Micro Sensor Technology for Advanced Extravehicular Activity Systems

Presented by:

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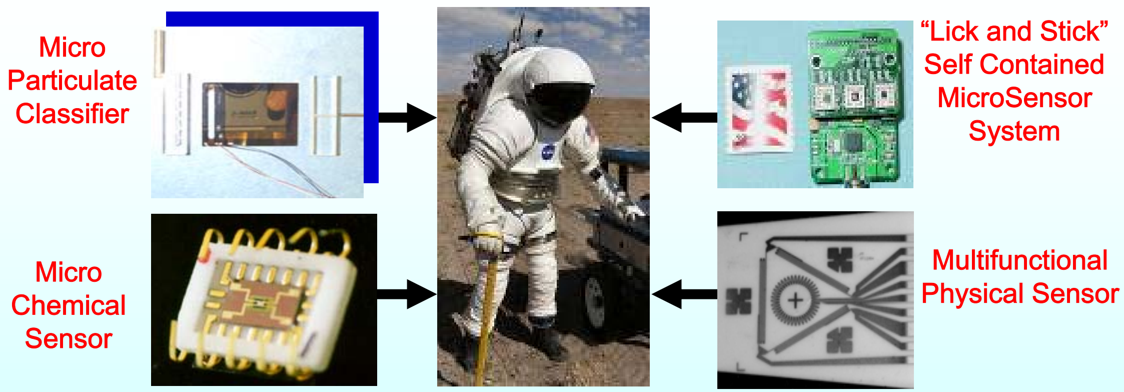
Possible EVA Sensor Systems Drivers

Sensor System Technology Challenges Include:

- **Advanced life support systems to minimize weight and decrease consumables**
- **Advanced thermal control to increase crew comfort, decrease consumables, and enable multiple destinations**
- **Dust and radiation protective materials and concepts**
- **Reduce suit check-out time and maintenance**
- **Sensor Systems To Monitor Health And Conditions of EVA Suite And Crew including improved measurement of metabolic rates**
- **Sensors must Have Minimal Size, Weight, And Power Consumption**

One Potential Vision: "Smart" Suit

- **Development of a "Smart" Suit which has self-monitoring, caution and warning, and control capabilities with high levels of reliability, durability, and safety.**
- **Small, lightweight, low power sensor systems, with increased packaging flexibility, will improve the effectiveness and extensibility of the EVA suits.**
- **Seamless integration of sensors throughout EVA system improving reliability and capability without significantly increasing system wiring and power.**
- **Monitor Both Inside And Outside the EVA Suit for Astronaut Health and Safety\Suit Maintenance**
  - **Inside: For Example, Monitor Suit CO2, O2, Temperature, And Pressure**
  - **Outside: For Example, Monitor Dust/Toxic Gas/Dangerous Conditions Before Brought Back Into Airlock Or Can Affect Astronaut Safety.**



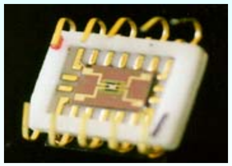
A "SMART" SUIT NEEDS TO MONITOR BOTH INTERNAL AND EXTERNAL CONDITIONS

A RANGE OF MICRO SENSOR TECHNOLOGIES ADVANCED CAPABILITIES FOR EVA APPLICATIONS

BASE PLATFORM CHEMICAL SENSOR TECHNOLOGY CAN BE TAILORED FOR THE APPLICATION:
MEASURE C02 AND HYDRAZINE

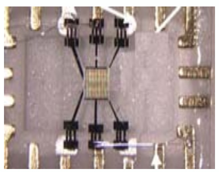
PHYSICAL SENSORS CAN BE INTEGRATED INTO STRUCTURE:
TEMPERATURE AND HEAT FLUX SENSORS FOR THERMAL MONITORING

SENSOR SYSTEMS INCLUDING ELECTRONICS AND COM CAN PLACED WHERE THEY ARE NEEDED:
LEVERAGE SMART SENSOR DEVELOPMENT FOR EVA

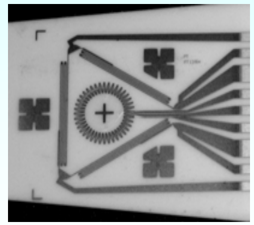


Oxygen Sensor (Electrochemical Cell)

Hydrocarbon Sensor (Schottky diode)

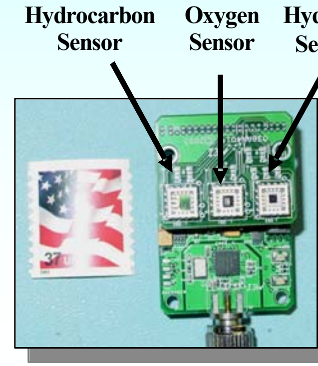


Nanocrystalline Tin Oxide (Resistor)



Multifunctional Sensor (Temp, Strain, Heat Flux, and Flow) Embedded onto a Substrate Surface

Heat Flux Sensor Array on a Flexible Substrate

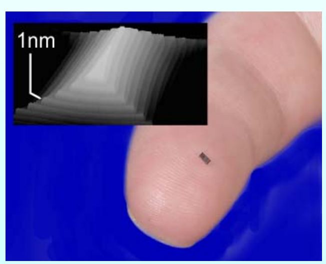


"Lick and Stick" Leak Sensor System

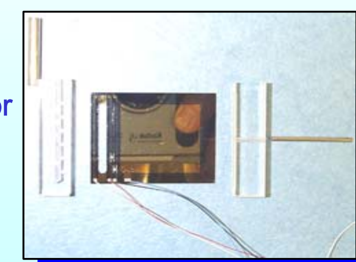
USE IMPROVED MATERIALS TO ENABLE REAL TIME RADIATION MONITORING :
SiC BASED SOLID STATE PERSONAL DOSIMETRY

DUST WILL BE A MAJOR ISSUE IN LUNAR ENVIRONMENTS :
MICROSCALE PARTICLE DETECTOR AND CLASSIFIER

2004 R&D 100 Award
SiC Growth Technology for Nanoscale Measurement Standards



MEMS-BASED Particulate Detector



A RANGE OF IN-HOUSE CAPABILITIES

Advance development of a wide range of sensors, electronics, and MEMS

Clean room facilities:1000 square foot Class 100 & 2000 square foot Class 1000
STS ICP & RIE deep etcher and 9 PVD rigs with high temperature capability
Full MEMS processing with photomask aligners & wet chemical etching stations
Can Also Leverage Local Clean Room Capabilities

SiC Epitaxy Growth

Improve epilayer growth for better SiC devices.

- doping control
- reduce defects
- atomically flat surfaces
- sensor structures

Microsystems Fabrication Clean Room

Improve processes for better sensors and SiC devices.

- full MEMS processing
- ion etching
- durable contacts
- sensor deposition
- electronics processing

Microdevice Characterization Facilities

Design, implement, test, and understand better SiC devices.

