Air Quality Monitoring: Risk-Based Choices

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Roadmap

- Controlling risk of toxic events
- Learning from adverse events
- Archival air sampling
- On-board, real-time analyzers
- Commercial vs. one-of-a-kind monitors
- Constraints on spaceflight hardware
- A dusty future-living on a distant celestial body
- Recap

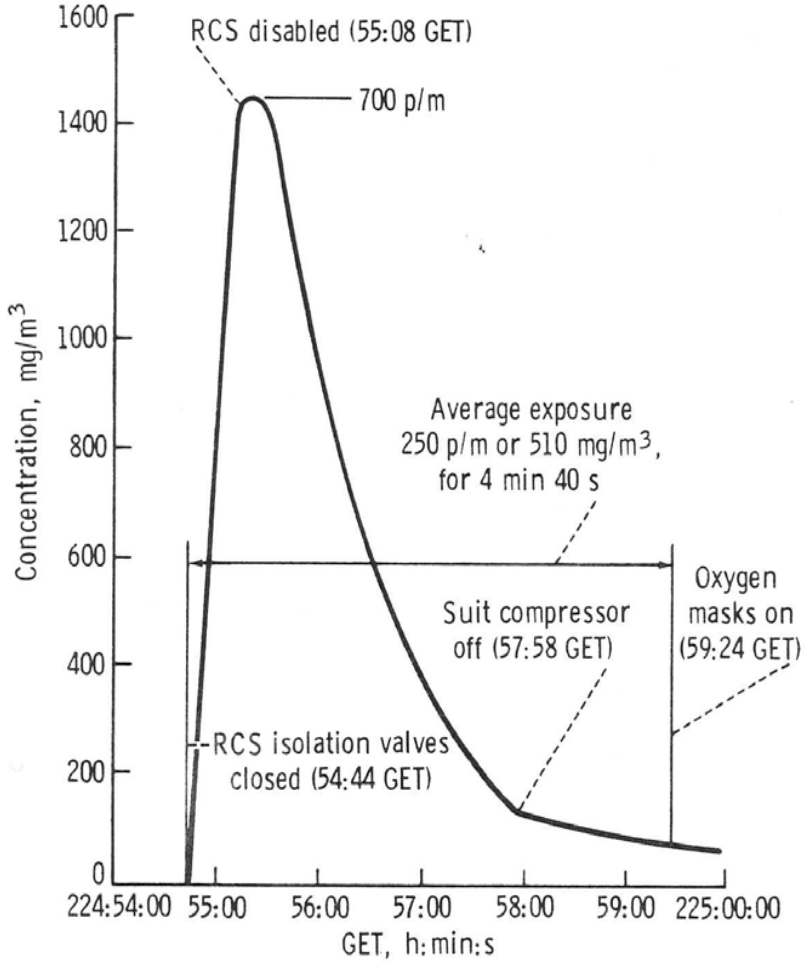
Controlling Risk of Toxic Exposure

- Use non-toxic systems chemicals
- Use materials that do not offgas much
- Contain toxicants in payloads
- Use non-toxic utility compounds
- Operationally limit access to toxic compounds
- Provide robust air scrubbing capability
- Personal protective equipment available
- Ability to escape spacecraft

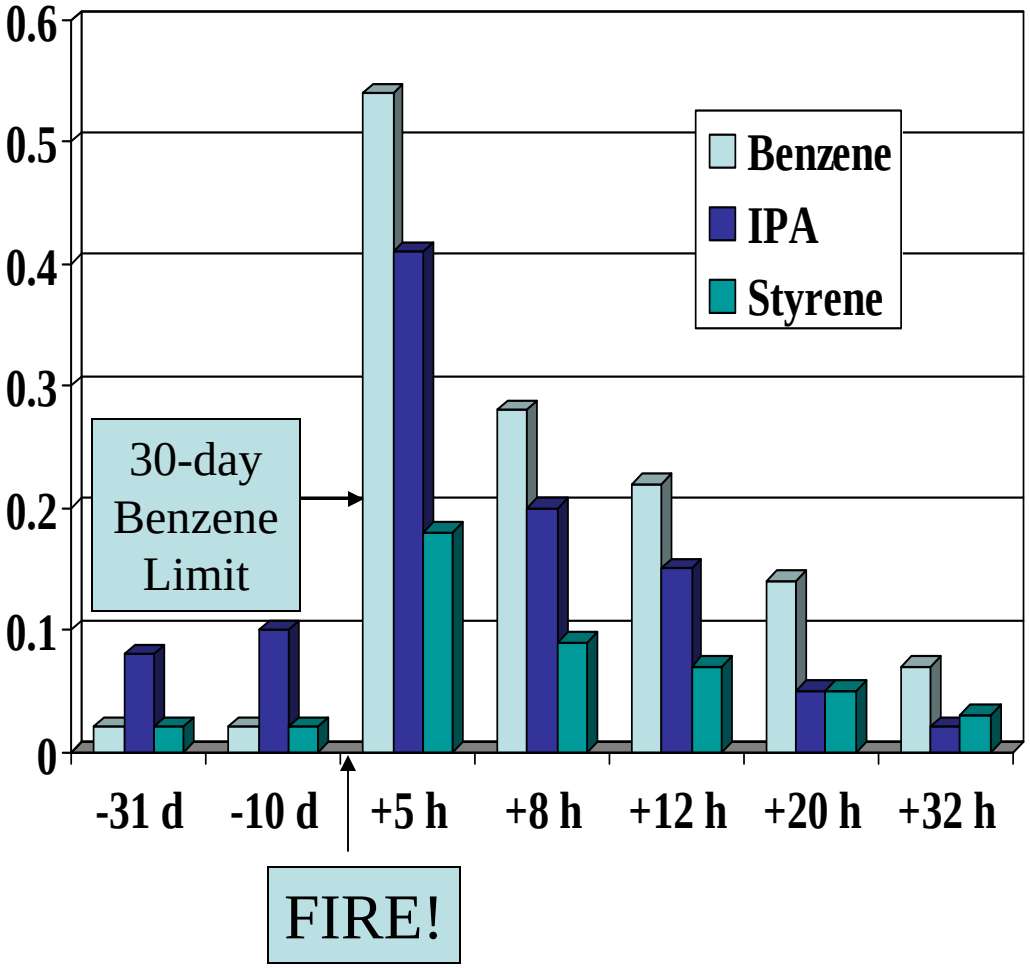
Learning from Adverse Events

- Toxic propellants
- Fires
- Pyrolysis events
- Leaky thermal control systems
- Excess carbon dioxide
- Formaldehyde accumulation
- Unpredictable events
- Dust

