

# Aircraft-based Volcanic Emissions Mass Spectrometer (AVEMS)



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# Overview

- KSC Goals
- Project Goals
- AVEMS System
- System Characteristics
- Houston Tests
- CARTA Mission 2003
- Future Work



# *Gas Monitoring at KSC*



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

# *Hazardous Gases*



- Explosives & Fuels
  - Hydrogen & Oxygen
  - Hydrazines
  - TNT, RDX, HMX
- Toxins
  - Hydrazines,  $\text{N}_2\text{O}_4$ ,
  - Volatile Organic Compounds (VOCs)

# *Applications for Gas Analysis Systems*

## *– “Tactical to Practical”*



- 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

# *Why Mass Spectrometry?*



- |                       |                     |
|-----------------------|---------------------|
| ↑ Extremely Specific  | ↓ Size              |
| ↑ Sample Variety      | ↓ Weight            |
| ↑ Qualitative         | ↓ Cost              |
| ↑ Quantitative        | ↓ Power             |
| ↑ Rapid Response      | ↓ Ruggedness        |
| ↑ Large Dynamic Range | ↓ Operator Training |

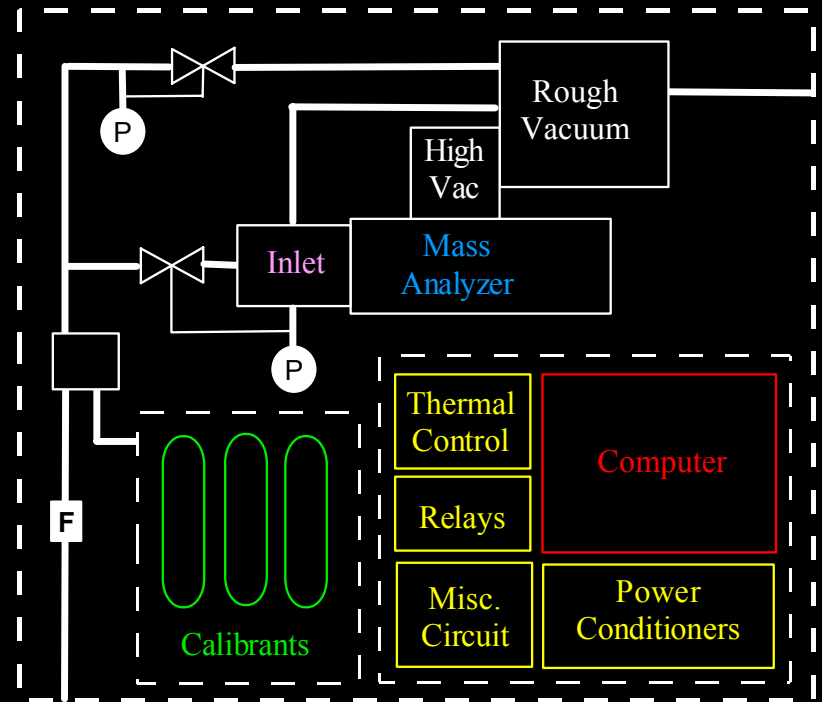
# *Project Goals*

- Success & Deficiency Areas in Development & Operation
- Monitor Volcanic Gas Emissions  
(He, CO<sub>2</sub>, SO<sub>2</sub>, H<sub>2</sub>S,...)
- Correlate to Volcanic Cycles



# Mass Spectrometer System

- Mass Spectrometer
- Pumping System
- Power System
- Control System
- Sample Delivery
- Calibration System
- Structural Framework