- surface analysis
- device characterization
- sensor testing facilities
- packaging and testing

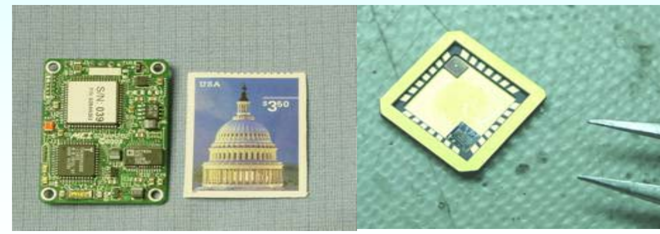
BASE PLATFORM SENSOR TECHNOLOGY

Integration of Micro Sensor Combinations into Small, Rugged Sensor Suites

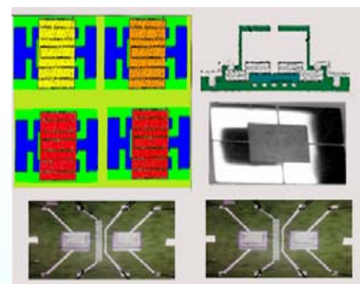
Example Applications: AEROSPACE VEHICLE FIRE, FUEL, EMISSIONS, ENVIRONMENTAL MONITORING CREW HEALTH, SECURITY

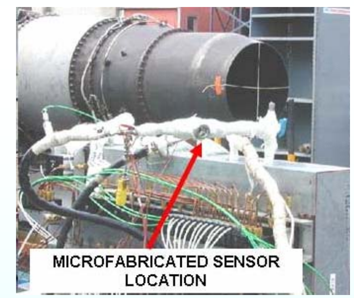
Multi Species Fire Sensors for Aircraft Cargo Bays

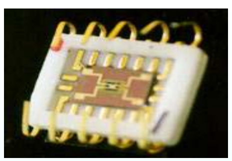
"Lick and Stick" Space Launch Vehicle Leak Sensors with Power and Telemetry



Aircraft Propulsion Exhaust High Temperature Electronic Nose

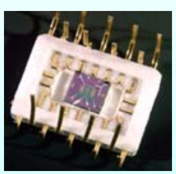




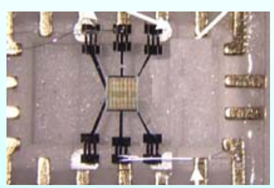


Oxygen Sensor

SiC Hydrocarbon Sensor



H2 Sensor

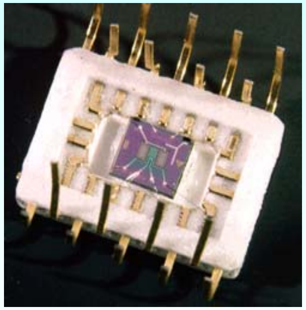


Nanocrystalline Tin Oxide NOx and CO Sensor

Sensor Equipped Prototype Medical Pulmonary Monitor

Hydrazine EVA Sensors (11 ppb Detection)

TECHNOLOGY EXAMPLES
HYDROGEN LEAK SENSOR TECHNOLOGY

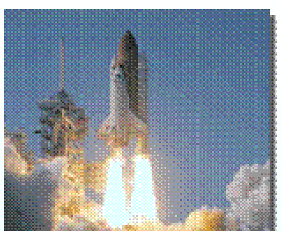


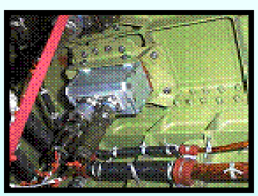
- **MICROFABRICATED USING MEMS-BASED TECHNOLOGY FOR MINIMAL SIZE, WEIGHT AND POWER CONSUMPTION**
- **HIGHLY SENSITIVE IN INERT OR OXYGEN-BEARING ENVIRONMENTS, WIDE CONCENTRATION RANGE DETECTION**
- **HISTORY OF TECHNOLOGY IMPLEMENTATION**