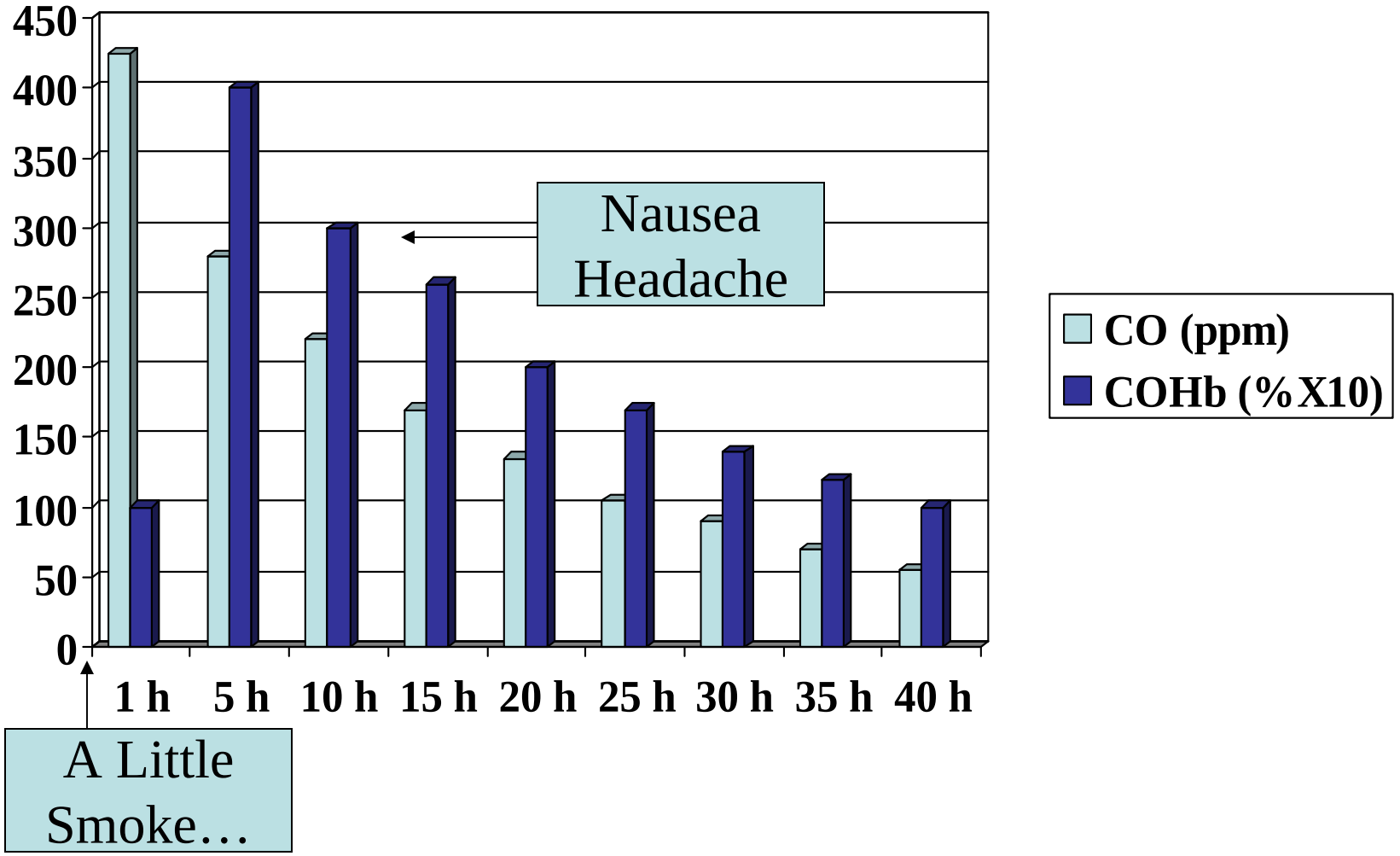
Apollo-Soyuz: Nitrogen Tetroxide Exposures-1975



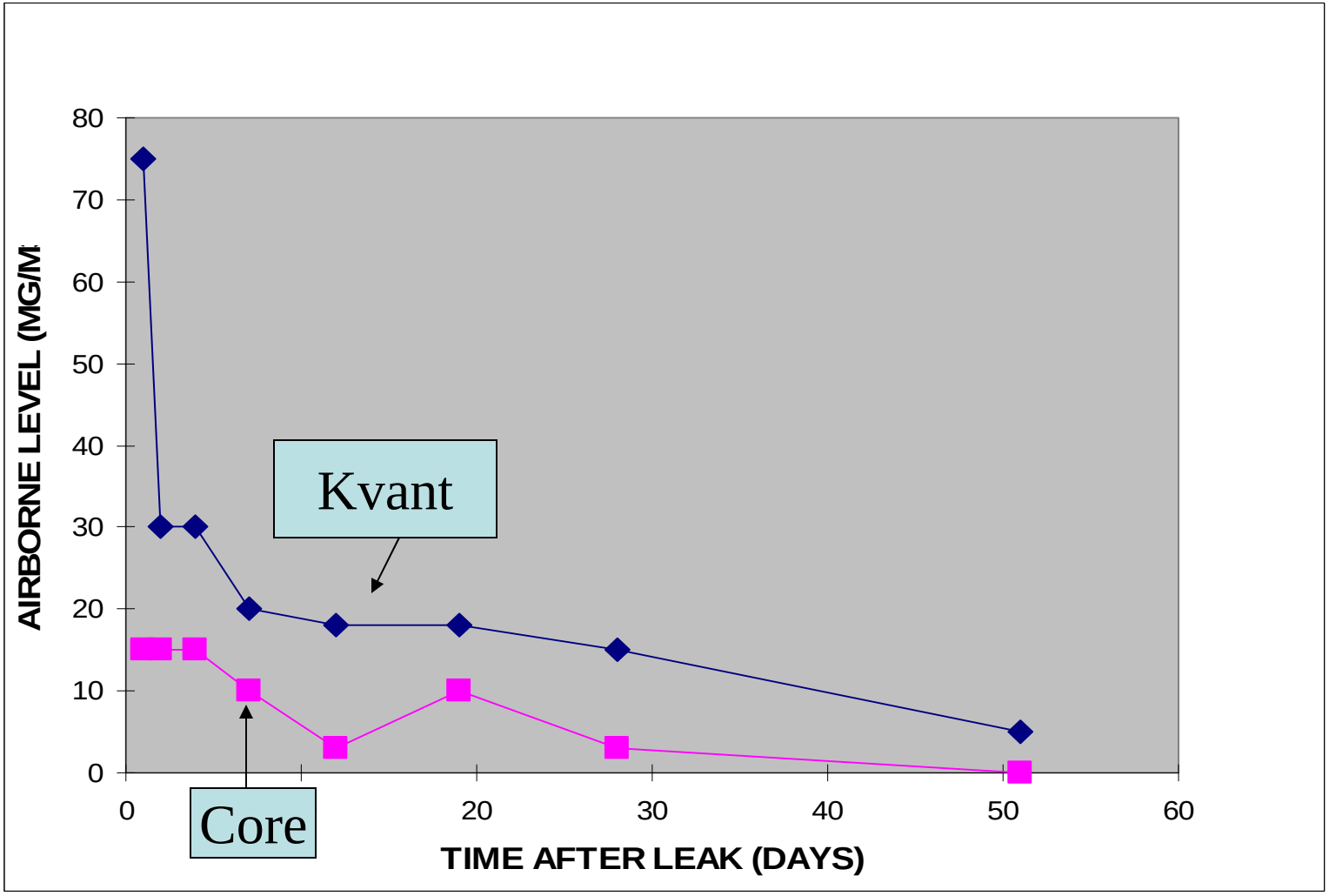
Selected Pollutants in Mir Air after the SFOG Fire (mg/m^3)

