program Deliverables - Task 1 Milestone 22

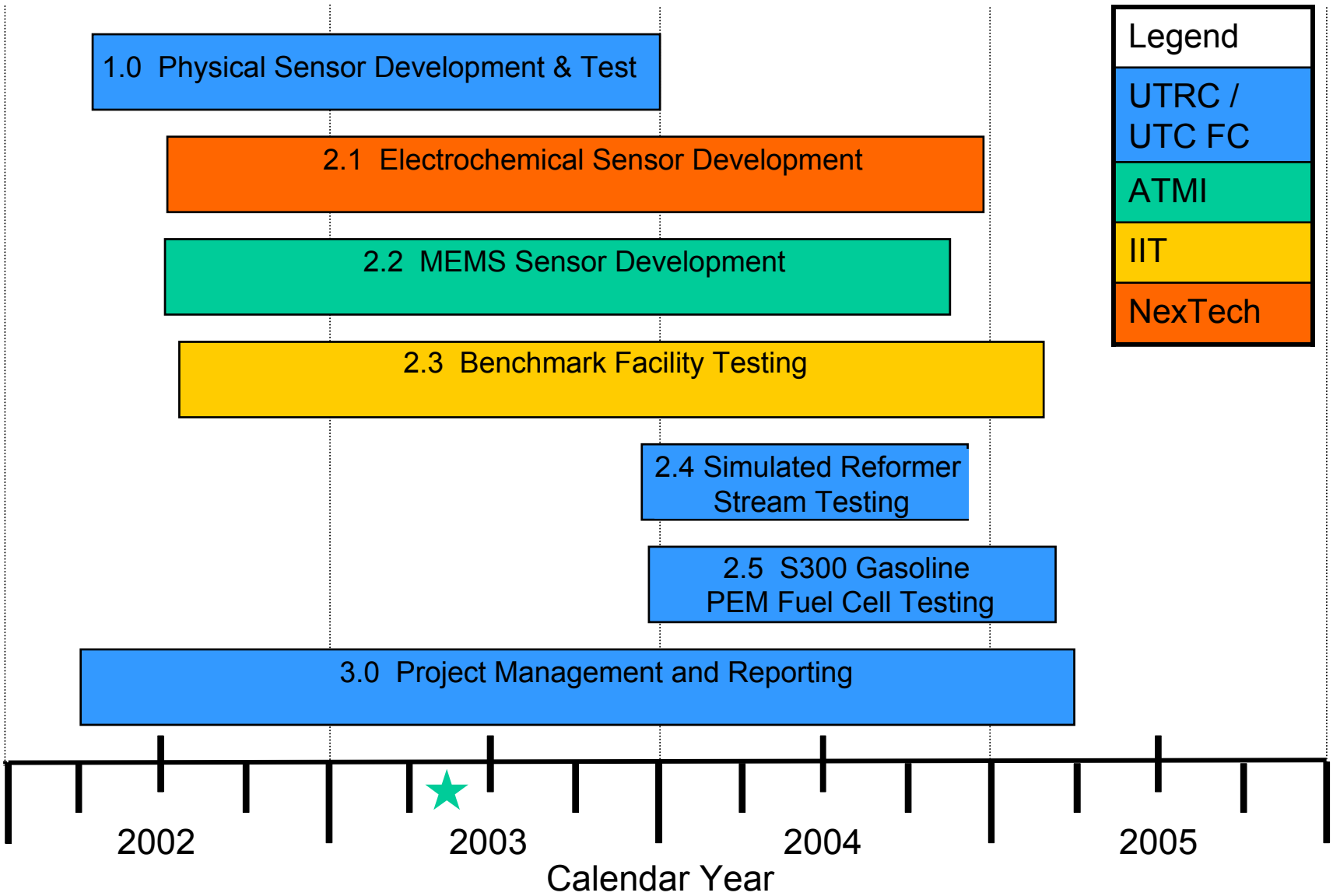
- Automotive PEM Fuel Cell Sensors Suite
  - Develop suite of sensors for CO, H_2, O_2, H_2S, NH_3, flow, temperature, pressure, and relative humidity
  - Meet performance requirements
  - Develop new measurement principles to meet sensitivity requirements
  - Improve reliability in harsh fuel cell system environments
  - Path to low cost (<$10 / sensor) at 500k qty
  - Develop test rig for sensor evaluation
- Program Reporting
  - Quarterly progress reviews
  - Annual and Final technical reports