1995 R&D 100 AWARD WINNER

NASA 2003 TURNING GOALS INTO REALITY SAFETY AWARD

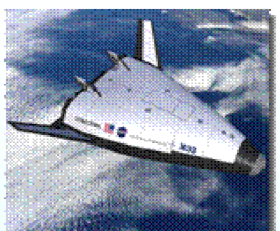
Shuttle

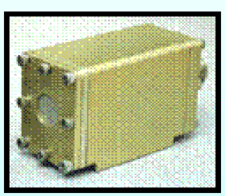




Aft Compartment Hydrogen Monitoring

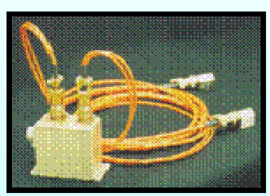
X33





Hydrogen Safety Monitoring

X43

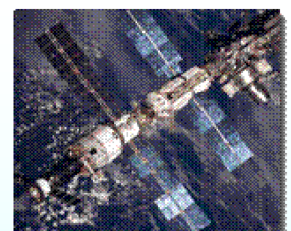


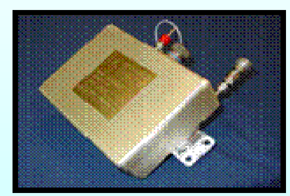
Hydrogen Safety Monitoring

Helios

Fuel Cell Safety and Process Monitoring

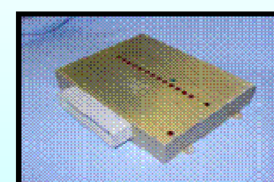
ISS





Life Support Process and Safety Monitoring

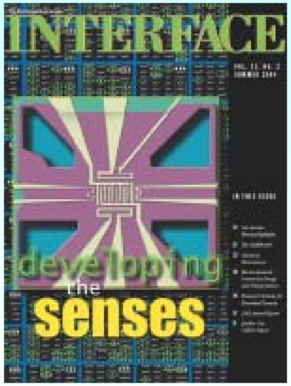
Model U



Vehicle Safety Monitoring

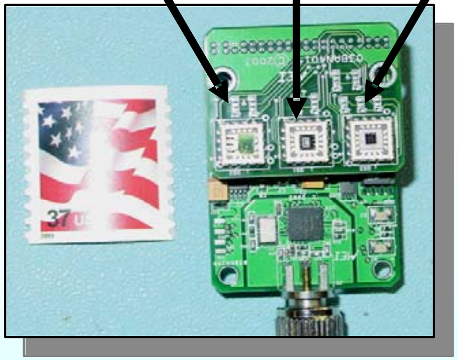
“LICK AND STICK” LEAK SENSOR SYSTEM

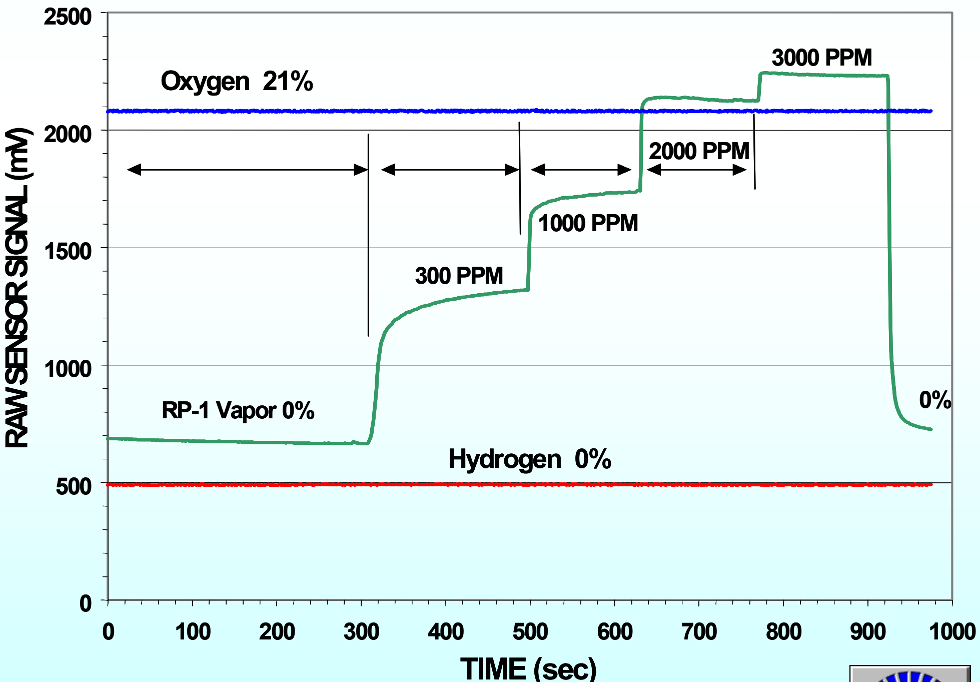
- THREE SENSORS, SIGNAL CONDITIONING, POWER, AND TELEMETRY ALL IN SINGLE PACKAGE
- MICROPROCESSOR INCLUDED
- BUILT IN TEST OF ELECTRONICS AND SENSOR
- BEING MATURED FOR CLV AVIONICS WITH H_2 AND 0_2



NASA GRC/CWRU O2 Sensor Featured On the Cover of the Electrochemical Society Interface Magazine

Hydrocarbon Sensor   Oxygen Sensor   Hydrogen Sensor





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Instrumentation and Controls Division

HYDRAZINE DETECTION FOR EVA/ENVIRONMENTAL APPLICATIONS

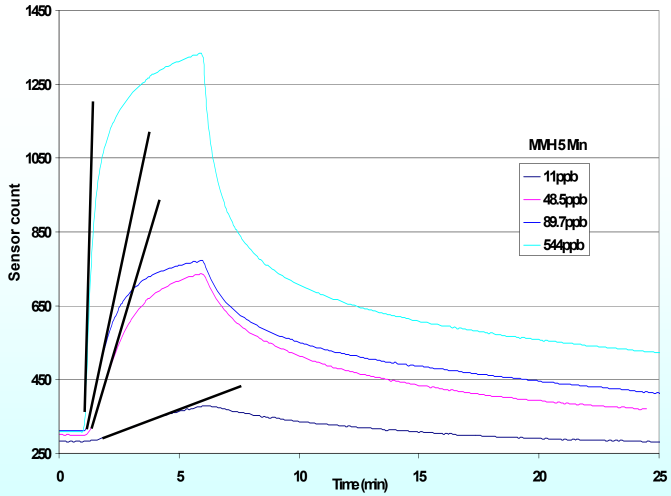
- PREVIOUS SPECIFICATIONS FOR THE HYDRAZINE DETECTION SYSTEM FOR AIRLOCK:

  25 ppb MINIMUM MEASUREMENT OF HYDRAZINE; 5 MINUTE RESPONSE TIME OVER A 10 MINUTE EXPOSURE; 5 psi AMBIENT PRESSURE;LACK OF RESPONSE TO AMMONIA

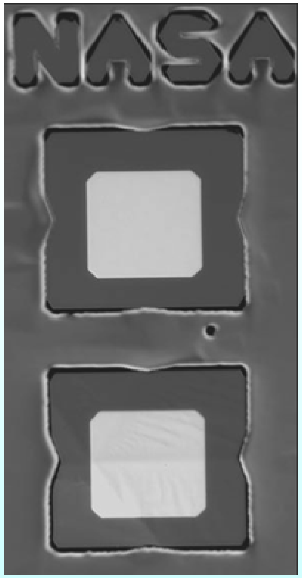
- SYSTEM GENERALLY MEETS SPECS BUT NEED TO VERIFY REPEATABLE RESPONSE OVER LONGER TIMES/POSSIBLE REPEATABILITY ISSUE AFTER AMMONIA EXPOSURE

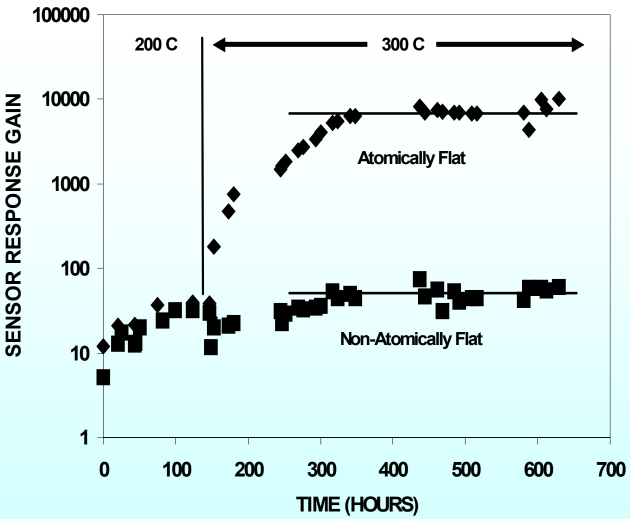
- DROP TEMPERATURE OF OPERATION/PACKAGING CHANGES FOR SUIT INCLUSION

- MOVING TO ATOMICALLY FLAT SiC/SYSTEM BEING MATURED FOR CLV HAZ GAS APPLICATIONS BUT FOR HIGHER CONCENTRATIONS



PdAg-SiO2-Si: RESPONSE VS CONCENTRATION (120C)





