Evaluation of Low-Gravity Smoke Particulate for Spacecraft Fire Detection

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Evaluation of Low-Gravity Smoke Particulate for Spacecraft Fire Detection

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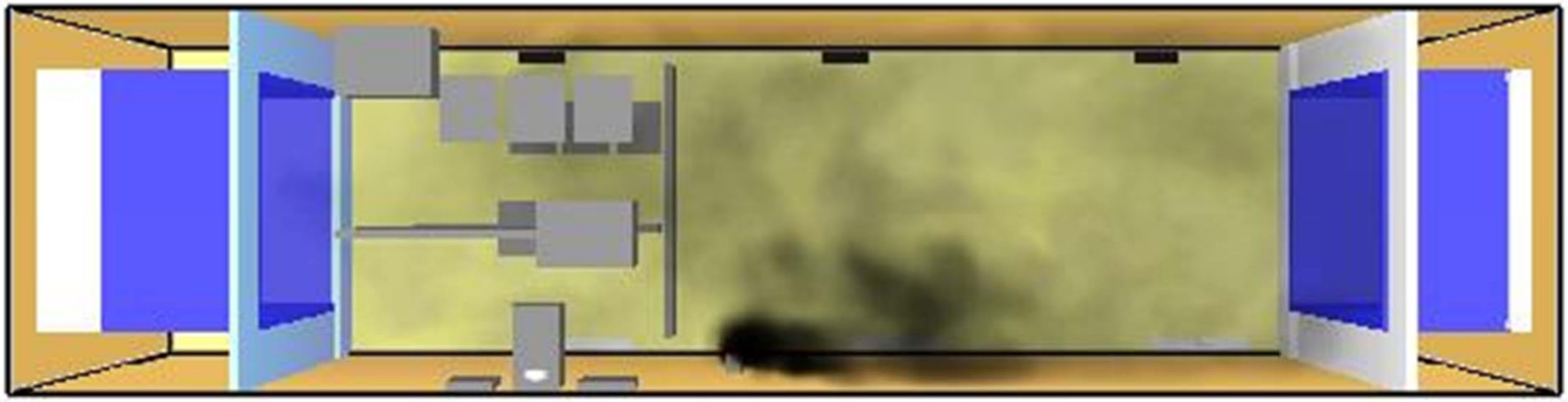
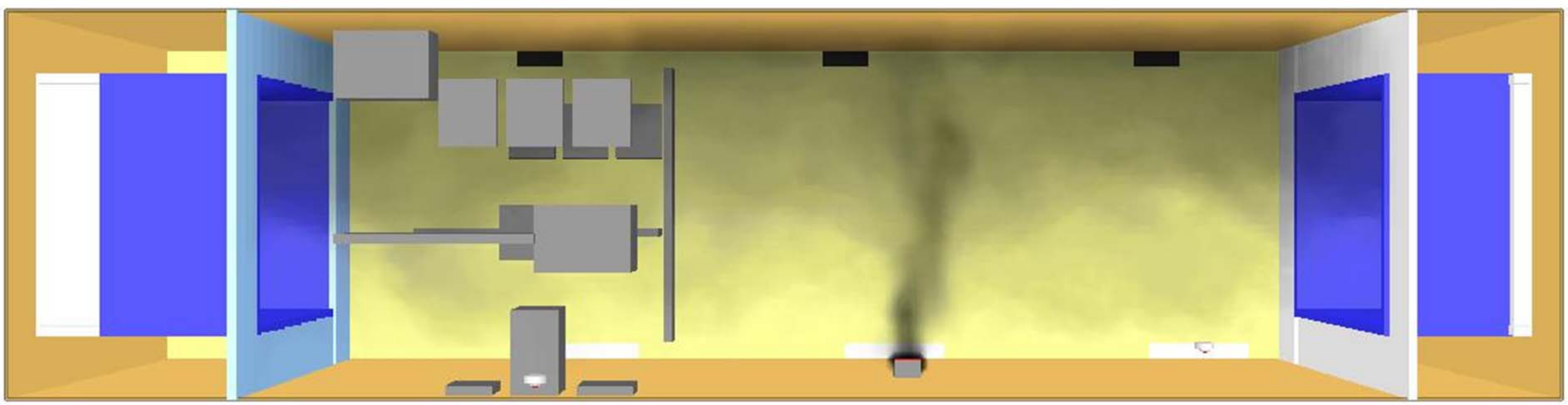
Smoke Detection Background:
Destiny Smoke Detection Simulation-25% Soot

effect of gravity

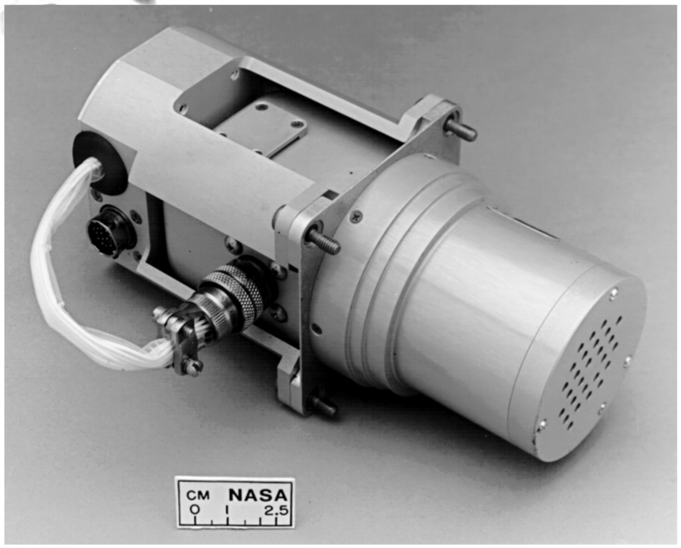


Low-gravity



Normal-gravity

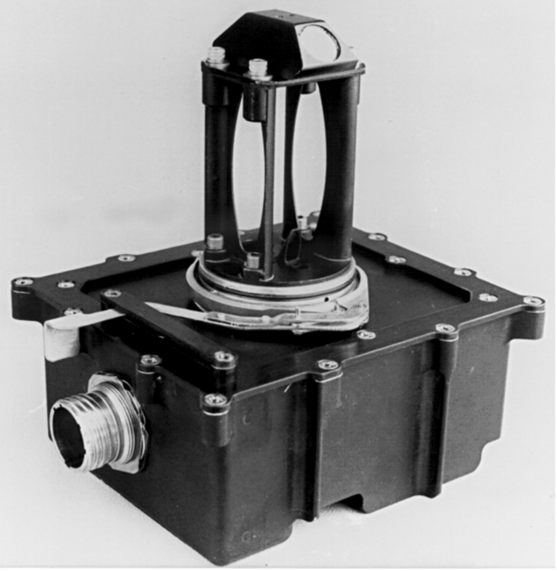
Background: Spacecraft Fire Detection



STS Detector: sensitive < 1 micron

•dual-chamber ionization with inertial separator which rejects particles larger than 1-2 microns.

•Developed in the late 70's when Ionization detectors were prevalent



ISS detector: sensitive > 0.5 micron

•2-pass IR laser-diode forward-scattering detector (30 degrees) minimum reported sensitivity is 0.3 µm.