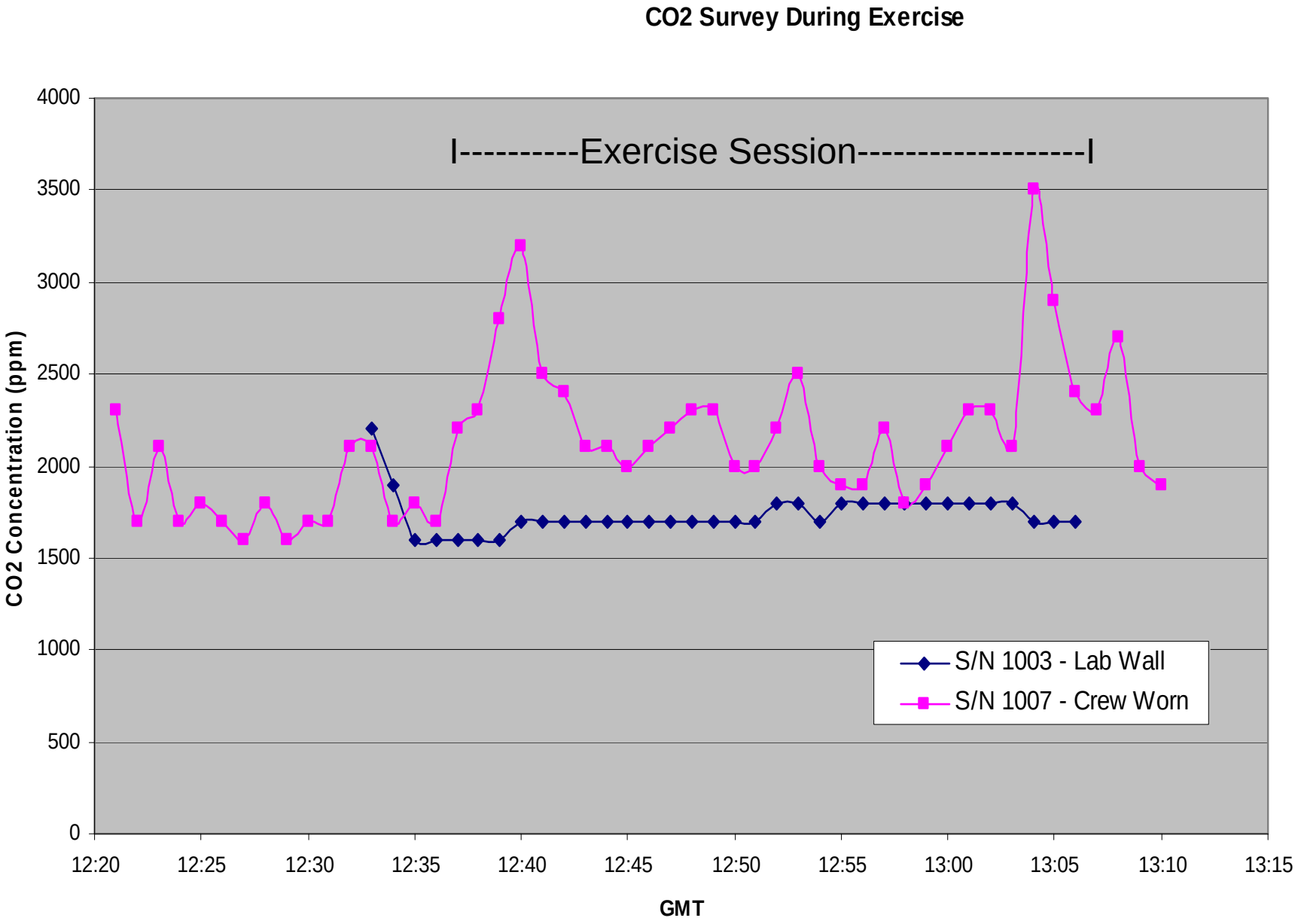


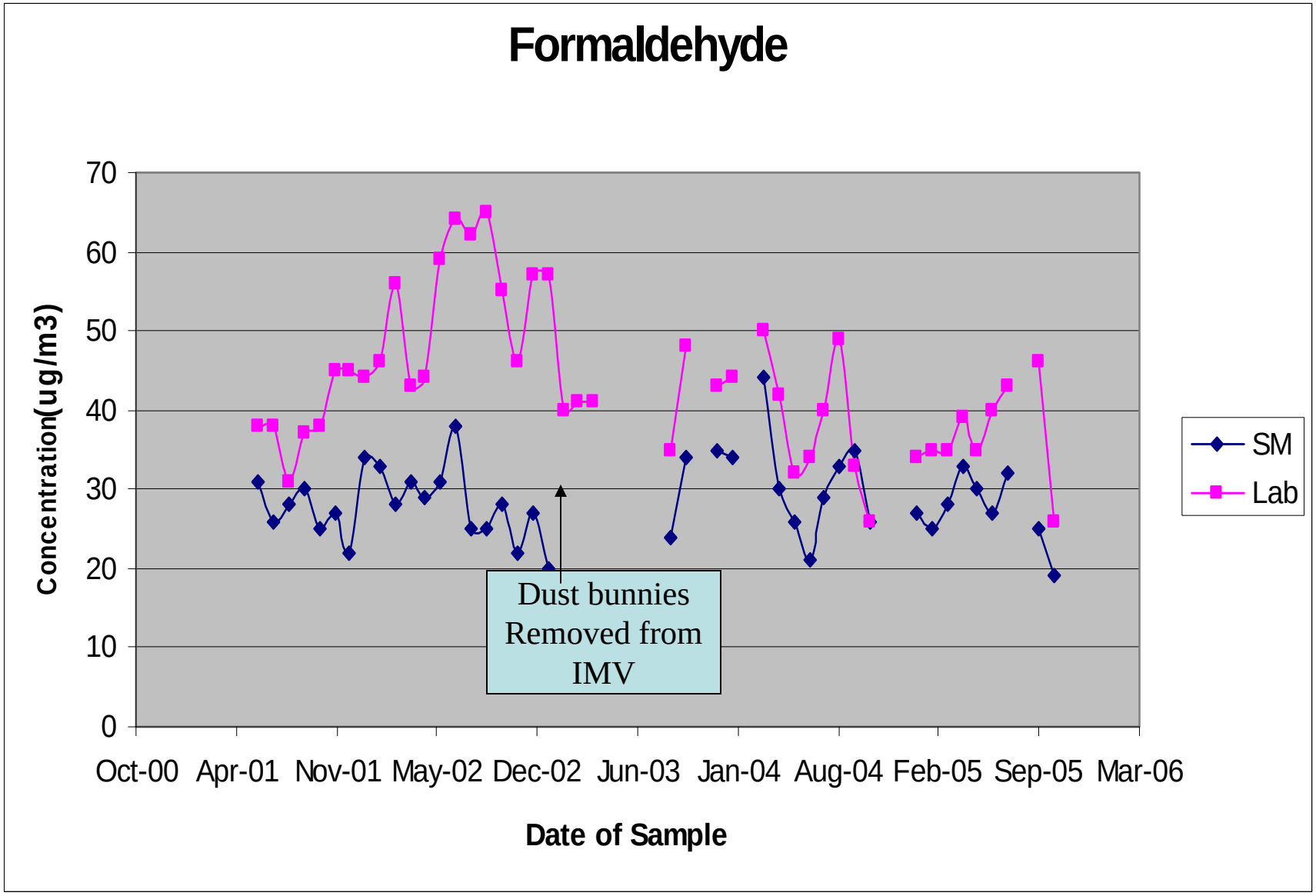
Carbon Monoxide and Carboxyhemaglobin Profiles after the SMALL BMP Filter Burn (CPA data)



