NASA’s Aerosol Sampling Experiment
Summary

Marit E. Meyer
Researcher in Spacecraft Indoor Air Quality & Fire Safety
NASA Glenn Research Center
Cleveland, OH
Outline

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

• Aerosol Sampling Experiment
  • Objectives
  • 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) – Multi-stage impactor and filtering system for size distributions, XRF & microscopy
- 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
• No measurements < 1 μm (1000 nm)
• Space Shuttle retired in 2011
• Cannot use this data for current spacecraft
International Space Station (ISS)

• 388 m$^3$ 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 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

• 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
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
Collect Airborne Particles on ISS

- Two different samplers
  - Collect a larger size range of particles
  - Some redundancy

Thermophoretic Personal Sampler, TPS100

- Collect particles from 10 nm to ~10 μm

Passive Aerosol Sampler (PAS)

- Collect particles up to 500 μm & larger
Thermophoretic Personal Sampler (TPS)

Active sampling:
• Contains pump, heater, cooler, circuit cards, battery
• Collection substrate (TEM grid) is housed in removable inlet cartridge
• Procedure:
  • Charge for ~4 hours, load cartridge, attach to wall panel (Velcro), sample for 6 hours, remove cartridge, stow
• 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 ($T_h=110^\circ C$)

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

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

(adjutable gradient)

3 mm

EM Grid
Thermal Solution for 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
  - Agglomerates
- Chemical composition
  - Elemental speciation
- Potentially identify sources of individual particles
  - Lint from clothing
  - Skin flakes
  - Metal particles from exercise equipment
Custom Passive Sampler

- **Aluminum** outer case with **brass** ‘drawers’
- Mounted with Velcro near air intakes of the ISS ventilation system to take advantage of incoming ‘dirty’ air flow
Passive Sampler

• 2-way sticky carbon tape on 29 mm x 15 mm collection surface (aluminum block)
• Each drawer compartment is individually bored to eliminate cross-contamination between samples
• 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

- Crewmembers close the drawers incrementally
- After 2 days, 4 days, 8 days, 16 days, and 32 days
- Goal is to obtain at least one long-term sample with optimal particle coverage for microscopic analysis
  - Not too few particles, and not too many particles (overlapping or touching each other)
Passive sampler locations on air return grills

Deployed in 7 locations and collecting for 32 days
Active Sampling Sessions

• Two are deployed 4 times within two feet of passive samplers
  • Sample the same air and collect different size ranges of particles
  • 8 total samples
• During exercising
• When a cargo vehicle arrives and docks to ISS
Summary

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

• Analysis after return to Earth

• RJ Lee Group will perform the sample analyses

• Results will ultimately improve air quality in spacecraft
  • Fundamental for future long-term manned space missions