ADVANCED CONTAMINATION KNOWLEDGE OF ASTROMATERIALS CURATION FACILITIES AT THE NASA JOHNSON SPACE CENTER: CONTINUOUS PARTICLE MONITORING. A. Hutzler[1,2] , J. A. Lewis[2], K. Righter[2] and R. A. Zeigler[2], [1]Lunar and Planetary Institute, USRA, Houston, TX; [2] NASA Johnson Space Center, Astromaterials Acquisition and Curation Office, Houston, TX; aurore.hutzler@nasa.gov.

Introduction: NASA Johnson Space Center's Curation Office is home to seven astromaterial collections, stored and processed in specifically designed cleanrooms ranging from ISO Class 4 to ISO Class 7 [1]. Keeping contamination under defined levels (Contamination Control, CC) while monitoring and recording the levels and nature of contamination (Contamination Knowledge, CK) is a mandatory part of clean curation, to ensure all samples stay as pristine as possible to enable science investigation for the indefinite future. Currently, the main CK effort is a weekly monitoring of particle levels [2]. Specific measurements have been done over the life of the facilities to target overall inorganic and organic contamination or specific compounds [3].

In the next decade, the Curation Office will receive new collections which necessitate the development of new CK and CC protocols, especially related to organic contamination. Advanced CK and CC studies are underway to get ready for these new challenges. Since January 2019, airborne molecular contamination (AMC), both inorganic and organic have been monitored in three curation cleanrooms: the Stardust Laboratory, the Meteorite Processing Laboratory and the Cosmic Dust Laboratory [4]. These tests are conducted to evaluate the potential impact of the nearby cleanroom construction site for the upcoming collections, as well as to understand the levels and variety of airborne molecular compounds.

Since AMC tests cannot be used to target specific events, due to logistical and financial constraints, a more continuous monitoring was needed to enable a faster response to potential contamination. An easy to implement CK setup is the continuous monitoring of particles. We explain in the following the rationale for this choice, as well as the protocol and preliminary results.

Continuous particle monitoring: Continuous particle monitoring is used in some industries, especially as a quality control protocol on a production chain. To the knowledge of the authors, such measurements have never been done at the Curation Office.

Rationale. The Curation Office has access to four handheld particle counters, making the measurements easy to implement. Continuous monitoring helps understand particle production and intake mechanisms, allowing the curation team to understand if certain activities or pieces of equipment produce excessive numbers of particles. If there is evidence for an influence from the outside environment, continuous monitoring allows for a finer scale understanding of potential contamination from the construction site nearby, something the AMC tests do not provide. Finally, continuous monitoring allows us to understand if the weekly particle monitoring is statistically reliable.

Protocol. The protocol was determined in the Meteorite Processing Laboratory (MPL), monitoring four locations. The TSI Aerotrak 9306-V2, a cleanroom-compliant handheld optical particle counter [5] has a flow rate of 2.83 L/min, and can measure six channels (particle size) of simultaneous data. We chose 0.3 µm, 0.5 µm, 1 µm, 3 µm, 5 µm and 10 µm in compliance with standard ISO 14644-1 section A.4.4. Results are given in particles/m^3, even though the sample size was smaller than 1 m^3. We do not consider the 0.3 µm particle counts, as the counter is not reliable (<50 %) for such small particles. The minimum sample size (volume of air) is determined in standard ISO 14644-1 to be the volume of air sufficient to detect 20 particles of a certain size and larger if this size of particles is at the class limit for the designated ISO Class. In the case of the Meteorite Processing Laboratory (ISO Class 6-7), 2 minutes of sampling (5.66 L) is enough to have reliable results on particles up to 1 µm. For larger particle channels (5 µm and larger and 10 µm and larger), a longer sampling is needed. Longer sampling times are currently being tested, but the Aerotrak 9306-V2 might not be adapted for larger particles, and a faster sampling rate might be required to keep sampling times under half an hour. This protocol is very similar to the one used for the weekly monitoring, with the exception of measuring particles 0.7 µm and larger rather than 1 µm and larger in our protocol.

We determined that once per hour is an adequate frequency of measurement to capture all major peaks. An automated sequence can run for several weeks at a time. Before and after every sequence, an HEPA filter is attached to the counter, and air is run through for 5 min, to make sure there are no residual particles in the counter and ensure an accurate measurement. Measurements were performed between July 2019 and January 2020 in four locations of the MPL (anteroom R237, and work rooms R239B, R239 and R255).

To correlate the data with the activities in the cleanrooms, we asked all personnel entering the rooms to indicate their time in and out and their activities.

