Considerations for Sensor Technology Development and Implementation

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NSF's Convergence Accelerator: Real-world Chemical Sensing Applications Panel Discussion
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APPROACH
Smart Sensing and Electronics Systems Branch (LCS)

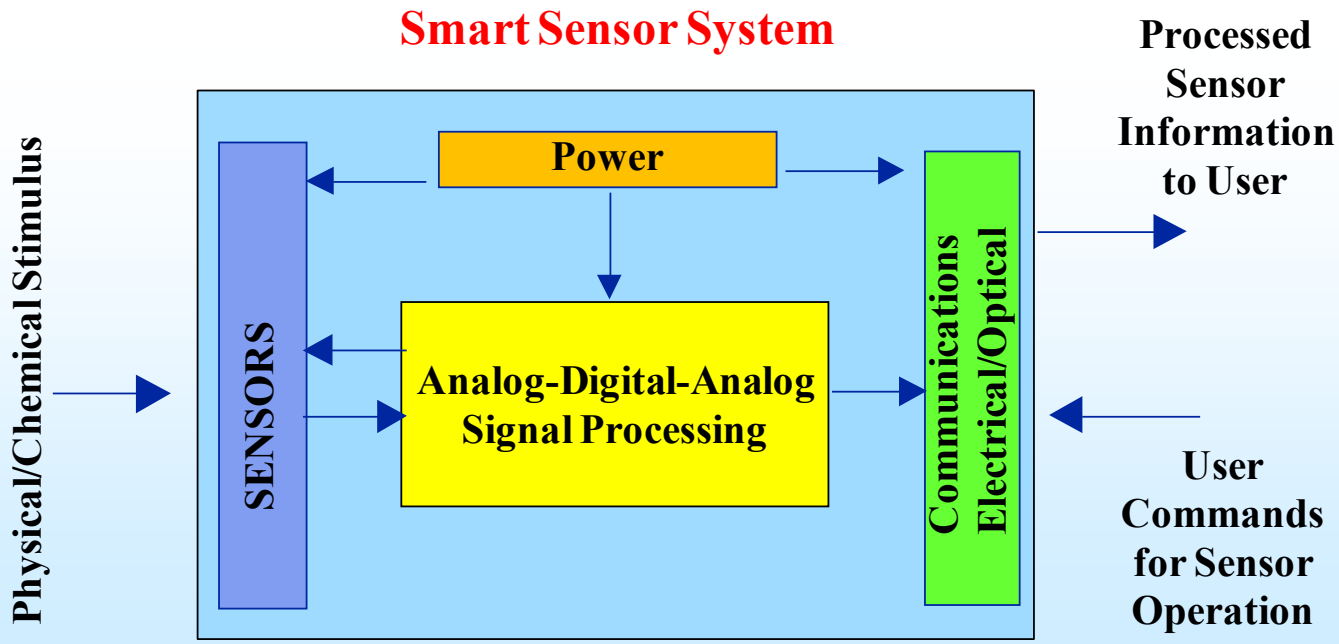
Interdisciplinary group of electronic engineers, chemists, materials engineers and physicists that can provide **Smart and Small Sensor Systems** to a broad range of aerospace applications.

- Using unique in-house capabilities, we produce ,cutting edge sensor system technologies that provide critical information (data), thus, enabling vastly improved decision-making capability, whether it be regarding designs, operations, the environment, or hazards.
- Our work, to quote Galileo, is to *"Measure what is measurable, and make measurable what is not so".*
- In this modern era, making a measurement does not just involve a sensor element (like a thermocouple), but rather a whole sensor system that provides:
  - Multiparameter information needed to understand the problem;
  - Local processing to optimize the quality and relevance of that information;
  - Communication of that information in a manner that best fits the application; and
  - Tailoring of each integrated sensor system to meet the needs of the application

In this Information Age, we suggest that small, smart sensor system technologies are an enabling first step in acquiring information (data) about an aerospace system and/or an environment, leading to cognition and decision-making capabilities.

