NASA
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PRESENTATION 4.3.8

SPACE TRANSPORTATION PROPULSION SYSTEMS SYMPOSIUM

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NASA/SSC

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NASA
Stennis Space Center

Presented to: "1990 Symposium on Space Transportation Propulsion Systems Technology"

At: Conference Center of Pennsylvania State University in University Park, Pennsylvania

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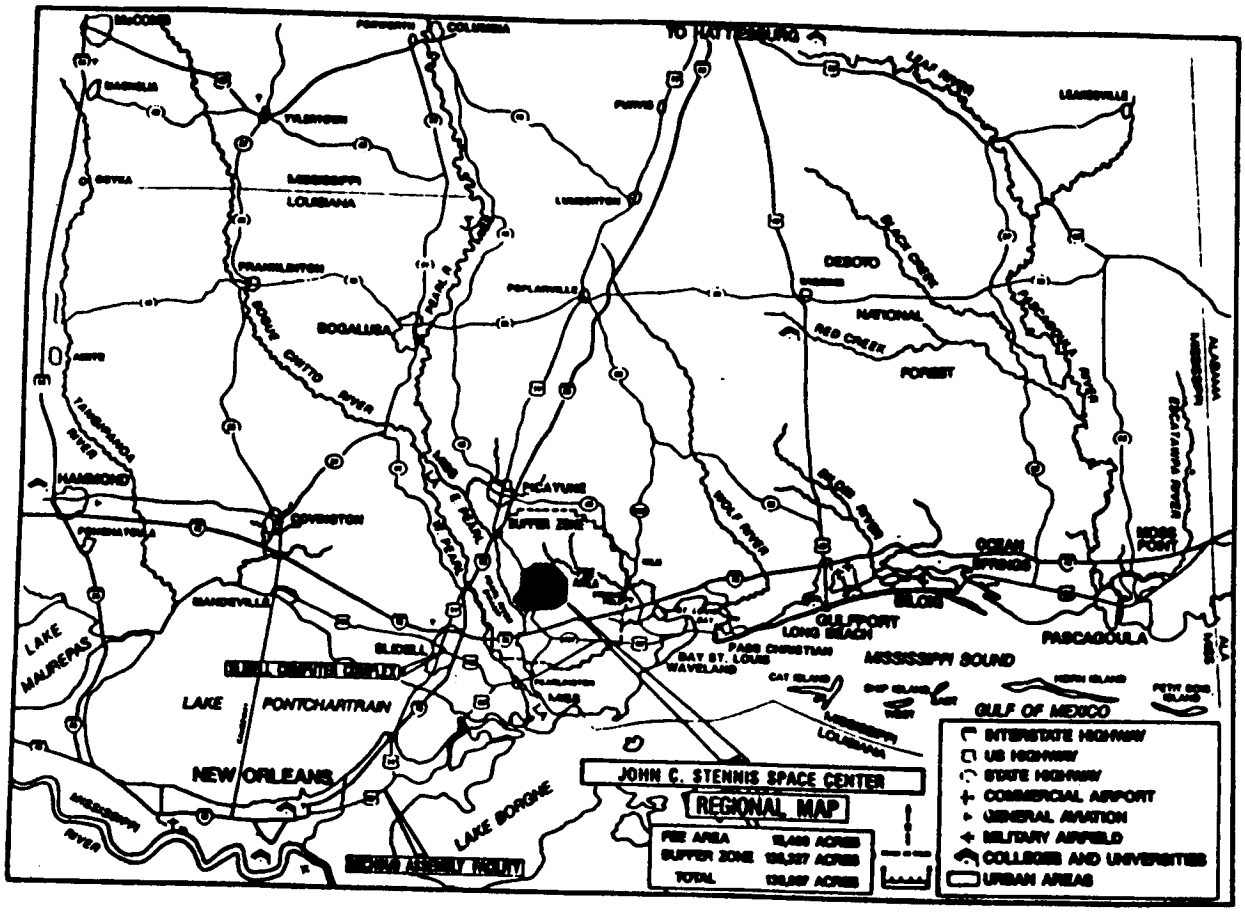

JOHN C. STENNIS SPACE CENTER
ROLES AND MISSIONS

- Provide, manage, and operate facilities, laboratories, and related capabilities essential to the development testing of propulsion systems including the Space Shuttle Main Engine, the Advanced Launch System, and the Advanced Solid Rocket Motor
- Conduct research and development in propulsion test technologies including cryogenics, high-pressure gas, metrology, engine diagnostics, and safe operations
- Conduct research and technology development to support NASA goals in earth and environmental system sciences and observations, commercialization of remote sensing, and applications development
- Provide technical and institutional support services to resident agencies

MAJOR CONTRACTORS AT SSC

- Rockwell International (MPTA)
- Rocketdyne (SSME Testing)
- Martin-Marietta (External tank Support)
- Ford Aerospace-BDM Division (Support)
- Pan Am World Services, Inc. (Facilities Services)
- Sverdrup Technology, Inc. (Technical Services)
- Lockheed Engineering and Sciences Company (Remote Sensing, R&D Support)
- Quad S Company (Security Services)
- Mason Chamberlain, Inc. (Mississippi Army Ammunition Plant)
- Computer Sciences Corporation (NOAA National Data Buoy Center Support Services)

PROPULSION TEST TECHNOLOGY DEVELOPMENT AT SSC

- Technology development complements test operations
- SSC has 25 years of large engine ground testing experience
- SSC has the capability for long duration static firings (2,000 seconds)
- Three active, greater than 500,000 pound thrust, test stands (one sea level and two altitude test stands)
- SSC has signficant experience in handling large quantities of liquid hydrogen, oxygen and nitrogen
- Current SSME test program and future test programs offer windows of opportunity for developing non-intrusive and diagnostic instrumentation and validating computational codes
- SSC has a very active plume diagnostic test program to develop advanced non-intrusive instrumentation systems
- Advanced ground test instrumentation/control systems and techniques can be developed economically
- SSC has extensive experience and expertise in non-intrusive remote sensing optical instrumentation sensors and systems
- Authorized by SSC charter

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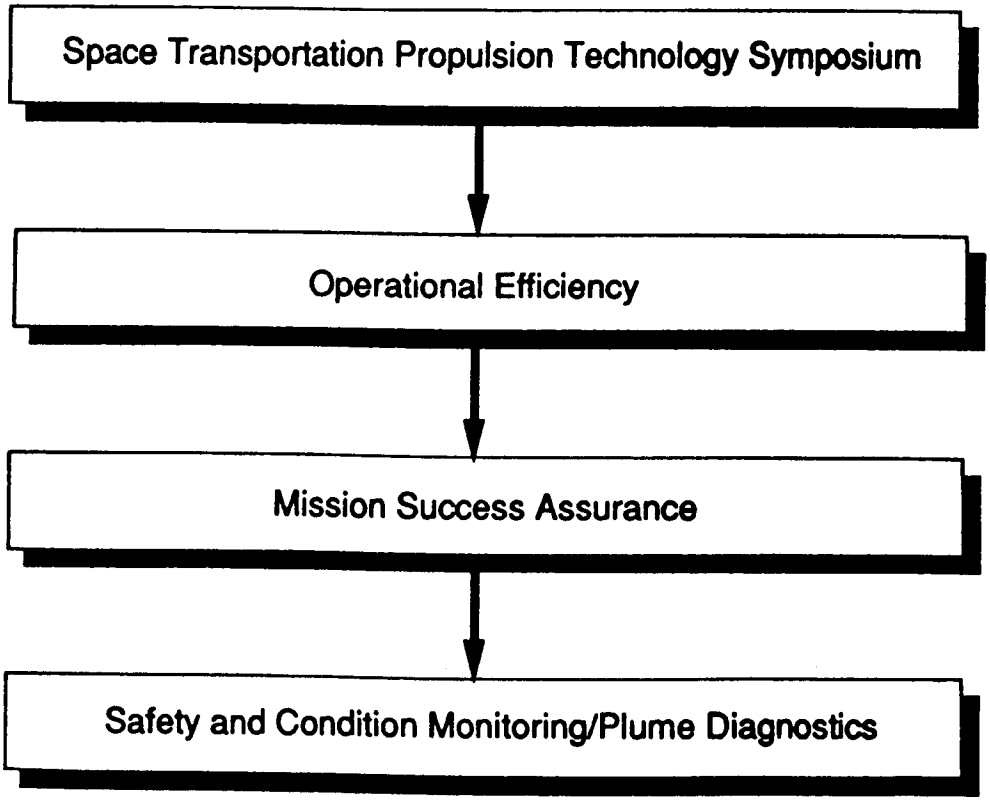
SPACE SHUTTLE MAIN ENGINE (SSME) TESTING PROGRAM

