

Smart Sensor Technology for Environmental Monitoring Applications

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OUTLINE

- INTRODUCTION
- SENSOR PLATFORMS AND SMART SENSOR SYSTEMS
 - “LICK AND STICK” HARDWARE
 - WIRELESS SENSOR AND NODES
- ENVIRONMENTAL MONITORING
 - FIRE/ENVIRONMENTAL MONITORING
 - WATER MONITORING
- SUMMARY AND CONCLUSION





BASE PLATFORM SENSOR TECHNOLOGY

Integration of Micro Sensor Combinations into Small, Rugged Sensor Suites
Example Applications: AEROSPACE VEHICLE FIRE, FUEL LEAKS, EMISSIONS, ENVIRONMENTAL MONITORING, CREW HEALTH, SECURITY

Multi Species Fire Sensors for Aircraft Cargo Bays and Space Applications



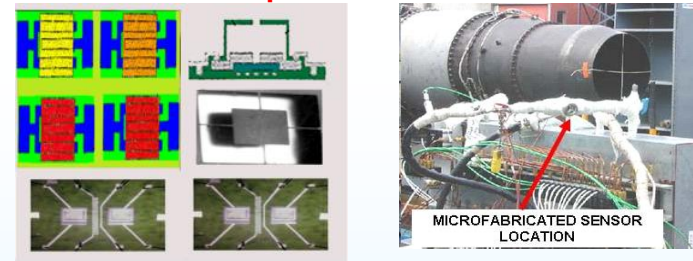
Environmental monitoring (ISS Whitesand Testing)



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



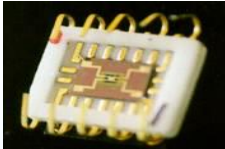
Aircraft Propulsion Exhaust High Temperature Electronic Nose




Breath Sensor System Including Mouthpiece, PDA Interface, And Mini Sampling Pump



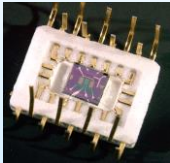
Hydrazine EVA Sensors (ppb Level Detection)

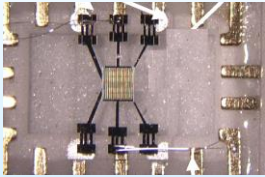
Oxygen Sensor



SiC Hydrocarbon Sensor



H2 Sensor



Nanocrystalline Tin Oxide NOx and CO Sensor



BASE PLATFORM SENSOR TECHNOLOGY

•SENSOR DEVELOPMENT RESULTING FROM:

- MICROFABRICATION AND MICROMACHINING TECHNOLOGY
- NANOMATERIALS
- SiC-BASED SEMICONDUCTOR TECHNOLOGY

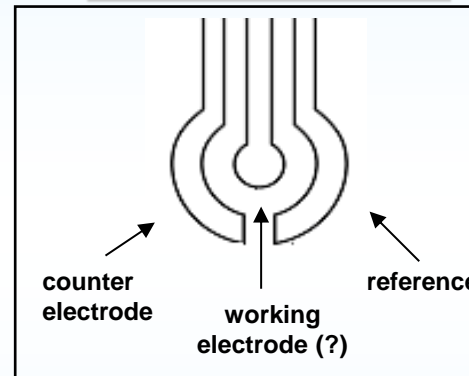
•TECHNOLOGY DEVELOPS PLATFORMS FOR A VARIETY OF MEASUREMENTS

- SCHOTTKY DIODE
- RESISTANCE BASED
- ELECTROCHEMICAL

• MODIFY PLATFORMS AND MATERIALS TO MEET NEEDS OF THE APPLICATION

• SELECTIVE DETECTION OF TARGETED SPECIES

BASIC APPROACH

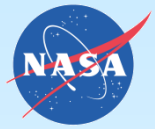


Electrochemical Cell Platform formed by Microprocessing

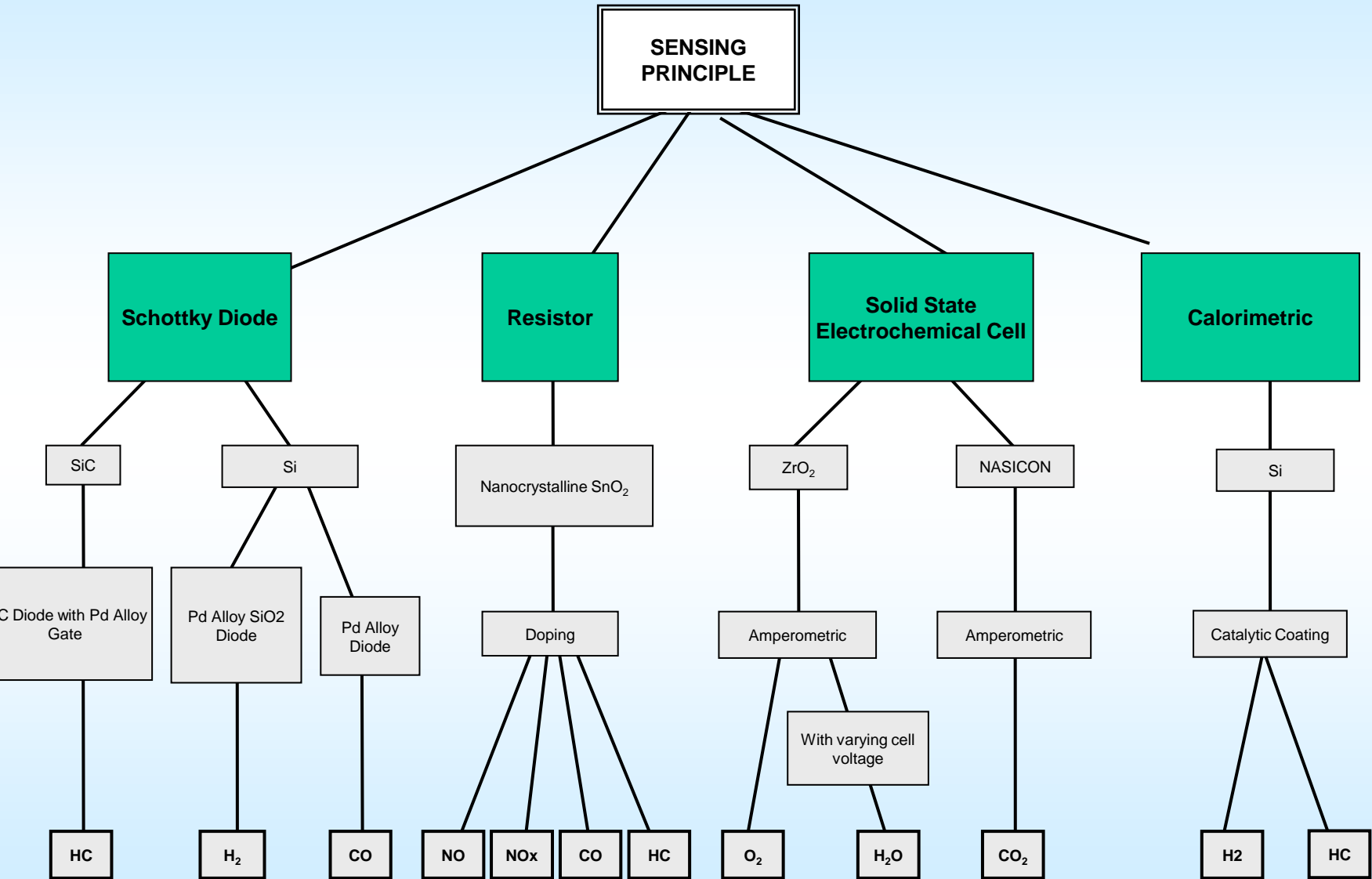
Vary Substrate and Sensor Materials Depending on Application