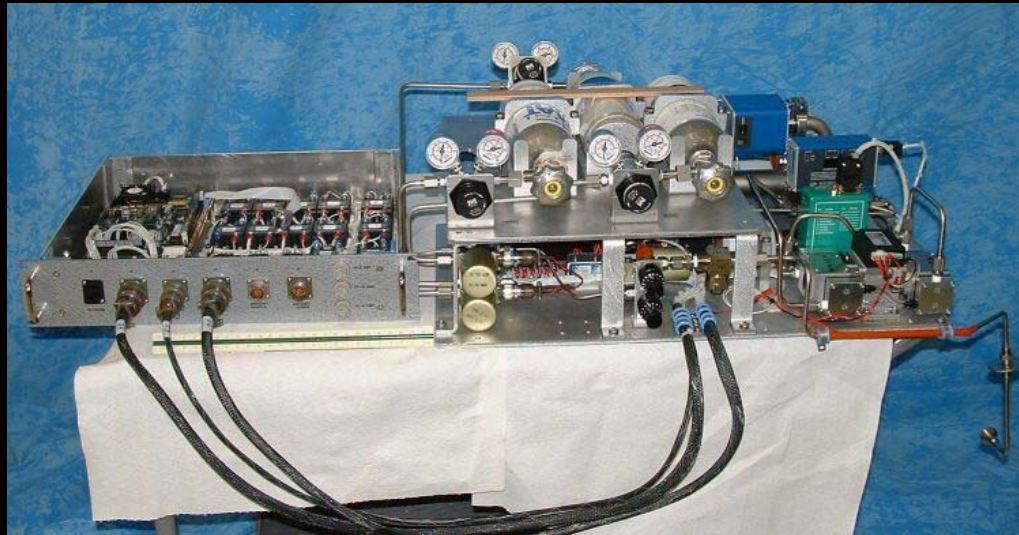




# *Monitoring Volcanic Emissions*

## Aircraft Monitoring

- Portable: 92,400 cm<sup>3</sup> (5,640 in<sup>3</sup>); 45 kg (104 lb)
- Power Efficient: 350 W steady state
- Rugged: 25 to -60°C; 760 to 50 torr
- Autonomous Operation

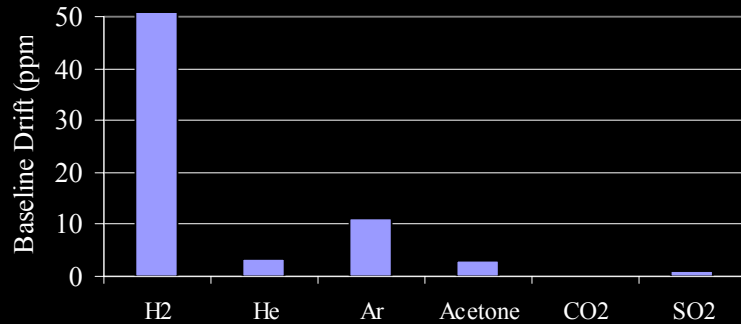
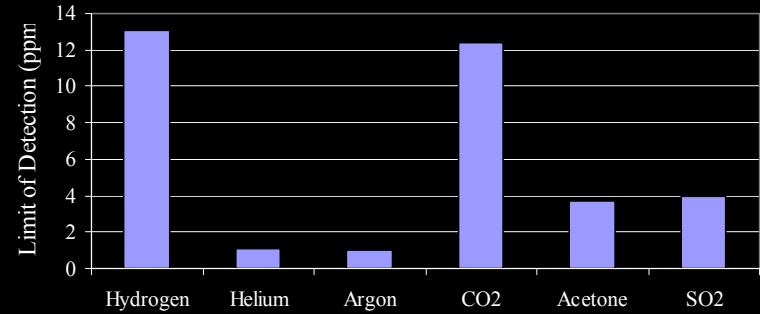
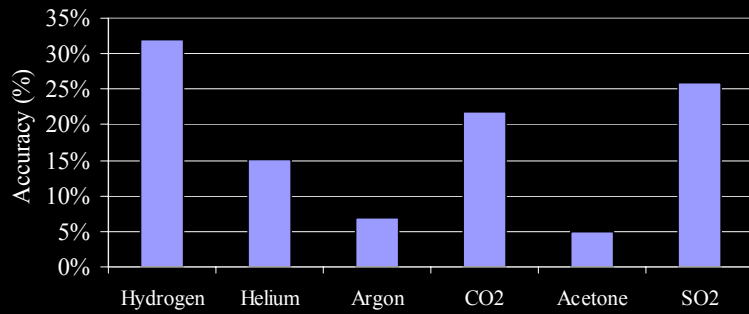