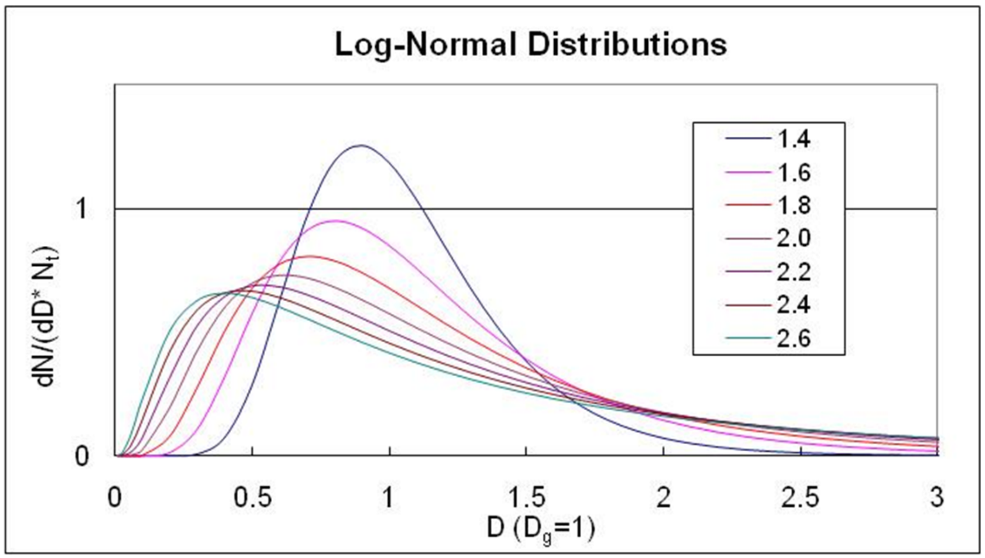
•Developed in the 90's and took advantage of the availability of stable diode light sources.

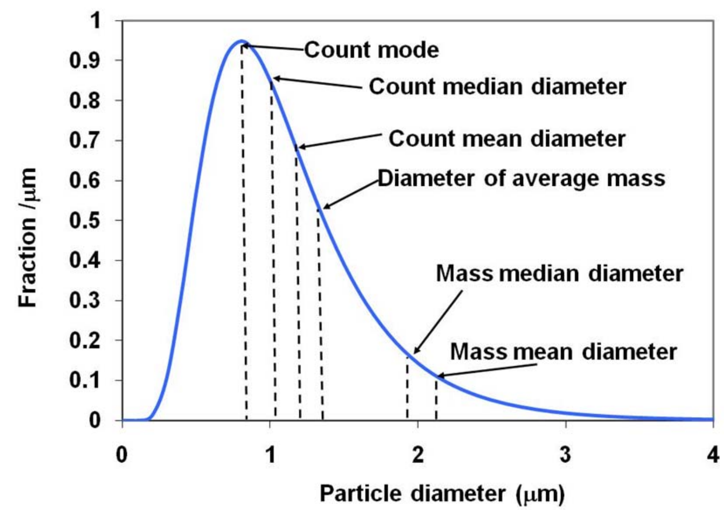
Log-Normal Distribution

$$f_N(D) = \frac{N_t}{(2\pi)^{1/2} D \ln \sigma_g} \exp\left(-\frac{(\ln D - \ln D_g)^2}{2 \ln^2 \sigma_g} \right)$$

Number is dominated by the smaller particles

Mass is dominated by the larger particles (tail)



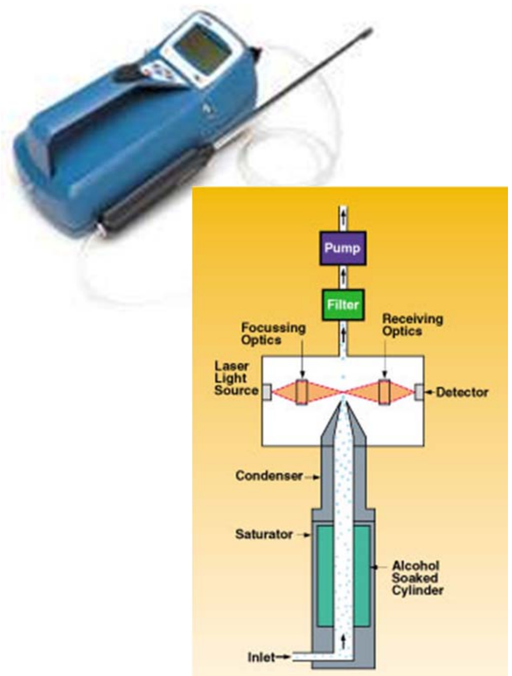


Log-normal distribution σ_g = 1.6, D_g= 1

SAME Experimental Diagnostic Measurements

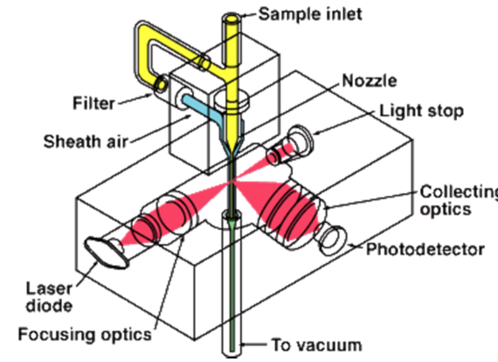
All measure moments of the particle size distribution

$$M_i = \int D^i f_N(D)\,dD$$



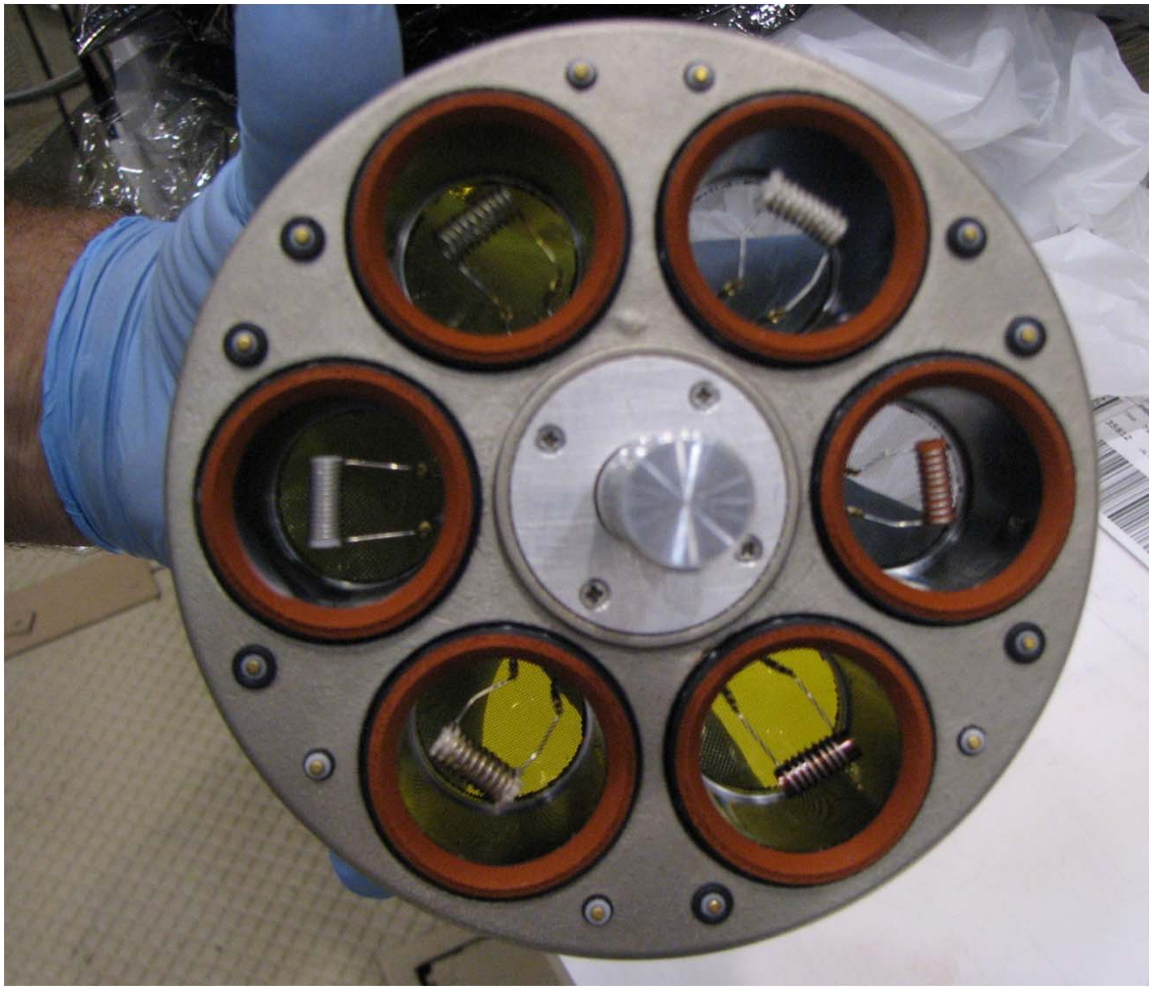
Zeroth Moment:
TSI PTrak™

First Moment:
First Alert™
Smoke Detector



Third Moment:
TSI Dust Trak™

SAME Sample Carousel



Sample Materials:

