The Role of Mass Spectrometry in Launching Space Equipment

C Richard Arkin, Ph.D.
ASRC Aerospace
Kennedy Space Center, FL

Mass Spectrometers used in Space

- Obtaining new Scientific Information
  - Pioneer, Viking, Huygens, etc
- Ensuring Safety in Space
  - Cabin Air Monitoring, Process Monitoring
- Ensuring Safe Launch
- Ensuring Proper Assembly
- Indirect Applications
  - Worker Safety, Environmental, …

Gas Monitoring at KSC

- Shuttle Processing
- International Space Station (ISS) Assembly Processing
- ELV Processing
- Environmental Monitoring
- Worker Health

Gases of Interest

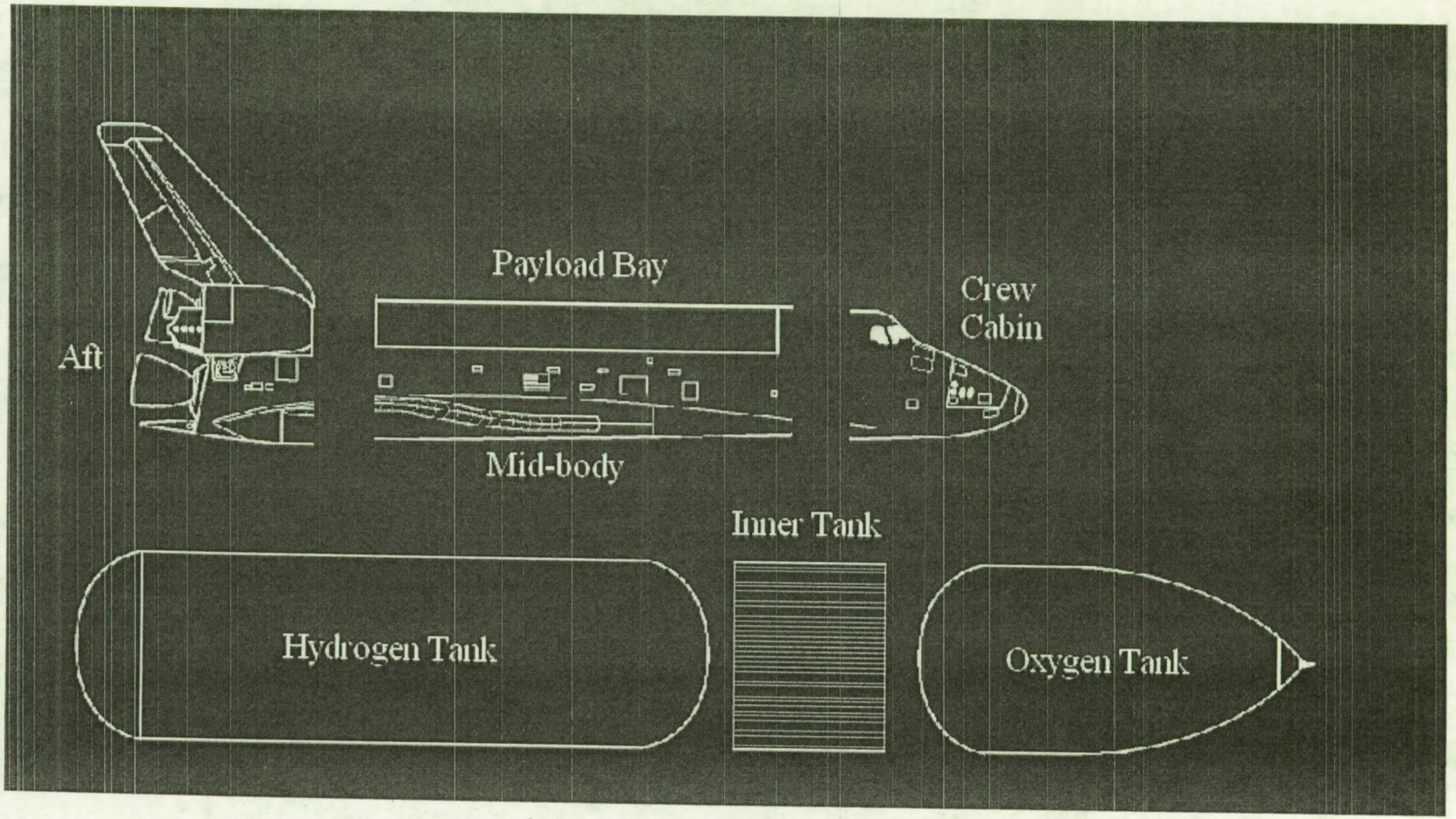
- Fuels & Oxidizers
  - Hydrogen, Oxygen (Cryogenic)
  - Hydrazines (Hz, MMH, UDMH), N_2O_4
- Toxins
  - Volatile Organic Compounds (VOCs)
  - Heat Transfer Agents (NH_3, Freons)
- Test Chemicals
  - Leak Testing (Helium, Argon, CO_2)

Why Mass Spectrometry?