# *AVEMS Automated Procedure*



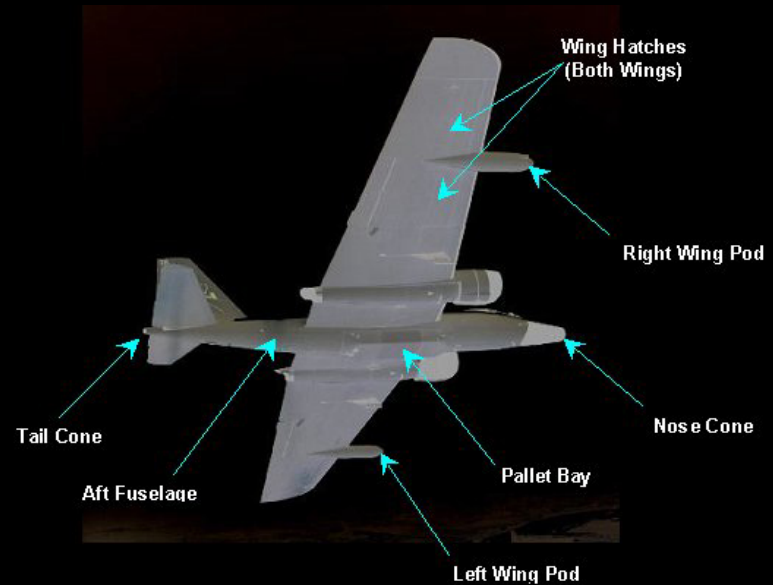
1. Turn On
2. Pump Down ~5 min
3. Stabilize ~5 min
4. Calibrate ~15 min
5. Measure Sample
6. Check for Pressure Change
7. If  $\Delta P$ , then 4, else 5

# Figures of Merit



# *Sampling from WB-57*

- Forward Transition
- 30 sec/scan
- 2.5 mile at 300 mile/hr
- 1.7 mile at 200 mile/hr

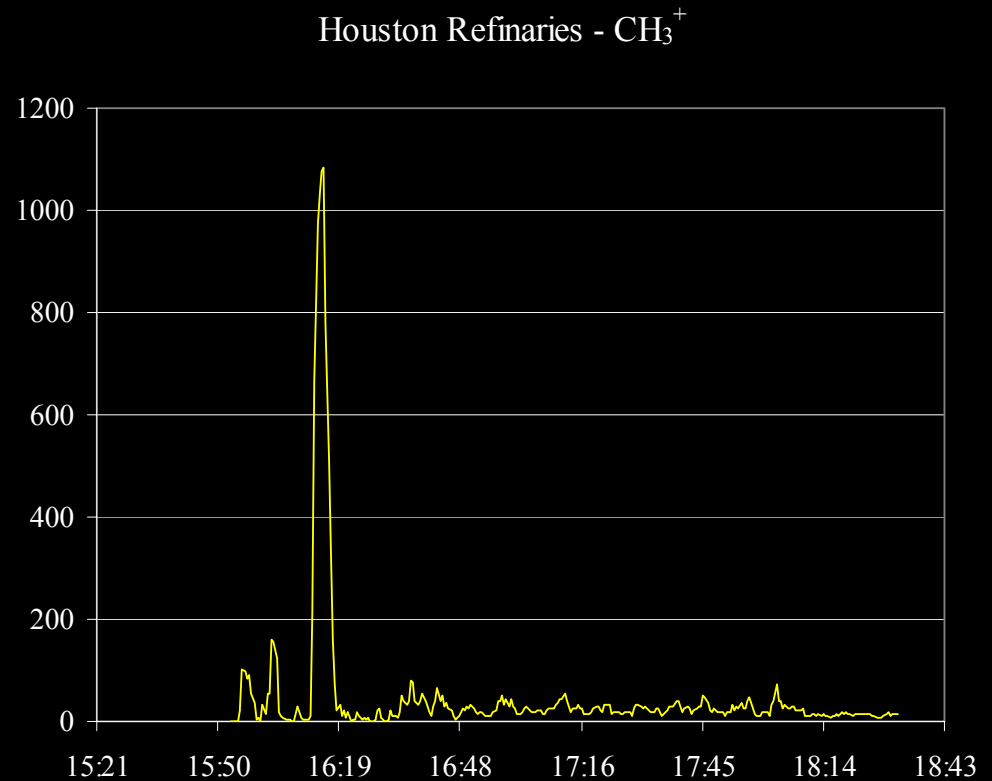


# *Sample Inlet on WB-57*



# *Tests in Houston – Petroleum Plants*

- 3 Successful Tests
- Water Problems
- Methyl ion
- 5000 ft.