Sensor Program Team Responsibilities

Team Member	T	ΔP	RH	flow	O_2	CO	H_2	SO_2	H_2S	NH_3	Technological Expertise / Responsibility
UTC FC	X	X	X	X	X	X	X	X	X	X	Testing on S300 Breadboard
UTRC	X	X	X	X	X	X	X	X	X	X	Testing in reformate simulator
ATMI							X	X	X	X	Develop Using MEMS Silicon Microhotplate
IIT	X		X		X	X	X	X	X	X	Testing in Benchmark Facility
NexTech						X		X	X	X	Develop Using Solid State Electrochemical


MEMS Sensor Development – ATMI
Program Lead And Evaluation UTC FC/UTRC
Sensor Test & Refinement – UTRC
Solid State/Chem. Sensor Devel. – NexTech
Benchmark Sensor Test – IIT
Sensor Test in S300 PEM Plant
Physical Sensor Evaluation – UTRC
Sensor Suite to DOE

Sensors for Fuel Cells Program Plan



Milestones and Deliverables

	Target Date
•Physical Sensors – UTRC	
—Develop physical and chemical sensor test facility	04/15/03
—Physical sensors survey and down-select	06/30/03
—Physical sensor test in simulated reformate stream	11/14/03
—Physical sensor performance review	11/24/03
•MEMS Sensor Development – ATMI	
—Deliver α prototype H2 sensor to IIT	04/14/03
—Deliver β prototype H2 sensor to UTRC	12/10/03
—Sensor performance review #1	02/04/04
—Deliver α prototype Sulfur sensor to IIT	08/25/03
—Deliver β prototype Sulfur sensor to UTRC	04/21/04
—Sensor performance review #2	06/17/04
—Deliver α prototype NH3 sensor to IIT	12/19/03
—Deliver β prototype NH3 sensor to UTRC	08/18/04
—Prototype delivery to UTC FC	10/21/04

Milestones and Deliverables

•Electrochemical Sensor Development – NexTech	Target Date
—Deliver α prototype CO, NH3, S-compound sensors to IIT	07/07/03*
—Sensor response optimization	09/30/03
—Sensor performance review #1	10/03/03
—Deliver β prototype CO, NH3, S-compound sensors to IIT	04/30/04
—Sensor performance review #2	06/25/04
—Deliver final prototypes to UTC FC	12/15/04