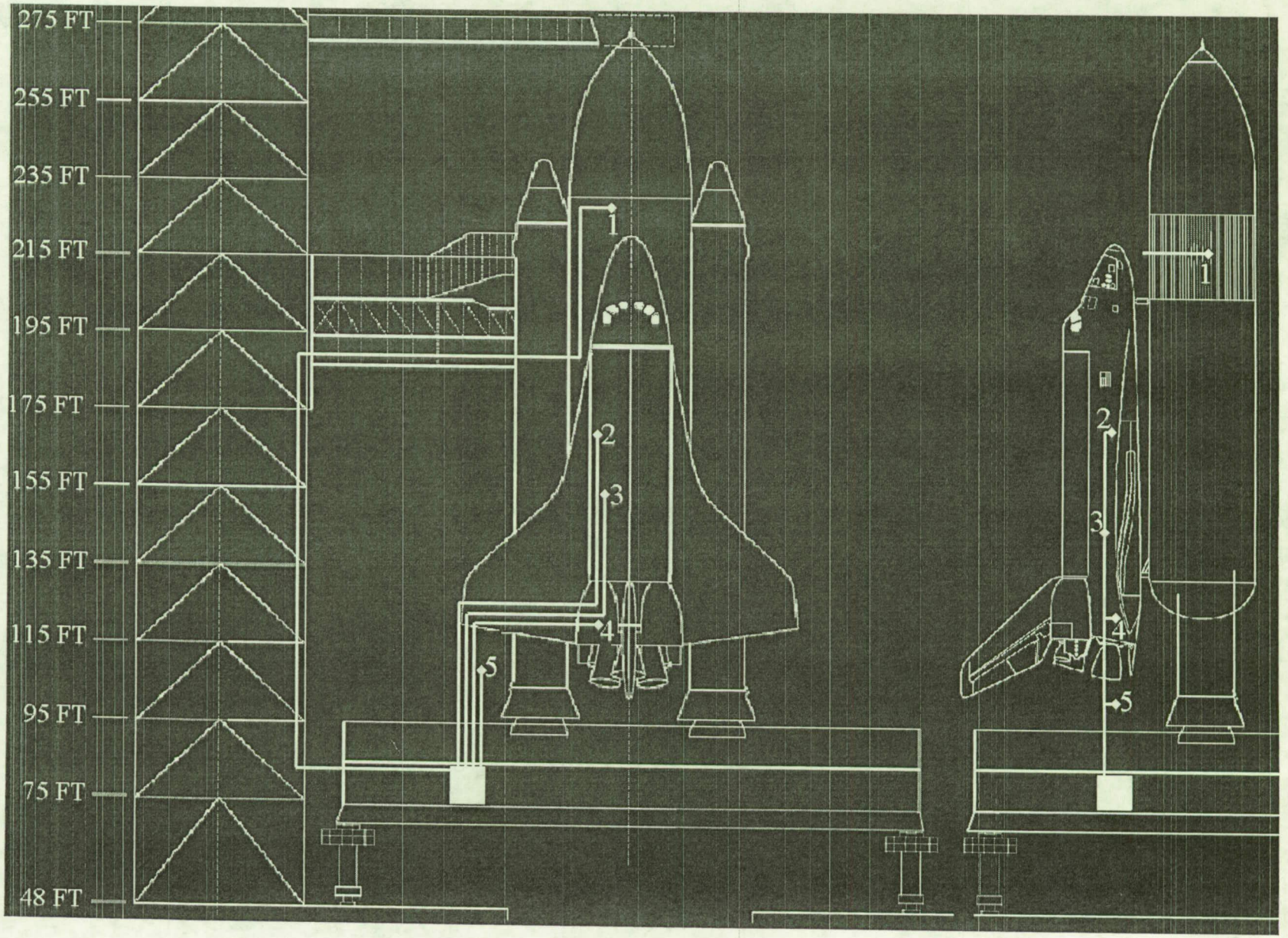
↑ Extremely Specific
↑ Sample Variety
↑ Qualitative
↑ Quantitative
↑ Rapid Response
↑ Large Dynamic Range

↓ Ruggedness
↓ Weight
↓ Size
↓ Cost
↓ Power
↓ Operator Training

Shuttle Regions Monitored



Shuttle

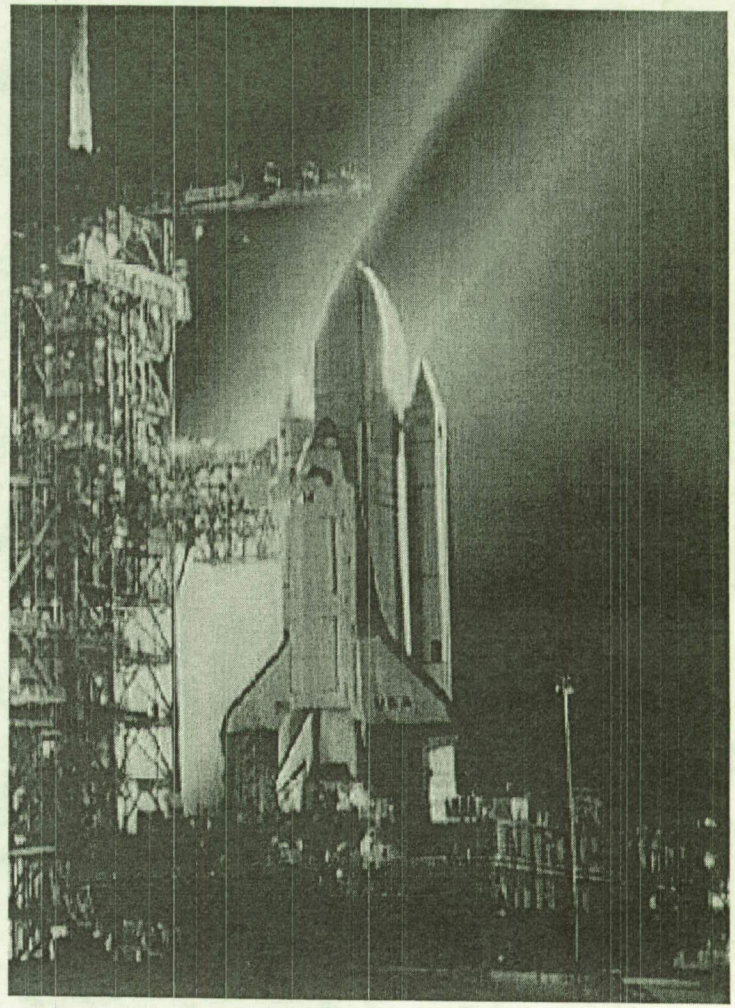

275 FT
255 FT
235 FT
215 FT
195 FT
175 FT
155 FT
135 FT
115 FT
95 FT
75 FT
48 FT
1
2
3
4
5
1
2
3
4
5

Hazardous Gas Detection Lab

- Real-time Quantification of Hazardous Gases in the Field
- Instrument Development
- Method Development
- Evaluate Commercial Components

Columbia SSME (1976-78)

- Stennis Space Center (1976 – 1978)
- Prototype HGDS, UTI-Q-30C
- Manual operation