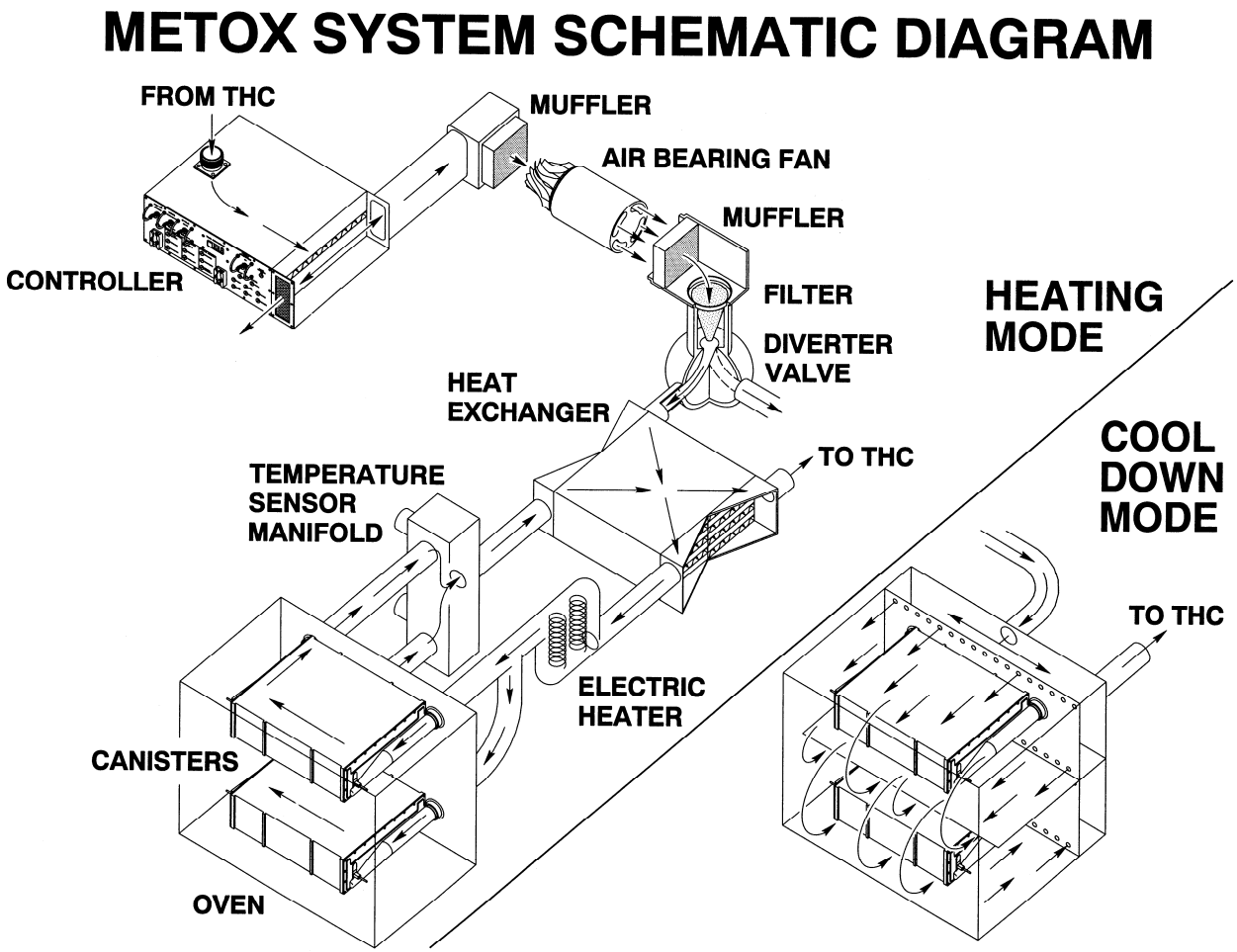
Ethylene Glycol in Mir Air after Leak from the Thermal Control System: Kvant and Core Module



