NASA COSMIC DUST CURRENT STATUS AND FUTURE DIRECTIONS M. Fries[1], R. Bastien[2], K. McBride[2] F. McCubbin[1], M. Rodriguez[3] and R. Zeigler[1]. [1]NASA Astromaterials Acquisition and Curation Office, Johnson Space Center, Houston, TX, [2]Jacobs, Houston TX, [3]Geocontrol Systems, Houston TX. Email: marc.d.fries@nasa.gov

Introduction: The NASA Cosmic Dust collection has been actively collecting, curating, and distributing material since 1981. The collection is composed of interplanetary dust collected from the Earth's stratosphere by NASA high-altitude aircraft. Recently, a suite of new policies and directions has been implemented. These policies will improve access to the collection and improve standardization of loan practice across the NASA collections. The new directions will improve Cosmic Dust acquisition of new material, and place new priority on "timed collection" of material from specific parent bodies. A description of the changes to Cosmic Dust is offered here.

Changes to Loan Procedures: When Cosmic Dust (CD) started lending material almost forty years ago, analytical instrumentation was not as capable as it is today. The typical measurement would consume an entire CD particle. As a result, material was loaned with no expectation that it would be returned to the CD collection. Since then, advances in instrumentation and sample processing allow multiple measurements on a single particle. Ultramicrotomy [1] and focused ion beam (FIB) [2] make sub-sectioning of CD material commonplace, allowing multiple sub-samples and many analyses per particle. This allows samples to be shared or re-issued for analyses between laboratories.

CD policies have been updated to reflect this modern reality. Requests for CD material now typically cover a period of five years and require an official loan agreement approved by the requesting institution and by NASA. If needed, a request for a loan extension can be made to the Cosmic Dust Curator. Material is subject to recall if requested by a different investigator, but in that case, completion of work under the initial request will be prioritized. These changes bring the CD collection to the same standards as other NASA small particle collections, including Stardust and NASA's portion of Hayabusa1 samples.

Changes to Cosmic Dust Collection: A series of updates is underway to improve CD collection methodologies and direction.

Test of Old Silicone Oil Properties: CD material is collected by high-altitude aircraft using silicone oil coated on flat-plate collectors. A test was performed to examine old silicone oil to test whether the oldest material in the CD collection can still be reliably extracted for allocation. Small-area collector W7016, which was flown in 1981, was drawn from curation storage for processing. One dozen particles were removed from W7016 and processed to include SEM/EDS analysis. McBride reports that the mechanical behavior of the silicone was indistinguishable from more recent collectors, and reports no problems in removing and handling the samples. The current CD particle inventory is over 4,000 unallocated particles (of all types), and knowing that the oil does not appreciably degrade over the current lifetime of the collection informs us that all of these particles are available for request.

Balloon-Based CD Collection: We have initiated an effort with Texas A&M to fashion a prototype dust collector for use on NASA high altitude balloons. *Balloon-based flights are intended to complement, not replace, aircraft-based collection.* The reasons for this include (in no particular order):

- Programmatic depth/resilience: Inclusion of a balloon-based CD collection platform improves resilience against aircraft unavailability due to scheduling, programmatic, and/or maintenance issues to ensure access to new material.
- "Timed Collections" improvement: Flights that are timed to attempt to collect material from a specific meteor shower are known as "timed collections" [3,4]. Balloon flights can be over 100 days long, allowing very specific collection times precisely targeting a specific meteor shower. This is an improvement over aircraft, which feature significant scheduling constraints.
- Sampling diversity improvement: Most aircraft-based sampling currently occurs in the northern hemisphere. Several long-duration balloon launch facilities exist in the southern hemisphere, allowing reliable collection of meteor showers that impinge predominantly on the southern hemisphere, such as the Southern Taurids (comet Encke) and Southern Delta Aquariids (96P/Machholz).