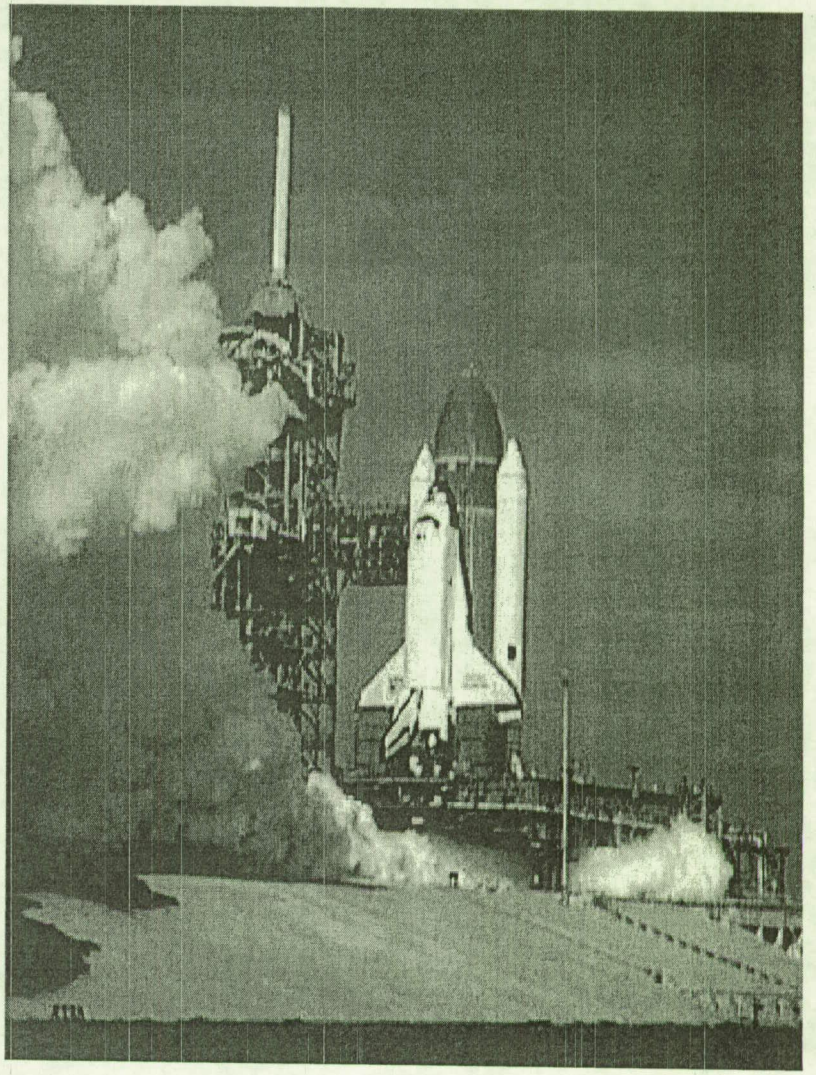


HGDS (Installed MLP-1, 1979)

- Four equipment racks, including cal gas
- Ion Pumped
- Quadrupole (UTI)
- Faraday Cup / Electron Multiplier
- Heated inlet / vacuum system, open source
- Hydrogen, Helium, Oxygen, Argon

STS-6 FRF (Dec 1982 & Jan 1983)

- Performed at KSC on Pad A
- Hydrogen concentration 600, 6,000 ppm
- Test repeated with identical results
- Hardware discovered leaking
- HGDS credited with saving vehicle

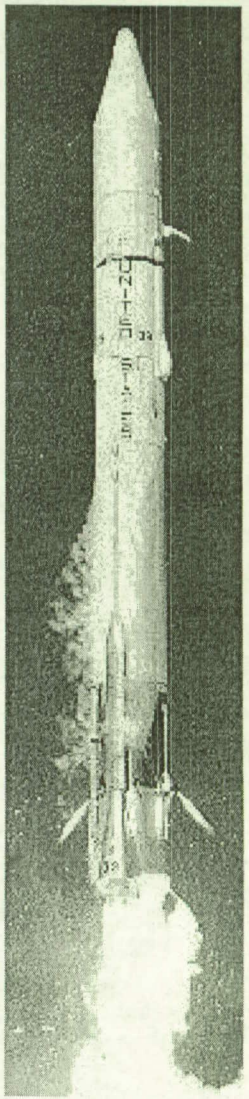


System Designated at 1S-Critical

- HGDS "Prime" Upgrades
  - Improved Software
  - Improved Power Stability
  - NIST Concentration Calibration Standards
- HGDS Back-up "B/U" Developed

Atlas Centaur (AC-60, 1982)

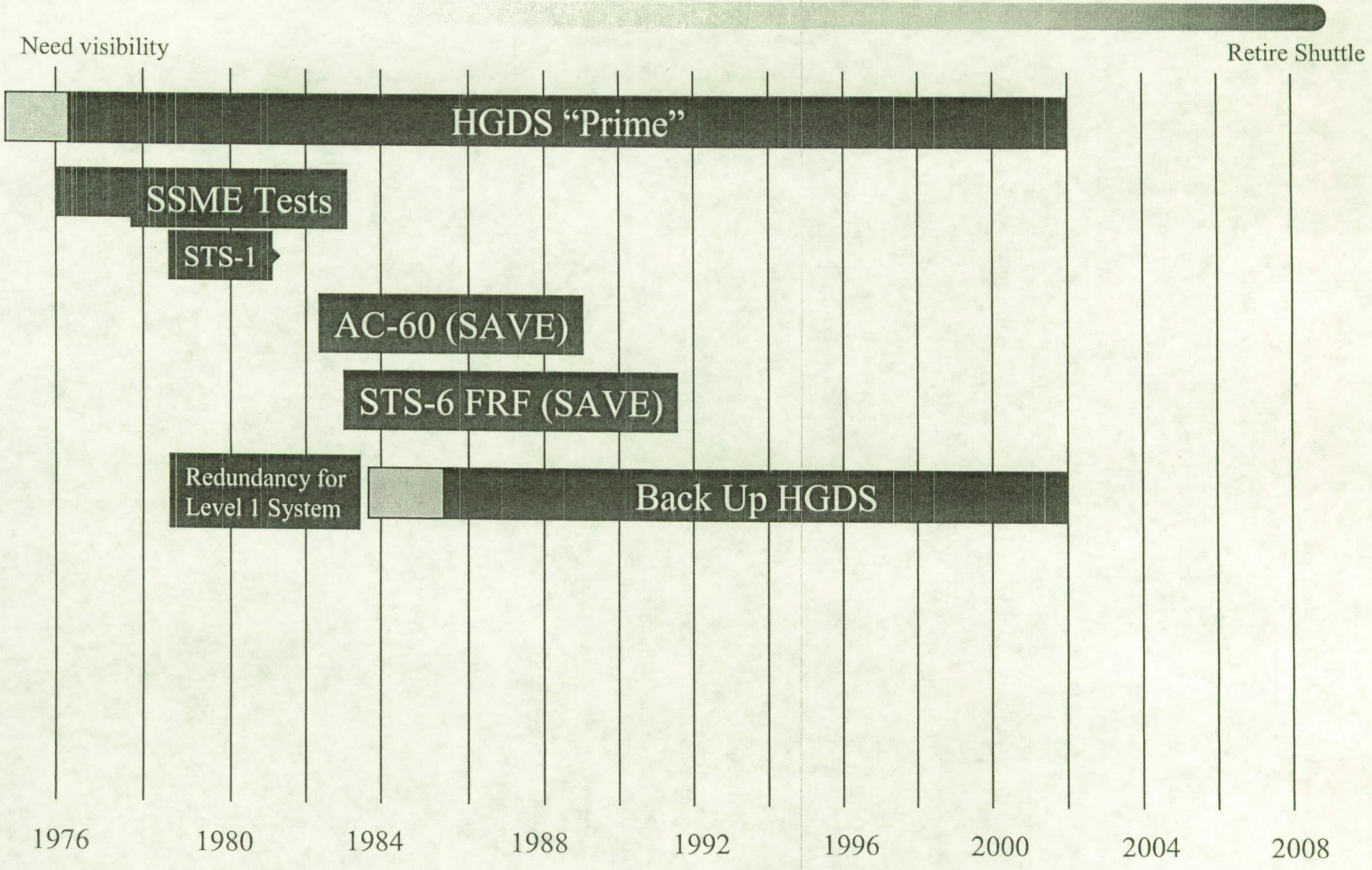
- Atlas-Centaur Vehicle (Centaur Upper Stage)
- Perkin Elmer system procured by General Dynamics (HGDS B/U)
- Discovered Oxygen leak
- Leak did not appear at room temperature
- Leak only occurred during cryo conditions
- System credited with saving vehicle