Silicone
Teflon
Kapton
LampWick
Pyrell
DBP

SAME in MSG (mockup)

Data Acquisition and Control Unit

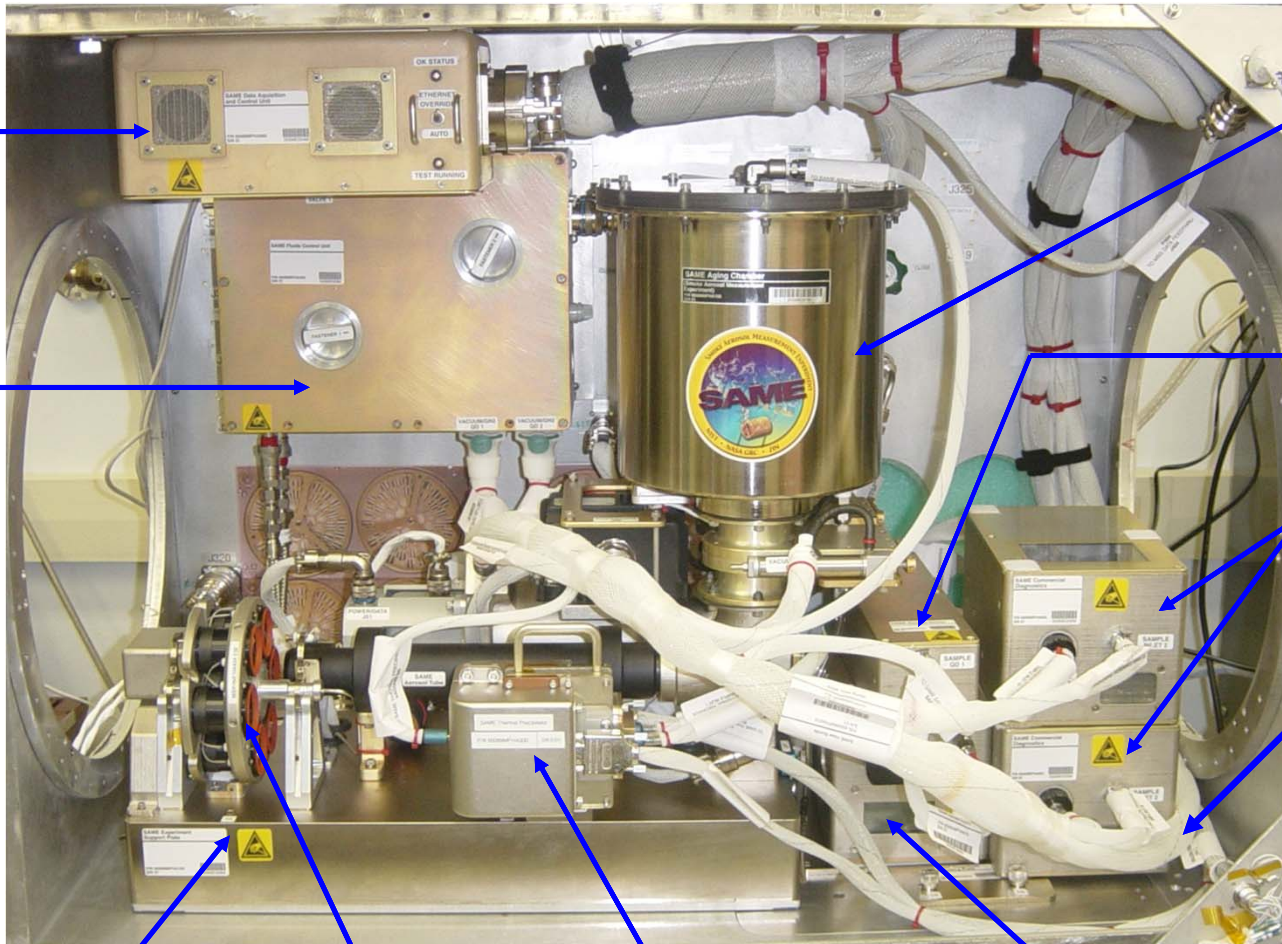
Fluids Control Unit

Aging Chamber

Sample Diluter

Commercial Diagnostics

Hose Bundle



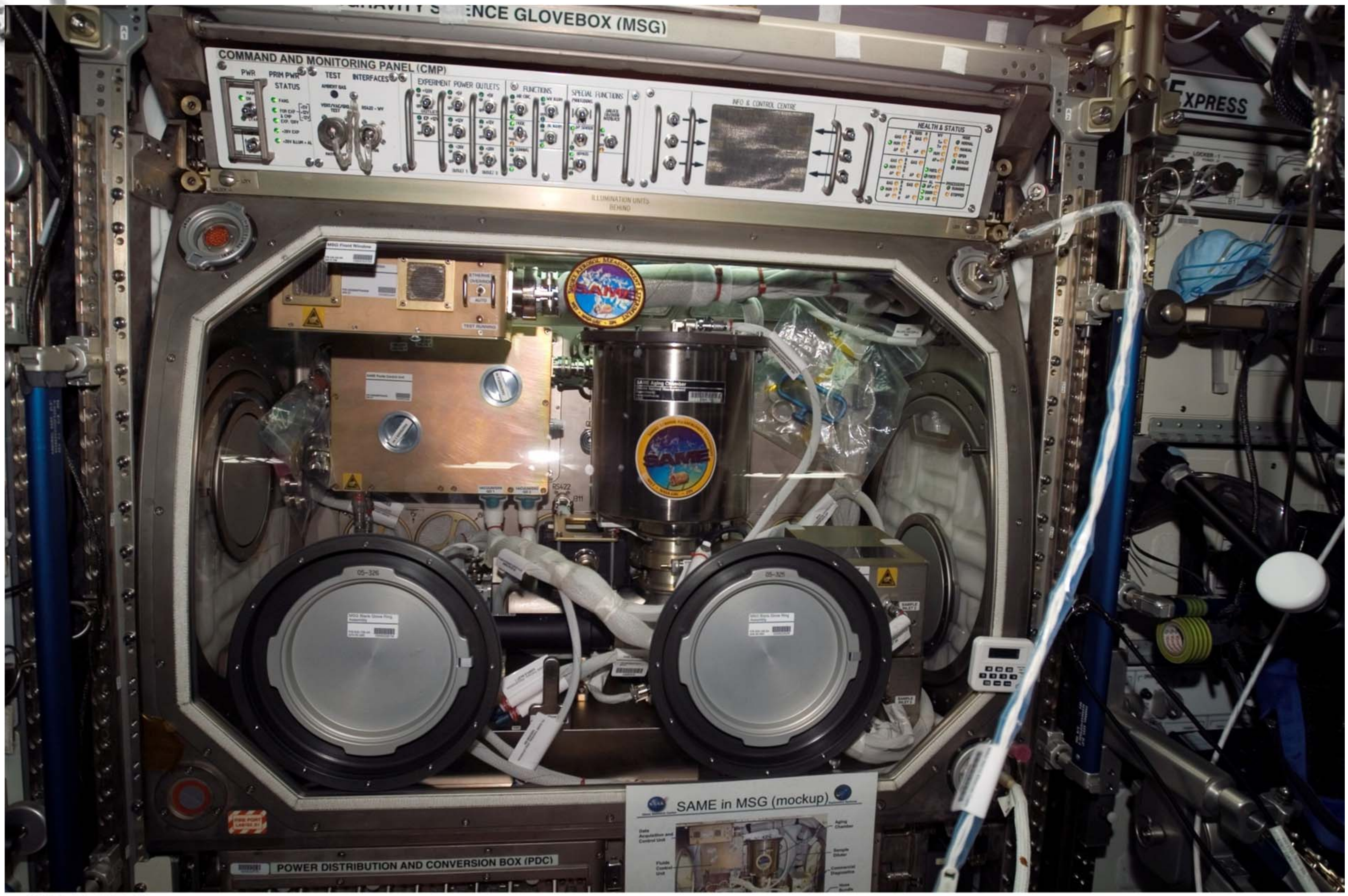
Experiment Support Plate

Sample Carousel