SMART SENSOR SYSTEMS BASED ON MICROSYSTEMS TECHNOLOGY

- A Range Of Sensor Systems Are Under Development Based On Microfabrication Techniques And Smart Sensor Technology
- Smart Sensor Systems Approach: Stand-alone, Complete Systems Including Sensors, Power, Communication, Signal Processing, And Actuation
- Microsystems Technology Moving Towards A Range Of Applications
- Enable System Level Intelligence By Driving Capabilities To The Local Level Using Distributed Smart Systems



BASIC APPROACH:
MAKE AN INTELLIGENT SYSTEM FROM SMART COMPONENTS
POSSIBLE STEPS TO REACH INTELLIGENT SYSTEMS

- **"LICK AND STICK" TECHNOLOGY (EASE OF APPLICATION)**
  - **Micro and nano fabrication to enable multipoint inclusion of sensors, actuators, electronics, and communication throughout the vehicle without significantly increasing size, weight, and power consumption. Multifunctional, adaptable technology included.**

- **RELIABILITY:**
  - **Users must be able to believe the data reported by these systems and have trust in the ability of the system to respond to changing situations e.g. decreasing sensors should be viewed as decreasing the available information flow about a vehicle. Inclusion of intelligence more likely to occur if it can be trusted.**

- **REDUNDANCY AND CROSS-CORRELATION:**
  - **If the systems are easy to install, reliable, and do not increase weight/complexity, the application of a large number of them is not problematic allowing redundant systems, e.g. sensors, spread throughout the vehicle. These systems will give full-field coverage of the engine parameters but also allow cross-correlation between the systems to improve reliability of sensor data and the vehicle system information.**

- **ORTHOGONALITY:**
  - **Systems should each provide a different piece of information on the vehicle system. Thus, the mixture of different techniques to "see, feel, smell, hear" as well as move can combine to give complete information on the vehicle system as well as the capability to respond to the environment.**

SENSOR SYSTEM IMPLEMENTATION

- OBJECTIVE: A SELF-AWARE INTELLIGENT SYSTEM COMPOSED OF SMART COMPONENTS MADE POSSIBLE BY SMART SENSOR SYSTEMS

- SENSOR SYSTEMS ARE NECESSARY AND ARE NOT JUST GOING TO SHOW UP WHEN NEEDED/TECHNOLOGY BEST APPLIED WITH STRONG INTERACTION WITH USER

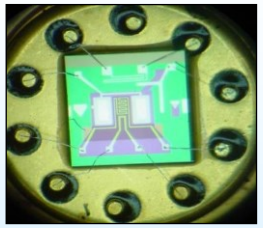
- SENSOR SYSTEM IMPLEMENTATION OFTEN PROBLEMATIC
  - LEGACY SYSTEMS
  - CUSTOMER ACCEPTANCE
  - LONG-TERM VS SHORT-TERM CONSIDERATIONS
  - SENSORS NEED TO BUY THEIR WAY INTO AN APPLICATION

- POSSIBLE LESSONS LEARNED
  - SENSOR SYSTEM NEEDS TO BE TAILORED FOR THE APPLICATION
  - MICROFABRICATION IS NOT JUST MAKING SOMETHING SMALLER
  - NEW SENSING MECHANISMS CAN HAVE A NOTABLE IMPACT
  - ONE SENSOR OR EVEN ONE TYPE OF SENSOR OFTEN WILL NOT SOLVE THE PROBLEM: THE NEED FOR SENSOR ARRAYS
  - SUPPORTING TECHNOLOGIES OFTEN DETERMINE SUCCESS OF A SYSTEM

"LICK AND STICK" SENSOR SYSTEM

- SENSORS, POWER, AND TELEMETRY SELF-CONTAINED IN A SYSTEM NEAR THE SURFACE AREA OF A POSTAGE STAMP
- MICROPROCESSOR INCLUDED/SMART SENSOR SYSTEM
- ADAPTABLE CORE SYSTEM WHICH CAN BE USED IN A RANGE OF APPLICATIONS
- MULTIPLE CONFIGURATIONS AVAILABLE, INCLUDING BATTERY OR CONNECTED POWER
- IN-FLIGHT AND GROUND OPERATION APPLICATIONS