HGDS B/U

- Duplicates HGDS capability to support launch
- Redundancy for Crit-1S system
- Ion pump
- Magnetic sector (PE MGA-1200, 5 channels)
- Closed source
- Faraday Cup detectors
- Single rack with independent calibration gas
- Operate via terminal in Firing Room
- Eight sample lines

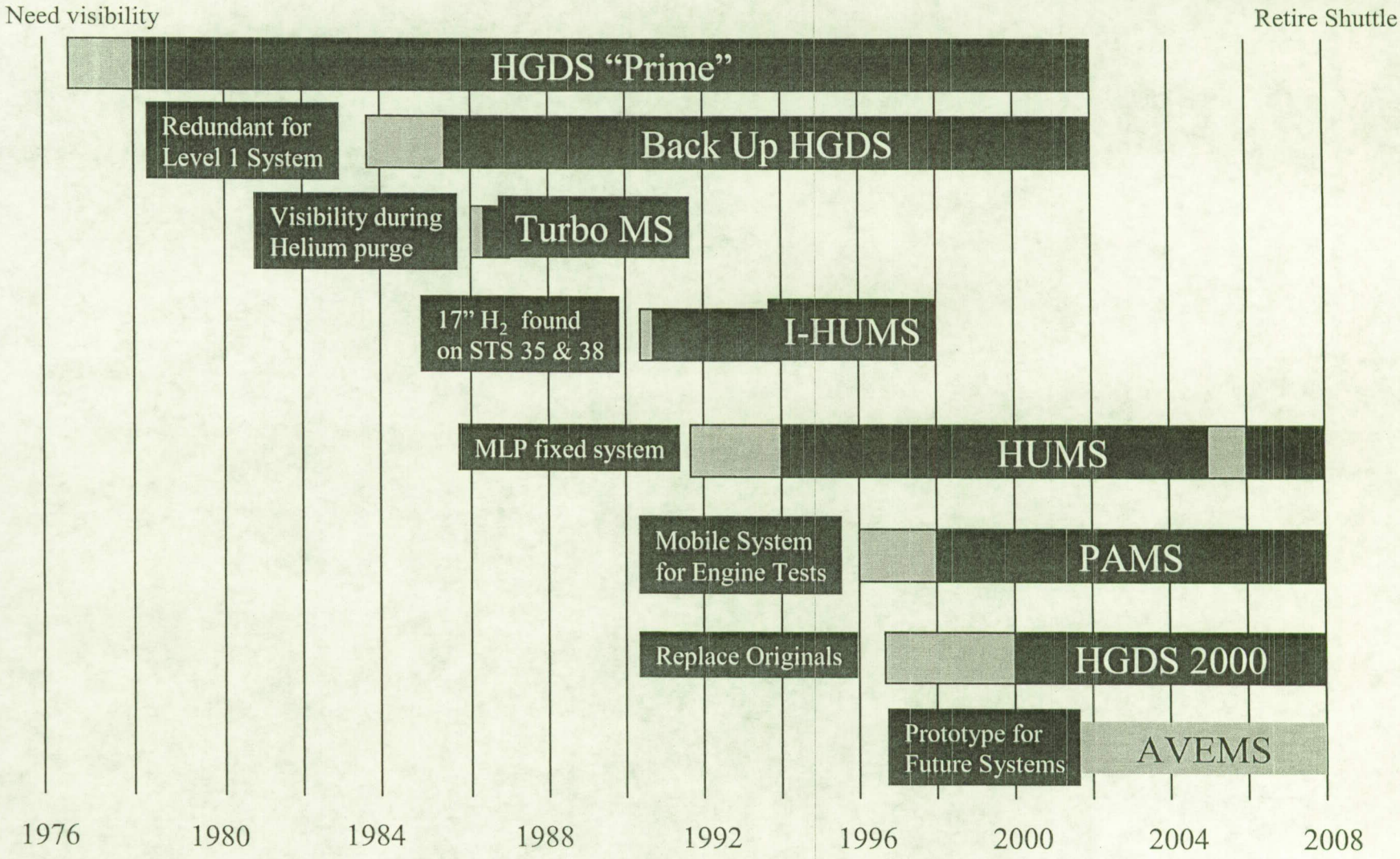
Timeline


Need visibility
Retire Shuttle
HGDS "Prime"
SSME Tests
STS-1
AC-60 (SAVE)
STS-6 FRF (SAVE)
Redundancy for Level 1 System
Back Up HGDS
1976
1980
1984
1988
1992
1996
2000
2004
2008

Turbo Mass Spec (1988)

- Installed for STS-26 (RTF) only
- SSME Leak Tests performed with Helium
- Prime & B/U use Ion Pumps
- Additional Shuttle Processing Tests with He
- First installation of turbo-molecular pump on MLP
- Based on Perkin-Elmer MGA-1200
- Two sample lines

Timeline


Need visibility
Retire Shuttle
HGDS "Prime"
Redundant for Level 1 System
Back Up HGDS
Visibility during Helium purge
Turbo MS
17" H_2 found on STS 35 & 38
I-HUMS
MLP fixed system
HUMS
Mobile System for Engine Tests
PAMS
Replace Originals
HGDS 2000
Prototype for Future Systems
AVEMS
1976
1980
1984
1988
1992
1996
2000
2004
2008