Thermal Precipitator

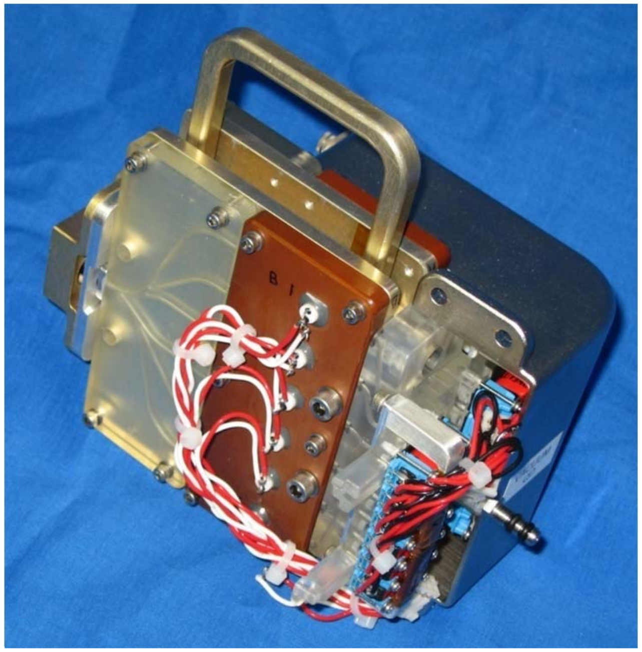
P-Trak Enclosure

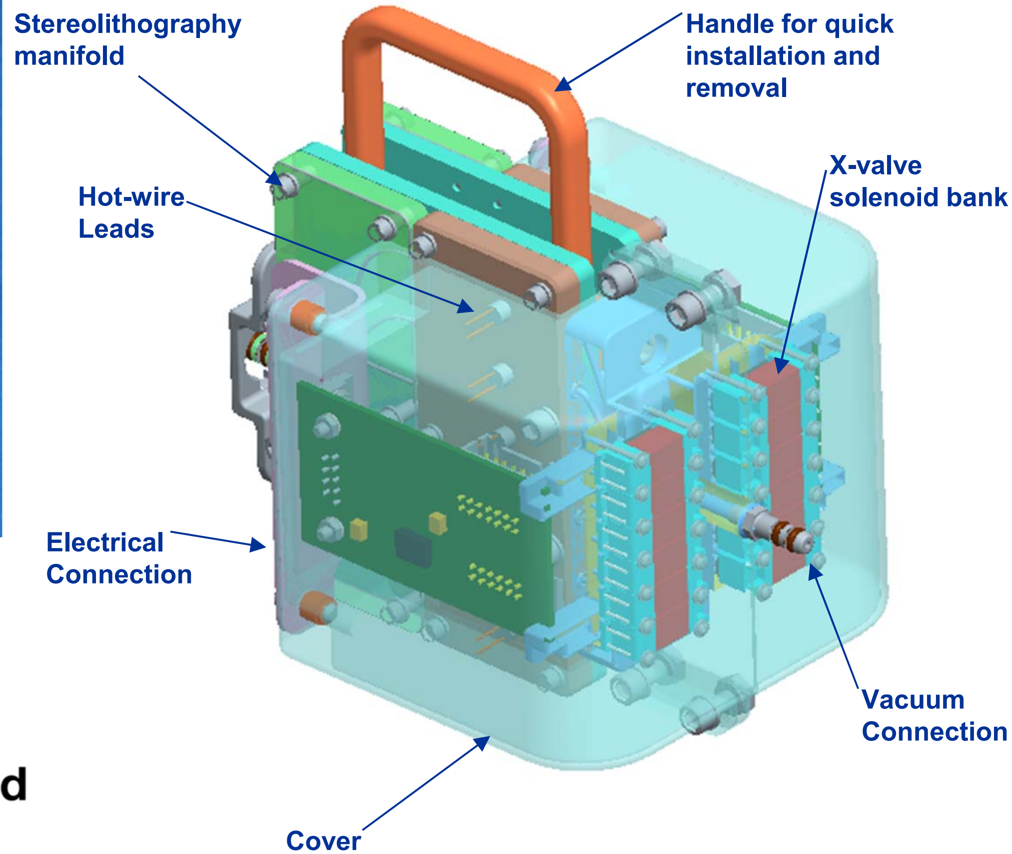
SAME Hardware on orbit

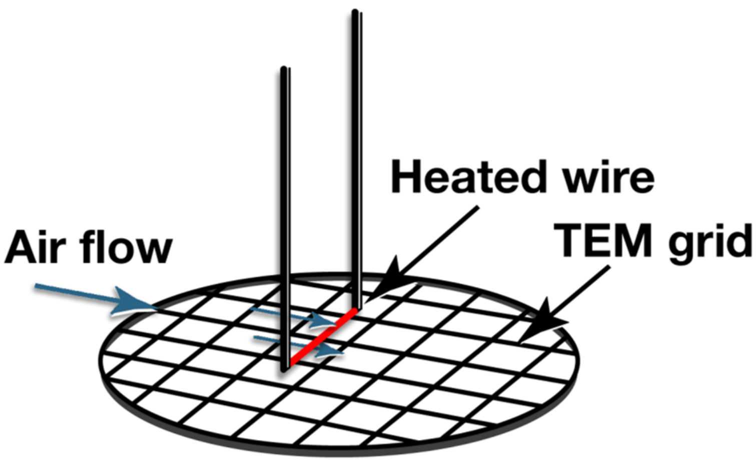


ISS015E26265

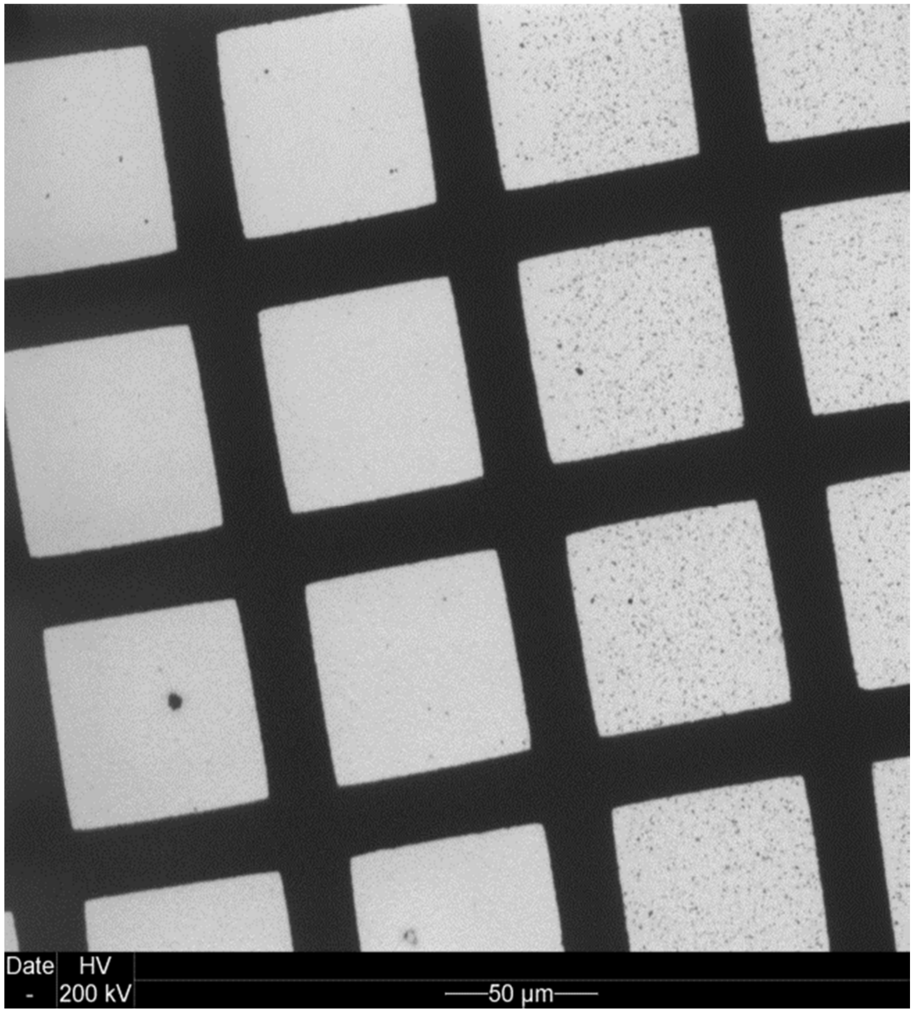
SAME Particle Capture







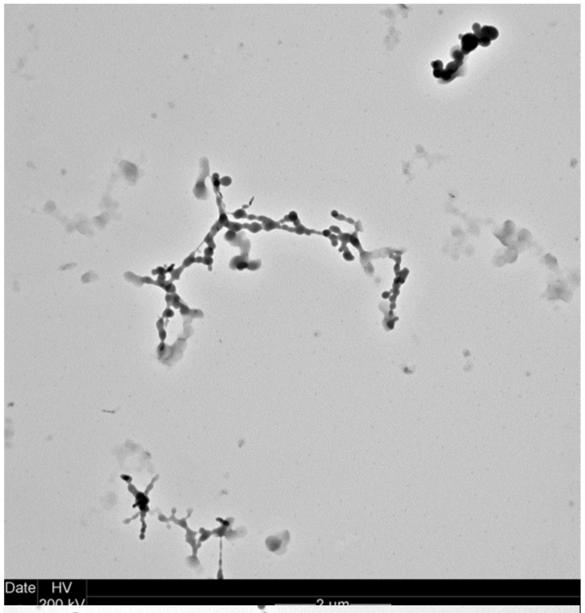