The prototype has been named Cometary and Asteroidal Research of Dust in Near-space Atmospheric Levels (CARDINAL), a name chosen by the undergraduate student team at Texas A&M. The device will use two collectors on a rotating arm, producing an airspeed over the collector surfaces that is much lower than that experienced in aircraft-based collection (see "dry collection", below). NASA long duration balloons (LDBs) can fly missions of over 100 days' duration, permitting a total number of particles on par or exceeding that of a typical aircraft flight. The collectors are sealed during ascent and descent of the balloon, and the size and spin rate are chosen to collect at least an estimated one particle/day/collector of flight. CARDINAL will be complete by the end of the 2019 academic spring semester. A request has been submitted with the NASA balloon program for two test flights in 2019. CARDINAL will fly as a small "piggy-back" payload, simplifying design and operations and minimizing cost.

Dry Collection: Collection of dust using oil-coated collectors is a proven and reliable method, but the oil is a contaminant for important investigations to include oxygen isotopes, native carbon/organics, and amorphous silicates. "Dry" (i.e. oil-free) foam collectors have been explored as an alternative [5] and are considered successful, with collection of a small number of particles to date. Collection efficiency for foam collectors is not rigorously known to date. Cosmic Dust will emphasize "dry" collection to provide oil-free material to the scientific community. Until the collection efficiency is quantified in a statistically meaningful fashion and other factors are understood, dry collection will proceed to complement, but not replace, oil-based collection. As an Advanced Curation activity, investigation of alternative dry collection media will be investigated starting in the next calendar year.

Dry collection may be especially well suited to balloon-based dust collection. Collection via aircraft involves airspeeds across the collector at speeds of up to 0.8 Mach, potentially shedding "captured" material from the collector over time. Balloon-based collection is much gentler, with airspeeds generally in the m/s range, with maxima dependent upon airflow over the balloon. Flight times for balloons are much longer to compensate for the lower collection rate. These effects will be quantified with a series of aircraft- and balloon-based flights with a combination of oil-coated and dry collectors.

Entire-Collector As-Received Imaging: CD is instituting an effort to collect visible-light imagery of all collectors post-flight. There are two principal reasons why:

- Good curation practice: Imaging the entire collector provides baseline as-received sample data for inclusion in the CD database.
- Identification of "timed collection" material: At present, material from "timed collections" is not differentiated from material arising from the sporadic background. Imaging the entire collector will allow particle size distribution (PSD) analysis which could identify when a "timed collection" collector has gathered material that differs significantly from that of the sporadic background.

The PSD analysis is especially important, because it offers the possibility of identifying material *from a specific meteor shower, and thus from a specific parent body*. This would effectively turn Cosmic Dust into a sample return-like endeavor, with the possibility of offering to the community material from the approximately two dozen cometary parent bodies responsible for significant meteor showers on Earth. These particles would experience various degrees of alteration upon capture by the Earth's atmosphere, but many of them arise from bodies that have never been visited by spacecraft. The potential for scientific discovery is significant. Moving forward, PSD analysis is sufficient to identify when a "timed collection" has collected material that differs from the background, but does not identify which exact particles come from that different population. PSD has been performed on a single collector thus far with promising results, and CD will pursue an investigation of older, but unsampled, collectors from various times of the year to establish baseline values. Pairing PSD with a non-destructive, non-contact means of identifying particle type (i.e. cosmic, terrestrial, artificial) is probably necessary to reduce errors due to non-cosmic particles, and to more definitively identify individual particles which deviate from the sporadic background. CD will pursue an investigation of reflectance IR spectroscopy for this purpose.

Newsletter Articles: CD will commence regular announcements of sample availability and updates on the Advanced Curation subjects described above in the upcoming Astromaterials Newsletter, to be published on a bi-annual basis.

Summary: Cosmic Dust has entered a period of significant changes in policy, procedure, and direction. All changes are intended to improve access to material, better our basic understanding of the state of the collection, diversify our particle collection capabilities, and increase research value of the collection. Material is available for request at any time with instructions found on the NASA Curation website: https://curator.jsc.nasa.gov/dust/

References: [1] Bradley, John P. *GCA* **52.4** (1988): 889-900. [2] Heaney, Peter J., et al. *Am. Min.* **86.9** (2001): 1094-1099. [3] Dermott, Stanley F., and J. C. Liou. AIP Conf. Proc. Vol. **310**. No. 1. AIP, 1994. [4] Messenger, Scott. *MAPS* **37.11** (2002): 1491-1505. [5] Messenger, Scott, et al. *MAPS* **50.8** (2015): 1468-1485.