PRISTINE STRATOSPHERIC COLLECTION OF COSMIC DUST. S. Messenger[1], L. P. Keller[1], K. Nakamura-Messenger[1,2], S.J. Clemett[1,2] [1]Robert M. Walker Laboratory for Space Science, ARES, NASA JSC, 2101 NASA Parkway, Houston TX 77058, USA [2]ESCG, Johnson Space Center, Houston TX 77058. (scott.r.messenger@nasa.gov)

Introduction: Since 1981, NASA has routinely collected interplanetary dust particles (IDPs) in the stratosphere by inertial impact onto silicone oil-coated flat plate collectors deployed on the wings of high-altitude aircraft [1]. The highly viscous oil traps and localizes the particles, which can fragment during collection. Particles are removed from the collectors with a micromanipulator and washed of the oil using organic solvents, typically hexane or xylene. While silicone oil is an efficient collection medium, its use is problematic. All IDPs are initially coated with this material (polydimethylsiloxane, $n(CH_3)_2SiO$) and traces of oil may remain after cleaning. The solvent rinse itself is also a concern as it likely removes indigenous organics from the particles. To avoid these issues, we used a polyurethane foam substrate for the *oil-free* stratospheric collection of IDPs.

Experimental: We prepared an IDP collector by attaching a ¼ inch thick sheet of polyurethane foam (McMaster Carr) to a standard small-area IDP collector using a cyanoacrylate adhesive. Structurally, the foam consists of a three dimensional network of 40 µm-thick strands and thin membranes forming ~400 µm-wide cells. Initial examination of the foam prior to flight confirmed that the surface was clean and essentially devoid of visible particles. The collector (W7262) was flown for 8 hours in October 2006.

The collector was scanned for candidate IDPs using a high-magnification stereo microscope in a clean room. Searching for particles on the foam collector proved to be much more time consuming compared with standard collectors. This is due to the fact that the depth of the cells is greater than the depth of field of the microscope and particles have less contrast against the substrate compared with standard IDP collectors. Relocating particles was also challenging due to the complex structure of the foam. We overcame these difficulties by first producing a high magnification photomosaic of the entire collector (Fig. 1). Image stacks at differing focal points were obtained and converted into best-focus images using a commercial software package. Secondly, we used a computerized stage to record the positions of the particles.

Candidate IDPs were first photo-documented and then removed with a micromanipulator, using dry glass needles. Several particles were directly embedded in epoxy and microtomed for scanning-transmission electron microscope (STEM) examination. Other particles were first examined with a field-emission scanning electron microscope (SEM), obtaining secondary electron images and energy dispersive x-ray (EDX) spectra. Several of these have been embedded in epoxy and examined by STEM.

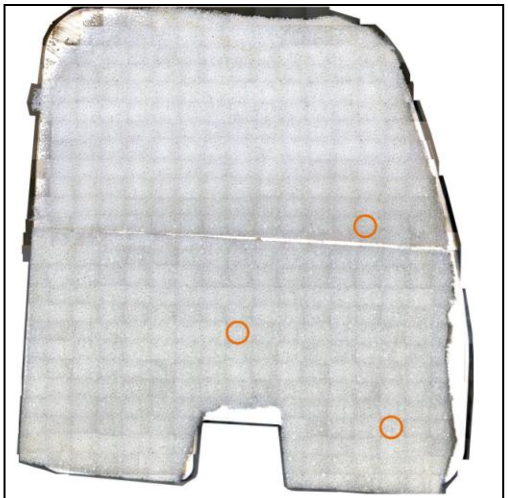

Fig 1: W7262 photomosaic showing locations of particles A2 (top), A3 (bottom), and A5 (left).

Results & Discussion: Two of the particles (A2 & A3) removed from the collector were confirmed to be IDPs and a third candidate IDP (A5) has been identified. Particles A2 and A3 are fragile, fine grained cluster IDPs. On the collector, these appear as compact but incoherent masses surrounded by numerous micrometer-sized grains (Fig. 2). In both cases, the particles are contained within a single cell, with the surrounding cells devoid of particles. Several apparent contaminant metallic grains were identified on the col-

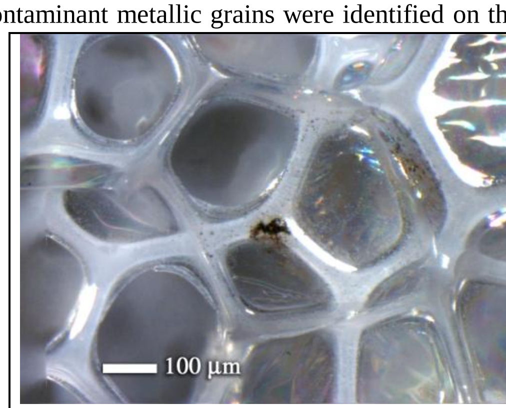

Fig 2: Cluster IDP W7262 A3; particles are distributed throughout the interior of a single cell.

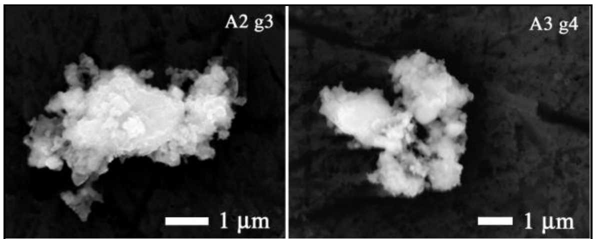

Fig 3: SEM images of fragments of IDPs W7262 A2 & A3

lector, perhaps originating from the aircraft.