Thermal Precipitator

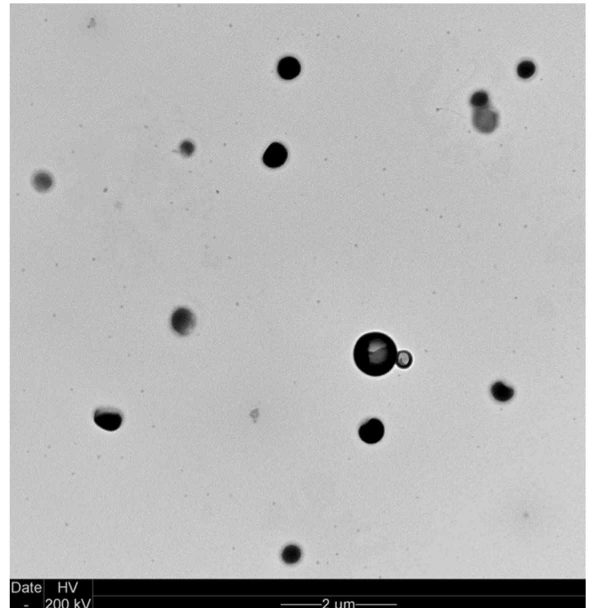


Overview image showing deposition boundary

TEM Results

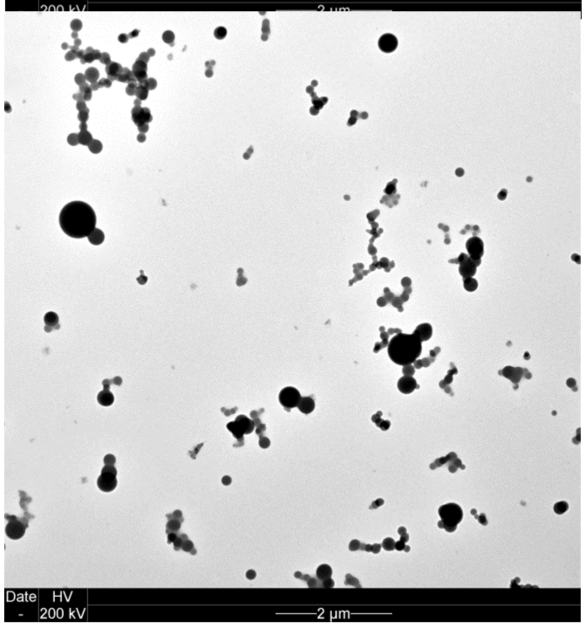
Teflon (Run 56)

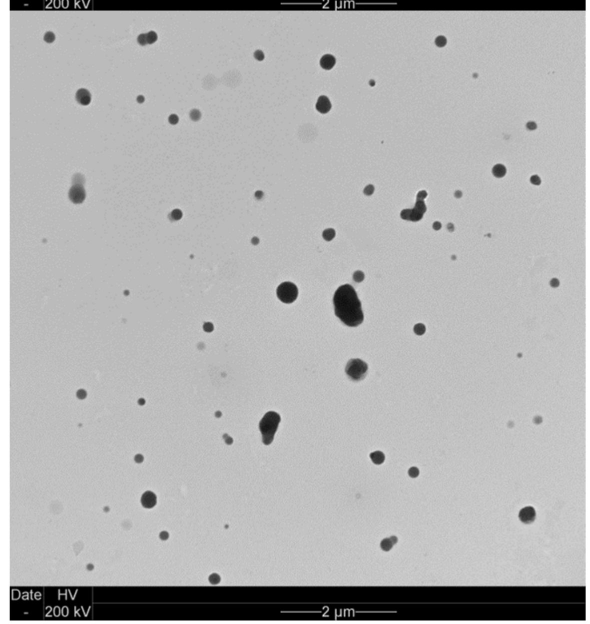




Lampwick (Run 54)

Pyrell (Run 63)

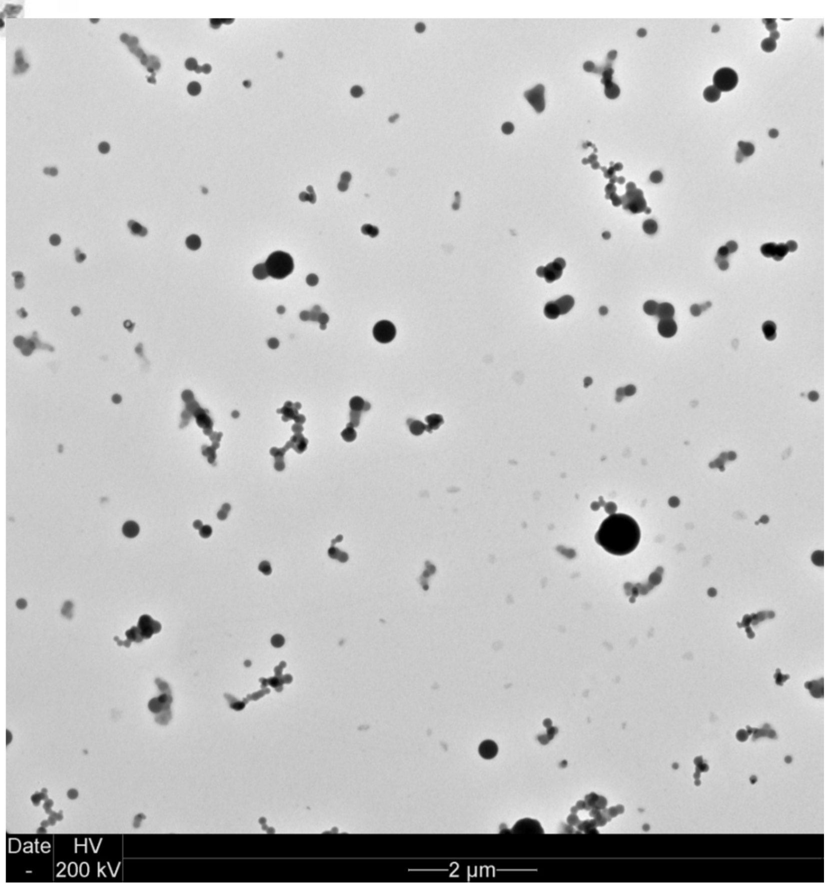




Kapton (Run 62)