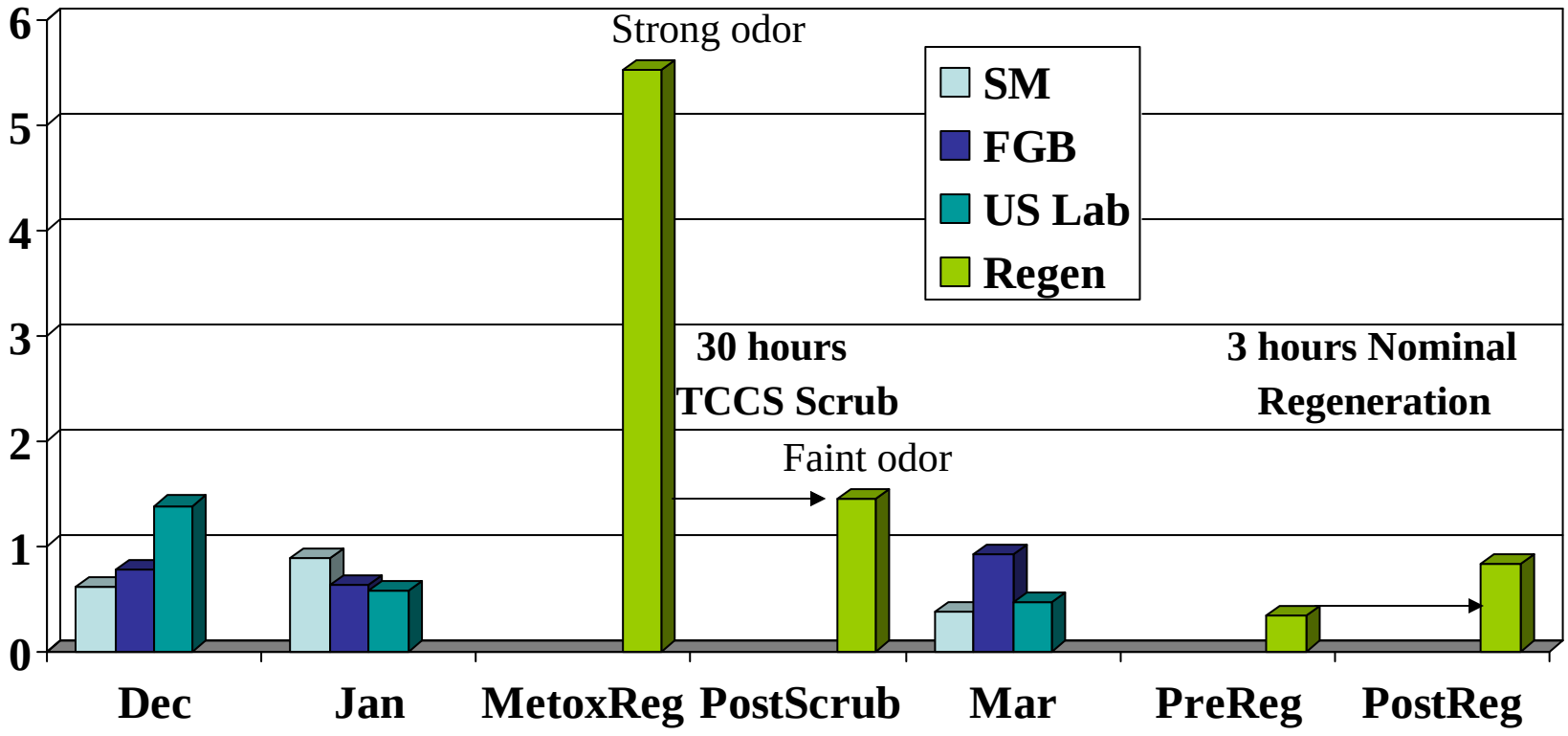

CO2 Survey During Exercise
I---------Exercise Session----------I
CO2 Concentration (ppm)
4000
3500
3000
2500
2000
1500
1000
500
0
12:20
12:25
12:30
12:35
12:40
12:45
12:50
12:55
13:00
13:05
13:10
13:15
GMT
S/N 1003 - Lab Wall
S/N 1007 - Crew Worn


Formaldehyde
Concentration(ug/m3)
70
60
50
40
30
20
10
0
Oct-00
Apr-01
Nov-01
May-02
Dec-02
Jun-03
Jan-04
Aug-04
Feb-05
Sep-05
Mar-06
Date of Sample
SM
Lab
Dust bunnies Removed from IMV

Unpredictable Event



Impact of Metox Regeneration on T Values [index of toxicity]



Archival Samplers

- 3 surrogate standards
- Sample is aspirated by vacuum in <5 seconds
- Analysis in Lab by GC and GC/MS
- Reactive compounds are lost
- Problem-valve not sealed well after sampling

-Formaldehyde trapped in badge matrix by diffusion
-Typical sample time is 24 h (in pairs)
-Formaldehyde eluted from badge and analyzed by spectrophotometry
-Limitations: must have sufficient face velocity of air

Hand-held air monitors

CSA-CP

- Commercial unit using electrochemical sensors
- First alert and source finding capability
- Zero capability
- Combustion tested and certified at 10.2 psia
- Carbon Monoxide-slight drift with closed storage
- Hydrogen Chloride sensor not specific
- Hydrogen Cyanide-depleted in use
- Oxygen-back up to the MCA
- Masking criteria after fire