Year	No. of Tests	Seconds of Testing	Cryogens/Gases Consumption			
			Lox (Tons)	LH2 (Tons)	LN2 (Tons)	GHe (SCF)
1987	81	33,738	26,285	4,067	12,604	19,636,000
1988	89	40,414	34,873	5,020	16,166	22,523,000
1989	83	35,319	29,665	4,304	17,567	18,043,000
1990*	49	18,454	15,523	2,314	7,914	8,580,000

**Through May 1990*

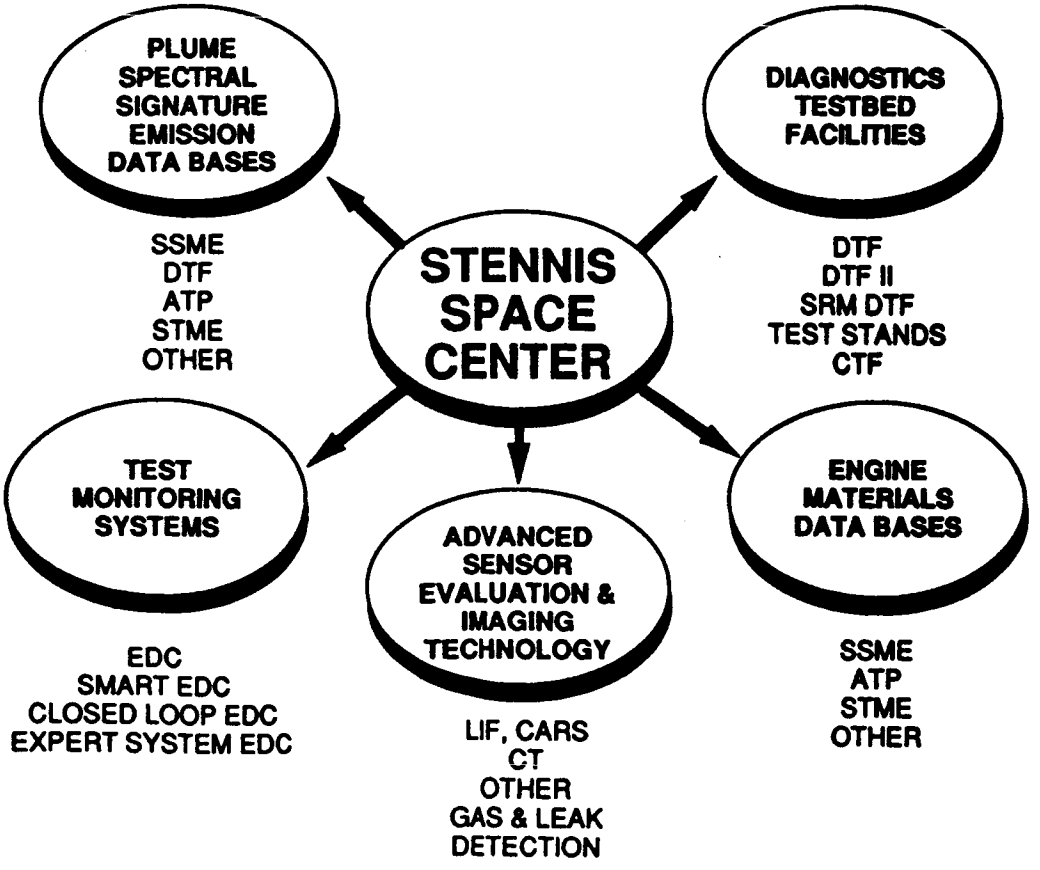


Plume Diagnostics:

- Diagnostics testbed facility (DTF) characteristics
- Engine plume diagnostics instrumentation
- DTF test/experiment results
- Applications on SSC test stands
  - A-1, Sea Level/Ambient
  - B-1, Aspirated/Diffuser

Safety and Condition Monitoring:

- Smart hydrogen sensor (SHS) and fugitive gas detection system (FGDS)
- Thermal infrared imaging technology development



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PROPULSION TEST TECHNOLOGY
RELATED TECHNOLOGY DEVELOPMENT FACILITIES

Facility	Accomplishments	Facility Use
*Diagnostics Testbed Facility • 1200# Thruster • LOX/GH2 and Alternate fuels capability • Thrust chamber seeding capability • Small, inexpensive, accessible, flexible, quick-turnaround facilty	EDC - Engine (Plume) Diagnostics Console SHS - Smart Hydrogen Sensor	• Development of engine diagnostics sensors, instrumentation, and systems • Training of propulsion test personnel • Propulsion test control and data acquisition technology testbed • Leak detection testbed • Propulsion testing sensor and cryogenics testbed
*Electro-Optics Laboratory • Lasers • Spectrometers • Optical tables • Reference Calibration Sources • Optical Systems	STI - Shuttle Thermal Imager IDS - Ice Detection System OMA - Optical Mulichannel Analyzer	• Non-intrusive systems development, prototyping, maintenance, and calibration area
*Advanced Sensor Development Laboratory • Airborne remote sensing systems • Field remote sensing systems • Learjet Model 23 aircraft	TIMS - Thermal Infrared Multispectral Scanner CAMS - Calibrated Airborne Multispectral Scanner IRIS - Infrared Intelligent Scanner PRT5 - Precision Radiation Thermometer	• Remote sensing systems design, development, maintenance, calibration, and electro-optic systems study

DIAGNOSTICS TESTBED FACILITY CHARACTERISTICS

DIAGNOSTICS TESTBED FACILITY

EXPERIMENT PROGRAM:

Use DTF and SSME test stands to develop non-intrusive instrumentation to assist in optimizing operational testing frequency and safety.

DTF'S FUNCTION:

Allow precise exhaust plume seeding with trace levels of material specie to quantify spectral sensitivity and response time of spectrometer and advanced sensor based plume diagnostics instrumentation systems.

DIAGNOSTICS TESTBED FACILITY USAGE TO DATE

Acquisition, evaluation, and compilation of spectral database for SSME related elements and materials

Development of engine diagnostics sensors, instrumentation and systems

Training of test operations personnel

Control system proving ground

OMA/OPAD field verification

Hydrogen detection field experiments

Thermal image cryogenic leak detection experiments

Cryogenic liquid level sensor experiments

Mass flowmeter evaluation (LOX and GH2)

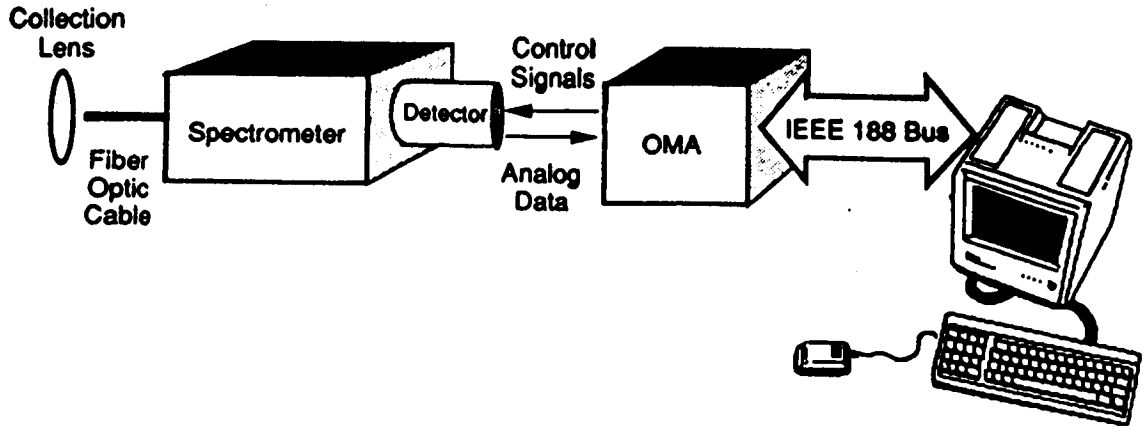
MSFC/LeRC Code R CSTI-ETO Projects

ENGINE PLUME DIAGNOSTICS INSTRUMENTATION

ENGINE PLUME DIAGNOSTICS

- Engine Plume Diagnostics System Development at SSC
  - OMA (Optical Multichannel Analyzer) on SSC test stands
  - EDC (Engine Diagnostics Console)
  - OMA & Video on Aspirated/diffuser Test Stand, B-1
  - OPAD (Optical Plume Anomaly Detector) Participant
- Bottom line - developed limited capability to look at SSME's exhaust plume to:
  - Call for engine shutdown to avoid major damage in many cases
  - Determine if a turbopump may be tested again before teardown
  - Post test anomaly resolution assistance

SYSTEM CONFIGURATION



DTF TEST/EXPERIMENT RESULTS

PLUME SEEDING TEST PLAN

Elements prioritized by:
A - Critical SSME component
B - Alloy or compound frequency of occurrence
C - Element frequency of occurrence