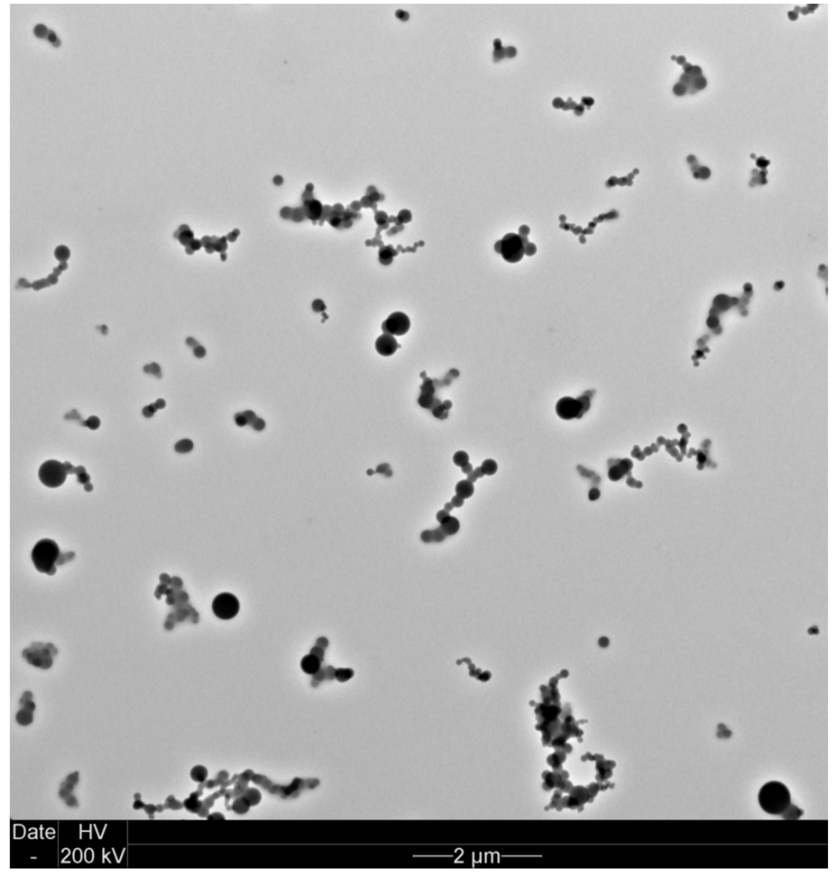
Length scale 2 µm

TEM Results - Pyrell Aging



Pre aging

2 microns

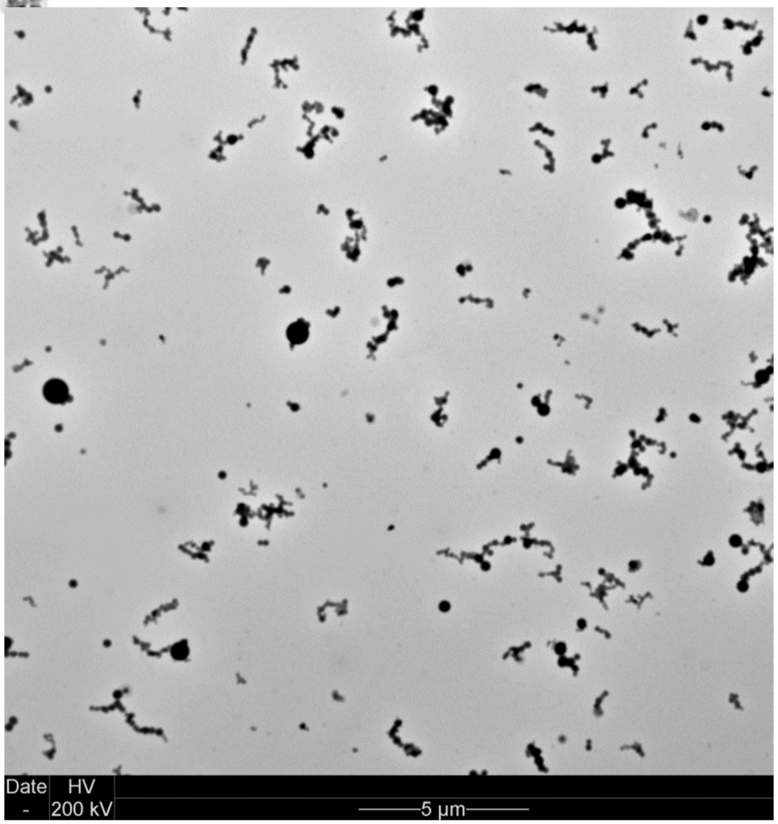


Post aging

2 microns

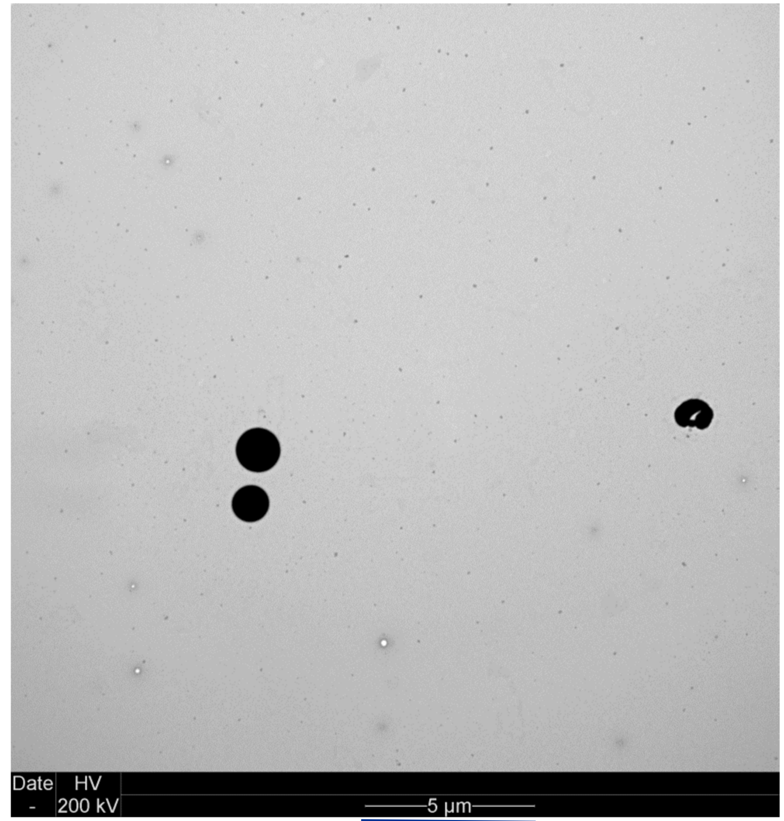
High Temperature Pyrell: 480 second aging run (Run 84)