Hydrogen Leak Sensor Technology



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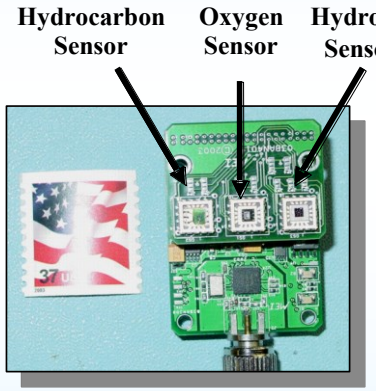
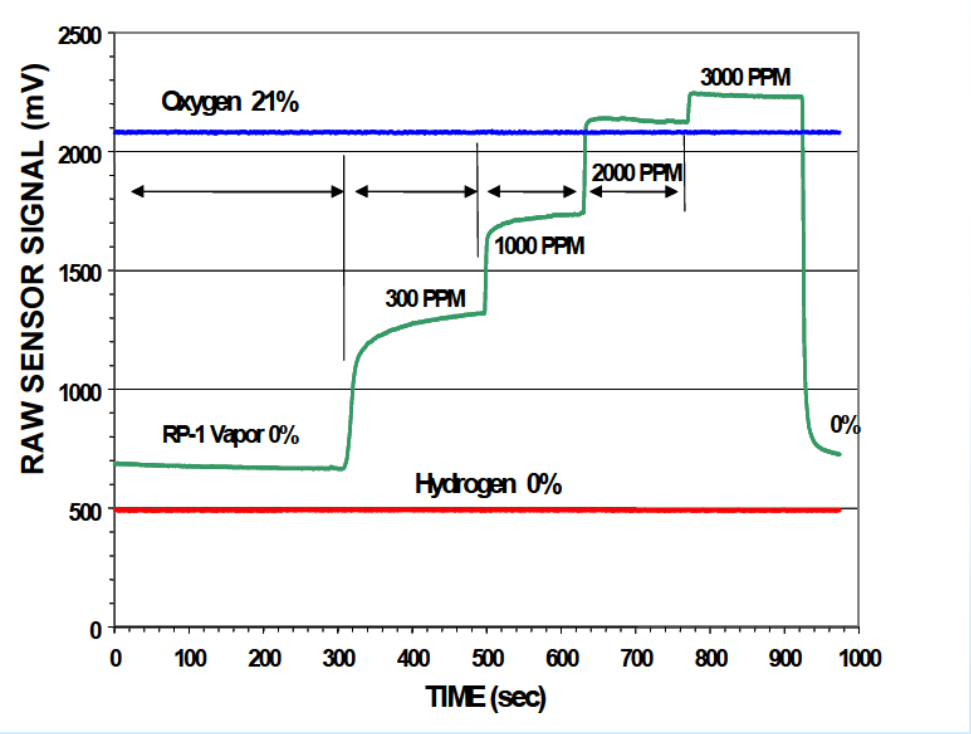
PACKAGED SiC-BASED SENSOR

NOMINATED TWICE FOR NASA INVENTION OF THE YEAR

Multiple Wireless Configurations



Wireless Data Transmission/Orthogonal Detection



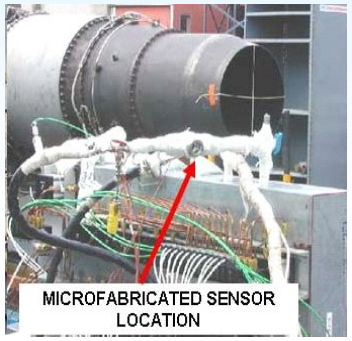
MAKEL ENGINEERING

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

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

International Space Station Safety System

Jet Engines Emissions



Aircraft Fire Detection

Exercise Monitoring

NASA Helios Fuel Cells

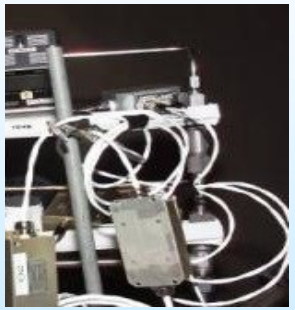
First Responder Monitoring

Human Health Breath Monitoring

Launch Vehicle Leak Detection

Rocket Engine Teststands

Environmental Monitoring



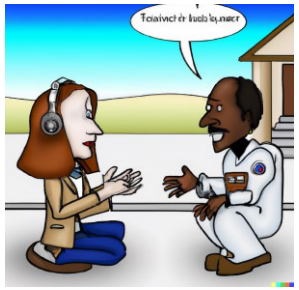
Cryogenic Fuel Line Monitoring

Long Lived Venus Surface Missions

Convergent Aeronautic Solutions (CAS) Project

COLLABORATE - Podcast series Foresight Series Modeling

SOURCES



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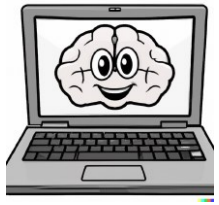
COLLABORATIVE EXPLORATION, ANALYSIS & IDEATION