TECHNOLOGY EXAMPLES

MICRO-FABRICATED GAS SENSORS FOR LOW FALSE ALARMS

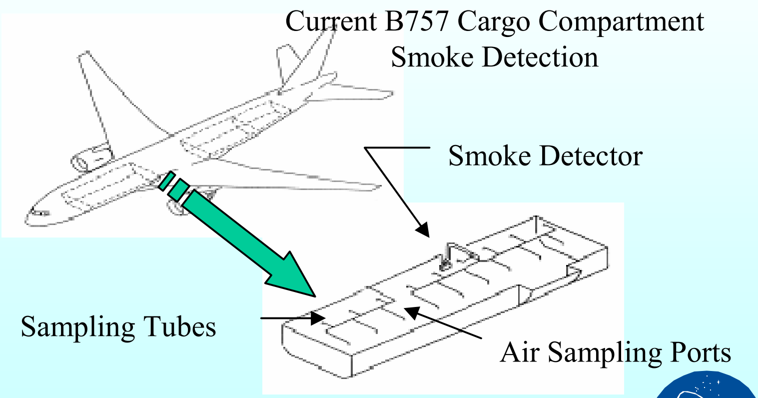
BEING MATURED FOR POTENTIAL CEV APPLICATION

2005 R&D 100 AWARD WINNER

NASA 2005 TURNING GOALS INTO REALITY AA's CHOICE AWARD

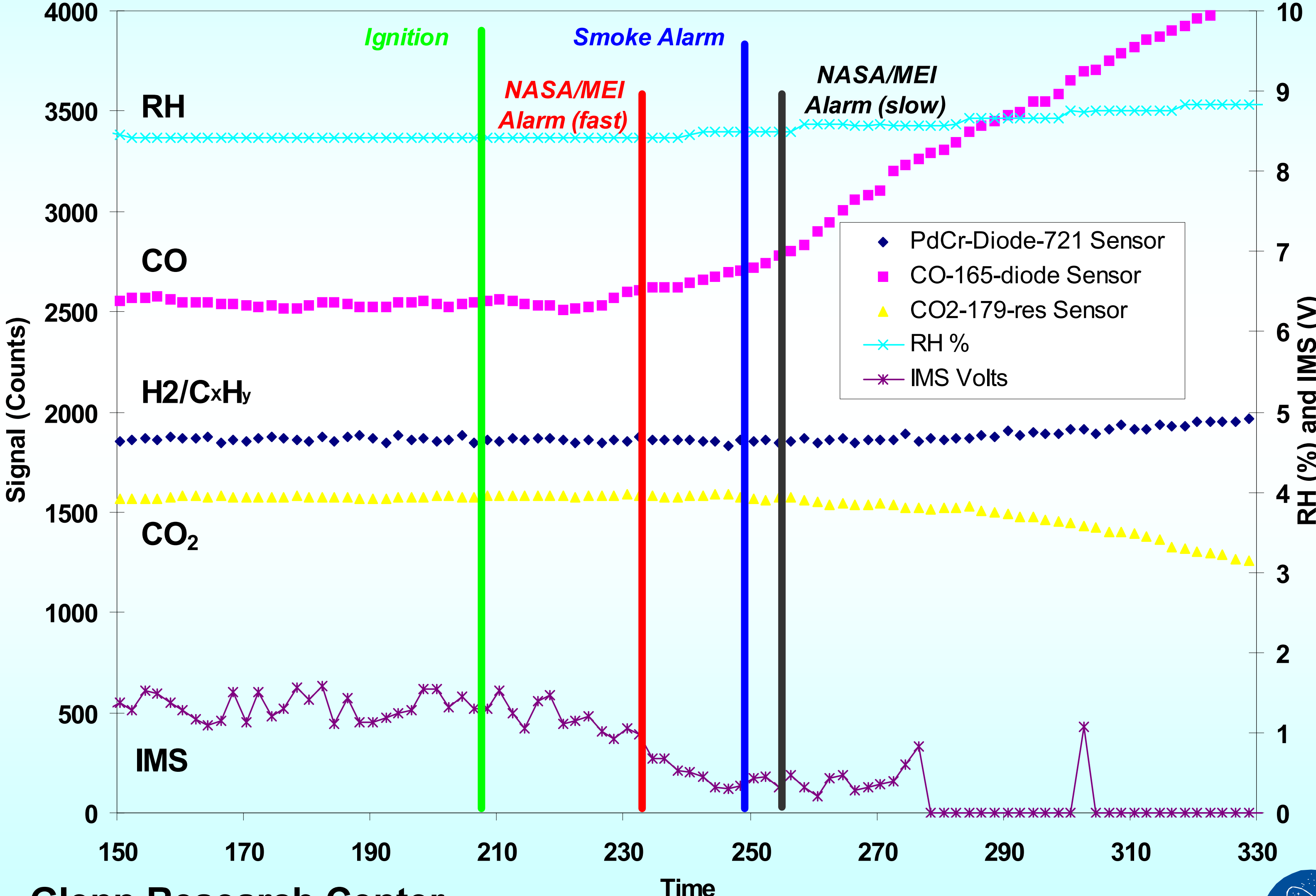
FEATURES

- **MICROFABRICATED CO/CO_2 GAS SENSOR ARRAY**
  - **AIM TO DECREASE FALSE ALARM RATE WHICH IS AS HIGH AS 200:1**
  - **CENTRAL TO APPROACH**
  - **NANOCRYSTALLINE MATERIALS (IN CO SENSOR) PRODUCE MORE SENSITIVE, STABLE SENSORS**
  - **TWO APPROACHES TO CO2 DETECTION**
  - **MINIMAL SIZE/WEIGHT/POWER**
- **CHEMICAL GAS SENSORS PROVIDE GASEOUS PRODUCT-OF-COMBUSTION INFORMATION**
  - **SENSOR ARRAY CAN DETECT RANGE OF GAS SPECIES**
  - **COMBINED WITH INTELLIGENT SOFTWARE FOR PATTERN RECOGNITION**
- **BENEFITS**
  - **DISCRIMINATE FIRES FROM NON-FIRES**



TECHNOLOGY EXAMPLES
MICRO-FABRICATED GAS SENSORS FOR LOW FALSE ALARMS

FAA Cargo Bay Fire Testing
No False Alarms/Consistent Detection of Fires



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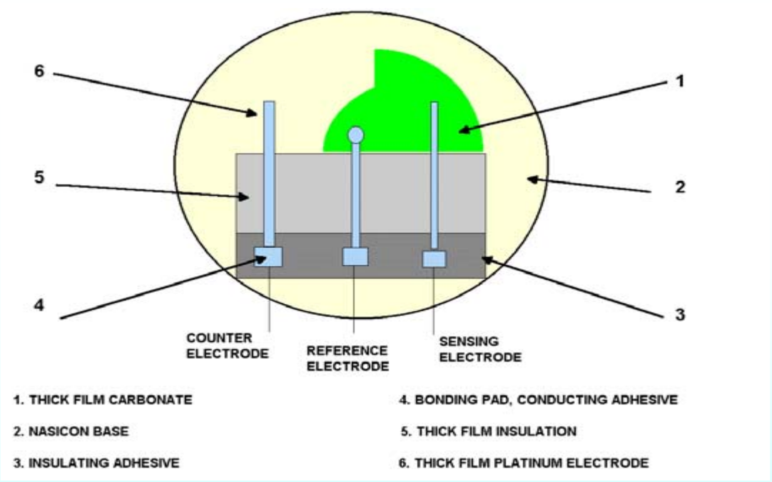
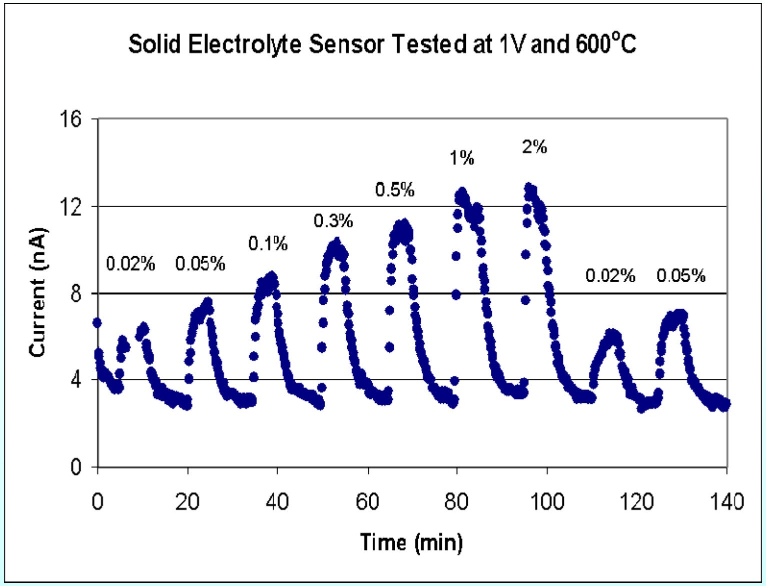
MICROFABRICATED CO2 SENSOR TECHNOLOGY

