Sampling Indoor Aerosols on the International Space Station

Marit E. Meyer
NASA Glenn Research Center
Cleveland, OH

Gary Casuccio
RJ Lee Group
Monroeville, PA
Outline

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

• Aerosol Sampling Experiment
  • Objectives
  • Streamlined flight hardware process for commercial devices
  • Two Samplers
    • Thermophoretic
    • Passive

• Summary
Aerosol Measurements on Space Shuttle

• Instruments developed by Particle Technology Laboratory at the University of Minnesota

• Space Shuttle Columbia experiments 1990 and 1991
Aerosol Measurements on Space Shuttle

- Shuttle Particle Sampler (SPS) - Multistage impaction and filtering system for size distributions, XRF & microscopy
  - Four stages, < 2.5 µm, 2.5 to 10 µm, 10 to 100 µm, and >100 µm
  - Two units sent for comparison of samples
- Shuttle Particle Monitor (SPM) - Nephelometer (photometric detection of scattered light) for time-resolved mass concentration
- RJ Lee Group performed automated SEM and EDS
• 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
• 90% of the particle mass was between 10 μm and 100 μm
• Focus was on PM10 at that time
• No measurements < 1 μm
• Space Shuttle retired in 2011
• Cannot use this data for current spacecraft
International Space Station (ISS)

• 388 m³ Habitable Volume

• Continuously occupied for 14 years
  • More than 200 people from 15 countries, typically 6 crewmembers at a time
Aerosols on ISS

• On Earth, our air benefits from gravitational settling
  • On ISS, all particles remain airborne until deposited on surfaces or on filters of the air handling system

• Dust and particle-laden air has been a recurring complaint of the crew as they have experienced nose and eye irritation as well as allergies
  • Indicates high concentrations of inhalable particles
Aerosols on ISS

• Airborne debris samples have been returned from ISS, but without the necessary delicate handling or not on appropriate collection substrates for quality microscopic analysis of individual particles

• There is currently no particle measurement capability on ISS to provide data

• Particle control technology is HEPA level filtration
• Filter face is 29 inches by 4 inches (74 cm x 10 cm)
• The ventilation system of the US segment has 21 filters
• Pleats are covered with Nomex mesh screen (841 μm openings)
Clean Filter

12 days accumulation

Node 3
Hygiene & Exercise Location

8 days accumulation

Node 1
Temporary Storage Location

8 days accumulation
Weekly chores on ISS
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
  • Estimate average number concentration, size distributions
  • Particle morphology and chemical composition
  • Measurement range: a few nanometers to 100’s of micrometers

• Simple experiment gives long-duration average data

• Low cost and low risk
Streamlined Approach for Flight Hardware

- NASA has a new initiative to flight certify commercial items with a reduced set of requirements
- Use commercial-off-the-shelf (COTS) equipment to reduce the preparation time and cost for the flight experiment
- Two different commercially available samplers
  - Collect a larger size range of particles
  - Some redundancy
Collect Airborne Particles Two Ways

Thermophoretic Personal Sampler, TPS100

Passive Aerosol Sampler (PAS)
Thermophoretic Personal Sampler

Active sampling:

- Contains pump, heater, cooler, circuit cards, battery
- Collection substrate (TEM grid) is housed in removable inlet cartridge to minimize particle losses and protect from contamination or damage
- Charges overnight, sample for 6 to 8 hours
- Fly two units for redundancy, less crew time for simultaneous sampling in two locations
Thermophoretic Collection

Sample air flow through

1 mm gap

Hot Surface \((T_h=110°C)\)

\[
\frac{dT}{dx} \sim 10^5 °C/m
\]

Cold Surface \((T_c=25°C)\)

(adjustable gradient)

EM Grid

3 mm
Need Thermal Solution for Low Gravity

• Current TPS design sinks heat to the outer case which can get rid of excess heat by natural convection

• However, in low gravity there is no buoyant flow of warm air, so a thermal design solution was created by Dan Miller-Lionberg (Colorado State University)
Passive Sampler

• No mechanical parts
• Collection substrate (SEM stub) protected by mesh cover
• Mount an array of 5 with Velcro, cap them incrementally to get different long-term average concentrations (2 days, 4 days, 8 days, 16 days, etc.)
• Five separate units deployed on/near various ISS filters to intersect ‘dirty’ air flow
Passive Sampler Array

• Design is in progress
  • Consider mesh, size
  • Mounting locations
  • Sampling durations

• Instead of terminal settling velocity (gravity), rely on terminal velocity of air into filter
Sampling Locations

• During exercising
• When a cargo vehicle arrives and docks to ISS
• Hygiene compartment
Summary

• Goal of sampling experiment is **data:**
  - Validate ISS aerosol inventory
  - Particulate monitor development for long-term manned missions
  - Understanding background aerosol signature is important for the next generation smoke detector design

• Expected launch in spring 2016 (SpX-9)
• Return to Earth hopefully by the end of the year, but possibly as late as 2017 (SpX-13)
  - Lack of crew time for experiments is driving factor
• RJ Lee Group will perform the sample analysis
• Results will ultimately improve air quality
  - Fundamental for future long-term manned space missions
Questions?
Back-up Slides
Aerosol Measurements on Space Shuttle

- Instruments developed by Particle Technology Laboratory at the University of Minnesota
- Two experiments on the Space Shuttle Columbia: 1990 for 11 day mission (STS 32), 1991 for 9 day mission (STS-40)
  - Columbia accident was in 2003
  - Space Shuttle program: 1981 to 2011 (135 missions) supporting Spacelab, Mir and ISS
- Shuttle Particle Sampler (SPS) - Multistage impactor and filtering system for size distributions, XRF & microscopy
- Shuttle Particle Monitor (SPM) - Nephelometer (photometric detection of scattered light) for time-resolved mass concentration
  - Recorded the minimum, maximum, and average particle concentrations (< 100 µm) over 15-minute intervals throughout the flight
  - 12 lpm
  - It was set to zero by running it in clean air and was calibrated by running it alongside the particle sampler
- SPM & SPS were delivered to University of Minnesota personnel within 6 hours of landing at Edwards Air Force Base.
Inlet screens for electronics cooling air

Airborne debris: lint, dust, toothpick, string, paper, plastic bags, screw, etc.
COTS Flight Hardware

- No sharp edges
- Maximum 40° C touch temperature
- Outgas testing waived for items < 5 lb
- Flammability testing can be waived by detailed list of materials
- Battery testing required, unless using previously certified model
  - COTS plug into ISS Power Inverter
- EMI emissions testing
- Avoid continuous noise
  - “Quieter than a computer”
- Simplified labeling, human factors, photo instead of source control drawing
- No structural or reliability assessments
- etc.
References

COTS Thermophoretic Sampler (TPS)


COTS Passive Aerosol Sampler (PAS)

Potential Launch Details

**March 21**  **Falcon 9 • SpaceX CRS 9**

**Launch window:** TBD

**Launch site:** SLC-40, Cape Canaveral Air Force Station, Florida

A SpaceX Falcon 9 rocket will launch the 11th Dragon spacecraft on the ninth operational cargo delivery mission to the International Space Station. The flight is being conducted under the Commercial Resupply Services contract with NASA. Delayed from Dec. 9.  [Sept. 29]
Future Proposal

• Potential follow-on experiment with a real-time reference quality aerosol instrument
  • Perform air quality surveys
  • Validate current estimates of emission rates of known aerosol sources
  • Instrument would remain on ISS as a crew resource
  • Repeat sampling with TPS for validation and cleanliness comparison with this experiment