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

- RCS disabled (55:08 GET)
- Average exposure 250 p/m or 510 mg/m³, for 4 min 40 s
- Suit compressor off (57:58 GET)
- Oxygen masks on (59:24 GET)
- RCS isolation valves closed (54:44 GET)
Selected Pollutants in Mir Air after the SFOG Fire (mg/m³)

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

A Little Smoke…

Nausea Headache
Ethylene Glycol in Mir Air after Leak from the Thermal Control System: Kvant and Core Module
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 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
- $O_2$, $N_2$, $H_2O$, $CH_4$, $CO_2$, $H_2$

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

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
Lunar Dust Properties

Larry Taylor, U of Tennessee
Mars • Global Dust Storm

June 26, 2001

June 26, 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