AMPEROMETRIC CO2 SENSOR
(FIRE DETECTION SYSTEM)

CWRU

- MICROFABRICATED FOR MINIMAL SIZE, WEIGHT AND POWER CONSUMPTION
- ELECTROCHEMICAL CELL DESIGN USING PROTON CONDUCTING NASICON AS ELECTROLYTE TO DETECT A RANGE OF CO2 CONCENTRATIONS
- TEMPERATURE DETECTOR AND HEATER TO BE INCORPORATED INTO SENSOR STRUCTURE
- HIGHER OPERATING TEMPERATURE/MICRO SIZE YIELDS LESS THAN 100 mW POWER CONSUMPTION



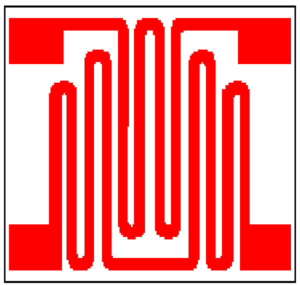


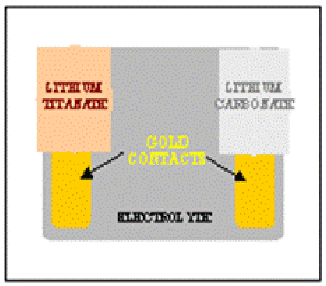
STRUCTURE OF A NASICON-BASED ELECTROCHEMICAL CELL CO2 SENSOR

MICROFABRICATED CO2 SENSOR TECHNOLOGY

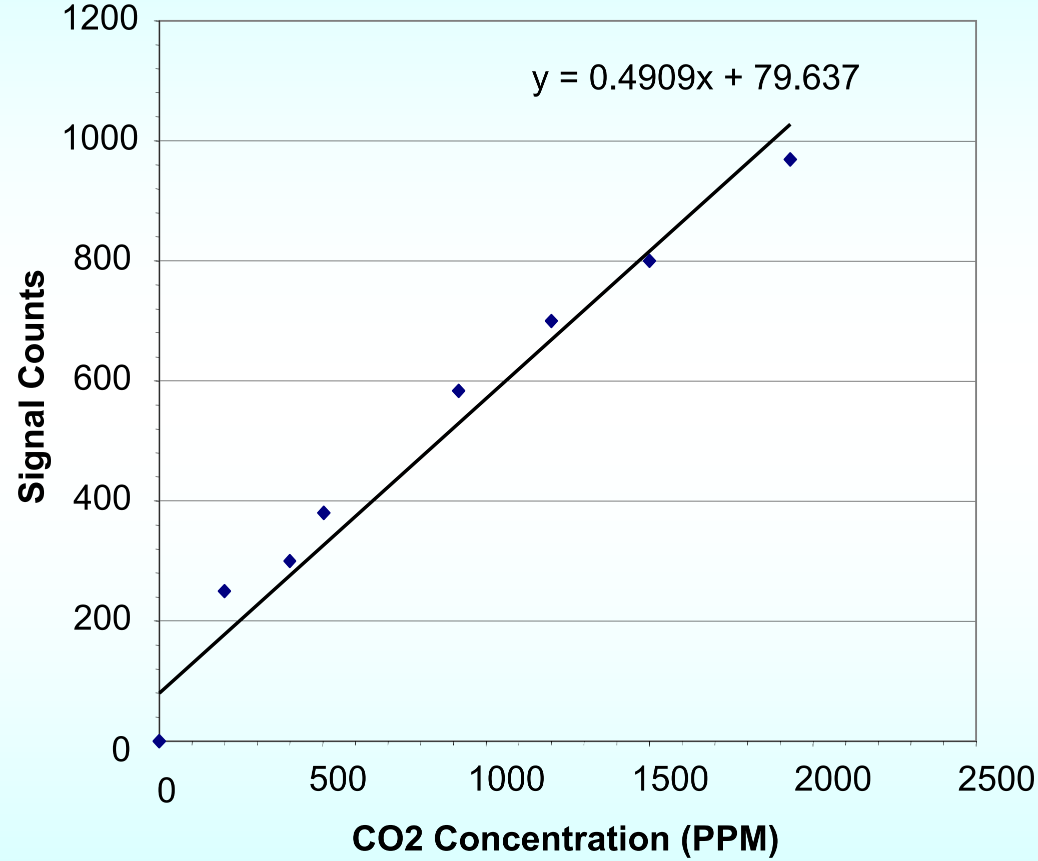
CO2 SENSOR INTEGRATED INTO “LICK AND STICK” TECHNOLOGY

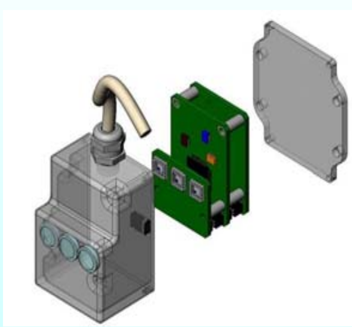
CO2 sensor layout





Back Side Heater   Front Side Sensor





“Lick and Stick” Sensors Platform

MEI Makel Engineering Inc.