Carbon Dioxide Monitor

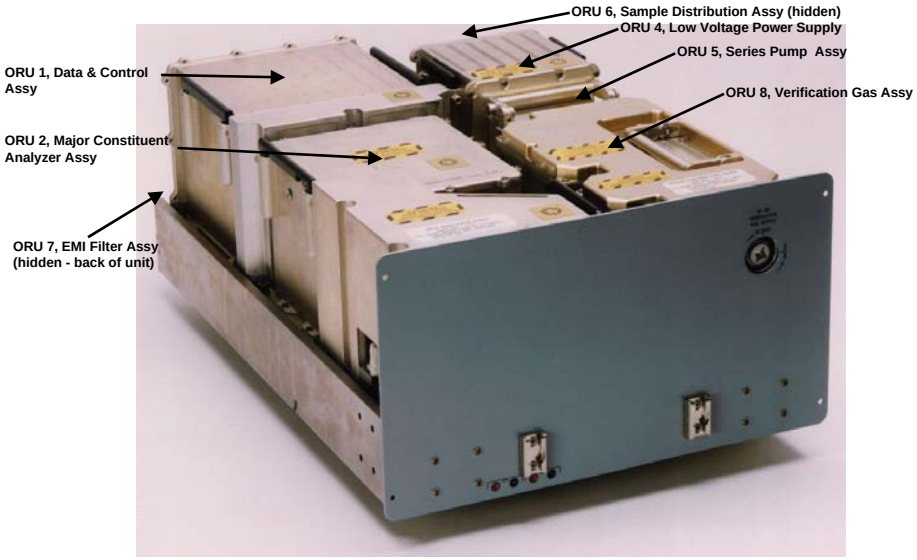
-Commercial unit
-6 % upper limit
-18 h battery life (sample is pumped)
-Water & particle filter
-Infrared absorption used to measure CO_2 in air
-Robust/stable device

Dräger Chip Measurement System

- Flown by Russian partners
- Two-year shelf life
- One analyte at time
- Up to 10 sequential measurements
- Less than 2 minute response time
- Few interferences
- Wide collection of analytes
- Lacks sensitivity to meet nominal monitoring requirement
- Effective in contingency

Major On-Board Instruments

- Major Constituents Analyzer
- Mass spectrometer
- O_2, N_2, H_20, CH_4, CO_2, H_2

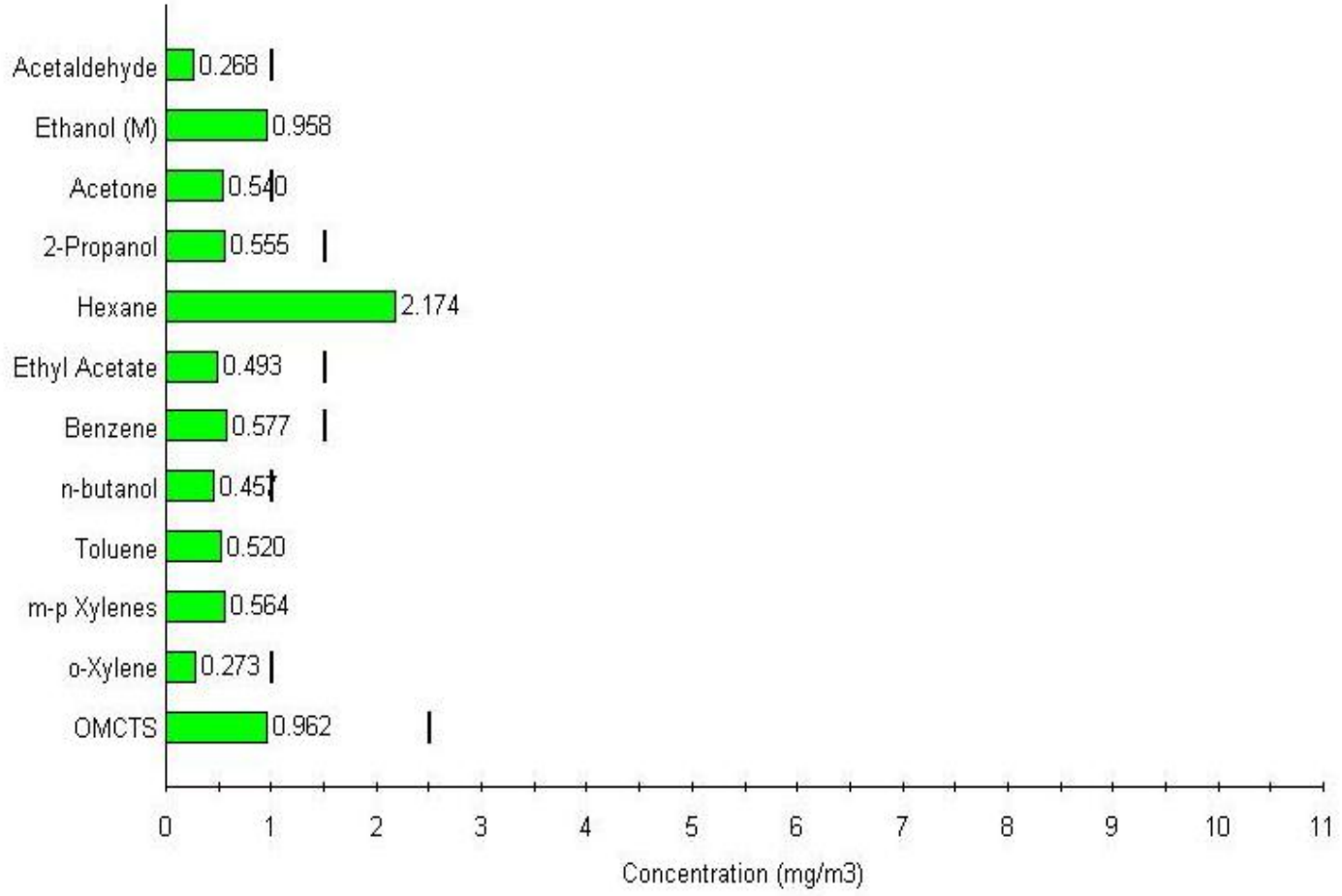


- Volatile Organics Analyzer
- GC-Ion mobility spectrometer
- Many trace organics

Other Air Quality Instruments

- ANITA-Trained system to deconvolute FTIR spectrum
- Electronic Nose-trained sensor array for target compounds
- VCAM-GC/MS system
- Air Quality Analyzer-GC/differential mobility spectrometer