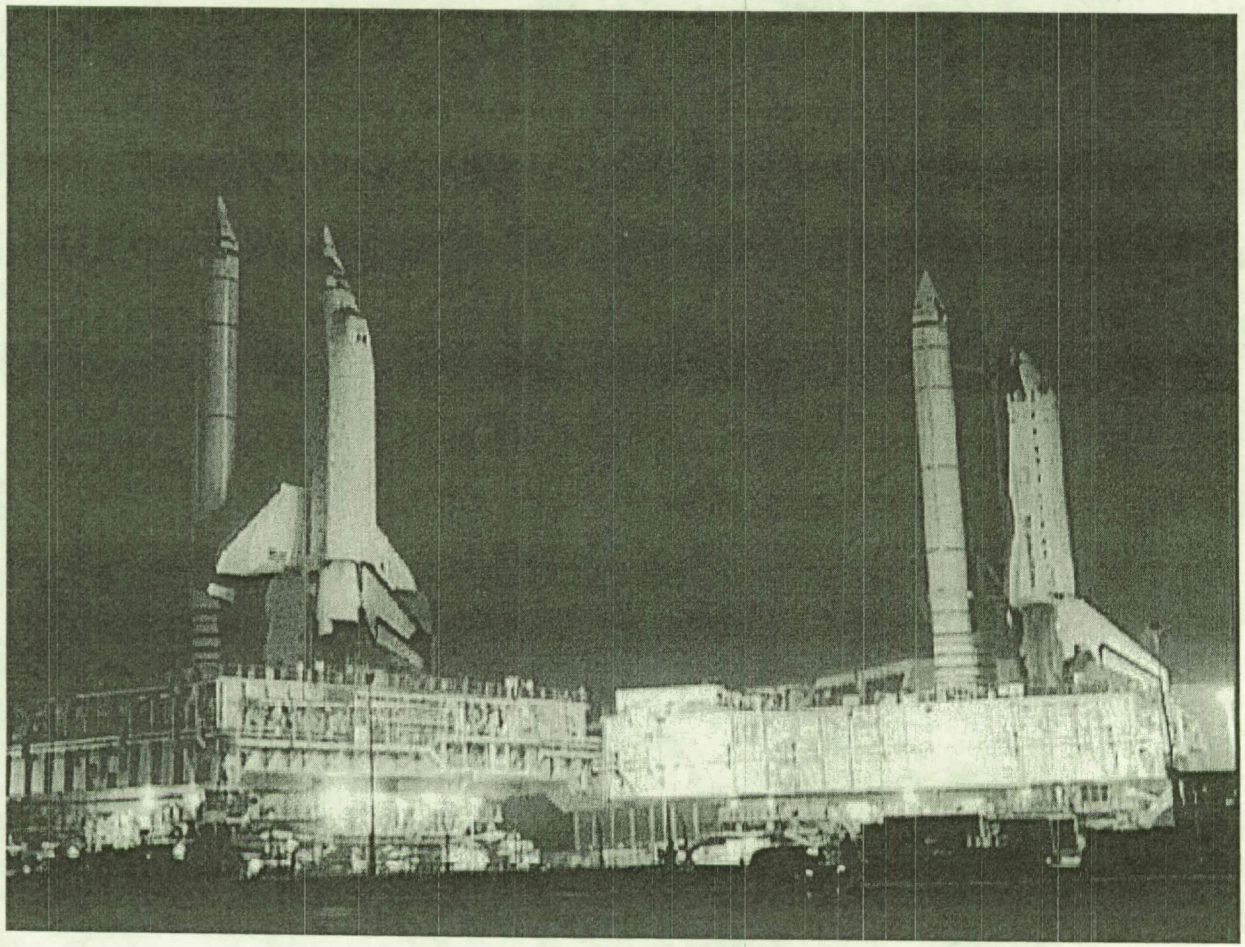
I-HUMS

- Turbo-pumped MGA-1200
- Developed to replace 17-In Turbo Mass Spec
- Calibrate or operate in nitrogen or helium backgrounds, selectable
- LabVIEW operator interface, RS-232 data link
- Eight Sample lines (20 sample line supplement)
- Single rack, two units manufactured
- Rotated on MLP's to support each launch

STS-38 (Aug 1990)

- 17 Inch Orb/ET Hydrogen Umbilical leaking
- Leak intermittent, leaked only during fast-fill
- Leak stopped during slow fill or static conditions
- ET component removed from vehicle and delivered to vendor's facility in Downey, CA
- Static testing using Gas Chromatograph unable to duplicate test results on pad
- Application of mass spec from KSC produced immediate results
- Mass spec credited with saving vehicle

STS-38 and STS-35

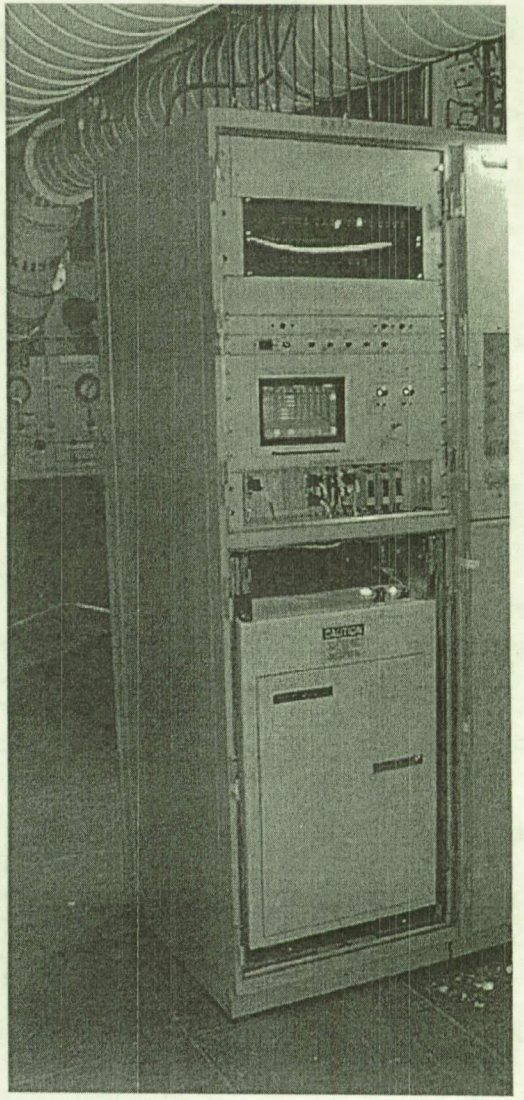


STS-35 (Sept 1990)

- STS-35
  - Leak indications similar to STS-38
  - Both Orbiter and ET components appeared to be leaking
  - Both components removed and delivered to MSFC for high-rate cold-flow testing
  - KSC Mass Spec requested by JSC System Engineer
  - Testing in work at MSFC < 24 hours from request
  - Failure mode identified different from STS-38
  - Mass spec credited with saving vehicle

Hydrogen Umbilical Mass Spec (HUMS)

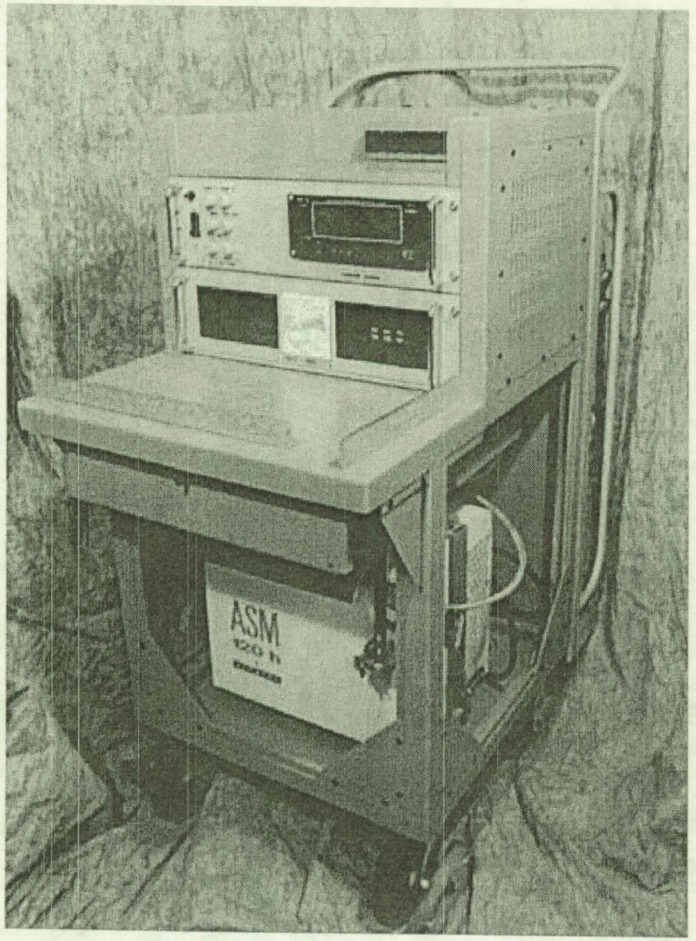
- Permanent installation of I-HUMS
- One system per MLP (4 units)
- Perkin-Elmer MGA-1200
- Eight sample lines
- Turbo-molecular pumped
- Custom, rugged VME embedded computer
- Firing Room data link added later