Group 1 Elements (High Priority)	Initial Survey Test Completed	Detection
Nickel (Ni)	X	YES
Iron (Fe)	X	YES
Chromium (Cr)	X	YES
Cobalt (Co)	X	YES
Calcium (Ca)	X	YES
Tungsten (W)	X	TBD
Manganese (Mn)	X	YES
Molybdenum (Mo)	X	TBD
Copper (Cu)	X	YES
Strontium (Sr)	X	YES

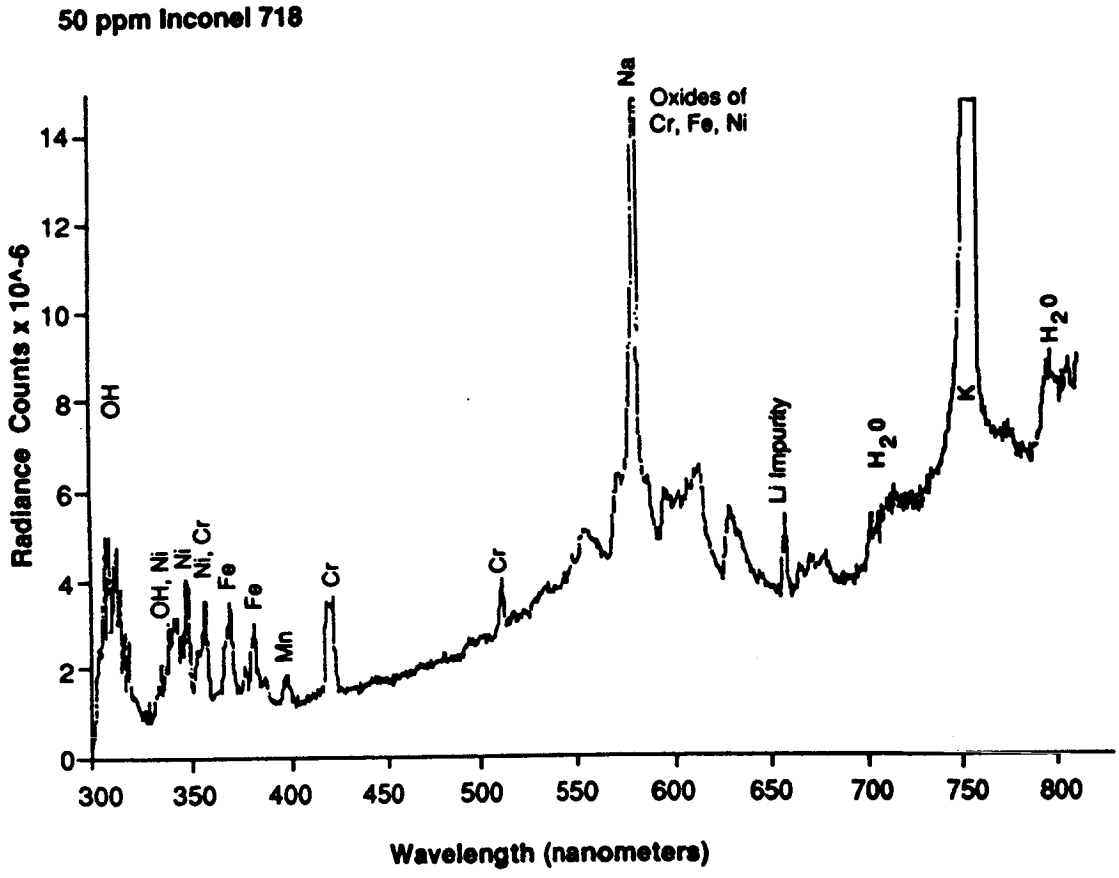
PLUME SEEDING TEST PLAN

Group 2 Elements (Intermediate Priority)	Initial Survey Test Completed	Detection
Aluminum (Al)	X	YES
Titanium (Ti)	X	YES
Silver (Ag)	X	YES
Tin (Sn)	X	TBD
Hafnium (Hf)	X	NO
Vanadium (V)	X	TBD
Yttrium (Y)	X	YES
Gold (Au)	X	TBD
Magnesium (Mg)	X	YES
Silicon (Si)	X	TBD
Tantalum (Ta)	X	TBD
Niobium (Nb)	X	NO
Zirconium (Zr)	X	TBD
Beryllium (Be)	Not to be Tested	TBD
Group 3 Element (Low Priority)		
Fluorine (F)		TBD
Chlorine (Cl)	X	NO
Carbon (C)		TBD
Zinc (Zn)	X	TBD
Lithium (Li)	X	YES
Rhodium (RI)	Not to be Tested	TBD
Palladium (Pd)	X	TBD

PLUME SEEDING TEST PLAN

Group I Materials	Initial Survey Test Completed
Inconel 718	X
Haynes 188	X
MAR-M 246+Hf	X
Waspaloy X	X
AISI 440C	X
NARloy-Z	X
MoS2	X
NiCrAlY	X
ZrO2 8% Y203	
PTFE	X
Armalon	

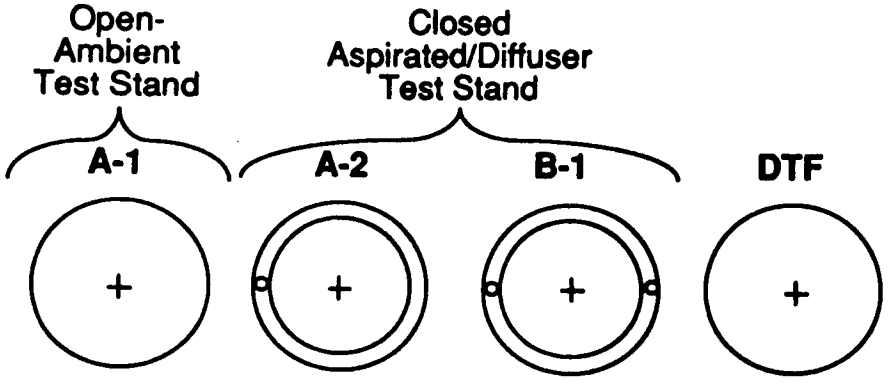
DTF DATA AT MACH DIAMOND LOCATION



ENGINE PLUME DIAGNOSTICS

APPLICATIONS ON SSC TEST STAND

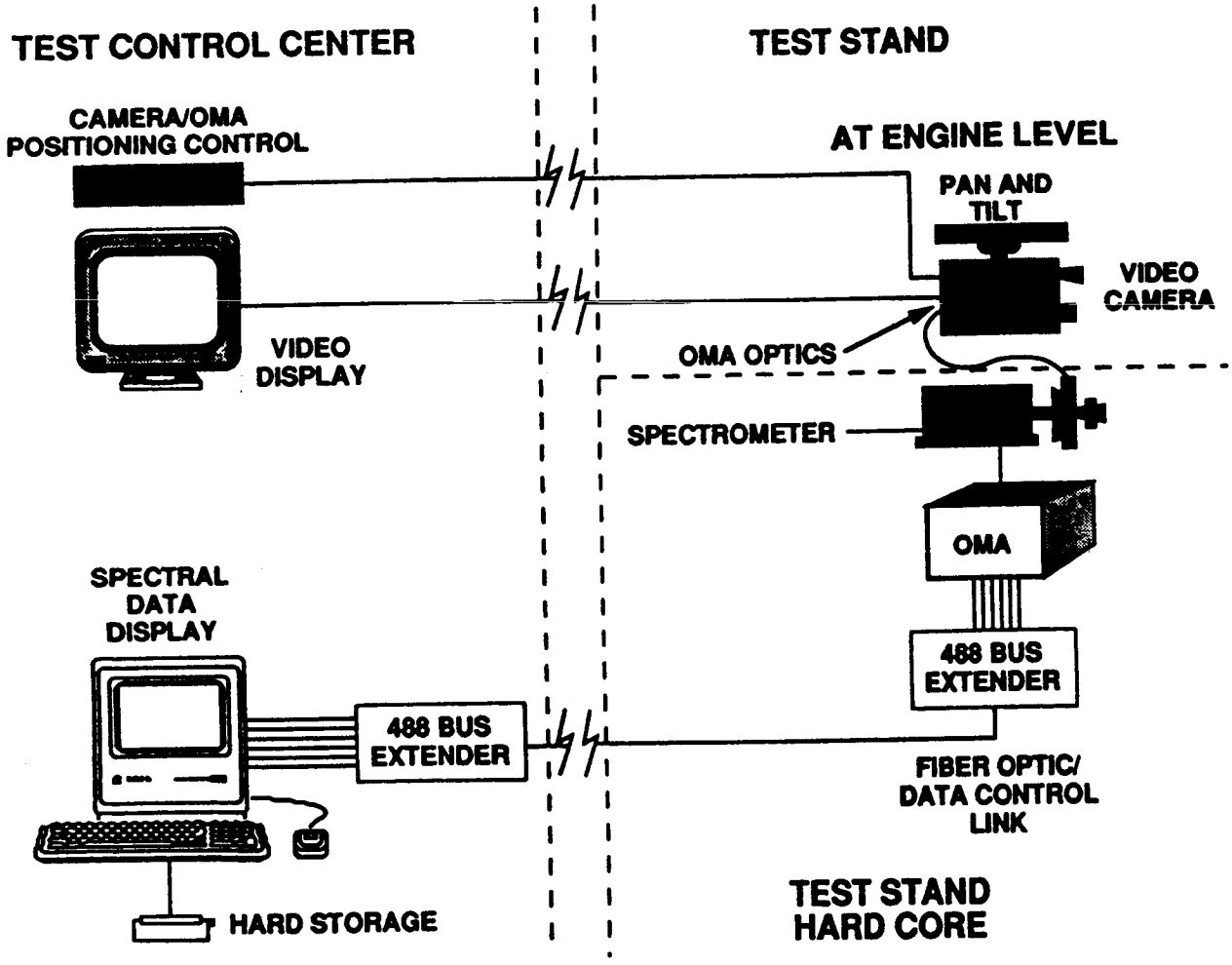
OMA Status:



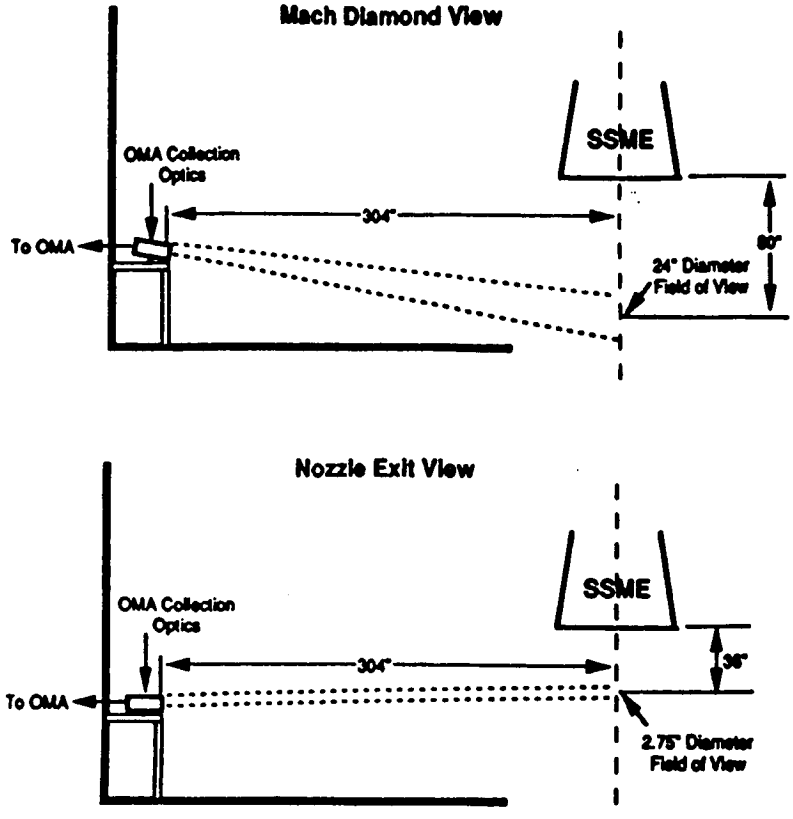
Planned:	3 OMAs	1 OMA	2 OMAs	1 OMA	= 7
Breakout:	2 OPS 1 EXP.	1 OPS	1 OPS 1 EXP.	1 EXP.	
Current Status:					
Under Development or Experimental	2 OMAs	Probe in Fabrication	1 OMA	1 OMA	
Operational	1 OMA	-	1 OMA	-	
Intensified array (IA)	1	1	1	1	= 4
Video	2	On-Order	On-Order	1	= 3 (2+1)

ENGINE PLUME DIAGNOSTICS

AMBIENT TEST STAND A-1

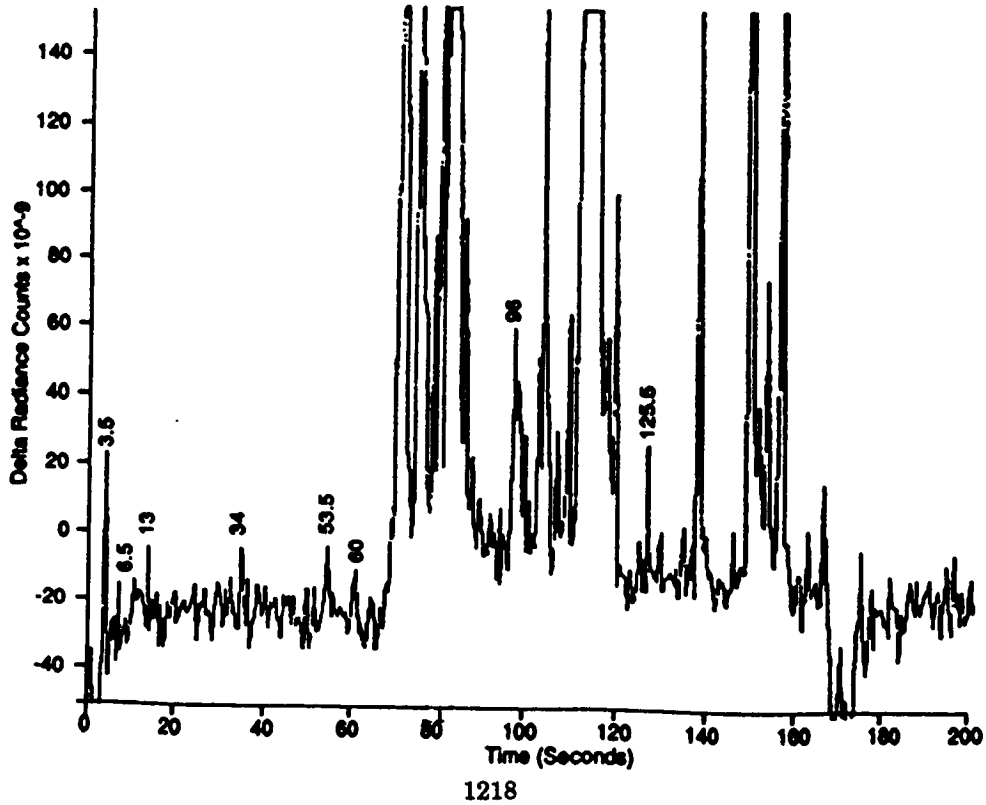


OMA CONFIGURATION



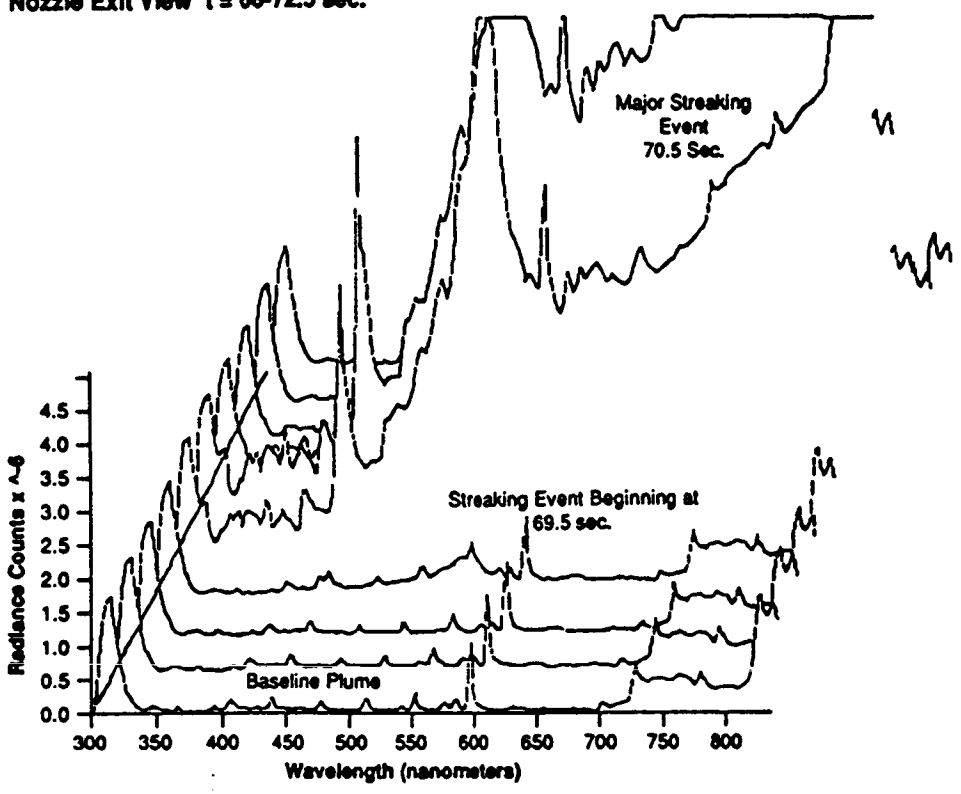
EXPANDED VIEW SHOWING MINOR FLASHES AND PRECURSORS TO MAJOR EVENTS

A1 Stand SSME Test: 901-619 Engine: 0209 1/31/90
CuH Peak Height (428 nm) Nozzle Exit View