TRENDS, NEEDS, CAPABILITIES

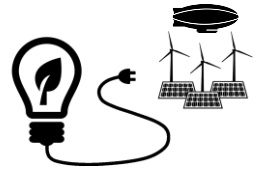
FUTURE SCENARIOS

DYSTOPIAN

UTOPIAN

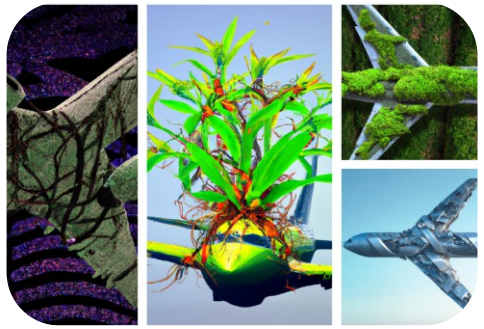
POTENTIAL PROBLEM AREAS

HIGH RISK
HIGH REACH
HIGH IMPACT

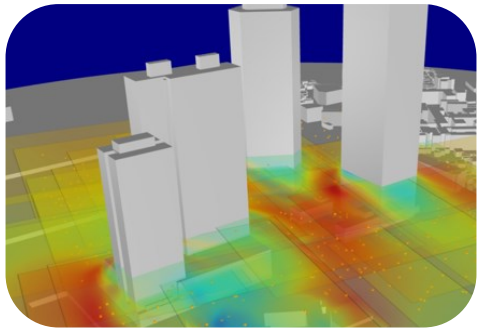


Examples of CAS work

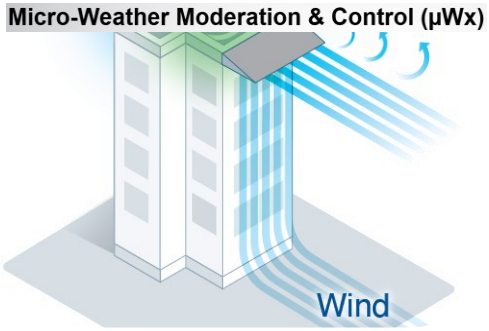
a new cooperative operating mode to complement VFR and IFR



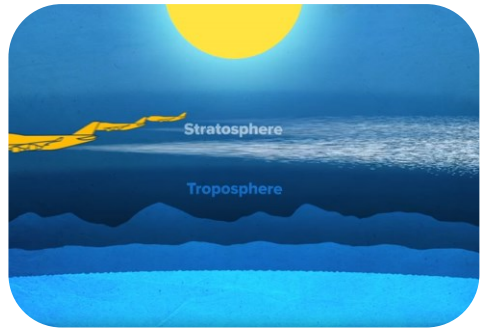
SUMAC (SUstainable Manufacturing of AirCraft)



Ubiquitous Weather Sensing (UWS)



demonstrate moderating microweather conditions to enable safe / reliable urban air operations

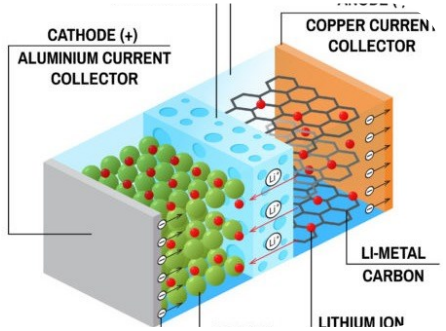


Carbon Negative Aviation

Scalable Traffic Management for Emergency Response Operations

Capabilities, Communities, Connectivity (3C)

Energy Augmentation for Vehicle Electric Systems (EAVES)



Sensor-based Prognostics to Avoid Runaway Reactions & Catastrophic Ignition (SPARRCI)

SUbsonic Single Aft eNgine (SUSAN)

Backup Slides

Smart Sensing and Electronics Systems Branch (LCS)

Description

Conducts research and development of **adaptable instrumentation to enable intelligent measurement systems** for ongoing and future aerospace propulsion and space exploration programs. Emphasis is on smart sensors and electronics systems for diagnostic engine health monitoring, controls, safety, security, surveillance, and biomedical applications**; often for high temperature/harsh environments**.