SEM examination of fragments from A2 and A3 revealed the typical fine grained, fragile appearance of chondritic porous (CP) IDPs (Fig. 3). Energy dispersive X-ray spectra obtained from several fragments of A2 and A3 are consistent with chondritic major element abundances.

The candidate IDP A5 also appeared as a cluster of grains within a single cell, though coarser grained in comparison to A2 and A3. We examined one fragment of A5 by SEM, and this appeared to be mainly a single mineral grain with the EDX spectra consistent with Fe-rich olivine. A Ni peak was also observed, consistent with an extraterrestrial origin. TEM work will be required to further evaluate the origin of A5.

Fragments of the cluster IDPs A2 (two samples) and A3 were embedded in low viscosity resin and thin sections were prepared using ultramicrotomy. Imaging data, diffraction patterns and quantitative chemical maps were obtained from microtome thin sections with the JSC JEOL 2500 STEM equipped with a thin-window EDX detector.

Both A2 (Fig. 4) and A3 have mineralogy typical of CP IDPs: GEMS grains, FeNi sulfides, crystalline silicates (enstatite and forsterite), FeNi metal, equilibrated aggregates and abundant carbonaceous material [2]. The clinoenstatite platelets and forsterite single crystals are Mg-rich. A small anorthite grain was also observed in A2. The particles underwent moderate heating during atmospheric entry as evidenced by thin, discontinuous magnetite rims on some of the sulfides and GEMS grains, vesicular carbonaceous material and a lack of solar flare particle tracks. The chemical compositions of 19 GEMS grains show heterogeneous compositions (Fig. 5), with mean Mg/Si, Ca/Si, Al/Si, Ni/S, and S/Si identical to our previous GEMS grain analyses [3]. The average Fe/Si ratio is somewhat lower than average GEMS grains.

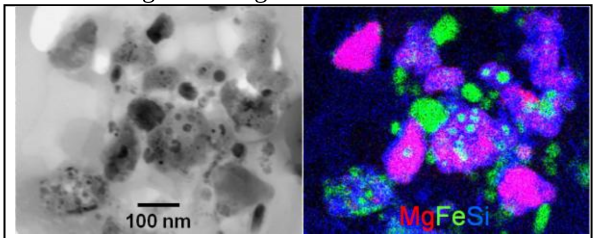

Fig 5: Left: Bright field TEM image of a cluster of GEMS grains in A2. Right: RGB (Mg,Fe,Si) composite elemental map of GEMS grains obtained by STEM.

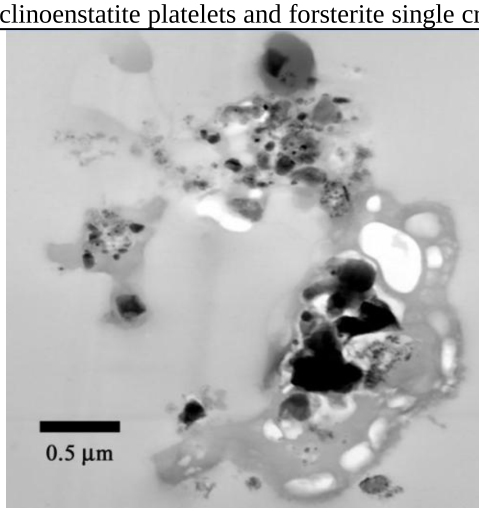

Fig 4: Bright field TEM image of a section of A2. The mineral grains and GEMS are contained within vesicular carbonaceous material (dark grey).

While we have not observed any differences in the mineralogy of these IDPs compared with previously studied IDPs attributable to the exposure to silicone oil or hexane, organic studies will clearly benefit from this type of dry collection. CP IDPs are very rich in isotopically anomalous organic matter that differs in some respects from carbonaceous chondrite organics [4-7]. These differences may reflect the fact that CP IDPs have not been affected by hydrothermal processing. However, it is also likely that soluble organic phases are removed from IDPs during the hexane rinse normally used to remove silicone oil. We are planning future organic and isotopic studies of these IDPs by coordinated NanoSIMS and *ultra*-L^2MS microprobe.

As a collection substrate, the polyurethane foam performed well compared with silicone oil coated collectors. We have identified two and perhaps three cluster IDPs, with additional smaller particles on the collector remaining to be studied. If flown for the typical exposure time of IDP collectors, we could expect to collect at least 10 IDPs with this type of foam. However, other types of materials should be investigated for optimal cleanliness and collection efficiency.

References: [1] Sandford S.A. (1987) *Fund. Cosmic Phys*. 12, 1-73. [2] Bradley J.P. (2004) in *Treatise on Geochemistry Vol. 1: Meteorites, Comets, and Planets* 689 [3] Keller L.P. & Messenger S. (2011) *GCA* 75, 5336 [4] Pizzarello S., Cooper G.W., & Flynn G.J. (2006) in *Meteorites and the Early Solar System II*, 625. [5] Clemett S.J. *et al*. (1993) *Science* 262, 721 [6] S. Messenger (2000) *Nature* 404, 968 [7] Floss C. et al. (2004) *Science* 303, 1355