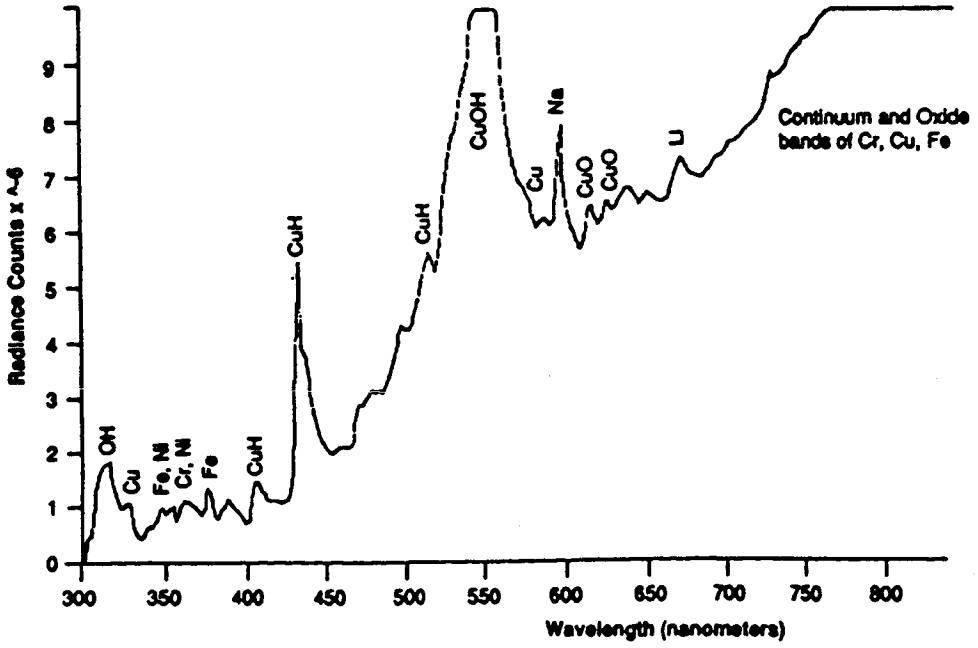
WATERFALL PLOT FROM 68 TO 72.5 SECONDS

A1 Stand SSME Test: 901-619 Engine: 0209 1/31/90
Nozzle Exit View t = 68-72.5 sec.



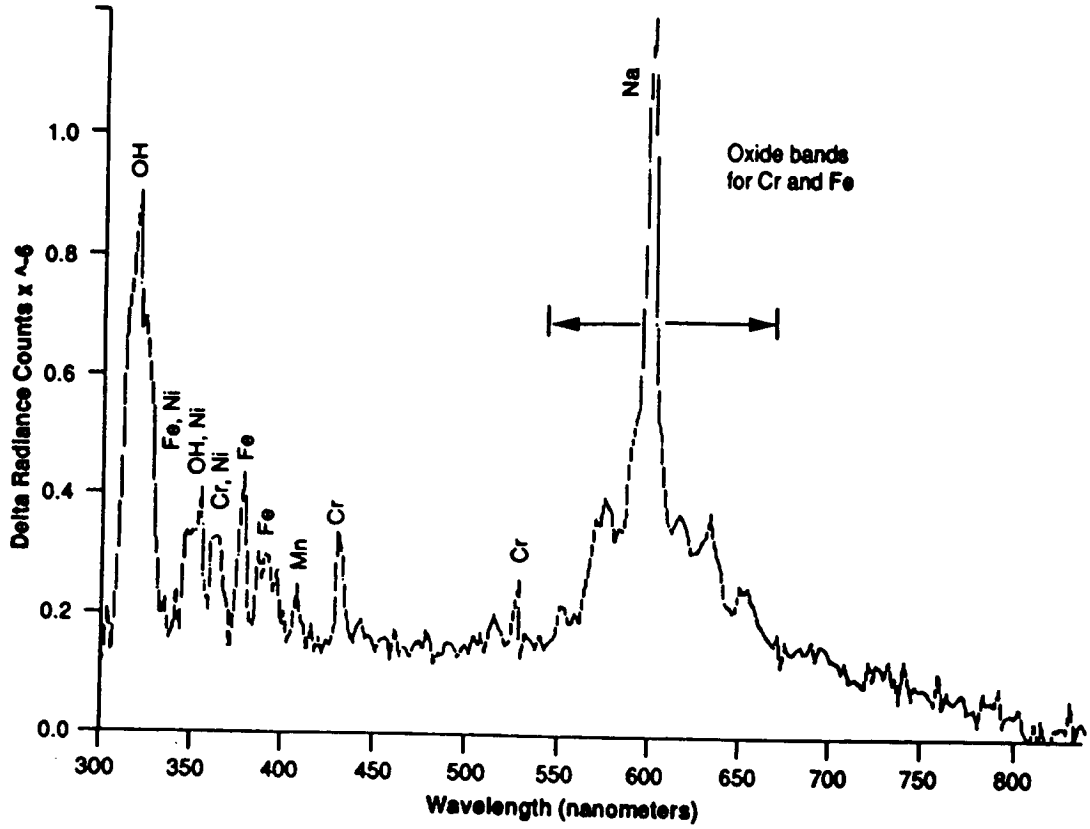
IDENTIFICATION OF MAJOR EMISSION PEAKS DURING STREAKING EVENTS AT 70.5 SECONDS

A1 Stand SSME Test: 901-619 Engine: 0209 1/31/90
Nozzle Exit View t = 70.5 sec.



MACH DIAMOND VIEW, SPECTRAL PLOT OF HARDWARE ENHANCED PLUME AT 71.0 SEC. AFTER IGNITION

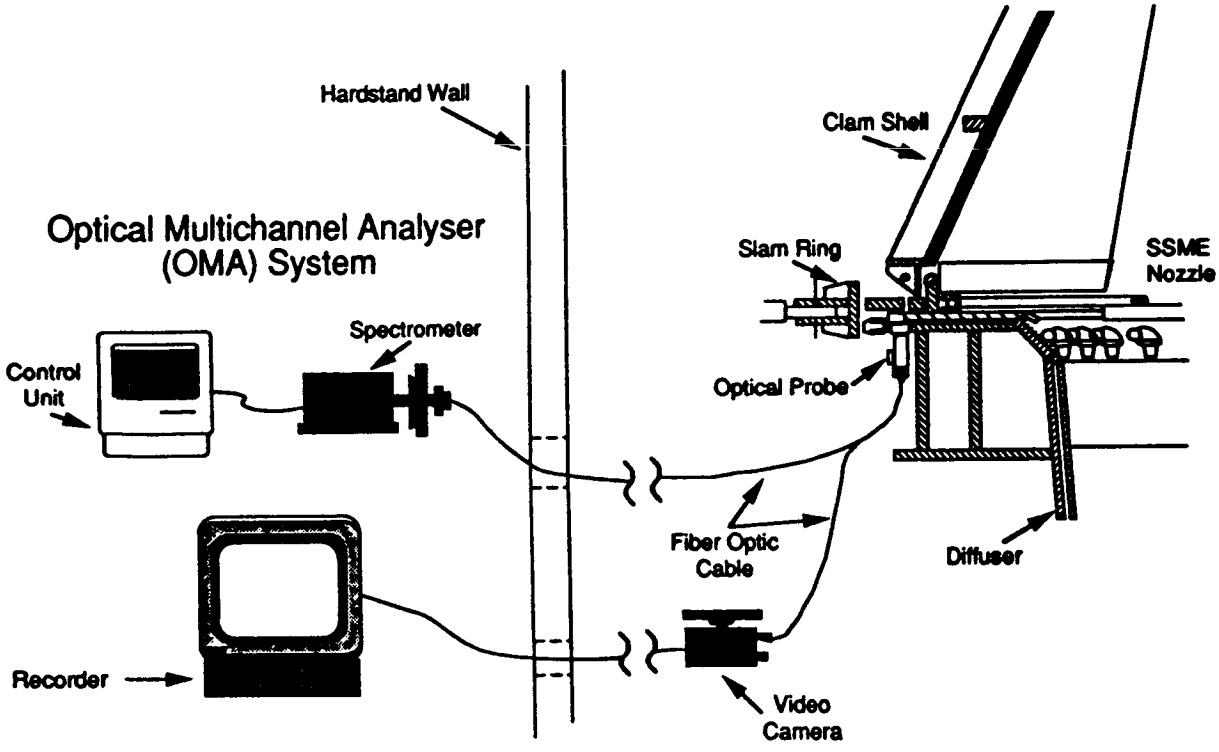
A1 Stand SSME Test: 901-619 Engine: 0209 1/31/90
Nozzle Exit View t = 71.0 sec.



