Advanced Environmental Monitoring Technologies

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Apollo 12 photograph, taken by lunar module pilot Alan Bean, mission commander Pete Conrad retrieves parts from the Surveyor.
Monitoring & Controlling the environment

- Air
- Water
- Plant chambers
- Food and Food Preparation surfaces
- Gradual buildup of toxic species
- Hazardous events
- Chemical
- Biological

Control

Water processor

Air processor

• Sensors
• Actuators
Gradual buildup of harmful chemical or microbials

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>DETECTION LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIORITY 1</td>
<td>PPM</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>0.1</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>0.01</td>
</tr>
<tr>
<td>Methanol</td>
<td>0.2</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>0.03</td>
</tr>
<tr>
<td>Perfluoropropane (F218)</td>
<td>10</td>
</tr>
<tr>
<td>Acetone</td>
<td>1</td>
</tr>
<tr>
<td>Octamethylcyclotetrasiloxane</td>
<td>0.05</td>
</tr>
<tr>
<td>2-Propanol</td>
<td>3</td>
</tr>
<tr>
<td>Freon 82</td>
<td>5</td>
</tr>
</tbody>
</table>

*Gradual buildup of harmful chemical or microbials

Hazardous event such as fire or leakage

*Microgravity combustion not shown
ILLUSTRATIVE EXAMPLE:

CANARY
Why a canary?

- Continuous air monitor
- Ground-based heritage
- Doesn’t require skilled operator
- Relatively low mass, low power
  - Can consider placing in several locations
- High sensitivity to many toxic gases
- Multifunctional potential:
  - air
  - water
  - food
  - music
- Probably will work in μgravity
- Built in signal processing
- Edible
Why not a canary?

- Requires fuel (food), water, maintenance
- Generates waste products
- Overload requires complete system replacement
- Quantitative capability suspect
- Limited life
- Difficult to interface and network
- Low precision display
  - Could be hard to read in µg
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Why not a canary?
A canary in water
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.
Ground-based Commercial technology

- High mass
- High power requirement
- High operator skill
- High capability
- May require gravity

- Lower mass
- Lower power requirement
- Low operator skill
- Low capability
- May require gravity

**Breakthroughs needed to achieve high capability and low mass/power plus autonomy**
Current Practice: in flight

Volatile Organic Analyzer (VOA):
measures about 30 volatile organic species

Major Constituent Analyzer (MCA):
Nitrogen, Oxygen, Carbon Dioxide, Water vapor
Current Practice: Post Flight

Grab Sample Bottles: Thorough analysis
By GCMS, over 100 species

Formaldehyde Badges

ICES 2003-01-2647 Toxicological Assessment of the International Space Station Atmosphere with Emphasis on Metox Canister Regeneration
John James, et al

ICES 2003-01-2646 Validation of the Volatile Organic Analyzer (VOA) aboard the International Space Station
Thomas Limero, et al
Current Practice: Post Flight

Figure 1. Overview of the airflow inside Zarya with opposed panels opened to 90 degrees. This diagram was adapted from Alibaruho et al. (1999) with addition of the flow arrows going from the walls toward the isle through open panels. The goal of the figure is to indicate the potential for disrupted airflow where panels have been opened.
Miniature Mass Spectrometer for Planetary Exploration and Long Duration Human Flight

- 0.5 amu resolution, 1-300 amu range
- Used by astronauts in Shuttle Mission 5A and beyond to detect ammonia and air leaks outside the International Space Station

The Quadrupole Mass Spectrometer Array (QMSA)

The QMSA Packaged as the Astronaut’s Trace Gas Analyzer (TGA)
HARDWARE AND DATA ACQUISITION SYSTEM

First Generation Enose: Flight Experiment
- Volume: 2000 cm³
- Mass: 1.4 kg
- Power: 1.5 W ave., 3 W peak
- Computer: HP 200LX
- Materials:
  - container: cast aluminum
  - wetted surfaces: glass, PTFE, polypropylene
  - seals: silicon rubber

Second Generation ENose
- Optimized sensors, faster analysis, improved sensitivity
- Volume: 760 cm³
- Mass: 0.8 kg
- Power: 1.5 W ave., 3 W peak
- Computer: Handspring Visor Neo PDA
- Materials:
  - container: anodized aluminum
  - wetted surfaces: alumina, parylene
  - seals: Kal-Rez
16S rDNA phylogenetic tree

Red clones are opportunistic pathogen

Liver abscess

hyperurecemia

Cat scratch disease;
Bone-marrow infection

Halogen-reducers

Endocarditis;
hepatic granuloma

Halogen-reducers

Potable water

Regenerated water