* Dependent upon budget release from DOE

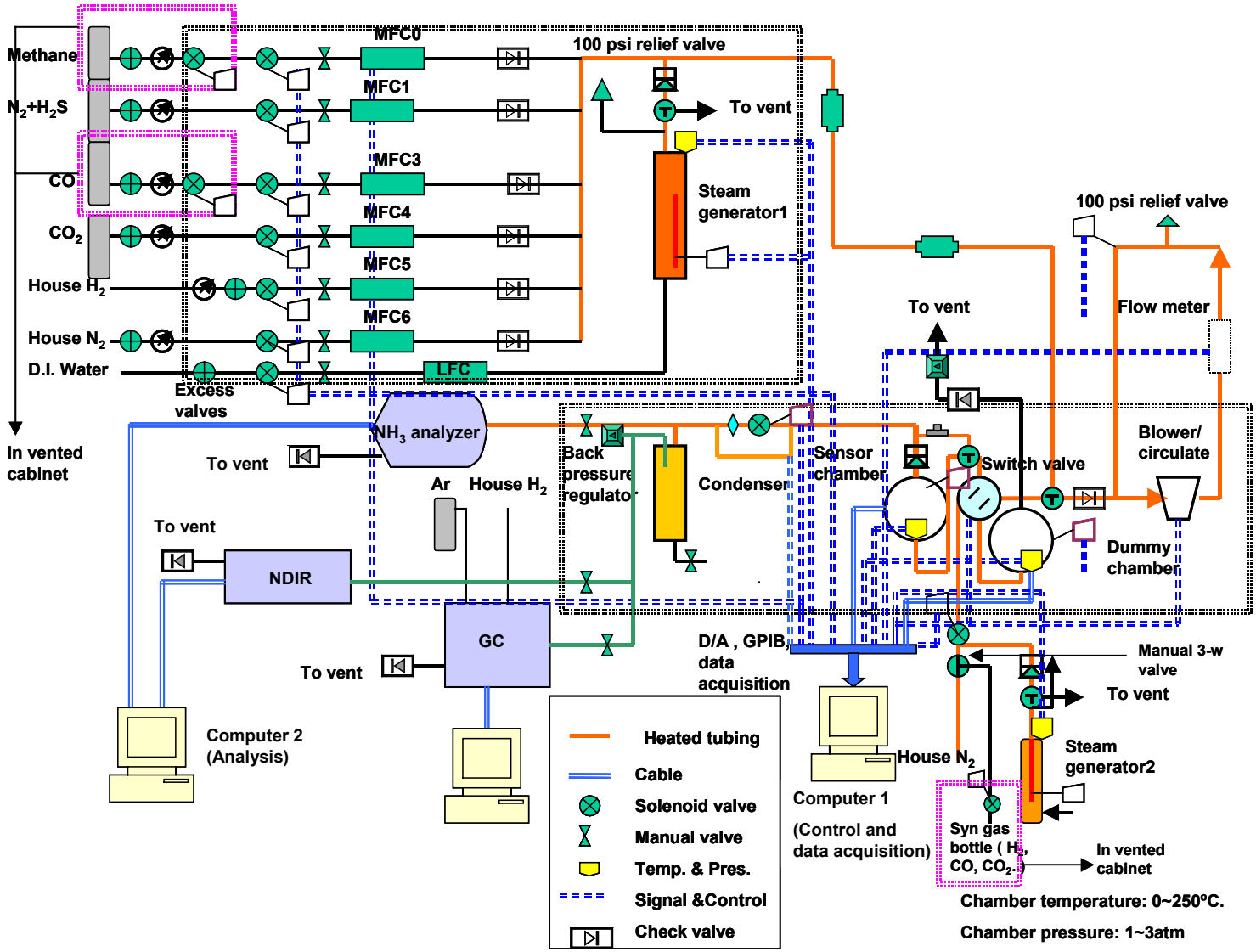
Milestones and Deliverables

	Target Date
•Benchmark Facility Testing – IIT	
—Overall sensor performance review	01/02/04
—Performance analysis and interface design	02/11/05
•S300 Gasoline PEM fuel cell testing – UTC FC	
—Physical sensor testing	06/15/04
—Chemical sensor testing	02/28/05
—Deliver sensor suite to DOE for go/no go decision	03/15/05

Technical Progress

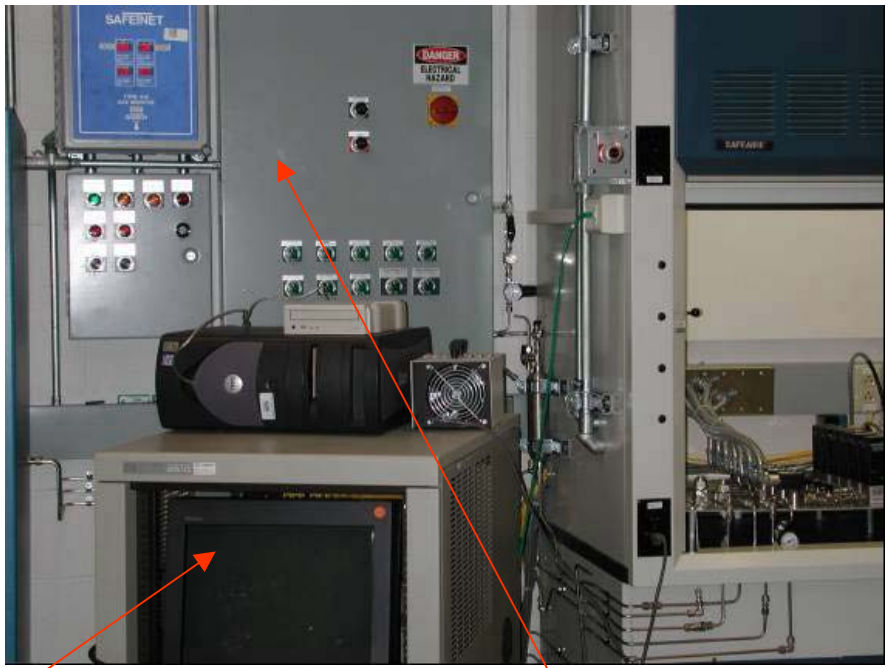
- ATMI
  - Alpha prototype H2 sensor delivered to IIT
- IIT
  - Modifying facility for new sensors; starting H2 sensor tests
- NexTech
  - Modifying CO sensor for integration with IIT/UTRC test facilities
- UTRC
  - Sensor Test Rig and Software Development complete
  - Preliminary Physical Sensor survey completed
    - Most promising technologies and corresponding vendors are identified; presently interacting with vendors and obtaining samples.