Results: Figure 1 presents a subset of data of particles 0.5 µm and larger, from September 9th to 17th, 2019 in room R239B of the MPL. Greyed areas are outside of working hours, from 5 pm to 8 am and on weekends, when the cleanrooms are at rest. Red dots indicate the maximum occupancy each hour. Data show peaks of varying intensity, with a very high peak on Wednesday the 11th, and smaller peaks during the other workdays. Particle counts are usually going down when the cleanroom is at rest, with some exceptions such as Saturday the 14th. Apart for a few exceptions, all counts are below ISO Class 7 (352,000 particles/m^3) permitted particle counts, and most are below ISO Class 6 (35,200 particles/m^3). All monitored locations show similar trends, but distinct levels. We interpret this as either the fact that the source responsible for peaks is impacting each room in a similar way, or that the air in the MPL is rapidly mixed, since the laboratory is non-unidirectional (the airflow is turbulent).

Discussion: We considered several parameters to explain peaks in the particle counts: temperature, humidity, differential pressure in between rooms and with outside unclassified environment, occupancy and activities, airflow, and weather and outside contaminants. Peaks do not appear to be correlated to one single parameter. Temperature and humidity do not correlate with particle counts. Outside environment seems to have some impact, with for example a high peak on September 11th, a day high in pollen according to the Houston Health Department [6]. During a few hours on November 25th, a day with dust-inducing activities in the Curation Office construction site, the counters recorded a spike of 1.5 million particles larger than 0.5 µm per m^3 (~4x the maximum ISO 7 value). It is not clear yet whether the influence of the outside environment is through a direct input of outside air, or because personnel carry more particles on ingress. Peaks seem to be loosely correlated to activities, but a better understanding of activities is needed to confirm the correlation.

We compared weekly monitoring measurements and median per day of our data (to eliminate the impact of peaks). Weekly particle counts are on average 5 times higher than the median daily particle counts for measurement days. Even though it means that the cleanrooms are cleaner than expected from the weekly monitoring, it would be recommended to revise the weekly monitoring protocol to more accurately reflect the particle levels in cleanrooms.

Conclusion and future work: Continuous particle monitoring shows that the Meteorite Processing Laboratory is a dynamic and complex environment, with no primary source of particles identified yet. The levels are still within the planned ISO Class, and do not pose threat to the collection. To understand better the data, monitoring of airflow and differential pressure is advisable. As a direct comparison, monitoring of the Apollo Curation laboratory will start soon, to understand which sources are more local to the cleanroom versus building-wide. The current data has already proven useful to propose recommendations to the curation team regarding adapting maintenance and protocols.

References: [1] ISO 14644-1:2015, Part 1: Classification of air cleanliness by particle concentration. [2] McCubbin et al. (2019). *Space Sci Rev* 215:48. [3] Calaway et al. (2014). NASA/TP-2014-217393. [4] Hutzler et al. (2019) *LPSC L*:2900. [5] ISO 21501-4:2018, Part 4: Light scattering airborne particle counter for clean spaces. [6] https://www.houstontx.gov/health/Pollen-Mold/.

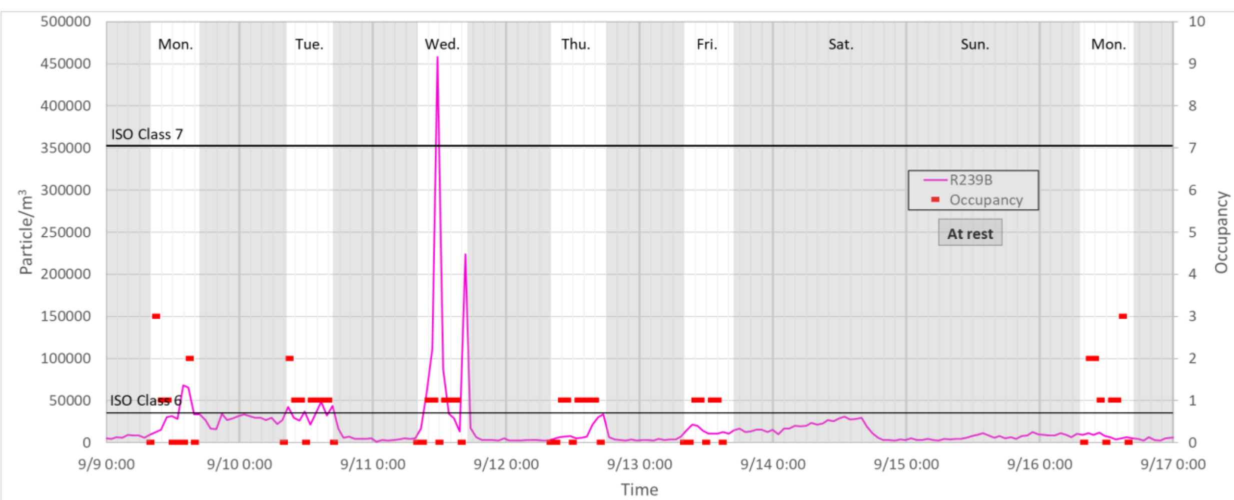

Figure 1: Particle counts (pink) of 0.5µm and larger in R239B of the Meteorite Processing Laboratory. Greyed areas are outside of working hours. Occupancy (red dots) shows the maximum number of people in the MPL each hour. The horizontal black lines indicate maximum particle counts for ISO Class 6 and ISO Class 7.