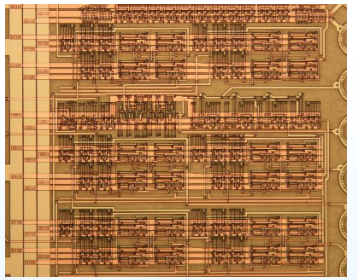
Microsystems Fabrication Facility

Facilities/Labs

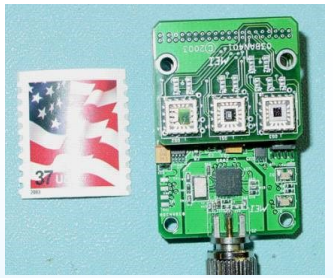
- Microsystems Fabrication Facilities
  - Class 100 Clean Room
  - Class 1000 Clean Room
- Chemical vapor deposition laboratories
- Chemical sensor testing laboratories
- Harsh environment laboratories
  - Nanostructure fabrication and analysis
  - Sensor and electronic device test and evaluation

Core Capabilities (technical areas)

- Silicon Carbide (SiC) - based electronic devices
  - Sensors and electronics for high temp (600° C) use
  - Wireless sensor technologies, integrated circuits, and packaging
- Micro-Electro-Mechanical Systems (MEMS)
  - Pressure, acceleration, fuel actuation, and deep etching
- Chemical gas species sensors
  - Leak detection, emission, fire and environmental, and human health monitoring
- Microfabricated thin-film physical sensors
  - Temperature, strain, heat flux, flow, and radiation measurements
- Harsh environment nanotechnology
  - Nano-based processing using microfabrication techniques

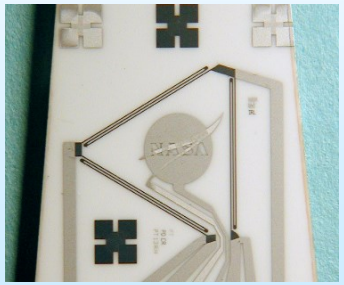


SiC Signal Processing



Leak Detection Sensors

Thin Film Physical Sensors



Emissions Sensor Suite Volcanic Ash Testing

OBJECTIVE

- Demonstrate the ability to diagnose engine faults and performance loss effects using a multiparameter emission sensor array

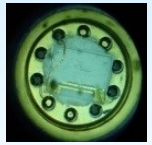
APPROACH

- Engine Emission Monitoring System developed using selective microsensors and smart electronics
- Includes the capability to measure CO, CO2, O2, hydrocarbons, and NOx.
- Sensor suite mounted at engine exhaust and exposed to both nominal conditions and simulated faults, as well as volcanic ash

RESULTS AND SIGNIFICANCE

- (Preliminary/Volcanic Ash)
- Emissions Sensor Array Monitored Engine Emissions during Days 1-3, 5 of Ash runs
- Days 1-3: Candidate “Steady-State” Emissions Parameter Identified
- Day 5 Deviation in “Steady State” Emissions Profile Suggestive of Change in Engine State During Heavy Volcanic Ash Deposition
  - ➢ Not Presently Explainable By Reference to Other Engine Parameters

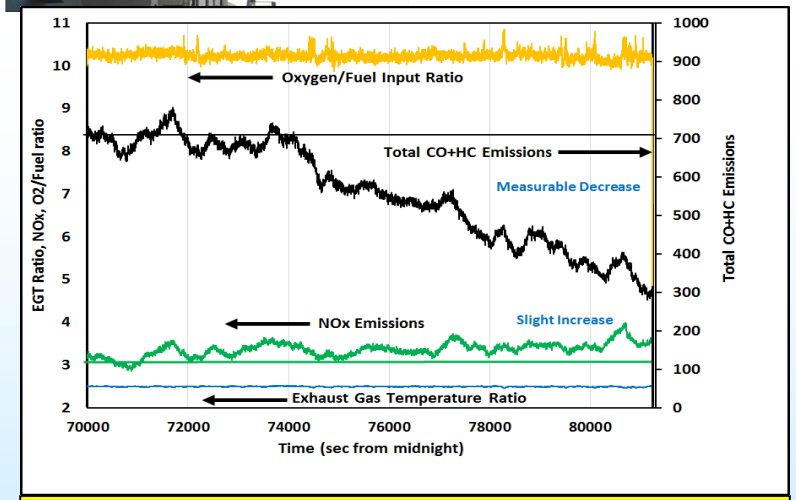
Multiparameter Engine Exhaust Measurements Track Major Species