ENGINE PLUME DIAGNOSTICS

ASPIRATED TEST STAND B-1

EDC OPTICAL PROBE SCHEMATIC FOR ASPIRATED TEST STAND



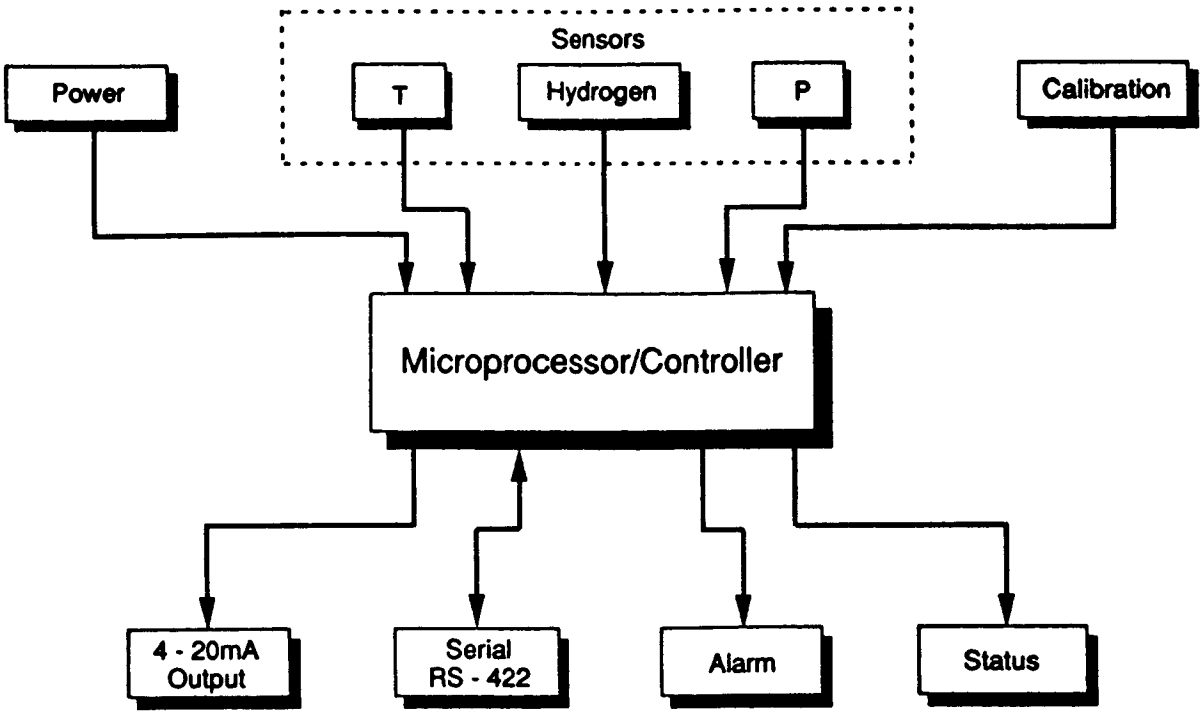
SMART HYDROGEN SENSOR AND FUGITIVE GAS DETECTION SYSTEM

SMART HYDROGEN SENSOR DESIGN GOALS

Project Goal: "Develop a reliable GH_2 sensor for Inert and Air Environments"

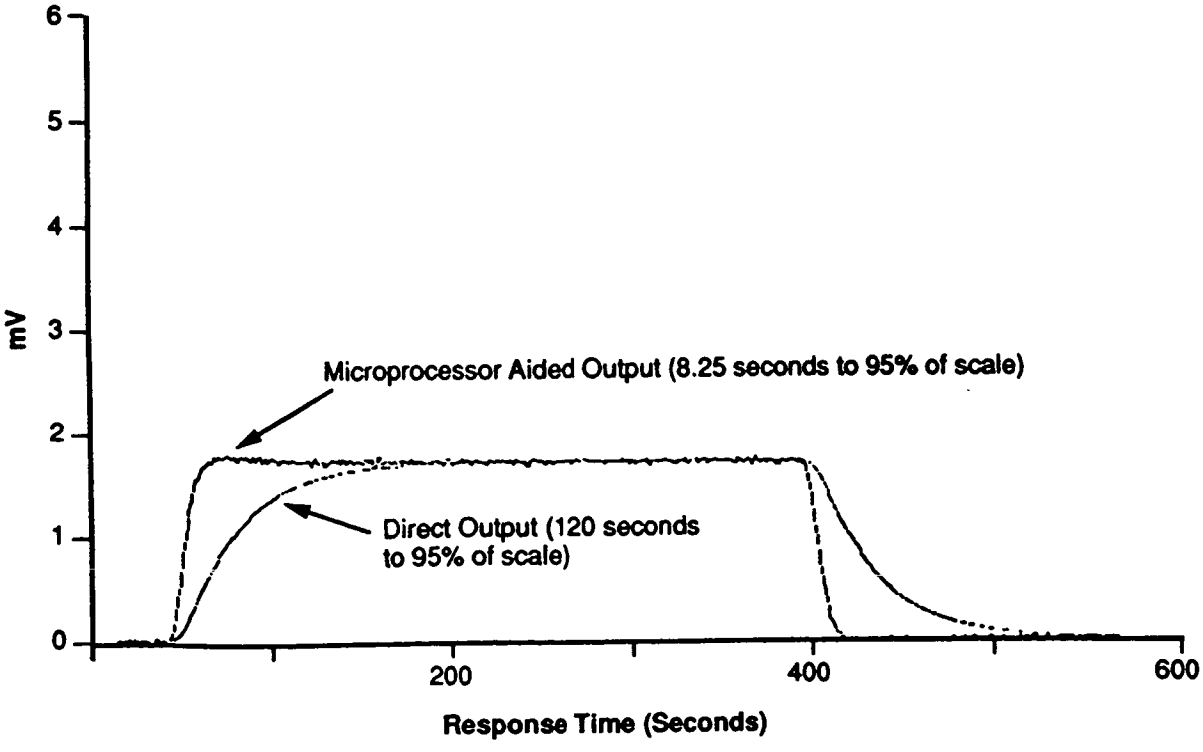
- Main Characteristics:
  - Background Gases
    - Air
    - Nitrogen
    - Helium
  - Range
    - 0-4 percent GH_2 by Volume

SMART HYDROGEN SENSOR



SENSOR RESPONSE TO 1.0% GH_2 BY VOLUME

Direct Analog vs. Microprocessor Aided Output In Nitrogen



SMART HYDROGEN SENSOR

Specifications

Temperature	Pressure	Humidity	Selectivity	Hydrogen
0 to 50 C*	0.5 - 1.5 atm	0 - 100% RH	Hydrogen Only	0 - 8% Vol 0 - 200% LeL 0 - 5,300 ppm (m) 0 - 80,000 ppm (vol)