Meet the Needs of a Range of Applications Based On Platform Technology

High Temp O ₂ Detection	High Temp CO ₂ Detection	Room Temp O ₂ Detection	Glucose sensor	Ca ⁺⁺ Detection
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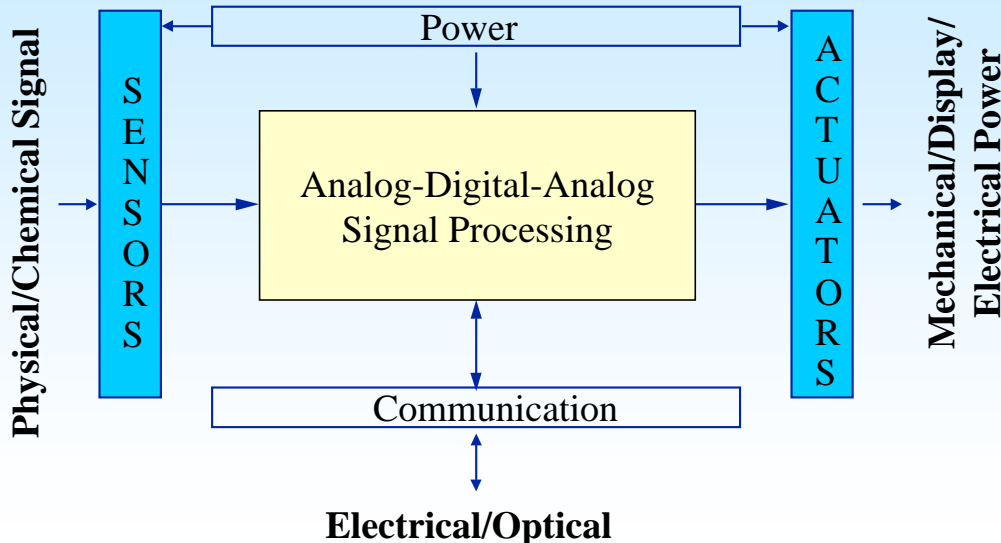


CHEMICAL SENSOR "FAMILY TREE"



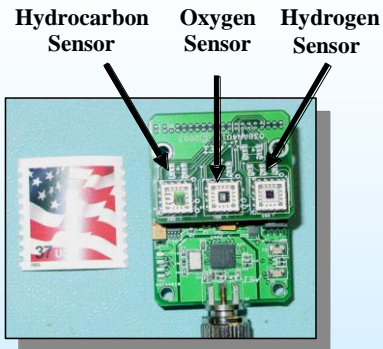
CORE MICROSYSTEMS TECHNOLOGY

Microsystems Approach: Stand-alone, Complete Miniaturized Systems Including Sensors, Power, Communication, Signal Processing, And Actuation to Enable a Smart Sensor System

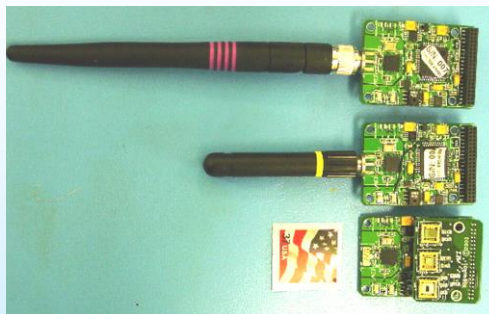


“LICK AND STICK” SMART LEAK SENSOR SYSTEM

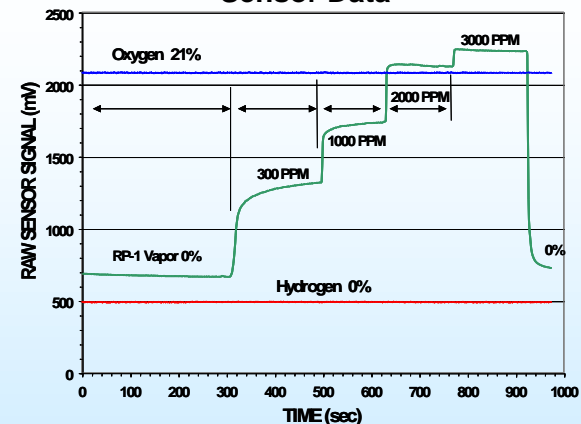
“Lick and Stick” Leak Detection Electronics and Three Sensors