Data Presentation to the Crew



Commercial vs. One-of a-kind Instruments

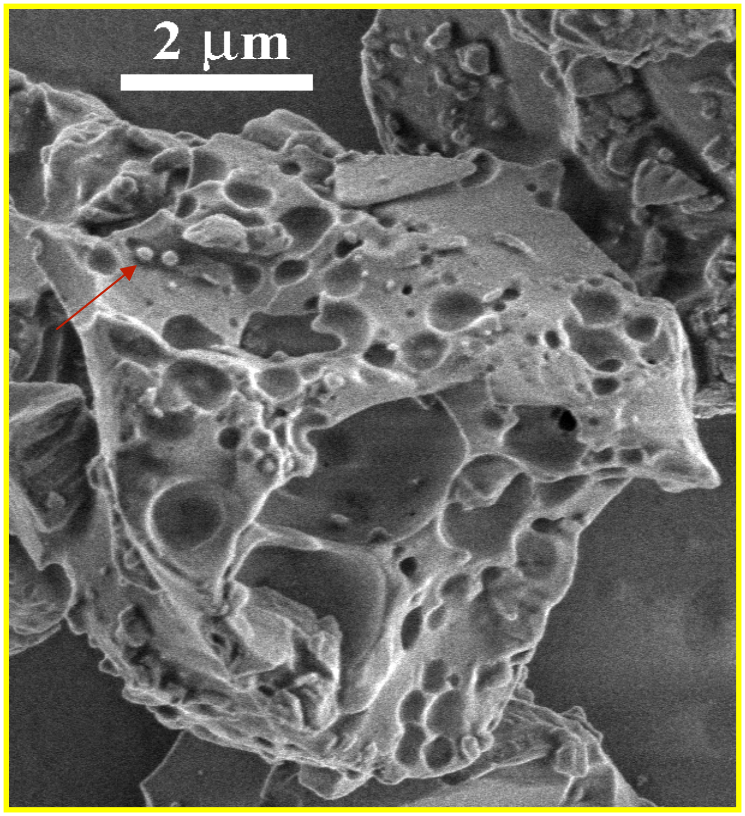
- Commercial
  - Inexpensive
  - Small
  - Experience history
  - Established support
  - Adapt to requirements
  - Easy sustainability
- One of a kind
  - Expensive
  - Large
  - Performance uncertain
  - Support may vanish
  - Build to requirements
  - Pain to sustain

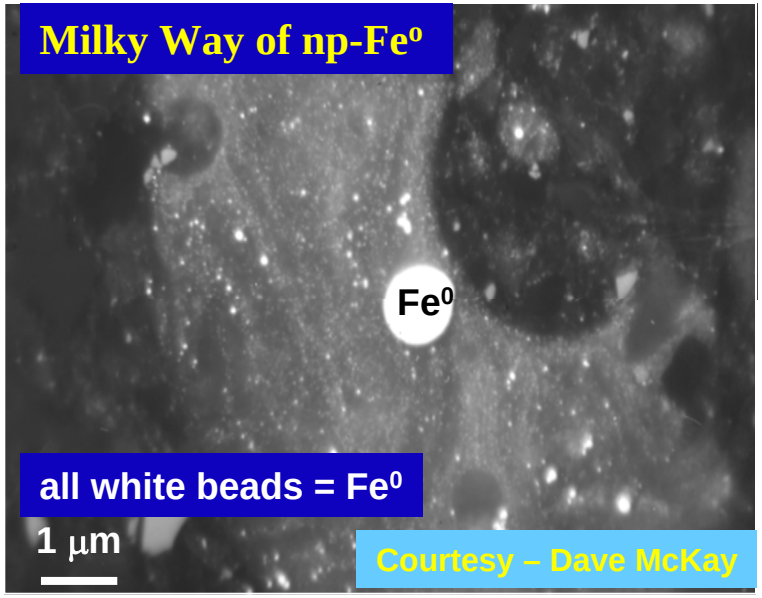
Constraints on Spaceflight Hardware

- Small and low mass
- Use minimal resources
- Little or no crew time
- Infrequent calibration
- Reliable performance for 2 years
- Follow cleanup in a contingency
- Perform after a combustion event
- Proper information conveyed to the crew