# *CARTA 2003 Mission*



## *Costa Rica Airborne Research and Technology Applications*

- 3 Instruments Involved
  - Mass Spectrometer (Air Analysis)
  - Hyper-spectral Analyzer (Ground Analysis)
  - Cameras (Ground Analysis)
- AVEMS
  - Low altitude, Above volcanoes
- Other Instruments
  - High altitude, Entire Country

# *Monitoring Volcanic Emissions*

- Current Methods
  - Large
  - Removed from Sample Location
  - High Power Requirements
  - Needs improved Reliability
  - GC-MS, NO<sub>x</sub>, O<sub>3</sub>

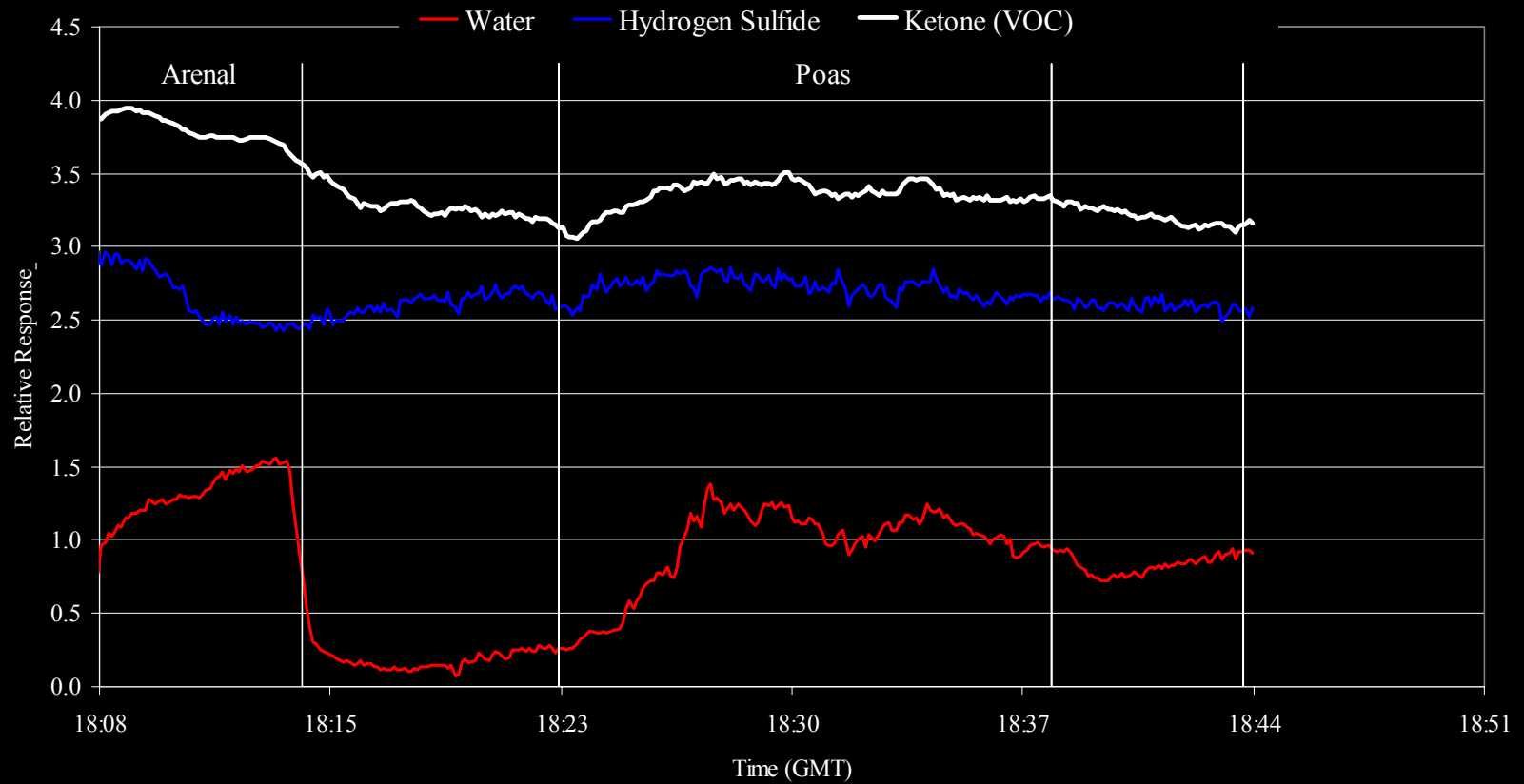




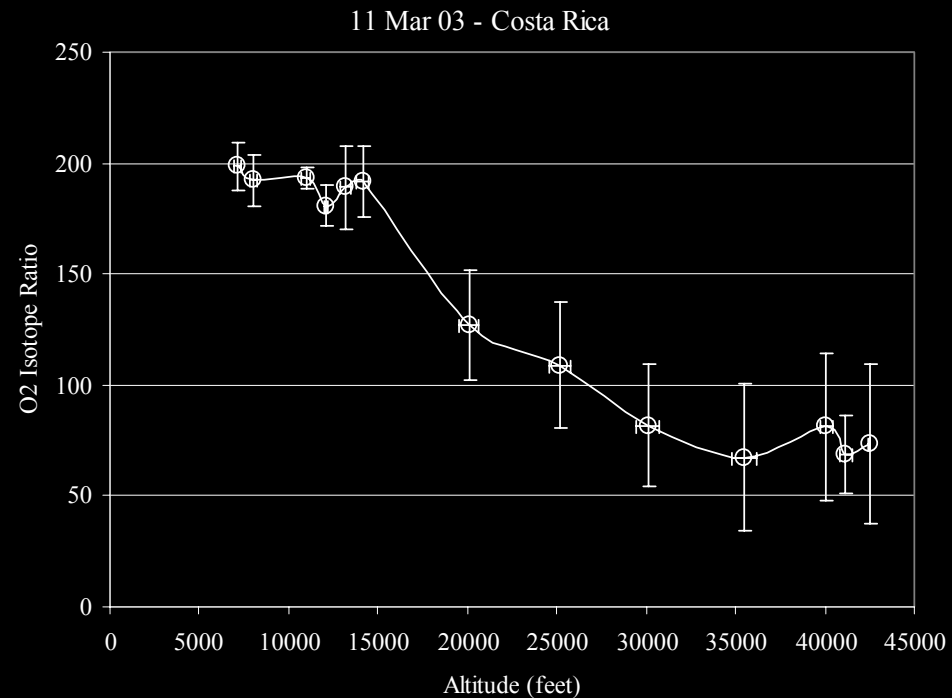
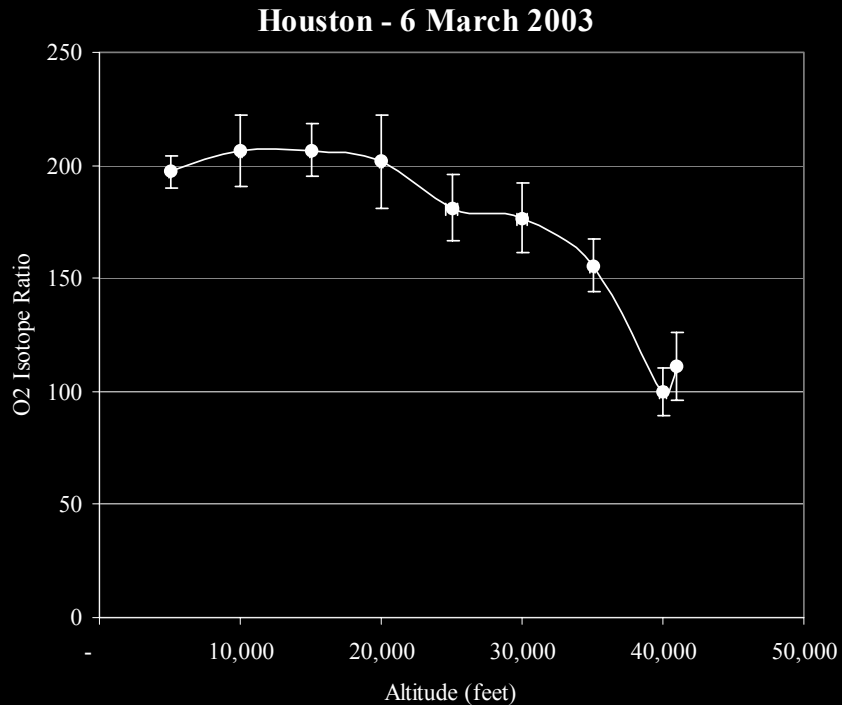
# *WB-57 in Costa Rica*