System Configured with Different Wireless Antennae



Wirelessly Transmitted 3 Sensor Data

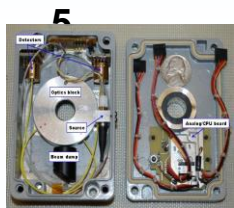


BASIC APPROACH: MEET THE NEEDS OF MULTIPLE APPLICATIONS BUILDING FROM A CORE SET OF SMART MICROSENSOR TECHNOLOGY

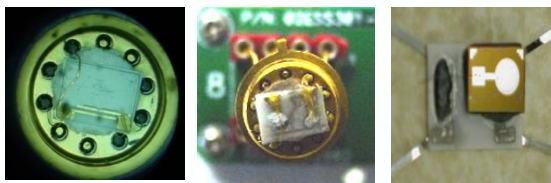


EXAMPLE APPLICATION: FIRE/ENVIRONMENTAL MONITORING COMBINE CHEMICAL SPECIES/PARTICULATE DETECTION IN SMART SYSTEM

- DECREASE FALSE ALARM RATE IN BOTH AERONAUTICS AND SPACE APPLICATIONS
- INTEGRATED FIRE AND ENVIRONMENTAL MONITORING SYSTEM
 - SINGLE SYSTEM COVERING BOTH FIRE AND ENVIRONMENTAL APPLICATIONS
 - COMPLEMENTARY SENSOR TECHNOLOGIES: CROSS-CORRELATION BETWEEN SENSOR ELEMENTS IMPROVES OVERALL SYSTEM MEASUREMENT
 - DEVELOPING MOBILE UNITS FOR FIRE FIGHTERS (HOMELAND SECURITY)
 - DATA STORAGE AND PROCESSING, BUILT-IN SELF CHECK; WIRELESS COMM OPTION

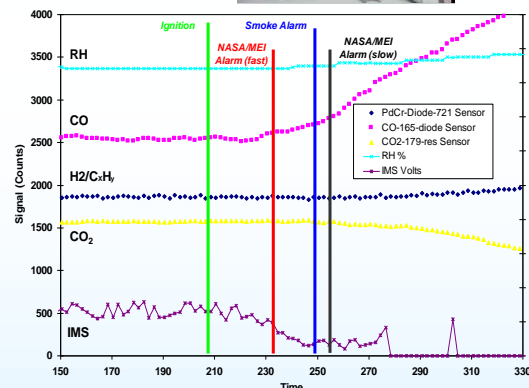


OPTICAL PARTICULATE SENSOR PACKAGE



REPRESENTATIVE PICTURES OF PACKAGE CHEMICAL SENSORS (CO, CO2, AND HYDROCARBONS)

Testing at FAA with Combined Particulate and Chemical Species System:
Advanced Detection of Fires with No False Alarms



Combine Particulate And Chemical Species Detection

Basic Approach:
Transition Hardware Into Core “Lick And Stick” Hardware Platform; Multiple Configurations Available



COMBINED FIRE/ENVIRONMENTAL MONITORING: STATIONARY AND HAND HELD UNITS (CHEMICAL SPECIES)

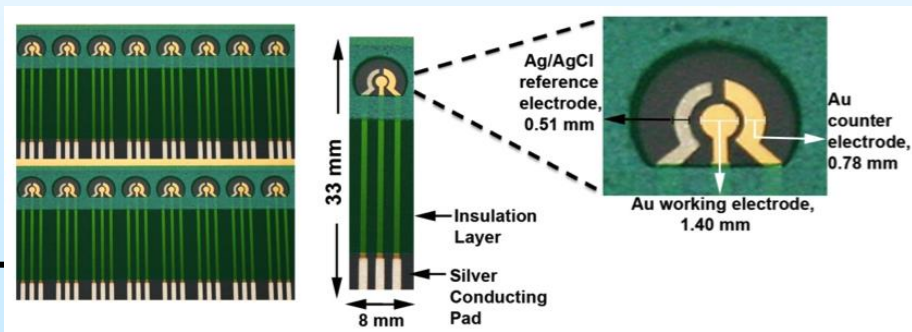


WIRELESS SENSOR AND NODE

WATER QUALITY MONITORING APPROACH

- **COMPLEMENT WATER BASED DETECTION WITH ATMOSPHERIC ENVIRONMENTAL MONITORING**
 - **WHOLE FIELD APPROACH**
 - **MULTIPLE SITES FOR REGIONAL COVERAGE**
 - **CORRELATE WITH OTHER MEASUREMENTS E.G. REMOTE MONITORING**
- **SENSORS TAILORED TO MEASURE TARGETED SPECIES AND PARTICULATES. EXAMPLE:**
 - **THREE ELECTRODE ELECTROCHEMICAL CELL: OPERATION IN BOTH AIR AND AQUEOUS ENVIRONMENTS**
 - **CAPABILITY TO BE TAILORED FOR DETECTION OF SPECIFIC SPECIES**
- **DEMONSTRATED AQUEOUS BASED CHEMICAL SPECIES MEASUREMENTS (INCLUDES MEASUREMENTS IN DIVERSE MEDIA, E.G., BLOOD):**
 - **BIOLOGICAL OXYGEN DEMAND (BOD)**
 - **pH**
 - **HEAVY METAL IONS**
- **PARTICULATE FLUID MONITORING DEMONSTRATED**
 - **SPACE ACT AGREEMENT ACTIVITY RELATED TO LIQUID-BASED PROCESS PARTICLE MONITORING**
 - **TECHNIQUE CAN BE TAILORED FOR SPECIFIC PARTICLE MORPHOLOGIES**

