Sampling Aerosols on the International Space Station

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Outline

• Background
  • Previous aerosol sampling experiment in space
  • International Space Station

• Aerosol Sampling Experiment
  • Objectives
  • Two Samplers
    • Thermophoretic
    • Passive

• Summary
Definition

Aerosols are tiny particles suspended in the air.

Aerosols in Earth's atmosphere include pollution, smoke, dust, pollen as well as particles from many other natural and man-made materials.

*We breathe in aerosols all day long.*
Aerosol Measurements on Space Shuttle

- Instruments developed at the University of Minnesota
- Space Shuttle Columbia experiments 1990 and 1991
Aerosol Measurements on Space Shuttle

• Shuttle Particle Sampler (SPS) – Multi-stage impactor and filtering system for size distributions, XRF & microscopy

• Shuttle Particle Monitor (SPM) – Real-time Nephelometer (photometric detection of scattered light) for time-resolved mass concentration
• 5 people on STS-32 Columbia
• 71.5 m³ Habitable Volume
• Sampled day 2 and 7 of the 11 day mission
• Average concentration: 56 μg/m3
• ‘Clean’ by indoor air quality standards
• No measurements < 1 μm
• Space Shuttle retired in 2011
• Data no longer useful
International Space Station (ISS)

• 388 m$^3$ Habitable Volume

• Continuously occupied for 14 years
  • 225 people from 18 countries, typically 6 crewmembers at a time
Aerosols on ISS

• On Earth, our air quality is improved by gravitational settling of large particles
  • On ISS, all particles remain airborne until deposited on surfaces or on filters of the air handling system

• ‘Dusty air’ has been a recurring complaint of the crew
  • Nose and eye irritation, allergies
  • Indicates high concentrations of inhalable particles
Weekly chores on ISS
Aerosols on ISS

• Aerosol mass concentration requirements exist
• There is currently no particle measurement capability on ISS

• Estimated inventory of aerosols on ISS
  • Literature review - aerosol emission rates associated with common activities
  • Forensic analysis of returned ISS vacuum bag and ISS filter returned
  • Fabric testing
Aerosol Sampling Experiment

• Funded by NASA Advanced Exploration Systems Life Support Systems Project (AES LSS)

• Obtain *quantitative* data on airborne particles in multiple ISS locations and associated with different activities

• Sample particles and return to Earth for microscopic analysis
  • Simple experiment gives long-duration average data
  • Low cost and low risk

• Launches August 22 (in 1 week!)
Collect Airborne Particles on ISS

• Start with two different commercially available samplers
  • COTS = commercial-off-the-shelf hardware

COTS Passive Aerosol Sampler (PAS)

Collect particles up to 500 μm & larger
Passive Sampler

- Custom array of **passive** samplers

Collect particles up to 500 μm & larger
Deploy with drawers open for a month, close drawers on days 2, 4, 8, 16 and 32
Crew Instruction Video

• NASA Marshall Space Flight Center Payload Operations Integration Center
• ISS US Lab mock-up in the Laboratory Training Complex
  • Simulation rooms used to prepare PAYCOMs for space station expeditions
    • (Payload Communications Manager)
COTS Thermophoretic Personal Sampler

Active sampler:
• Contains pump, heater, cooler, circuit cards, battery
• Samples for 6 hours
• Collect particles from 10 nm to ~10 μm

TEM grid -small parts that can float away!

TEM = Transmission Electron Microscope
Thermophoretic Collection

Sample air flow through 1 mm gap

Hot Surface ($T_h=110^\circ C$)

\[ \frac{dT}{dx} \sim 10^5 ^\circ C/m \]

Cold Surface ($T_c=25^\circ C$)

(adjustable gradient)

EM Grid

3 mm
Thermal Modification of COTS Active Sampler

- Outer case (metal)
- Fan
- Fins
- Copper plate
Example Data from Microscopic Analysis of Particles Collected by TPS

- Identify particle morphology
  - Shape
  - Coated or multi-component particles

- Chemical composition
  - Elemental speciation

- Potentially identify sources of individual particles returned from ISS
  - Lint from clothing
  - Skin flakes
  - Metal particles from exercise equipment

- Computer-generated particle size distribution

Two images of a particle from a small electric motor and the chemical compositions of different portions of the same particle
Sampling Locations

- 7 Passive sampler locations
  - Keep-out zone exceptions
- 12 Active sampler locations, 7 within 60 cm of passive samplers
  - During exercising
  - When a cargo vehicle arrives and docks to ISS
  - Hygiene compartment
Summary

• Goal of sampling experiment is **data:**
  • Validate inventory
  • Input for realtime instrument (stage 2 flight experiment)
  • Understanding background aerosol signature is important for the next generation smoke detector design

• Scheduled crew time mid-January to mid-February 2016
• Return samples to Earth to get results
  • SpaceX early March 2017
  • Contractor will perform the sample analysis (microscopy)
• Results will ultimately improve air quality in spacecraft
  • Fundamental for future long-term manned space missions
Questions?
Backup Slides
• **Thermal Testing by RJ Lee Group:**
  • When TPS was insulated (eliminating the benefit of natural convection) the outer case exceeded 40 °C touch temperature

• **Absolute temperature control guarantees optimal sampling**
  • If the large thermal gradient is not maintained (if waste heat is not eliminated from the internal thermo-electric coolers), the TPS will shut down

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**General Specifications** (Original COTS)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight</td>
<td>320g</td>
</tr>
<tr>
<td>Sampler Dimensions</td>
<td>122mm x 63mm x 38mm</td>
</tr>
<tr>
<td>Sample Cartridge Dimensions (3mm Diameter EM Grid)</td>
<td>46mm x 18mm x 15mm</td>
</tr>
<tr>
<td>Battery Duration (from full charge)</td>
<td>~8 hours</td>
</tr>
<tr>
<td>Charging Time</td>
<td>&lt;3 hours</td>
</tr>
<tr>
<td>Battery Lifespan</td>
<td>&gt;300 complete charge/discharge cycles</td>
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<tr>
<td>Recommended Hot Side Temperature Range</td>
<td>85 to 120°C</td>
</tr>
<tr>
<td>Recommended Cold Side Temperature Range</td>
<td>25 to 35°C</td>
</tr>
<tr>
<td>Volumetric Flow Rate</td>
<td>5 mL/min</td>
</tr>
</tbody>
</table>
Passive Sampler

• 2-way sticky carbon tape on 29 mm x 15 mm collection surface (aluminum block)

• Collection plate samples can be archived for potential future analysis

• Units can be cleaned and re-used with a new aluminum block

Carbon tape pieces & 5 o-rings are the only non-metal parts
Passive Sampler

• Porous frit is incorporated into the design to relieve the very small delta pressure that may occur when closing drawer
  • Will not allow particles in which could contaminate the sample