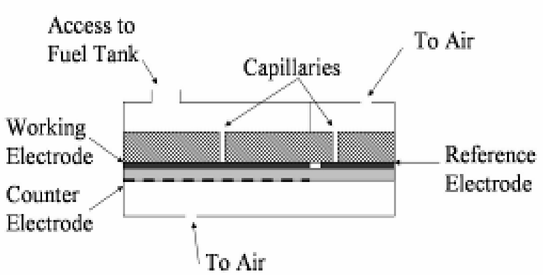
CWRU

THE OHIO STATE UNIVERSITY

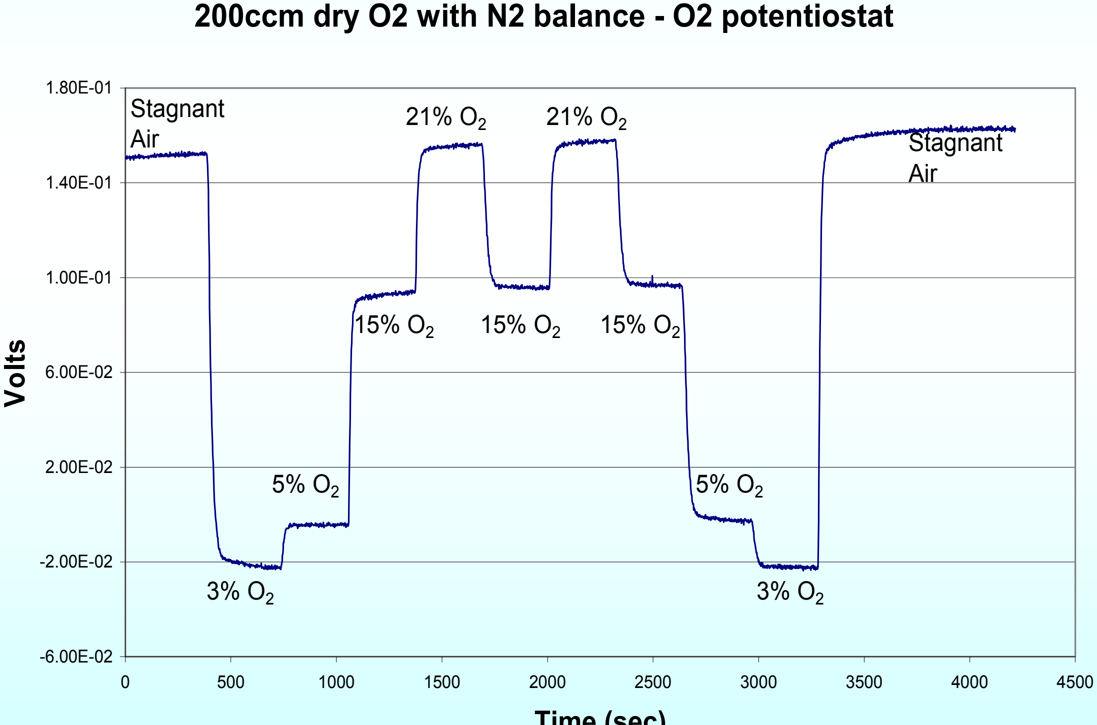
NASA

MICROFABRICATED O2 SENSOR TECHNOLOGY

- LEVERAGE FUEL TANK O2 SENSOR DEVELOPMENT
  - ELECTROCHEMICAL CELL OPERATIONAL AT ROOM TEMPERATURE
  - DESIGNED FOR EXPLOSIVE ENVIRONMENTS
  - POSSIBLE CANDIDATE FOR SHUTTLE EXPERIMENT
- IMPROVE MINIATURIZATION
- MODIFY ELECTRODE DESIGN FOR CO2 DETECTION



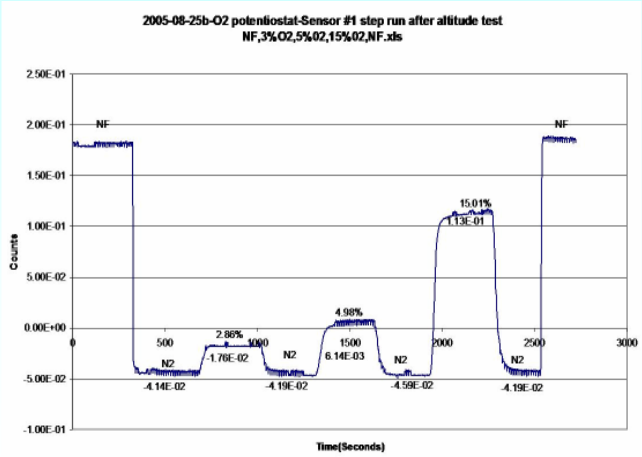
NAFION O2 Sensor Structure



Preliminary NAFION O2 Sensor Data

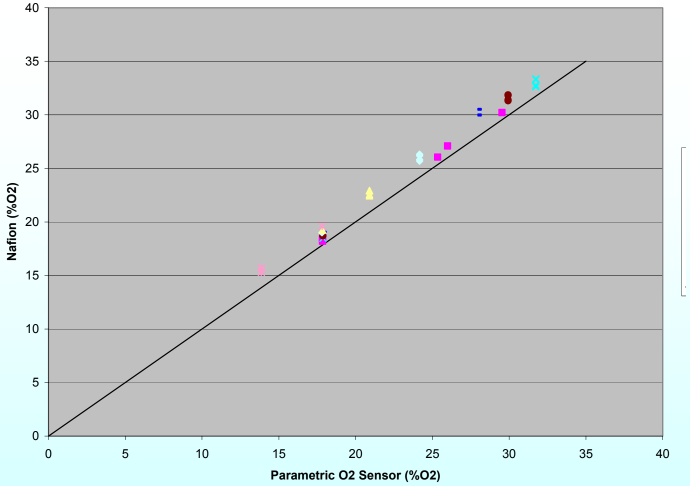
WHITE SANDS O2 SENSOR TESTING

- BOTH HIGH AND ROOM TEMPERATURE O2 SENSOR WERE TESTED IN AT WHITE SANDS FOR A ISS ENVIRONMENTAL MONITORING FUNCTION
- HIGH TEMPERATURE SENSOR WOULD HAVE PASSED ISS FUNCTIONAL REQUIRMENTS
- LOW TEMPERATURE ONES PERFORMED WELL, BUT STILL REQUIRE DEVELOPMENT OF A WELL-DEFINED MANUFACTURING PROCESS.
- FURTHER TESTING ON-GOING



Nafion sensor performance at varying oxygen concentrations and pressures

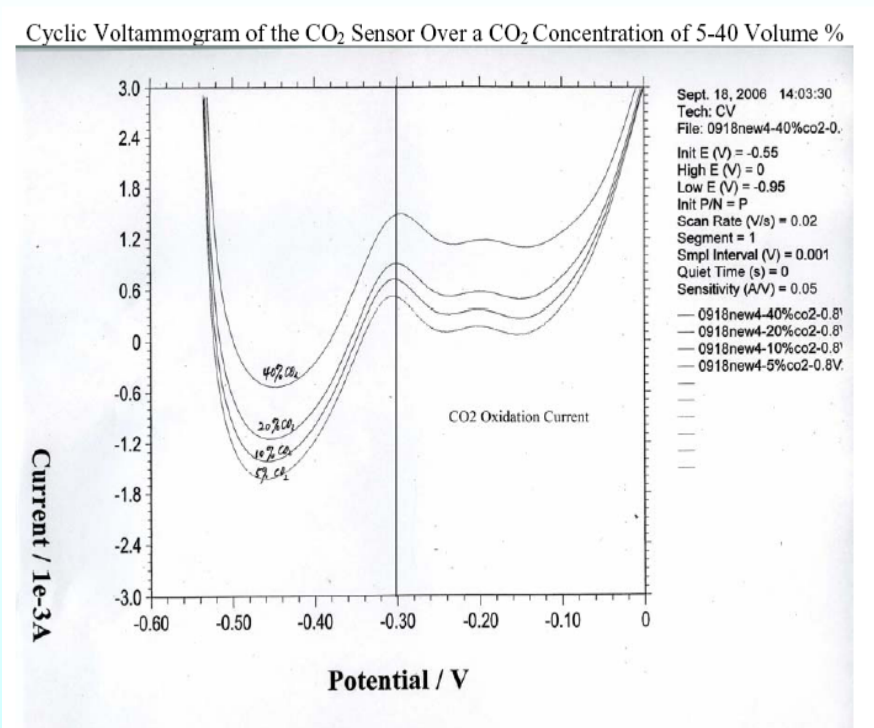
Current polymer electrolyte oxygen sensor (left) and sensors during piggyback testing with NASA CSA-O2 systems