Response Time < 10 Seconds

Estimated Values, Actual TBD → Accuracy: 0.5 - 2.0% of scale

Calibration: Built in menu driven software
90 day calibration interval

Maintenance and Reliability: Rugged Construction/Built-in self-diagnostics

Outputs: 4 - 20 Milliamps/serial RS-422

Power: 24 - 28 VDC/800 Milliamps

**Current test results indicate that this specification could be widened significantly in the final production units*

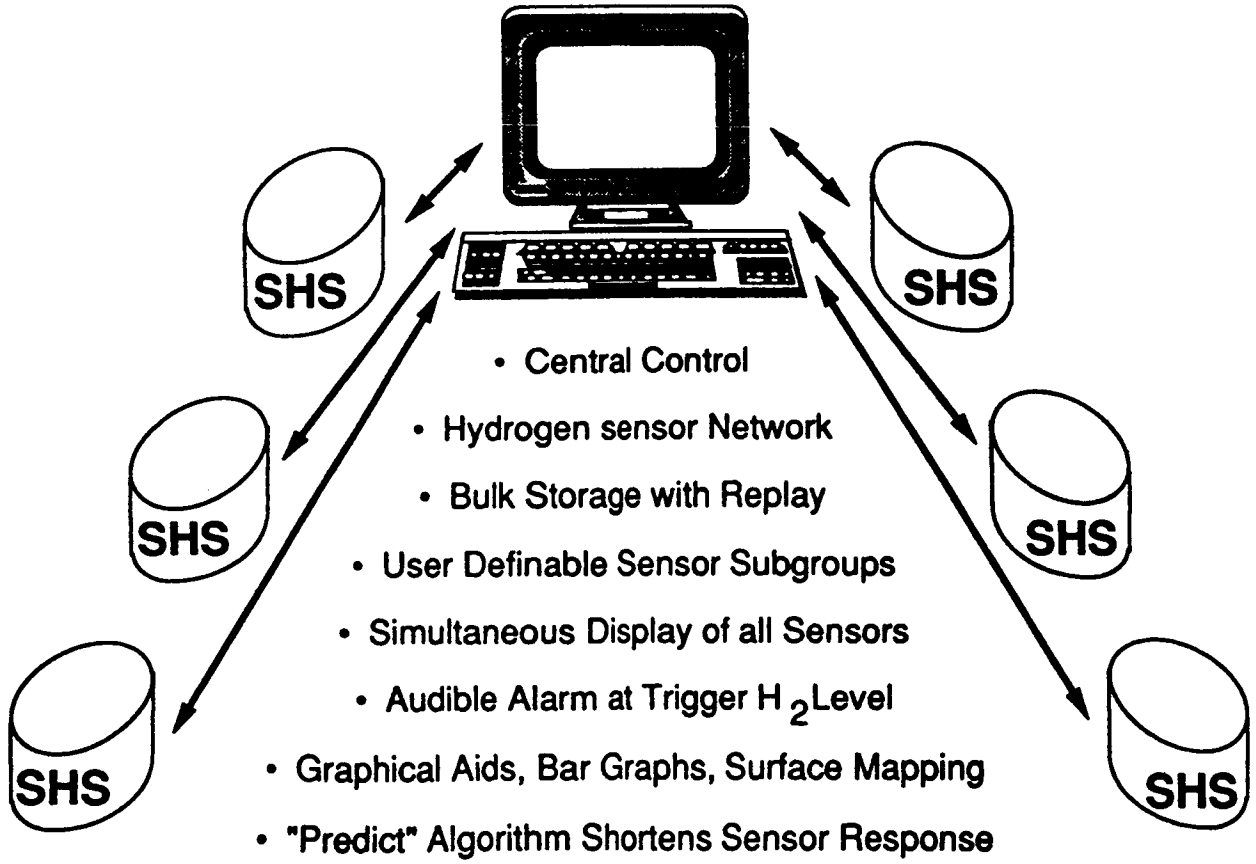
SMART HYDROGEN SENSOR PROGRAM STATUS AND PLANS

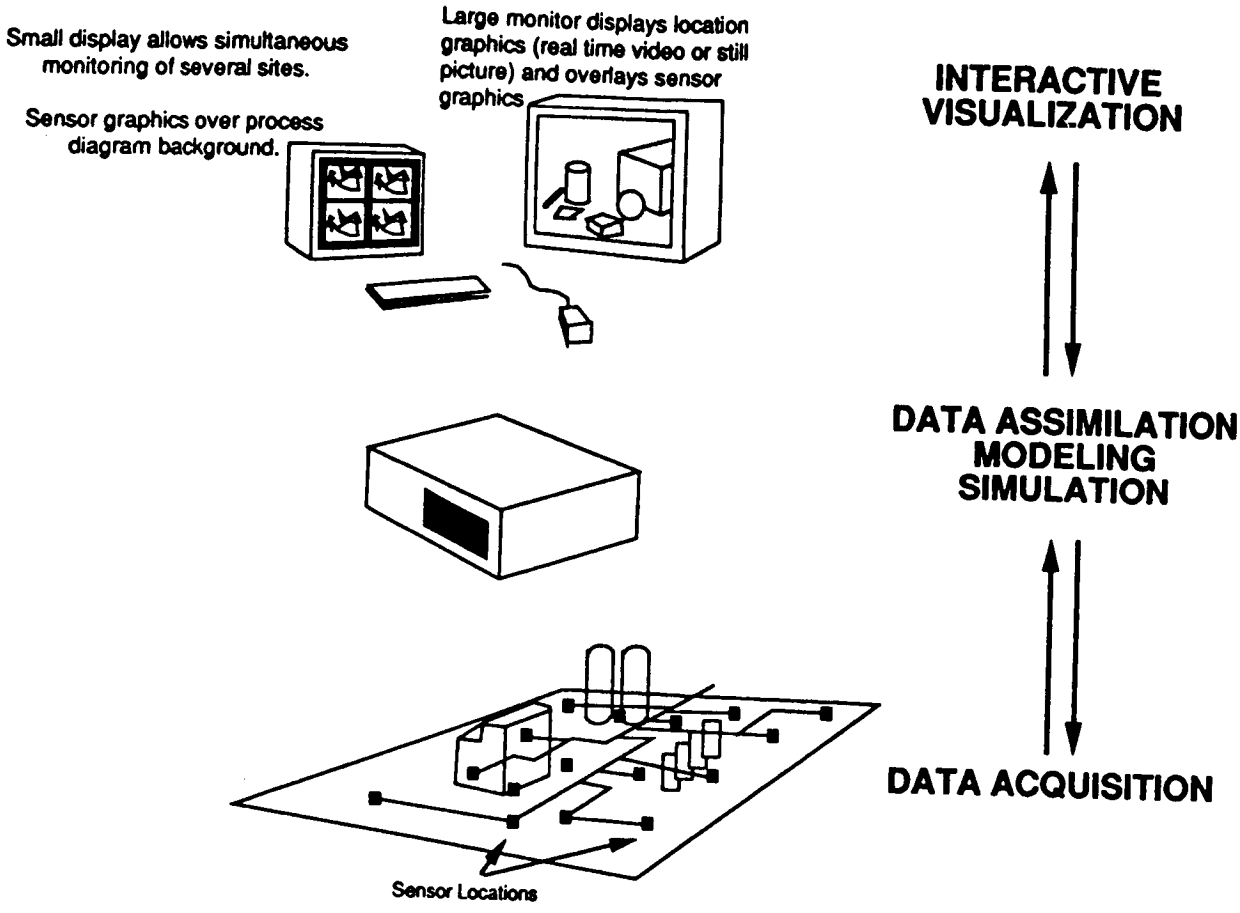
- Prototype - testbed
- Field testing first pre-production prototype
  - One year in engine test environment with exposure to high acoustic loads, overpressure, temperatures, cryo-soak to LN $_2$ temperature and deluge spray—still functioning
- Patent Application submitted to Patent Office
- Fugitive Gas Detection System Spin-Off
- Qualification Testing by KSC - FY90-91
- Technology Utilization Office Commercialization Initiated

FUTURE PLANS

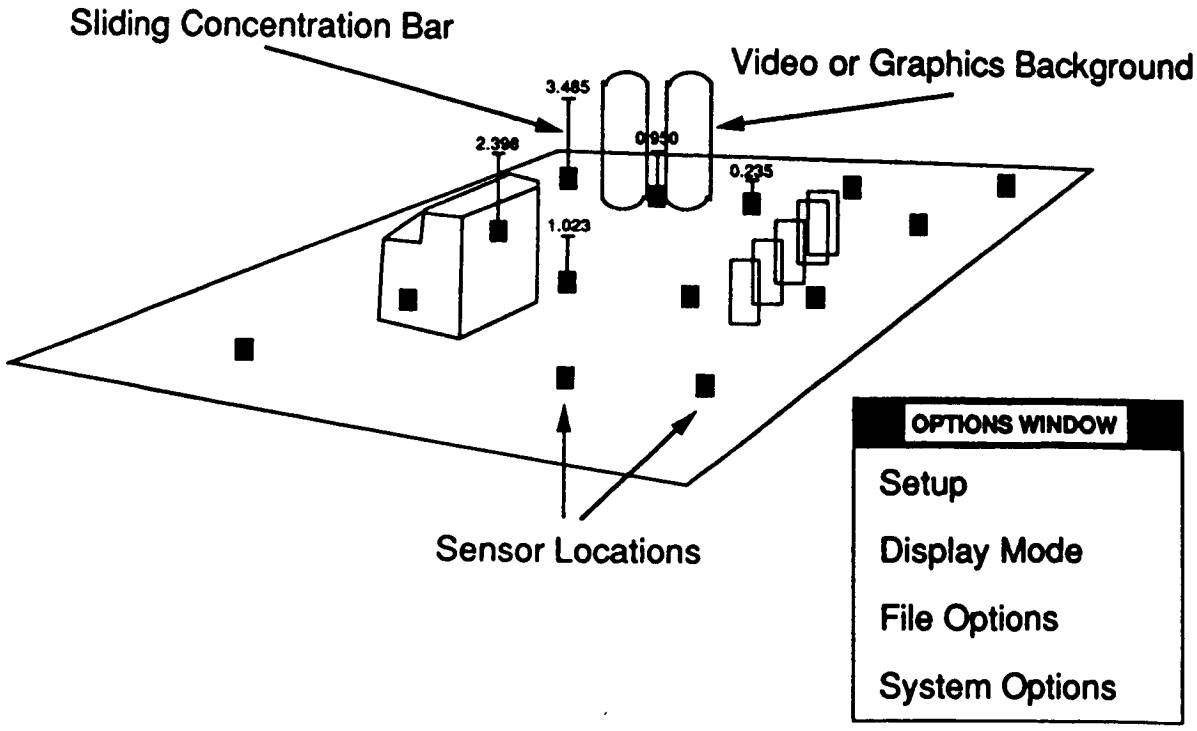
SSC	- LH_2 Barges - High Pressure Gas Facility - All Engine/Component Test Stands
KSC	- Launch OPS - Flight Orbiter AFT Fuselage ET Intertank
RTOP	- Fugitive Gas Detection System