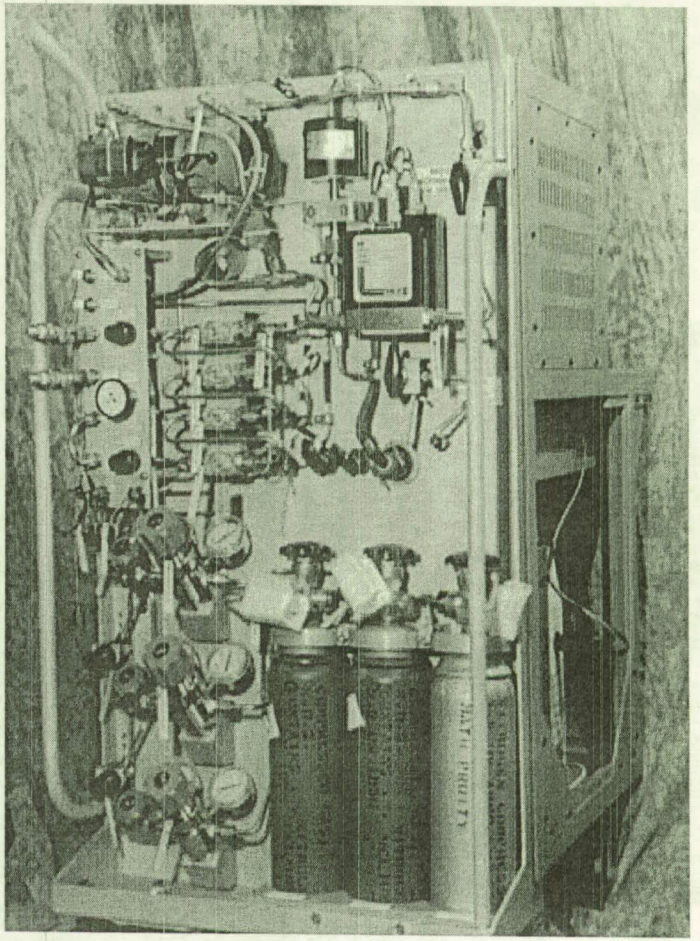


Portable Aft Mass Spec (PAMS)

- Helium detector, calibrated in parts per million
- Replace HGDS for performing Aft Helium Signature Leak Test
- Protects HGDS Ion Pump
- 20 ppb stability and resolution
- 20,000 ppm full scale
- NIST Traceable calibration gas

PAMS

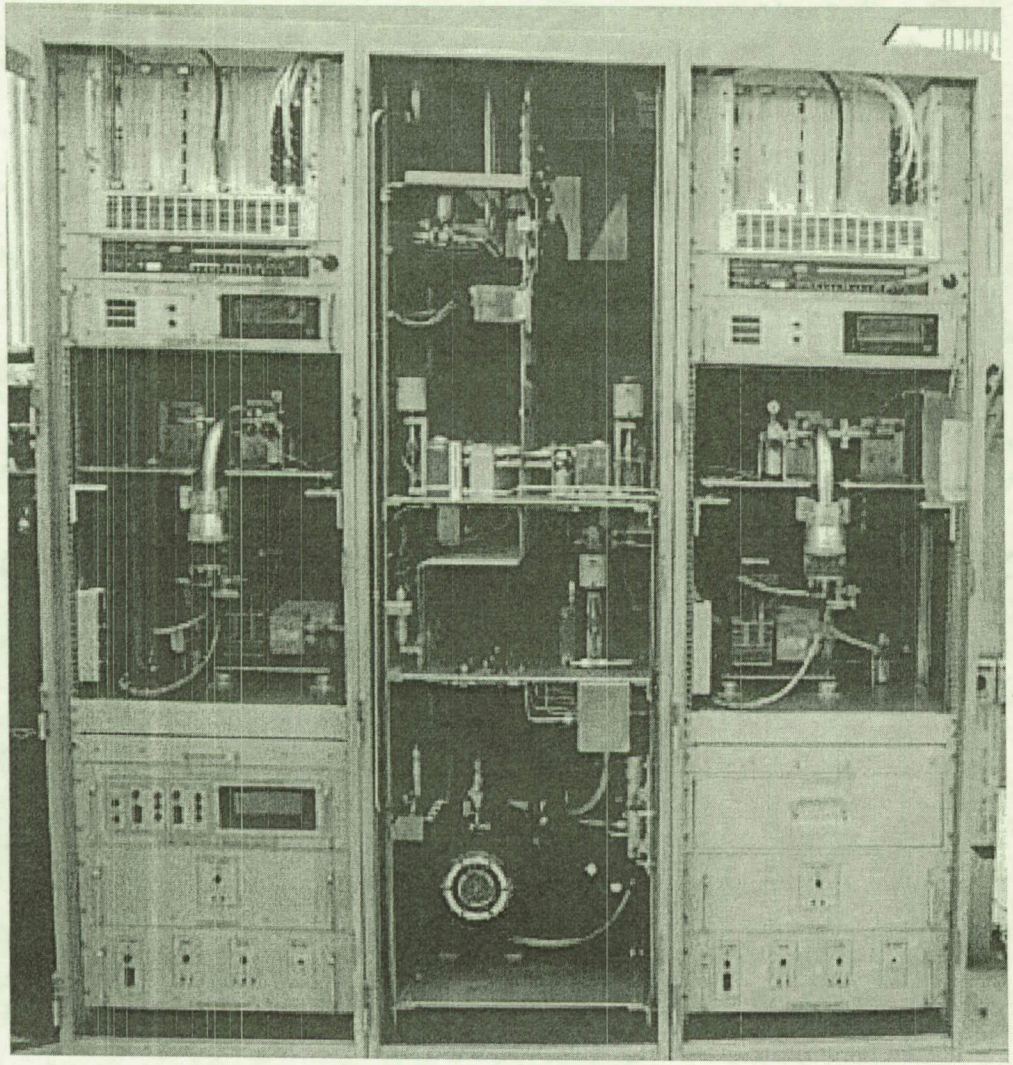




HGDS 2000

- Replace HGDS and HGDS B/U
- In-house vacuum, sample system design
- Two, online redundant mass spectrometers
- Independent calibration gas for each system
- Each system capable of monitoring any line
- Any sample line can be monitored by both
- Independent power and data / control from Firing Rooms or Local operation