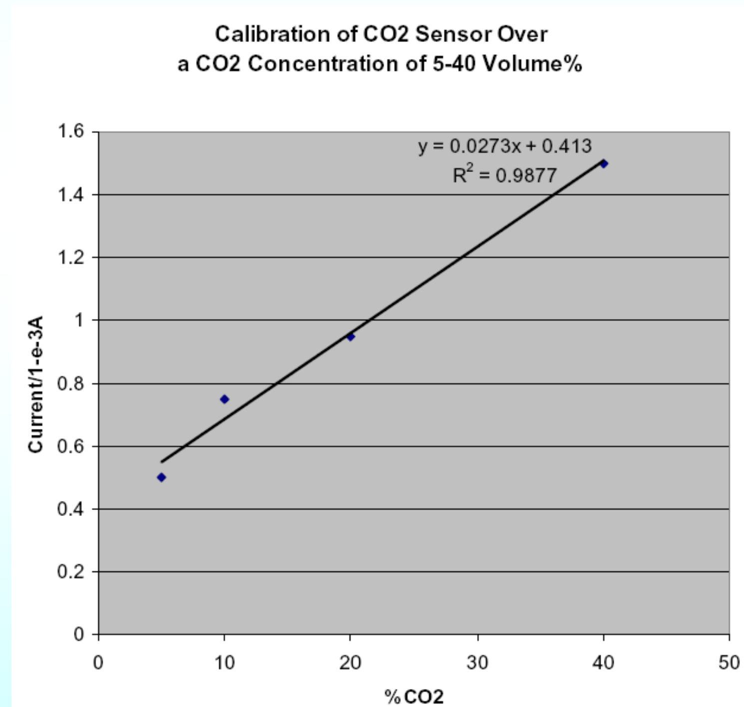


Sensor 018 (Low Temperature Nafion) O2 Sensor Output vs. Paramagnetic O2 Detector

PRELIMINARY ROOM TEMPERATURE CO2 SENSOR RESPONSE

- **Use O2 sensor and electrochemistry to determine O2 concentration**
- **FY 06 Objective: Demonstrate basic room temperature CO2**
- **Approach to be integrated into "Lick and Stick" electronics/ demonstration on Shuttle**





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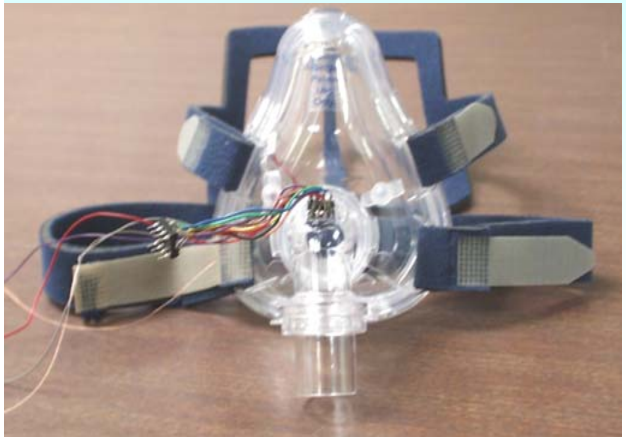
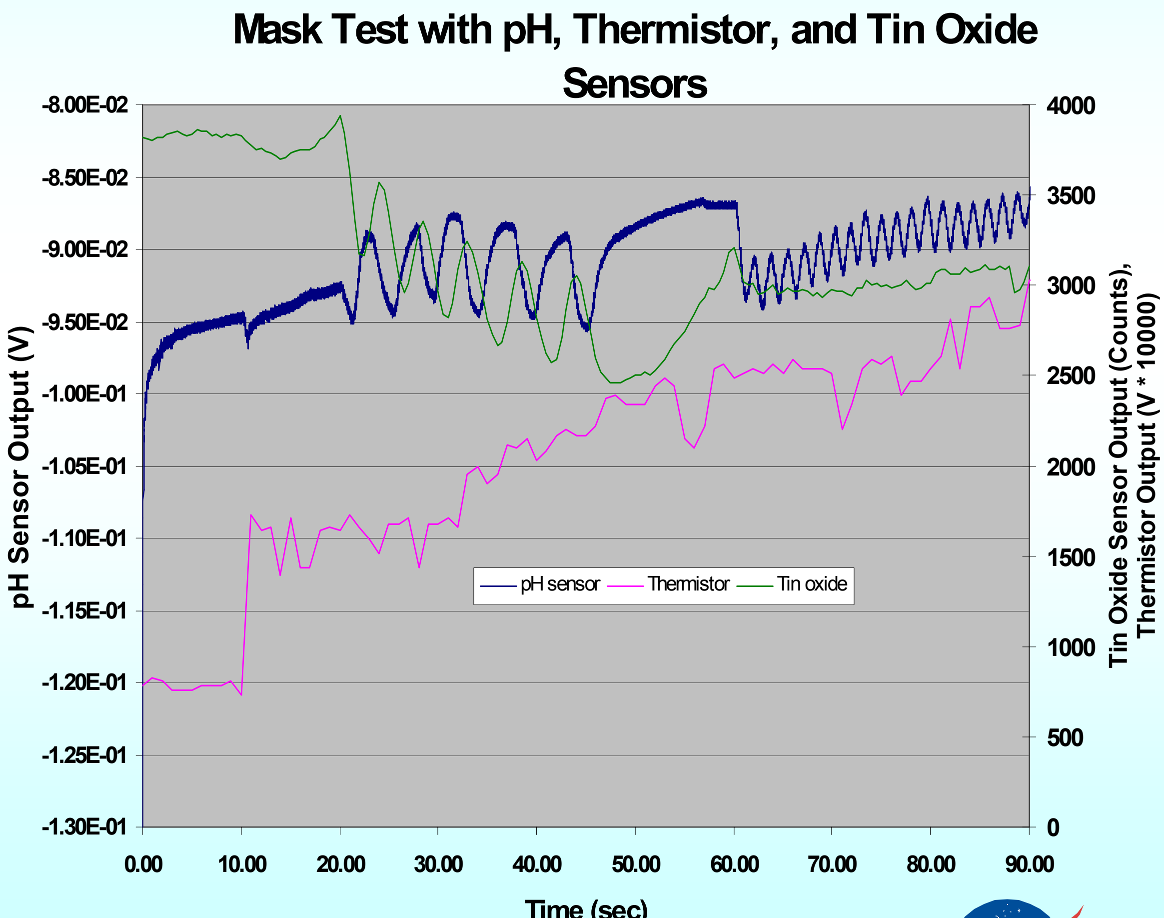
BREATH ANALYSIS USING MICROSENSORS