PEM Fuel Cell Gas Stream Simulator and Sensor Testing Rig



Sensor Test Facility at UTRC

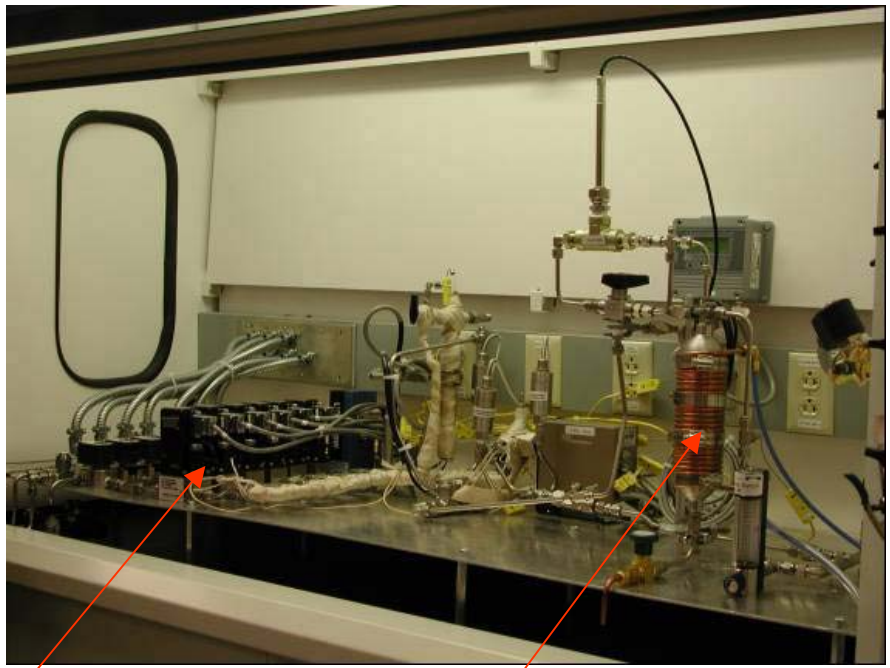
Overall System and Controls



Data Acquisition
And Control Computer

Facility Interface and
Safety System Control

Gas Flow Control and Test Chamber



Mass Flow Controllers

Steam Condenser

Physical Sensor Survey

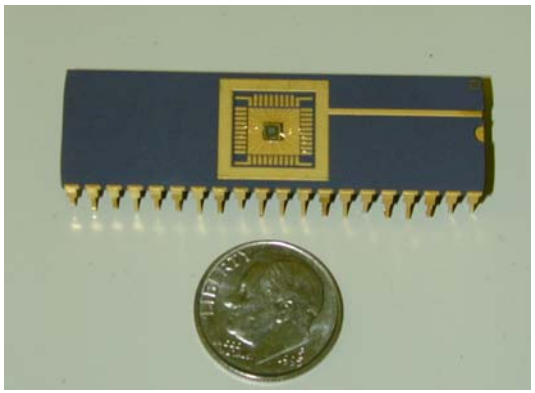
- Humidity Sensors
  - —Polymer Capacitive and MEMS Strain Gauge investigated
- Flow Rate Sensors
  - —Ultrasonic vortex shedding
  - —Turbine meter
  - —Thermal Dissipation
  - —Differential pressure flow sensing
- Differential Pressure Sensors
  - —Strain gauge
- Temperature Sensors
  - —Thermocouples, thermistors and RTD's

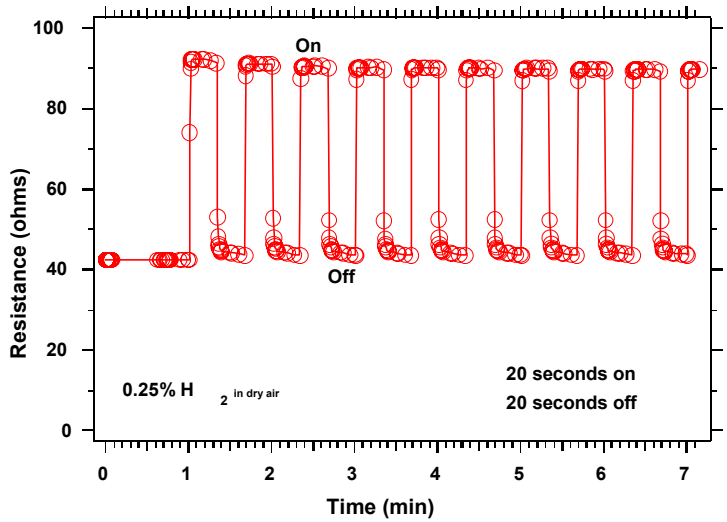
Selection of Physical Sensors for PEM Fuel Cell Power Plant