FUGITIVE GAS DETECTION SYSTEM

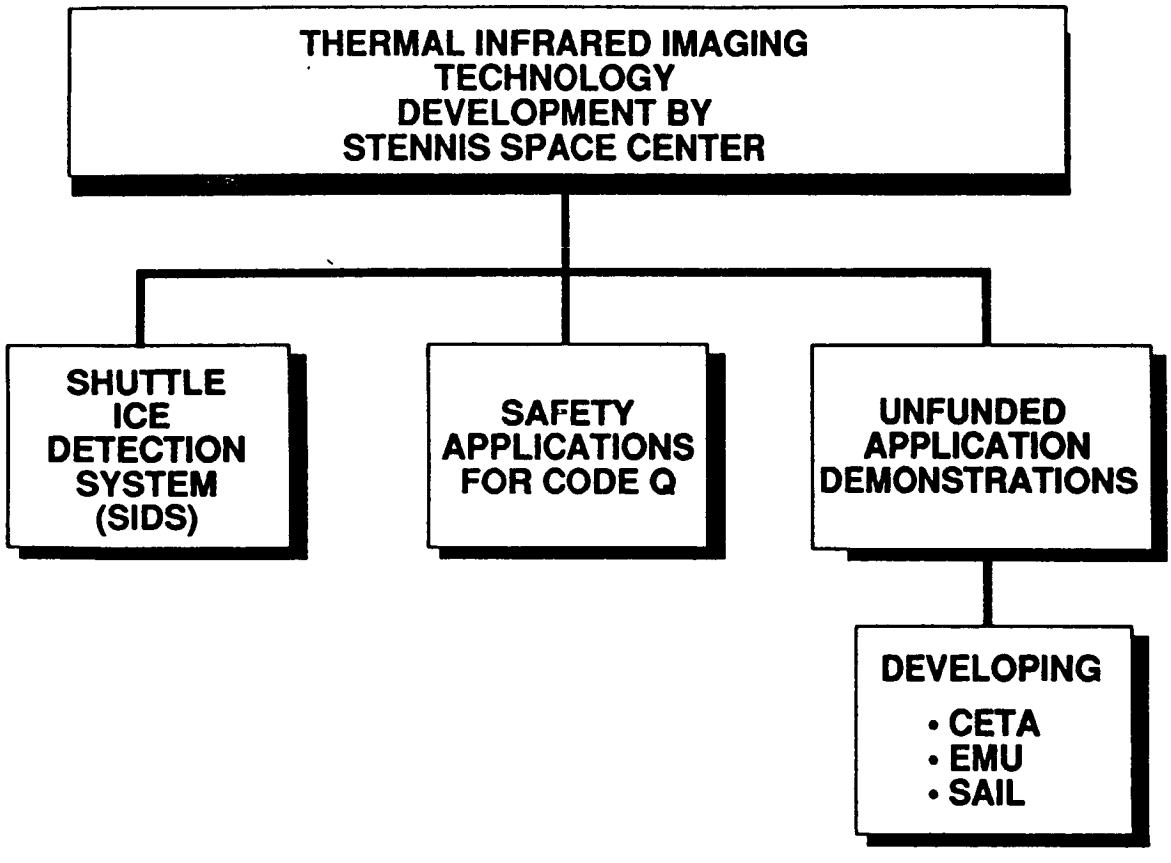




SLIDING BAR SENSOR GRID VISUALIZATION



THERMAL INFRARED IMAGING TECHNOLOGY DEVELOPMENT



SHUTTLE ICE DETECTION SYSTEM (SIDS)

- **Shuttle Thermal Imager (STI)**

  Provide real-time capability to remotely monitor/measure the launch stack temperatures.

  - **7 units operational at KSC**
  - **Upgrades and additional units ongoing**

- **Ice Detection System (IDS)**

  Differentiate between Dry TPS Surfaces, Water/ Condensate, and Ice/Frost Formations/Accumulations.

  - **Plan to test/evaluate prototype**

THERMAL INFRARED IMAGING TECHNOLOGY SAFETY APPLICATION

PHASE I

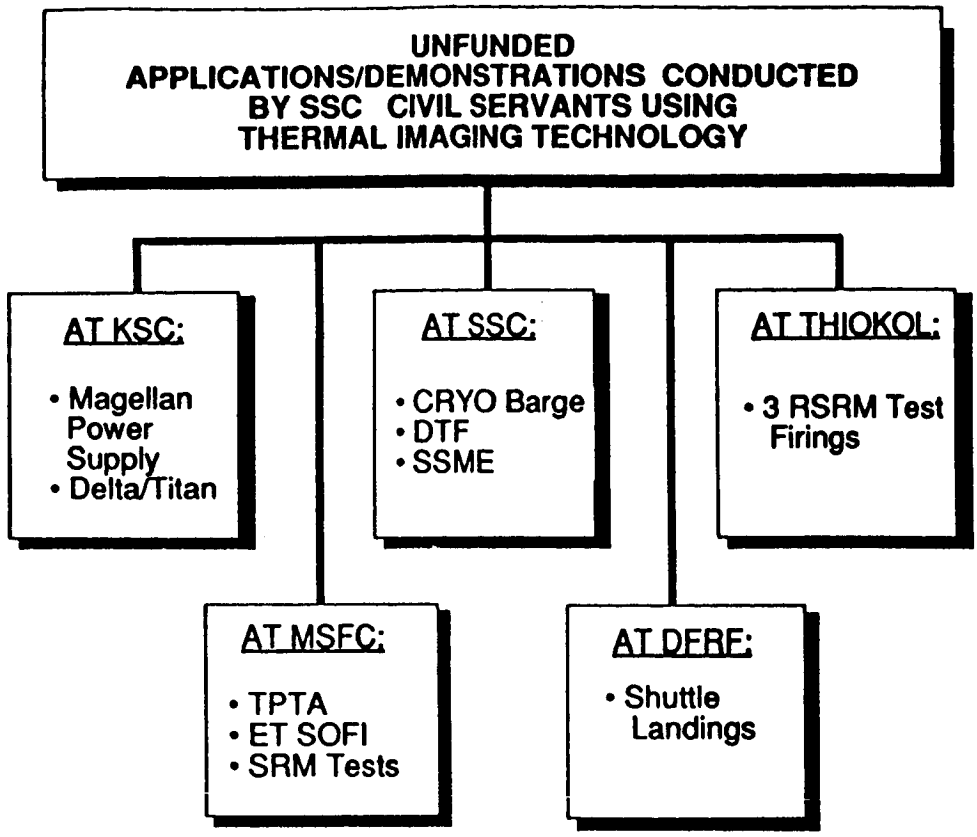
- LOX LEAKS
- REPORT IN REVIEW
- NOT A PROMISING METHOD TO DETECT LOX LEAKS

PHASE II

- FIRE DETECTION
- VARIOUS FLAMMABLE MATERIALS

PHASE III

- RESEARCH EMPHASIS TBD FROM PHASE II



OPERATIONAL APPLICATIONS OF STENNIS SPACE CENTER THERMAL INFRARED IMAGING TECHNOLOGY

- Real-time precision temperature measurement and monitoring
  - Fire detection/monitoring
  - SRB case temperature mapping
  - GOX vent hood seal
  - Cryogenic leak detection
  - Thermal modeling of launch stack
  - ET/SRB attach strut thermal isolation
  - Operations verification
  - Post-launch MLP damage assessment
  - Landing operations support
    - Tire & brake temperatures
    - Nose cone temperature
    - Leading edges temperatures
    - APU operation & shutdown
    - Missing/damaged tile/FRSI assessment
    - Fire detection
    - Night vision

DEVELOPING APPLICATIONS/DEMONSTRATION ACTIVITIES IN WHICH FUTURE SSC DEVELOPMENT IS LIKELY

JSC CREW AND THERMAL SYSTEMS DIVISION SHUTTLE SUPPORT BRANCH (CODE EC6)

- Crew equipment translational aid (CETA) potential for other hardware testing in the 24 foot chamber (e.g. PDAS)
- Extravehicular Mobility Unit (EMU) suit component testing, 11 foot chamber
- Shuttle Avionics Integration Lab (SAIL) Cold Plate verification on OV105