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/m³)

- Benzene
- IPA
- Styrene

30-day Benzene Limit

FIRE!
Carbon Monoxide and Carboxyhemoglobin Profiles after the SMALL BMP Filter Burn (CPA data)

A Little Smoke...
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)

GMT

S/N 1003 - Lab Wall
S/N 1007 - Crew Worn
Formaldehyde

Date of Sample

Concentration (ug/m³)

Dust bunnies
Removed from IMV

SM
Lab

0 10 20 30 40 50 60 70

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
Unpredictable Event

METOX SYSTEM SCHEMATIC DIAGRAM

- FROM THC
- MUFFLER
- AIR BEARING FAN
- MUFFLER
- FILTER
- DIVERTER VALVE
- HEAT EXCHANGER
- TEMPERATURE SENSOR MANIFOLD
- CANISTERS
- ELECTRIC HEATER
- OVEN
- TO THC

HEATING MODE

COOL DOWN MODE

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

- SM
- FGB
- US Lab
- Regen

30 hours TCCS Scrub
- Strong odor

3 hours Nominal Regeneration
- Faint odor

- Dec
- Jan
- MetoxReg
- PostScrub
- Mar
- PreReg
- PostReg
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 CO₂ 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$_2$O, 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

- Acetaldehyde: 0.258 mg/m³
- Ethanol (M): 0.958 mg/m³
- Acetone: 0.540 mg/m³
- 2-Propanol: 0.555 mg/m³
- Hexane: 2.174 mg/m³
- Ethyl Acetate: 0.493 mg/m³
- Benzene: 0.577 mg/m³
- n-butanol: 0.451 mg/m³
- Toluene: 0.520 mg/m³
- m-p Xylenes: 0.564 mg/m³
- o-Xylene: 0.273 mg/m³
- OMCTS: 0.962 mg/m³

Concentration (mg/m³)
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

Hubble Space Telescope • WFPC2

September 4, 2001

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