TEM Results – Pyrell- effect of flow



5 microns

8 cm/s air flow

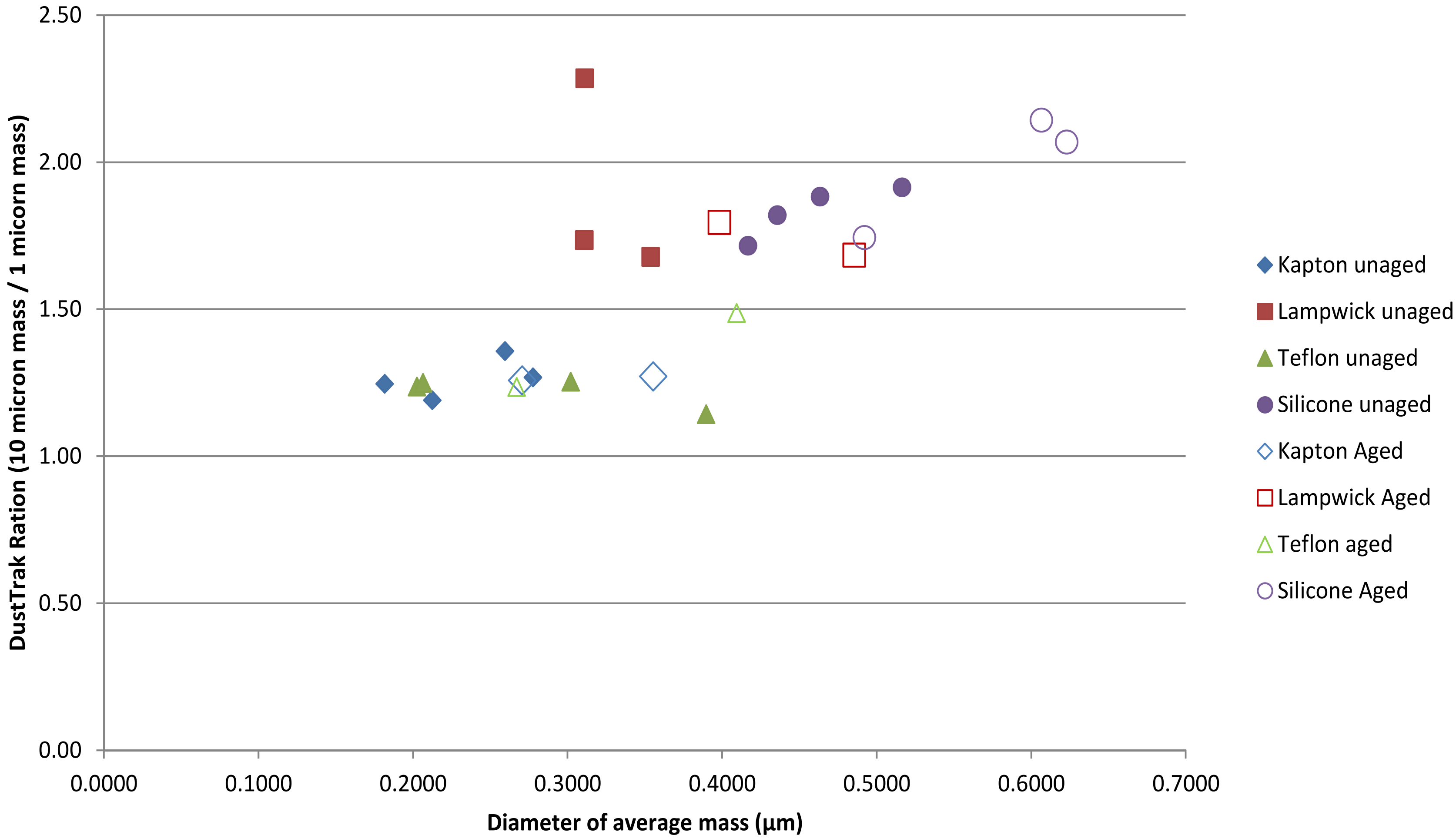


5 microns

No air flow

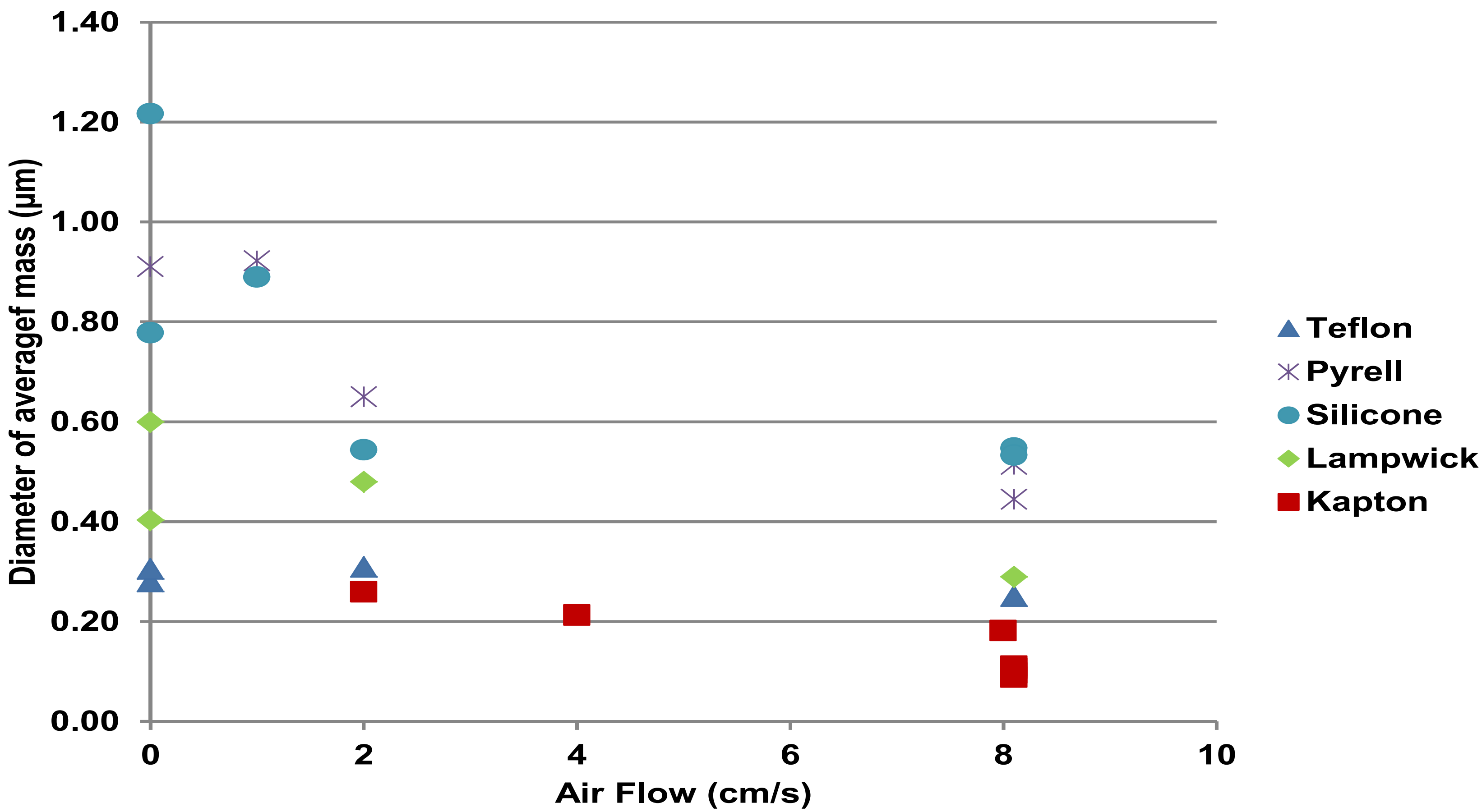
Pyrell with and without flow

10 Micron versus 1 micron Mass ratios



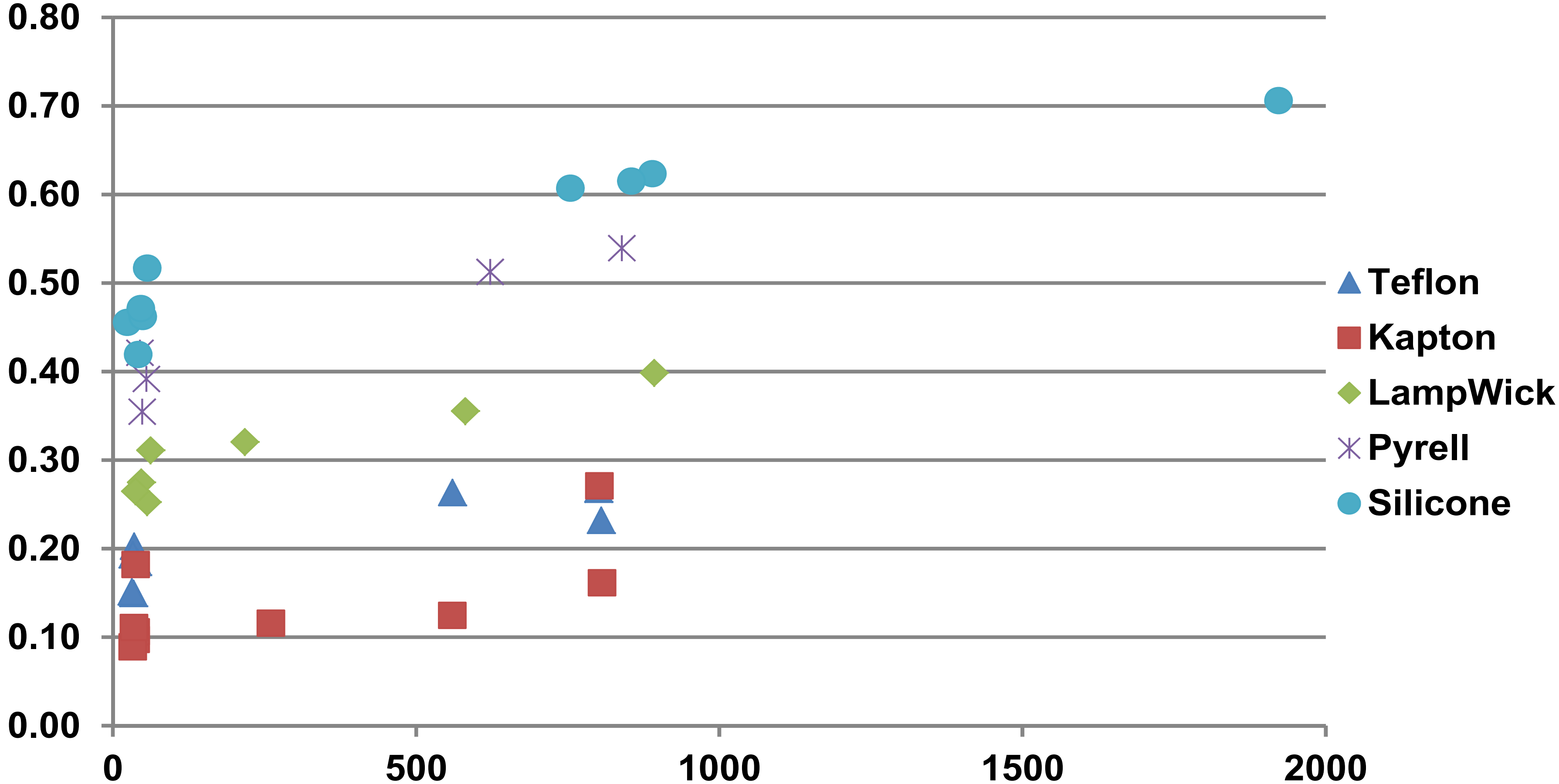
10 micron versus 1 micron impactor ratios for different flow rates and sample temperatures

Effect of Air Flow on Diameter of Average Mass



Constant temperature for each material with no aging.

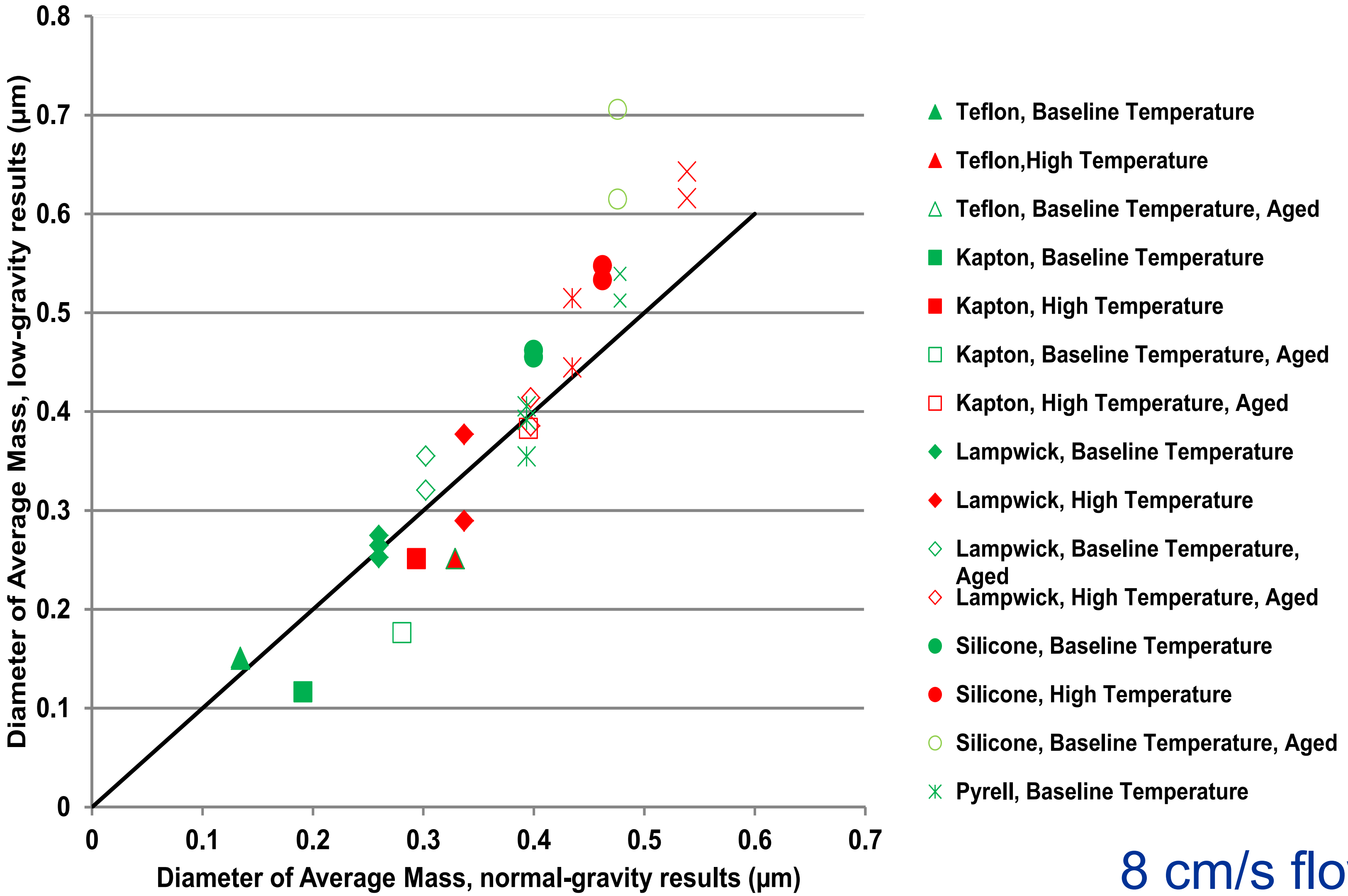
Effect of Aging on Diameter of Average Mass



8 cm/s airflow

Constant temperature for each sample.

Effect of Gravity on Diameter of Average Mass



8 cm/s flow

Conclusions

- Particle sizes ranged from 100 to 600 nm
- Consistent with a log-normal distribution.
- Particle sizes increase substantially with aging.
- Particle dimensions increase substantially as air flow was decreased.
- TEM showed a significant range of distinct particle morphologies
- For lampwick and silicone approximately 40% of the aerosol mass had aerodynamic diameters greater than 1 µm
- Ground based testing at 8 cm/s showed particle dimensions very close to the flight results.

Spacecraft fire conditions include an even wider array of materials and conditions.
Spacecraft background aerosols can be quite large
Detection methods that can measure more than one moment of the size distribution may show more successful detection and false alarm rejection than single moment detectors.