# Flight Results



# Flight Results – Isotope Ratios



# *Ground Tests Around City*



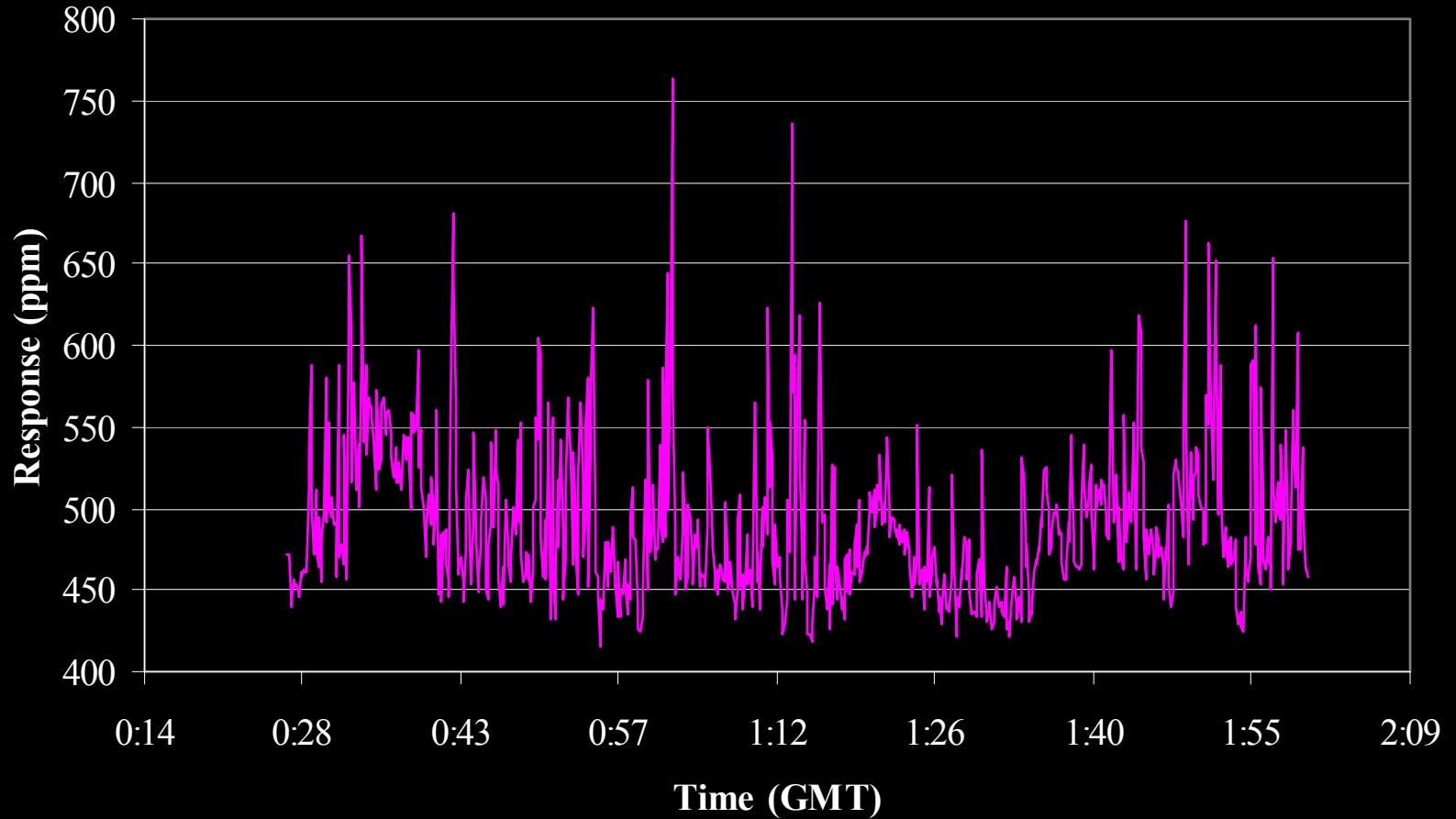
- Operate in Other Vehicles
  - Operate on Automobile Power
  - Take to Remote Location Via Automobile/Human
- Mounted System in Car
- Drove Around Metropolitan Area
  - San Jose
  - Highway CR-1 (Main Highway)
  - Alajuela
- Able to Monitor Changes for each area