Technical and Cost Gap Findings

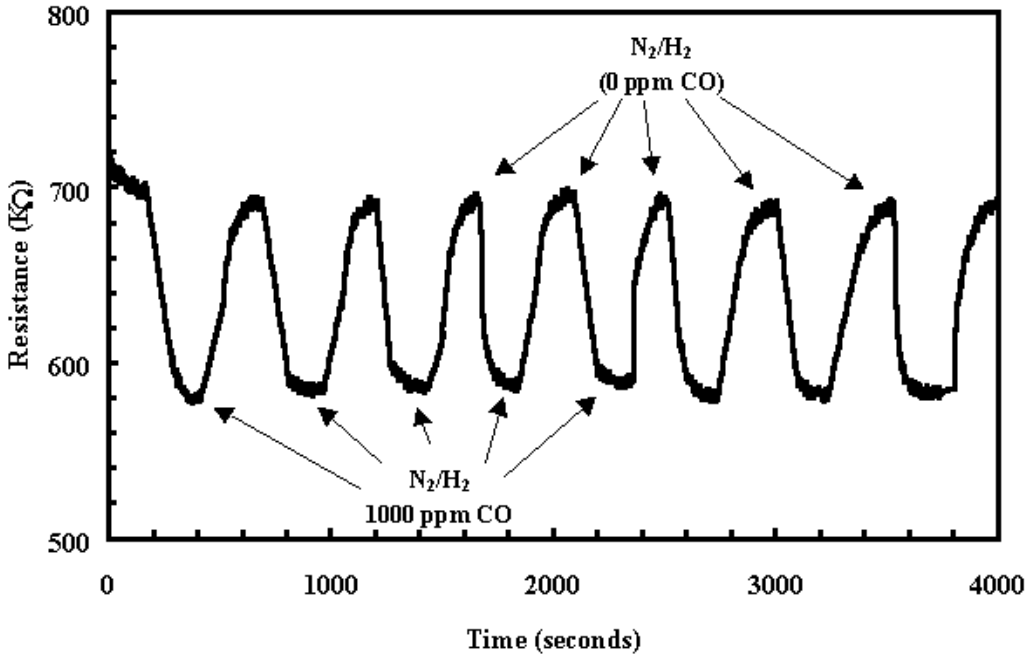
Sensor	Meet DOE/FC tech. specs	Further effort	Technical / Cost gap
Humidity	Most	Validate new technologies (MEMS sensors) to improve the condensation recovery time.	Medium
Flow rate	Most	Collaborate with vendors to improve stability. Identify new technologies.	High
Differential pressure	Most	Collaborate with vendor for miniaturization and significant cost reduction. Needs major development and modifications.	Medium
Temperature	Most	Identify inexpensive thermistor for high temp. Improve response time.	Low

- ATMI
  - H_2, SO_2, H_2S, NH_3 Sensor Development
  - Patented micro hotplate for H_2 detection
  - New sensing technologies being explored for fast response, sensitivity, and cost reduction





- NexTech Materials
  - –CO, SO_2, H_2S, and NH_3 Sensor Development
  - –Demonstrated sensitivity for ppm level CO in 75% H_2
  - –New sensing materials and technologies being explored for PEM systems to meet sensitivity, robustness, and cost requirements



Effect of carbon monoxide (1000 ppm) on resistance of NexTech sensor in a baseline gas composition of 50% hydrogen and 50% nitrogen.

Program Status Summary

- Physical and chemical sensor facility at UTRC built and physical sensor testing begun
- ATMI, IIT, and NexTech fully engaged in program as budget allows
  - Monthly telecons between UTRC and other subcontractors to focus closely on coordination issues started in March 2003
  - UTRC to visit all subcontractor sites within the next two months to increase direct communication and knowledge transfer
- Physical sensor evaluation underway
- H_2 sensor testing underway at IIT and UTRC