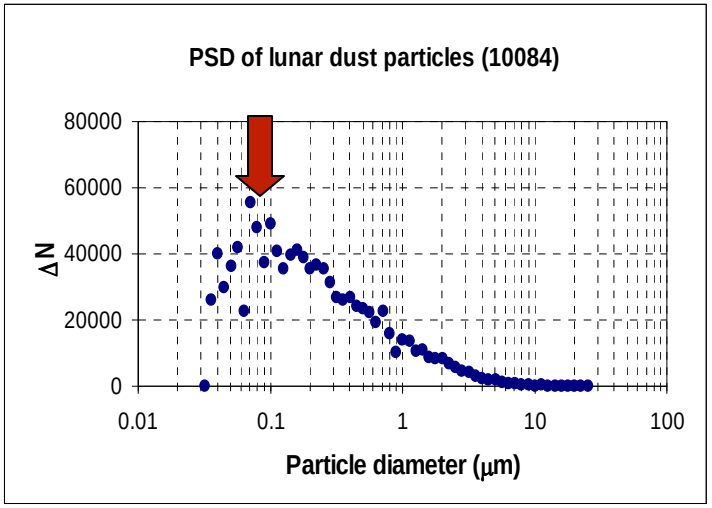
DUST

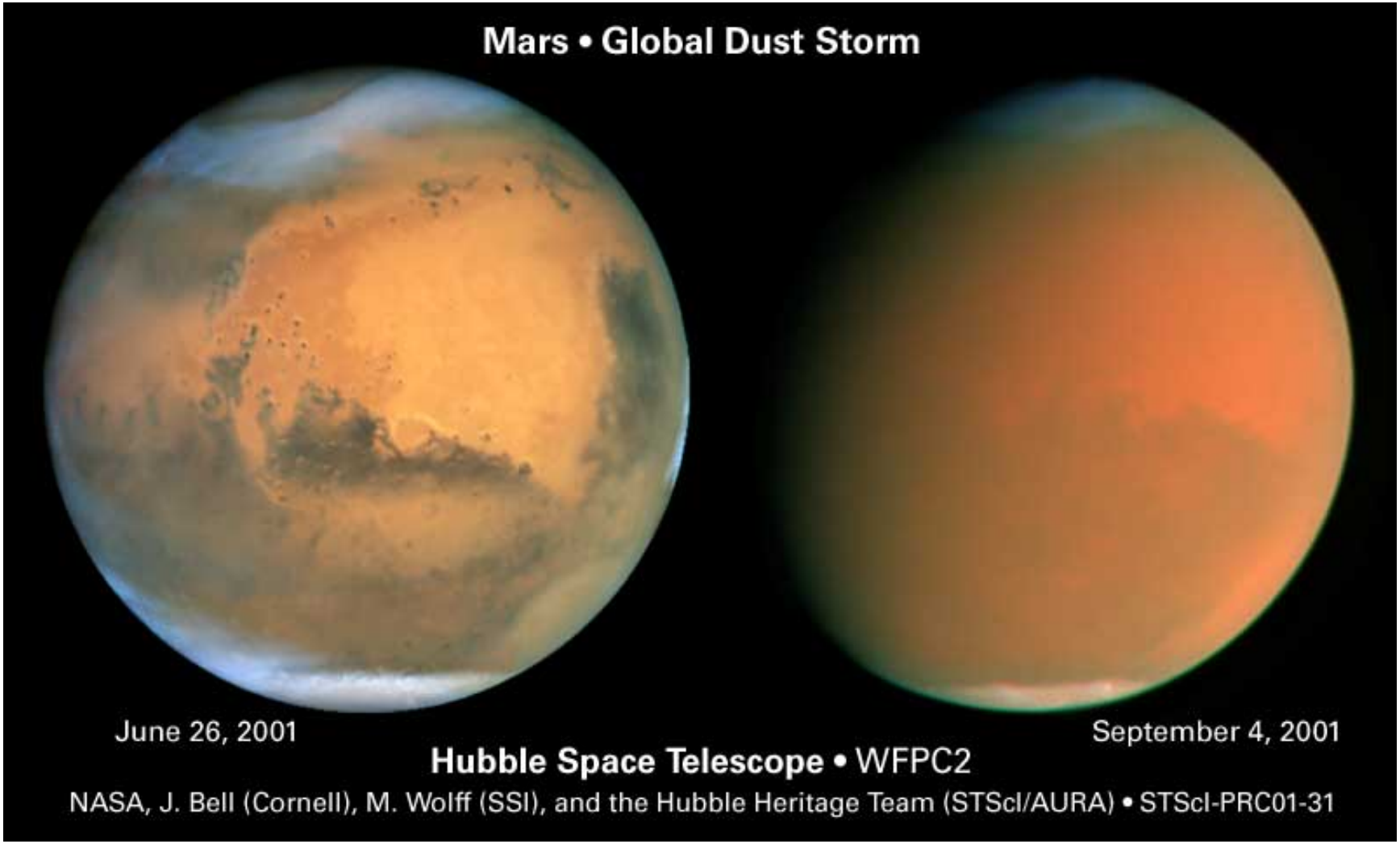
Lunar Dust Properties



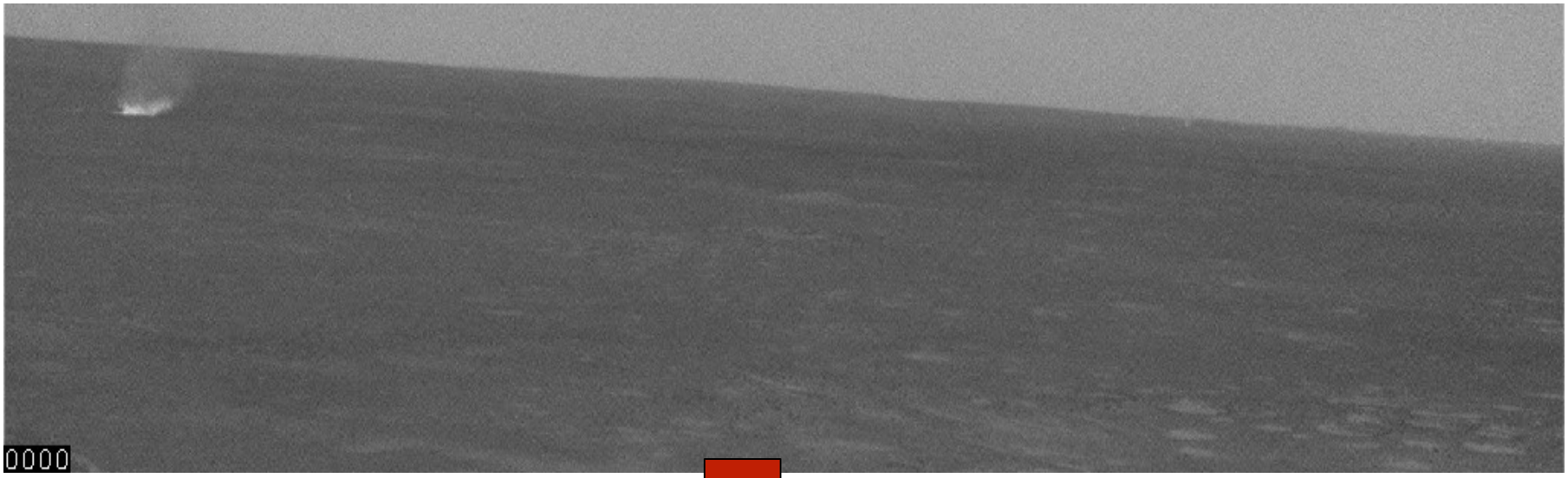


Larry Taylor, U of Tennessee

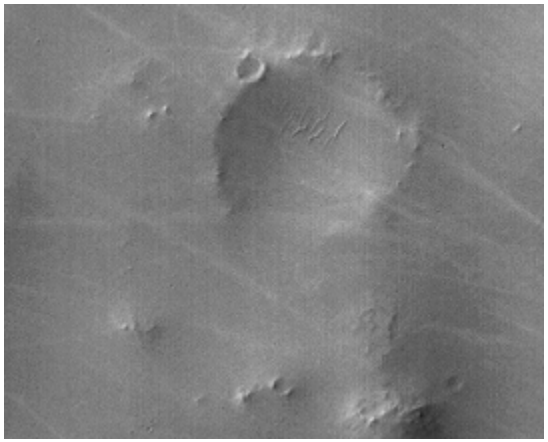



Mars • Global Dust Storm
June 26, 2001
September 4, 2001
Hubble Space Telescope • WFPC2
NASA, J. Bell (Cornell), M. Wolff (SSI), and the Hubble Heritage Team (STScI/AURA) • STScI-PRC01-31

A Dusty Future



Phobos



Martian Dust Devils

Ida and Dactyl

Recap

- Air monitoring is secondary to rigid control of risks to air quality
- Air quality monitoring requires us to target the credible residual risks
- Constraints on monitoring devices are severe
- Must transition from archival to real-time, on-board monitoring
- Must provide data to crew in a way that they can interpret findings
- Dust management and monitoring may be a major concern for exploration class missions