Portable Mass Spectrometer Applications for in situ Environmental Gas Monitoring

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Collaboration

**NASA/KSC**
- ISS
- Human Exploration
- Robotic Exploration
- Earth Science

**CENET/Costa Rica**
- Volcanic Emission
- Volcanic Activity
- City Air Quality
- Pollution Levels
Purpose of Project

Primary Goal:
Design/build a flexible system to monitor air contamination
Learn requirements for operating system in low pressure
and low temperature environments
Design/build system for integration into aircraft and
automobiles

Secondary Goals/Offshoots:
Fly aboard different aircraft
Hand-carry unit
Drive unit in automobiles
# Current Sampling Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Benefits</th>
<th>Shortcomings</th>
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</thead>
<tbody>
<tr>
<td>Infrared (IR) Spectroscopy</td>
<td>- Irrefutable Identification in Simple System</td>
<td>- Water is Interfering</td>
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<tr>
<td></td>
<td>- Good Detection Limits (mid-ppb)</td>
<td>- Optics not Rugged</td>
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<tr>
<td></td>
<td>- Good Quantitation</td>
<td>- Poor for Complex Mixtures</td>
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<td></td>
<td><strong>Electrochemical Detection</strong></td>
<td>- Poor response to noble gases</td>
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<tr>
<td></td>
<td>- Capable of High or Low Specificity</td>
<td>- Mediocre Response Time</td>
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<tr>
<td></td>
<td>- Generally Inexpensive</td>
<td></td>
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<tr>
<td></td>
<td>- Small, Lightweight, Power Efficient</td>
<td></td>
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<tr>
<td></td>
<td>- Excellent Quantitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Good Detection Limits (mid-ppb)</td>
<td></td>
</tr>
<tr>
<td>Mass Spectrometry (MS)</td>
<td><strong>Highest Specificity</strong></td>
<td><strong>Weight &amp; Size Issue</strong></td>
</tr>
<tr>
<td></td>
<td>- Excellent Identification</td>
<td><strong>Power Efficiency Issue</strong></td>
</tr>
<tr>
<td></td>
<td>- Good Quantitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Reasonable Detection Limits (upper-ppb)</td>
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<tr>
<td></td>
<td>- Rapid Response &amp; Analysis Time</td>
<td></td>
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<tr>
<td>Sample Bottle</td>
<td>- Simple, No Complex Instruments at Site</td>
<td>- No Real-time Analyses</td>
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<tr>
<td></td>
<td>- Ease of Use</td>
<td>- Degradation of Sample</td>
</tr>
<tr>
<td></td>
<td>- Light Weight</td>
<td>- Difficult to Map Region</td>
</tr>
<tr>
<td></td>
<td><strong>Unknown if Issue With Sample</strong></td>
<td>- Unknown if Issue With Sample</td>
</tr>
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Design Considerations

Short Timeline of the Project (< 6 months)
Use of Proven Technologies
- Linear Quadrupole
- Proven Flow Design
- Valves/Fittings/Flow controllers

Allowed New Work in Specific Areas
- New Architecture
- New Automated Operation
- New Data Archiving/Retrieval
- Use in New Environments
# AVEMS Specifications

<table>
<thead>
<tr>
<th></th>
<th>H\textsubscript{2} (2 Th)</th>
<th>Helium (4 Th)</th>
<th>O\textsubscript{2} (32 Th)</th>
<th>Argon (40 Th)</th>
<th>CO\textsubscript{2} (44 Th)</th>
<th>Acetone (43 Th)</th>
<th>SO\textsubscript{2} (64 Th)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy (%)</strong></td>
<td>32.0</td>
<td>1.6</td>
<td>4.5</td>
<td>1.7</td>
<td>8.8</td>
<td>4.9</td>
<td>2.1</td>
</tr>
<tr>
<td><strong>Precision (%)</strong></td>
<td>3.9</td>
<td>5.7</td>
<td>2.9</td>
<td>3.3</td>
<td>1.7</td>
<td>1.2</td>
<td>1.3</td>
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<tr>
<td><strong>LOD (ppm)</strong></td>
<td>13.1</td>
<td>1.3</td>
<td>225</td>
<td>1.0</td>
<td>12.4</td>
<td>3.7</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>2-hr Drift (ppm)</strong></td>
<td>472*</td>
<td>3.4</td>
<td>-</td>
<td>11</td>
<td>160*</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Response (s)</strong></td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td><strong>Recovery Time (s)</strong></td>
<td>7</td>
<td>3</td>
<td>-</td>
<td>4</td>
<td>8</td>
<td>-</td>
<td>8</td>
</tr>
</tbody>
</table>
Monitored Volcanoes

- Flew unit over and around volcanoes
- Drove unit to volcanoes
- Map volcanic plume
- Issues with GPS resolution on ground data
Drove Unit Around San Jose, Costa Rica

Reason for San Jose
- 2/3 of people live in San Jose Area ??
- No smog control on vehicles
- Large bus/semi traffic
- Manufacturing area

Areas of Concern
- Hospitals
- Schools
- Parks
- City Center
AVEMS in Vehicle
Conclusions

• Unit successfully monitored air quality around city regions
• Unit very versatile: fly, hand-carry, drive
• Large areas of pollution around important areas in city
• Main reason for pollution in downtown primarily from vehicles
• Can use the data, GPS and concentration to map location of major pollution
Future Work

- Use new/improved mass analyzer
- Use smaller/lighter valves/controllers
- Improve autonomous operation
- Investigate pre-concentration techniques
- Incorporate an improved GPS
Acknowledgements

- Thank CENET and NASA/KSC for funding for this project

- Thanks to others on the project
Costa Rica Team Members