# *AVEMS in Back of 4x4*

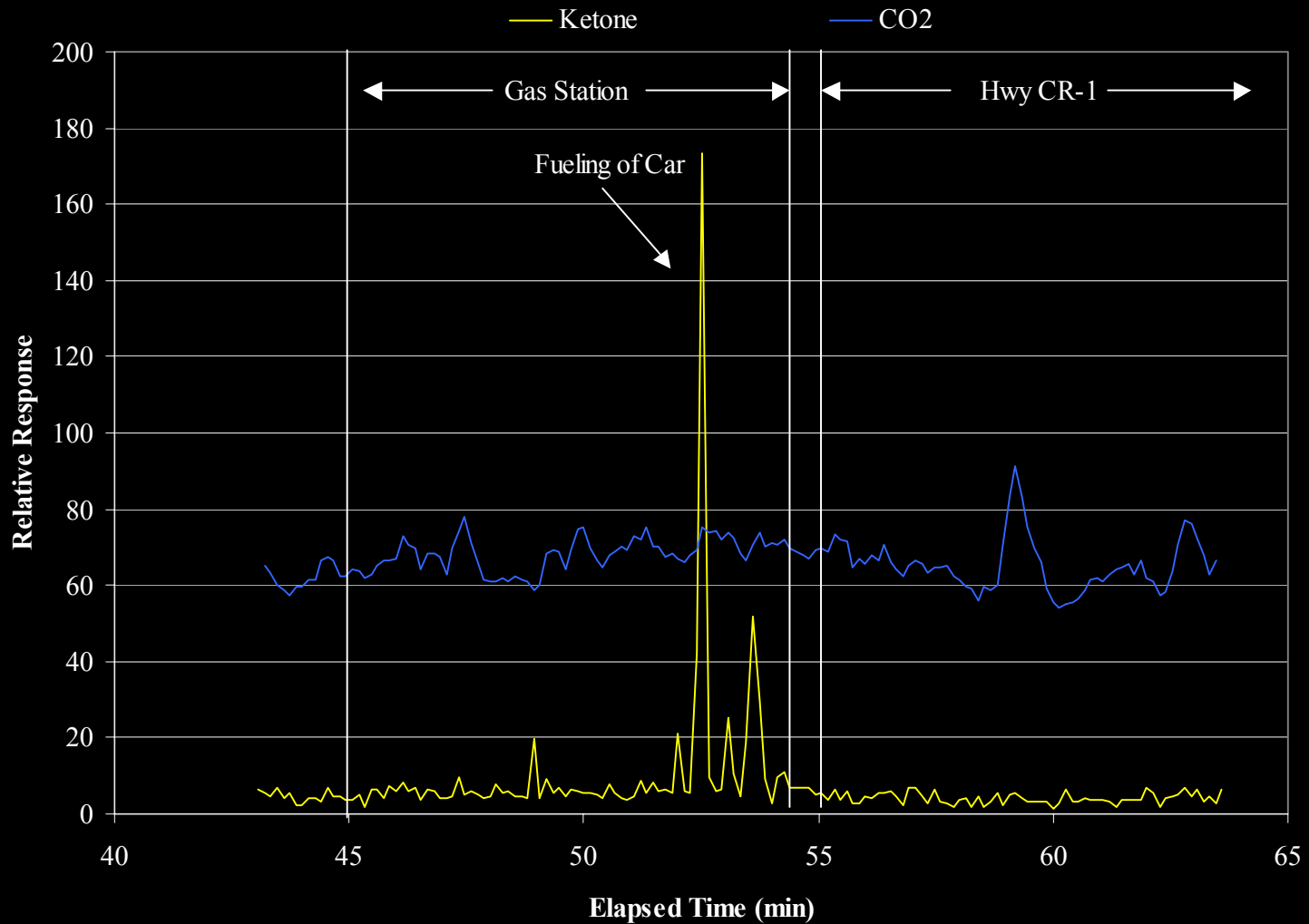


# *Driving Results*

CO2 (ppm)



# Gas Station Results



# *Ground Tests at Volcano*



- Background
  - Central Costa Rica (10.03 °N, 83.77 °W)
  - Summit Elevation 3340 m (10,960 ft)
- Transported AVEMS to Turrialba
  - In back of 4x4
  - By hand
- Collected Fumaroles Data
  - On-site monitor with AVEMS
  - Sample bottle for later analysis



# *Hand Transport to Field*



- Intimate Understanding of Miniaturization
  - 105 lbs, 2 mile trail, 2 car batteries, laptop
  - Diagnostic for locating lost muscle groups