HGDS 2000



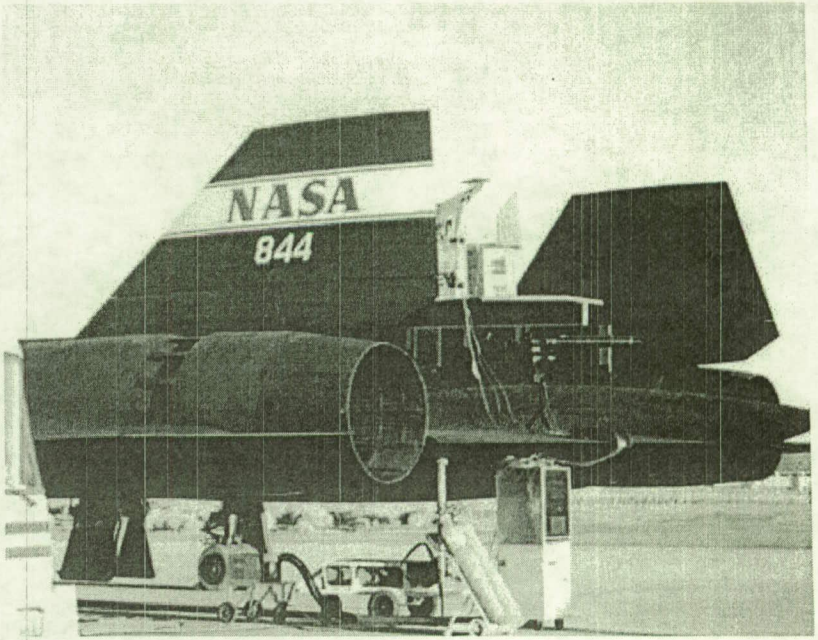
- Linear Quadrupole
- < 30 s Response Time
- Accuracy – 10%
- LOQ < 25 ppm
- Redundant Systems
- Local & Remote Control
- 1800 lbs (820 kg)

National Aerospace Plane, X-30 ('94)

- Stennis Space Center
- 1/3 Scale of Hydrogen Fuel Tank
- Filled to mass equiv. to liquid hydrogen with LN2, helium purge
- Tank ruptured internally
- Nitrogen leaking into helium purge detected by mass spec

X-33/LASRE (1998)

- Support requested by DFRC
- Test Article X-33 Aerospike
- Verify test-article integrity
- Mass Spec demonstrated inadequate purge
- Hydrogen pooling indicated unsafe conditions
- Flight tests cancelled due to leaks concerns



Atlas-Centaur Payload Purge

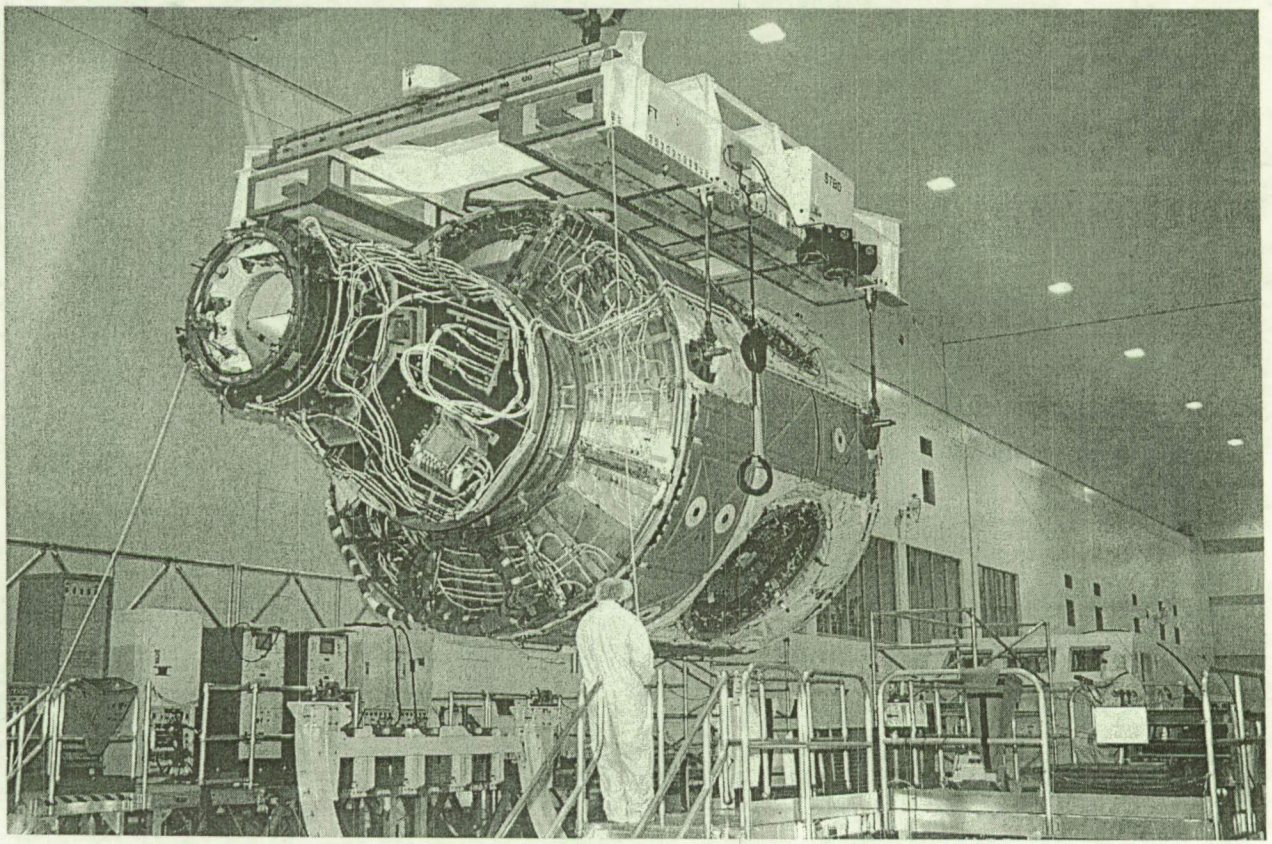
- Payload Nitrogen purge line traverses vehicle helium purge
- Payload guidance system subject to damage from helium intrusion into ring-laser gyros
- Test using PAMS indicated diffusion through protective coating
- Launch of payload continued without incident