Three Electrode
Electrochemical Sensor
Configuration: Modify for
Selective Monitoring of
Targeted Constituents





WATER QUALITY/ATMOSPHERE MONITORING APPROACH

ESTABLISH MULTIPARAMETER SMART SENSOR CAPABILITIES

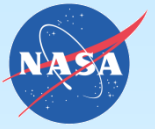
- **COMBINE CHEMICAL SPECIES AND PARTICULATE DETECTION APPROACHES TO TARGET WATER TOXINS AND POLLUTANTS**
 - **BASELINE: BOD, PH, HEAVY METAL IONS**
 - **EXPAND ARRAY TO SPECIFIC TOXINS E.G., ARSENIC, FLUORIDE AND CHLORINE**
 - **TARGET MORPHOLOGIES OF BIOLOGICAL SPECIES**
- **DETECTION OF OTHER TARGETS OF INTEREST, FOR EXAMPLE, MICROCYSTIN-LR**
 - **BIND ANTIBODY TO SENSOR ELECTRODE STRUCTURE**
 - **CHANGES IN ELECTRICAL SIGNAL DUE TO CHANGES IN ANTIBODY**
 - **CAN BE INCLUDED IN WATER MONITORING ARRAY**
- **PROVIDE SMART SENSOR SYSTEM TECHNOLOGY TO MONITOR BOTH ATMOSPHERE/WATER**
 - **COUPLED WITH SMART HARDWARE FOR DATA PROCESSING AND STORAGE**
 - **ESTABLISH MONITORING STATIONS OVER A REGION (BOTH WATER BASED AND ATMOSPHERIC)**
 - **WIRELESS NODES TO FORM BROAD REGIONAL NETWORK**
 - **CORRELATION OF MEASURED PROPERTIES TO:**
 - **SEASONAL PATTERNS (E.G. FARM RUNOFF) AND POLLUTION**
 - **OCCURRENCE OF DISRUPTIVE EVENTS (E.G., ALGAE BLOOMS)**
 - **INDICATIONS OF CHANGE IN LOCAL PROPERTIES**

CORE POINT: IN ORDER TO UNDERSTAND WATER QUALITY, A MULTIPARAMETER, REGIONAL APPROACH NEEDED TO IDENTIFY CAUSATION AND CHANGES