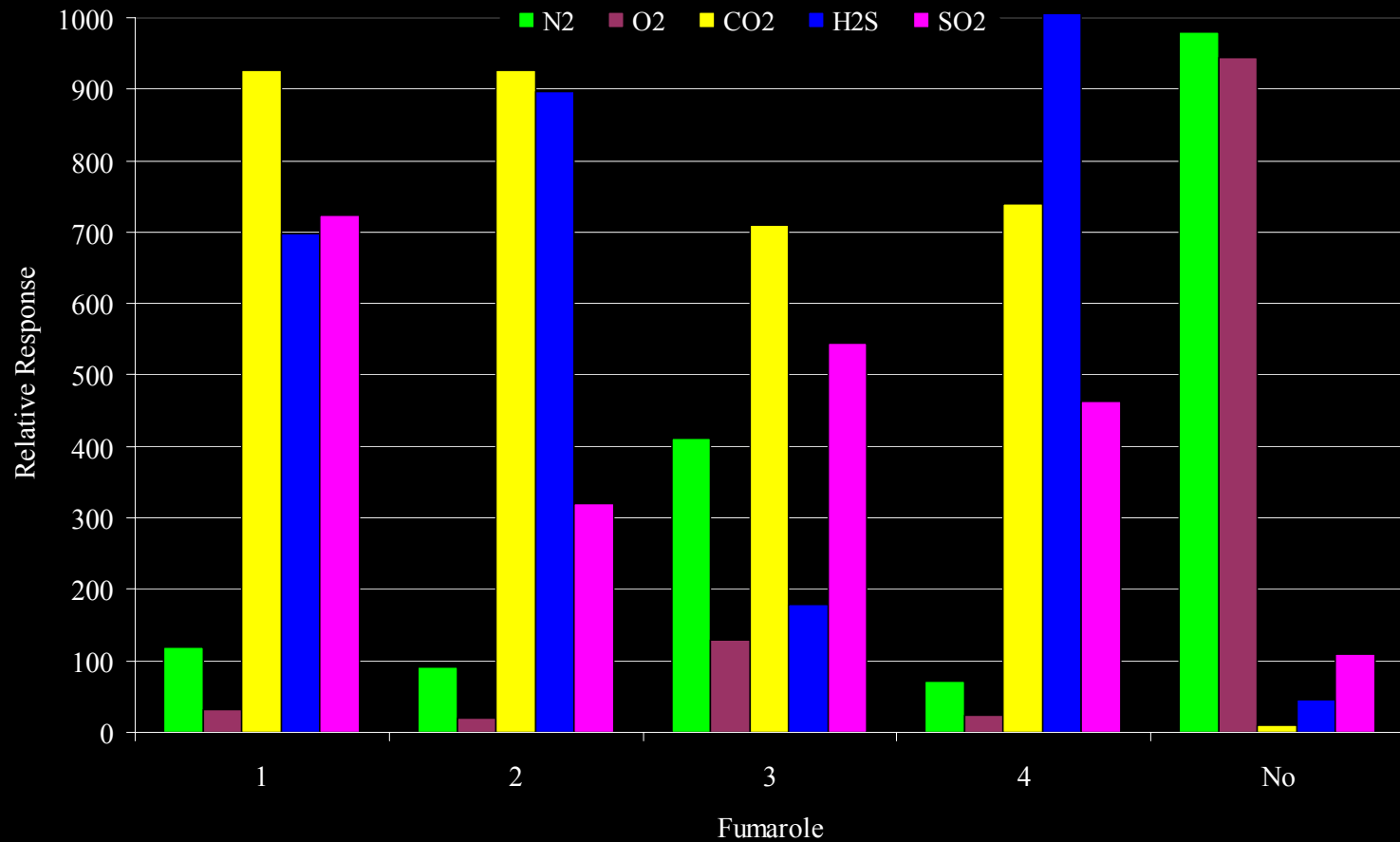
# *AVEMS at Turrialba Volcano*



# *Collecting Sample at Turrialba*



# *Turrialba Data*



# *Future – CARTA II*



- Atmospheric Analysis
  - Pollutants (CO<sub>2</sub>, VOC, ...)
  - Isotope Ratios (O<sub>2</sub>, Ar, ...)
- Volcanic Analysis
  - Emissions (SO<sub>2</sub>, H<sub>2</sub>S, ...)
- Upgrades to AVEMS
  - Standby Mode
  - Better H<sub>2</sub>O Tolerance
  - Use less calibrant gas
  - Increased altitude
  - Improved data analysis

## *Future Work*



- Reduce Size and Weight of System
- Improve MS and SDS to Increase Performance
- Larger Range of *In-Situ* Applications
  - Municipal & Industrial Air Quality
  - Municipal & Industrial Water Quality
  - Biochemical Warning
- Small, Rugged System for Shuttle/ISS/ELV

# Conclusions



- Pluses
  - + Detected Components Over/In Volcanoes
  - + Rugged – Survived Trip to Turrialba, around San Jose, and in the WB-57
  - + System Worked as Designed
  - + Identified Items Specific to Field Deployment
- Minuses
  - Detection Limits too High
  - Update Rate too Slow
  - Heavy for Hand Carrying

# *Acknowledgements*



- NASA
  - Tim Griffin
  - Ric Adams
  - Duke Follistein
  - Dean Lewis
  - Eric Thaxton
- ASRC
  - Guy Naylor
  - Bill Haskell
  - Charles Curley
  - David Floyd
  - Mike Blalock
- University of Costa Rica
  - J. Andres Diaz