OPF Helium Background

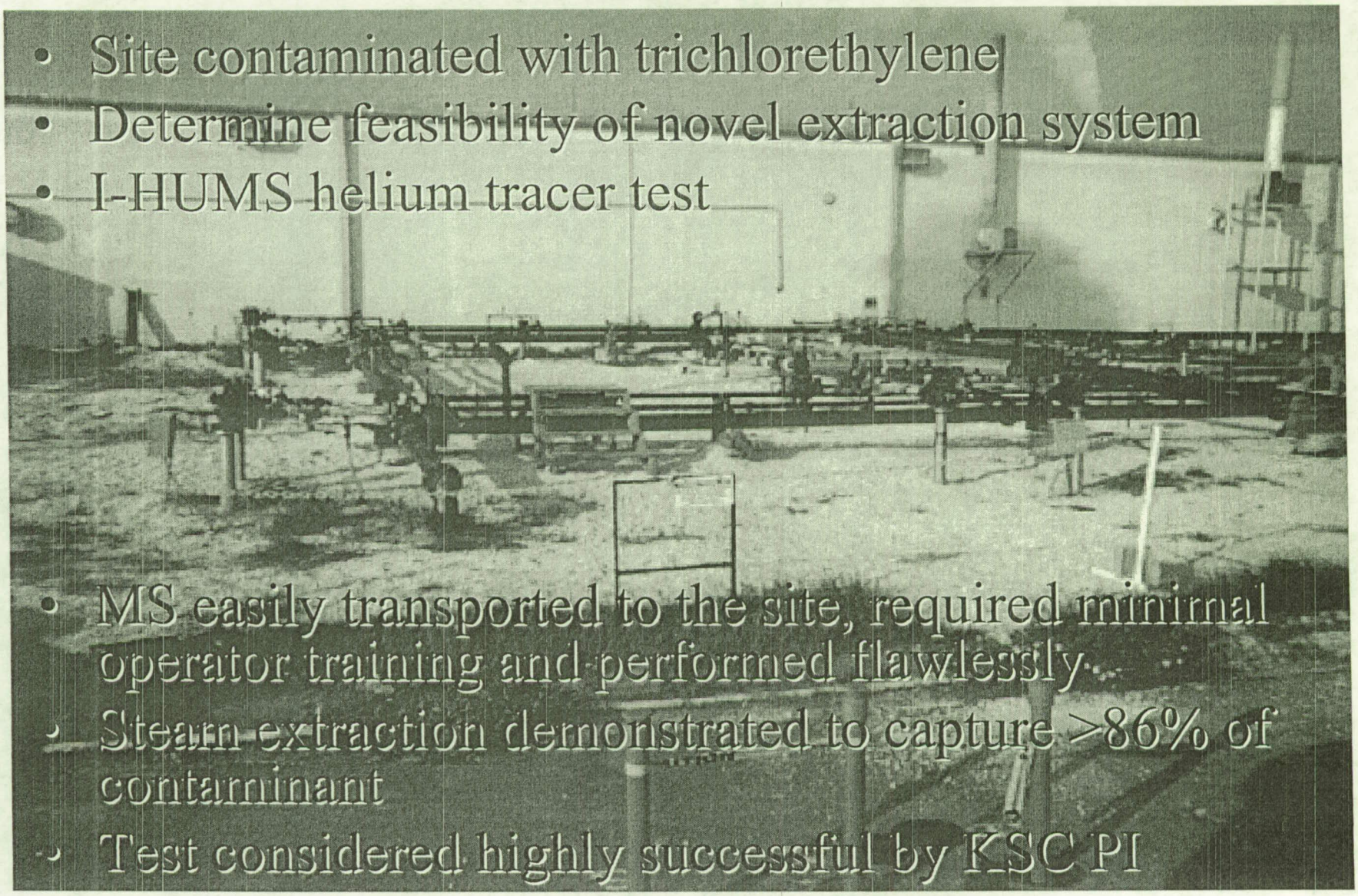
- Quality of Air Purge for V-1201
- Questioned multiple times over several years
- Initial thought to install perm HGDS in OPF
- Used PAMS Proof-of-Concept system calibrated to ppm (rather than sccm)
- OPF ambient = 17-35ppm
- Air pulled from outside OPF = 5ppm

ISS Processing

- Leak check Node-1 in canister in High Bay
- PAMS used during leak testing



Environmental Remediation



- Site contaminated with trichlorethylene
- Determine feasibility of novel extraction system
- I-HUMS helium tracer test

- MS easily transported to the site, required minimal operator training and performed flawlessly
- Steam extraction demonstrated to capture >86% of contaminant
- Test considered highly successful by KSC PI

Current & Future Work

↓ Ruggedness (Turbo Pumps, Filaments, …)

↓ Weight (Pumps, Vacuum Chambers, …)

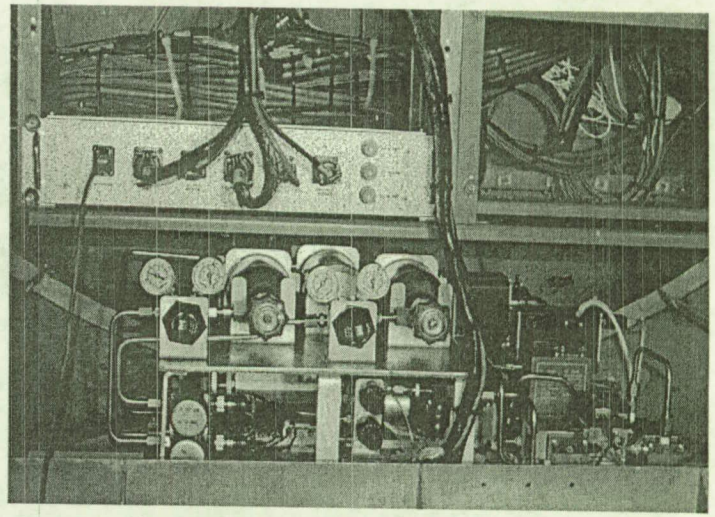
↓ Size (Pumps, Vacuum Chambers, …)

↓ Cost (Development, Maintenance, Operator)

↓ Power (Pumps, Valves, Filaments, …)

↓ Operator Training

Example Systems



Potential Spin-off Applications

- Air Quality
  - Environmental
  - Workplace
- Leak Detection
  - CRT Industry
  - Refrigeration Industry
  - Automotive Industry
  - Food Industry
- Process Monitoring
  - Semiconductor
  - Petrochemical
  - Cross-Country Pipeline
- Medical Analysis
  - Blood Analysis
  - Liver Analysis
- Battlefield Threat
  - Chemical Weapons
  - Biological Weapons
  - Land Mine
- Contraband Detection
  - Explosives
  - Drugs
- Geological Prediction
  - Volcanic Eruption
  - UV Hazards

Acknowledgements

- NASA
  - Tim Griffin
  - Ric Adams
  - Carolyn Mizell
  - Duke Follistein
  - Steve Czaban
  - Eric Gore
  - Ozzie Fish
- ASRC
  - Guy Naylor
  - Bill Haskell
  - Charles Curley
  - David Floyd
  - Don Young
  - xxx

And Many Others…