CO sensor

Sensor probe

Sensor probes in emissions testing rig manifold



Preliminary Emissions Data –
- **Pattern Established Over Several Runs**
- **Deviations from Baseline Observed Suggesting Possible Volcanic Ash Effects**

Micro-Fabricated Gas Sensors for Fire Detection and Environmental Monitoring

- Enhanced Environmental/Hazard Monitoring With Multiparameter Approach
- Demonstrated Reduction Of Fire False Alarms In Aircraft Cargo Bay With Improved Understanding Of The Environment
  - FAA Cargo Bay Simulation Testing: *No False Alarms/Consistent Detection Of Fires*
- Environmental Monitoring nd Fire Detection; Dual Use System Targeting Key Species Of Interest To Human Health In Multiple Configurations
- First Responder Applications On-going: Portable Monitor For Exposure To Hazardous Species And Improved Situational Awareness

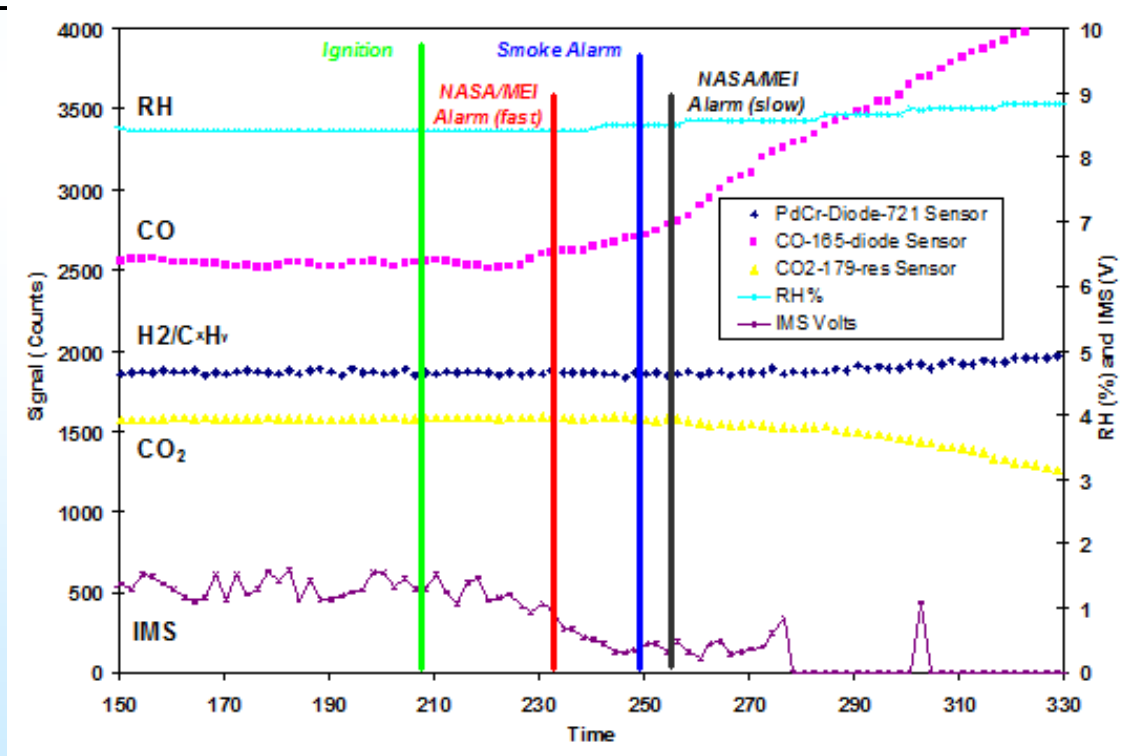
SMART SPACE FIRE DETECTION SYSTEM

HAND HELD UNIT

WIRELESS MODULE

FAA Cargo Bay Fire Simulation Aircraft

AIRCRAFT CARGO BAY FIRE DETECTION



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