Advanced Environmental Monitoring Technologies and Their Applications to Medical Diagnosis and Pathogen Detection

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Monitoring & Controlling the environment

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

-airprocessor
-waterprocessor
-control

○ sensors
● actuators
Gradual buildup of harmful chemical or microbials

Hazardous event such as fire or leakage

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>DETECTION LIMIT</th>
<th>PPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>0.2</td>
<td>0.03</td>
</tr>
<tr>
<td>Methanol</td>
<td>0.2</td>
<td>0.03</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Perfluoropropane (F218)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Acetone</td>
<td>0.05</td>
<td>3</td>
</tr>
<tr>
<td>n-Decane/hexane/tetra</td>
<td>0.05</td>
<td>3</td>
</tr>
<tr>
<td>2-Propanol</td>
<td>0.05</td>
<td>3</td>
</tr>
<tr>
<td>Freon 12</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

*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 \( \mu \)gravity
• Built in signal processing
• Edible
Why not a canary?

- Requires fuel (food), water, maintenance
- Generates waste products
- Low precision display
  - Could be hard to read in \( \mu g \)
- Overload requires complete system replacement
- Quantitative capability suspect
- Limited life
- Difficult to interface and network
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

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Optimizing Size vs Capability
AEMC Vision: Hierarchical monitoring/control

- **Analysis Instrument**: eg GCIMS, GCMS, FTIR
  - Analyzes for almost everything
  - Complex, expensive (although low mass)
  - Probably only one on board
  - "Fill-in" covers the few things that the Analysis Instrument doesn’t cover (eg, formaldehyde, O2, CO2...)
    - eg TDL, SERS
- **Sensor is simpler, cheaper, more robust**
  - May be fixed or portable
  - Much more capable than off the shelf
  - eg Enose, Bioarray
High Capability & Low Mass/Power + Autonomy = key to future SpaceFlight
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
**ELECTRONIC NOSE**

**SPACE STATION ENVIRONMENTAL MONITORING**
Event monitor - spills, leaks, clean up

**OTHER ENVIRONMENTAL MONITORING**

**INDUSTRIAL MONITORING AND PROCESS CONTROL**
Identity and condition of raw materials, leaks and buildup of toxic compounds. Monitor food processing.

**MILITARY APPLICATIONS**
Air quality monitor, detection of explosives and other hazards.

**MEDICAL APPLICATIONS**
Diagnosis through breath or body fluid analysis; remote monitoring of patient condition.

**PLANETARY EXPLORATION**
Study planetary atmosphere to determine constituents and fluctuations.

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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)

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Portable array biosensor miniaturization
Fran Ligler, Naval Research Lab
NASA Plans/Options

- **Internal development**
  - GCMS: *not much more internal development*
  - Enose:*not much past our current plans*

- **Partnering/Collaboration/Sponsorship**
  - *Would look for expertise in GC analysis and medical breath analysis*
  - Enose: *manufacturing, user interface*

- **Patent/licensing**
  - GCMS: *MS is patented and licensed.*
  - Enose: *ready to be licensed*
Future Developments

Remaining R&D

◆ Technical risk
  - GCMS: very little risk remaining to technology; needs manufacturable design
  - Enose:

◆ Remaining milestones
  - GC development
  - Enose: finish operations prototype

◆ Future enhancements
  - GCMS: Electronics miniaturization
  - Enose: more sophisticated design with more capability

◆ Need for outside expertise or resources
  - GCMS: GCexpertise
  - Enose: clinical applications expertise: breath analysis, patient compliance, veterinary applications
Applications Identified

◆ Commercial / Government
  – Air quality
  – Medical breath analysis

◆ By industry
  – Manufacturing
  – Clinical
Examples: (Industry wants to know what’s in it for them, what will make them want to use what you have developed. Bus. Development managers will need this info to pitch to their management)

- GCMS: small size -> field portable
- Enose: Quantitative, unlike other Enoses
  - Better air quality monitoring performance
Commercial Advantages

- Opens new market applications
  - GCMS: smaller, portable, more numerous placement
  - Enose: multiple placement with more information
Next steps

- Contact Darrell Jan for technical info
- Contact JPL Technology Affiliates office, 818-354-3821
Long Term

- Expectation of benefits to NASA and industry if partnerships are developed
  - Basis for a viable product
  - Benefits of mass production, ergonomic interface and design