SUMMARY AND LONG-TERM VISION

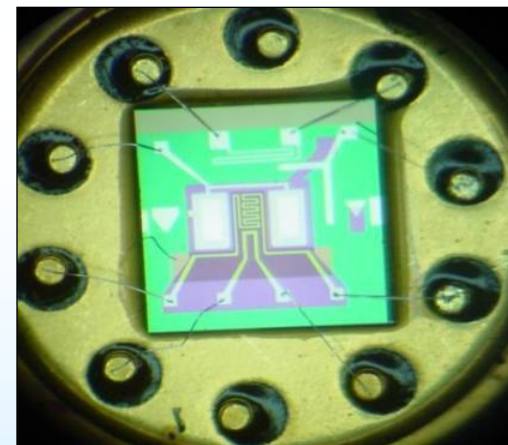
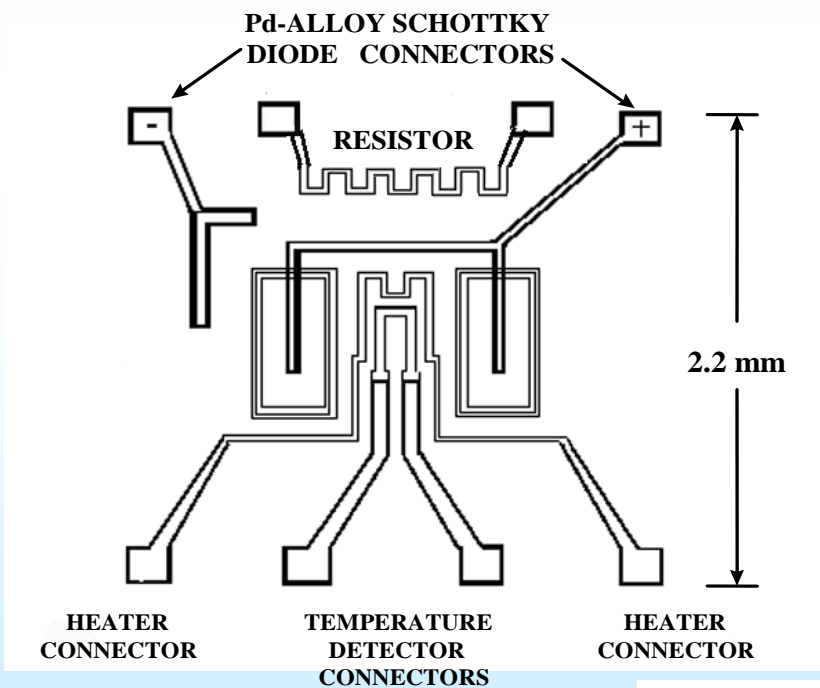
- **SMART SENSOR SYSTEM TECHNOLOGY DEVELOPED USING BASE PLATFORM TECHNOLOGY AND MICROSYSTEMS**
 - **MULTIPARAMETER, SELECTIVE MICROSENSOR APPROACH**
 - **INTEGRATION INTO SMART SENSOR SYSTEMS WITH A MICROPROCESSOR, DATA STORAGE, AND COMMUNICATION CAPABILITIES**
 - **SYSTEMS FOR TARGETED APPLICATIONS DEMONSTRATED**
- **WATER QUALITY MONITORING: WHOLE FIELD APPROACH: BOTH WATER AND AIR MONITORING IN PARALLEL**
- **ADOPT SMART SENSOR SYSTEM APPROACH**
 - **SELECTIVE, MULTIPARAMETER SENSOR TECHNOLOGY**
 - **INTEGRATED WITH SMART SYSTEM HARDWARE**
 - **REGIONAL MONITORING WITH WIRELESS NODES**
- **CORE TECHNOLOGIES EXIST; TARGETED DEVELOPMENT NEEDED FOR THIS APPLICATION**
 - **SPECIFIC TOXINS AND BIOLOGICAL PARAMETER**
 - **IMPLEMENTATION OF SYSTEMS**
 - **CORRELATION OF RESULTS**
- **THE WATER SYSTEM IS A CONNECTED SYSTEM: MONITORING WATER QUALITY NEEDS A WHOLE FIELD APPROACH**
 - **SMART SENSOR SYSTEMS CAN BE USED TO PROVIDE BASIC IN-SITU INFORMATION FOR MODELS AND CORRELATION OF EVENTS**

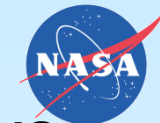


Back-Up Slides

HYDROGEN LEAK SENSOR TECHNOLOGY

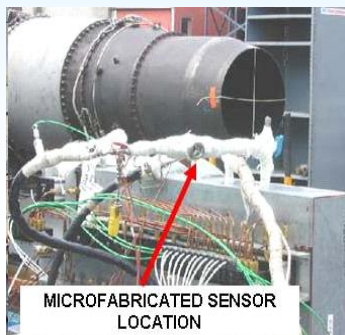
- **MICROFABRICATED USING MEMS-BASED TECHNOLOGY FOR MINIMAL SIZE, WEIGHT AND POWER CONSUMPTION**
- **DESIGNED TO OPERATE WITHOUT OXYGEN AND IN VACUUM ENVIRONMENTS**
- **HIGHLY SENSITIVE IN INERT OR OXYGEN-BEARING ENVIRONMENTS, WIDE CONCENTRATION RANGE DETECTION**
- **TWO SENSOR SYSTEM FOR FULL RANGE DETECTION: FROM PPM LEVEL TO 100%**





A WIDE RANGE OF SYSTEM DEMONSTRATIONS AND APPLICATIONS “LICK AND STICK” CORE HARDWARE

**Jet Engines
Emissions**



**Aircraft Fire
Detection**



Breath Monitoring



**NASA Helios
Fuel Cells**



**International Space
Station Safety System**



**Rocket Engine
Teststands**



**Environmental
Monitoring**