ASTHMA MONITORING

USE BASE SENSOR TECHNOLOGY FOR BIOMONITORING APPLICATIONS



EXTERNAL MONITORING APPARATUS/MASK WITH EMBEDDED SENSORS

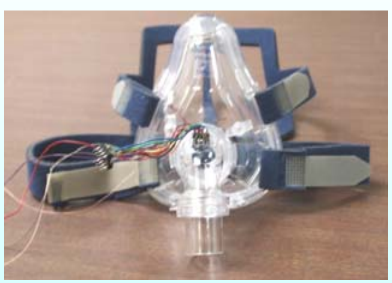


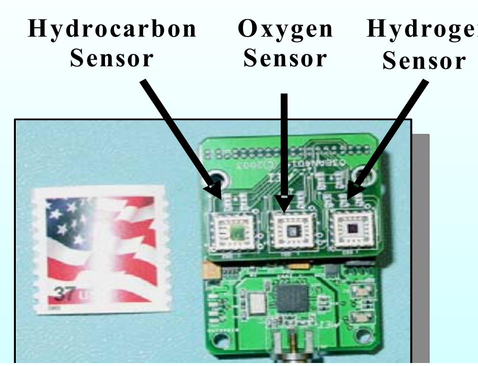
THEMISTOR SENSOR IN MASK

BREATH ANALYSIS USING MICROSENSORS

A MicroSensor Array for Exercise and Health Monitoring
John Glenn Biomedical Engineering Consortium (JGBEC)

- **EXPAND ON PREVIOUS BREATH ANALYSIS WORK**
- **USE ARRAY OF SENSORS OF VERY DIFFERENT TYPES TO MONITOR BREATH FOR EXERCISE AND HEALTH**
  - **CO_2 and O_2 MONITORING WILL BE EXPANDED TO INCLUDE NO_x, H_2S, HYDROCARBONS, CO, pH, and T**
  - **NASA GRC, CLEVELAND CLINIC FOUNDATION, MAKEL ENGINEERING, TRANSDUCERS INC, CASE WESTERN RESERVE UNIVERSITY**
- **USE GAS PATTERN MEASURED FOR EXERCISE PARAMETERS BUT ALSO AS INDICATORS OF OVERALL HEALTH**
  - **CCF AND OTHER COLLABORATORS INDEPENDENTLY SHOWED CORRELATION OF BREATH WITH PRESENCE OF CANCER**





Lick and Stick Sensor System

MEI Makel Engineering Inc.

The Cleveland Clinic Foundation

CWRU

Breath Sensor System Overview

Sensor operates using PDA
or Laptop for user interface

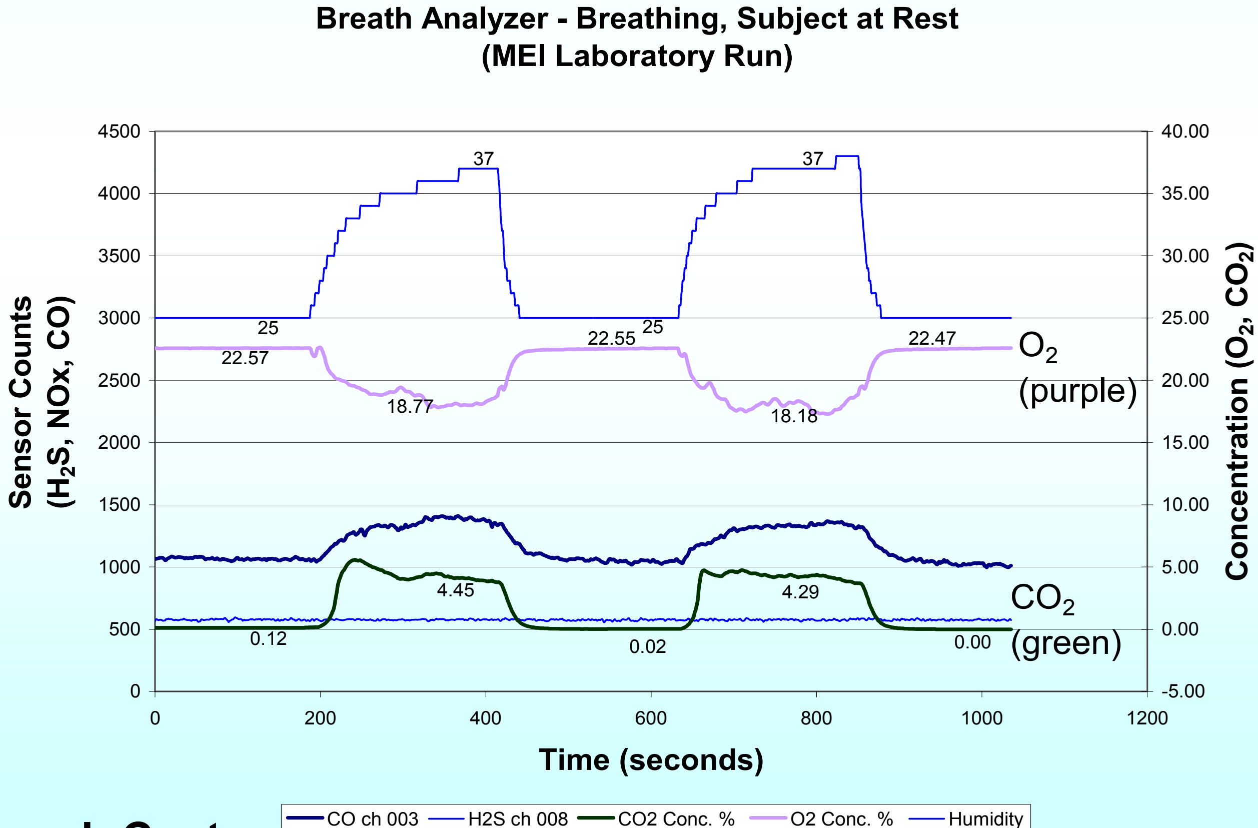
•Sensors include:

- •CO2 – Solid State sensor
- •O2 – Nafion based sensor
- •CO – Electrochemical Cell
- •NOx – Electrochemical Cell
- •H_2S – Electrochemical Cell

Breath Sensor System – includes mouthpiece for breath collection, Nafion drying tube in sample line, sensor manifold with PDA interface, and mini sampling pump

Breath Sensor Response Data

- **Testing at Cleveland Clinic to occur early Dec. 2006 – will allow comparison to clinical test equipment**
- **Baseline lab test results show response to O_2, CO_2 during breathing**
  - **Small response from CO sensor**
  - **Time response of sensors will be evaluated by comparison to clinical equipment**



Summary

- **New Technology Innovations Will Be Necessary To Implement Safe, Efficient, Effective, And Affordable Exploration Missions Where EVAs Can Be Accomplished On A Routine Basis.**
- **Architecture Decisions Will Drive The Requirements And Specific Technology Developments That Will Be Pursued By The EVA Project.**
- **Sensors Have A Role To Play In Enabling A Next Generation, Smart Suit System.**
- **Suggested Steps:**
  - **Tailor The Sensor For The Application/Customer Input**
  - **Ease Of Application/Miniaturization, Smart Systems**
  - **Reliability**
  - **Redundancy And Cross-correlation**
  - **Orthogonality**
- **Moving advanced technologies toward Shuttle and CLV applications**
- **Previous development of O2 and CO2 sensors**
- **Moving toward room temperature operation**
  - **ISS and Shuttle application and development is on-going**
- **Complete chemical species breath measurement to be tested in the near future**