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Each sub-image is 51.6 x 51.6 arc-seconds in size. Horizontal lines are stars (in figure 5, the star tracks are slightly tilted to the upper right). Approximately one-third of the detections show a series of three or more flashes during each 5-s exposure. One interpretation is that the detected objects are tumbling. Objects that are non-uniform streaks are tumbling at a rate close to our 5-s exposure time; objects with flashes are tumbling faster. Approximately 25 percent of the detected objects show glints (a momentary flash).

None of the faint objects detected are in the public U.S. Satellite Catalog. The rate of detection of objects with GEO rates is approximately 10 per hour per square degree.

This can be compared with the detection rate of GEO debris on MODEST during previous observing campaigns. The CCD camera in this telescope had a field-of-view of 1.3 x 1.3 degrees, a somewhat broader filter close to the same central wavelength of the Magellan Sloan r′ filter, the same 5-s exposure time as Magellan, and a different survey technique. The average detection rate of objects with angular rates consistent with those at GEO in the range of 15th to -18th R magnitude was approximately one object per hour per square degree. Magellan's average detection rate, including objects in the 15th to 21st r′ magnitude regime, was 10 times greater. With only 6 hours of observing time using Magellan, the statistics are unfortunately small at the faint end, but more GEO objects were detected in 6 hours of observing with Magellan in a smaller field-of-view than were detected with MODEST in an 8-hour night with a camera covering an area of sky eight times larger. However, the Magellan and MODEST results are consistent with a rising population of GEO objects as one reaches fainter limiting magnitudes. Future observations with Magellan can help us begin to understand the small and faint debris population in GEO.

Coring the Wide-Field Planetary Camera 2 Radiator for Impactor Trace Residue Assessment

Phillip Anz-Meador and J.-C. Liou

After approximately 16 years in low Earth orbit aboard the Hubble Space Telescope (HST), the Wide Field Planetary Camera 2 (WFPC2) was returned to Earth in 2009 by the crew of STS-125's Servicing Mission 4. The WFPC2 radiator was exposed to the micrometeoroid (MM) and orbital debris (OD) environment and provides a unique record of the environment due to the length of time it spent in orbit as well as its relatively large 1.76 m^2 surface area. This surface was optically surveyed for impact features by a NASA and contractor team from JSC, Marshall Space Flight Center, and Goddard Space Flight Center in the summer of 2009. Approximately 700 features limited to a size of approximately 300 µm – estimated to correspond to a 100 µm OD projectile – were located and documented using a Keyence VHX-600 digital microscope.

The observed crater record will be used to bound the integrated flux, but requires a knowledge of the HST's attitude history, damage equations to correlate the crater features found on the WFPC2's surface to estimated projectile size, and a discrimination between the MM and OD components of the environment. This discrimination is required, as the two components possess quite distinct velocity, density, and directional distributions. As the damage equations depend upon these variables, they must be inferred or determined by direct measurement to implement the damage equations correctly and thereby assess the MM and OD fluence.

Project planning began in 2009 and was predicated upon prior sampling campaigns to characterize surfaces returned from space [*i.e.*, the Long Duration Exposure Facility (LDEF)]. In these campaigns, samples or cores were cut from select surfaces and analyzed using standard Scanning Electron Microscope–Energy-Dispersive X-ray spectroscopy (SEM-EDX) techniques to assess the elemental composition of the impactor. The elemental constituents revealed the impactor to be MM, OD, or an indeterminate category. However, the WFPC2 radiator presented unique challenges due to its geometry (a rectangular section from a right circular cylinder's lateral surface), thickness (approximately 4 mm), coating (YB-71 Zinc Orthotitanate [ZOT] thermal control paint), and the size and extent of many impact features. Collecting core samples from the thick surface using a core drill offered the greatest probability of success within two major constraints: 1) not contaminating the sample during collection and 2) not compromising the integrity of the clean room in which sampling would be conducted.

The Technique

A unique sampling tool was developed to perform clean room coring of the WFPC2 impact features. The annular cutter is shown in figure 1. In this case, a standard 5/8–in.-diameter cutting tool was modified with a concentric, spring-loaded, phosphor-bronze cylinder. The cylinder is tipped with a standard O-ring to protect the feature being cored. As the core drill is brought into contact with the radiator's surface, friction between the surface and the O-ring brings the cylinder to rest within the rotating annular cutter. As the cutter is advanced into the surface, the cylinder retracts, allowing the radiator's aluminum substrate to be cut while protecting the feature of interest.

Figure 1.– The coring device developed at JSC. Cores taken have a diameter (measured at the core's painted surface) of approximately 7 mm, corresponding to the inner diameter of the annular cutter.

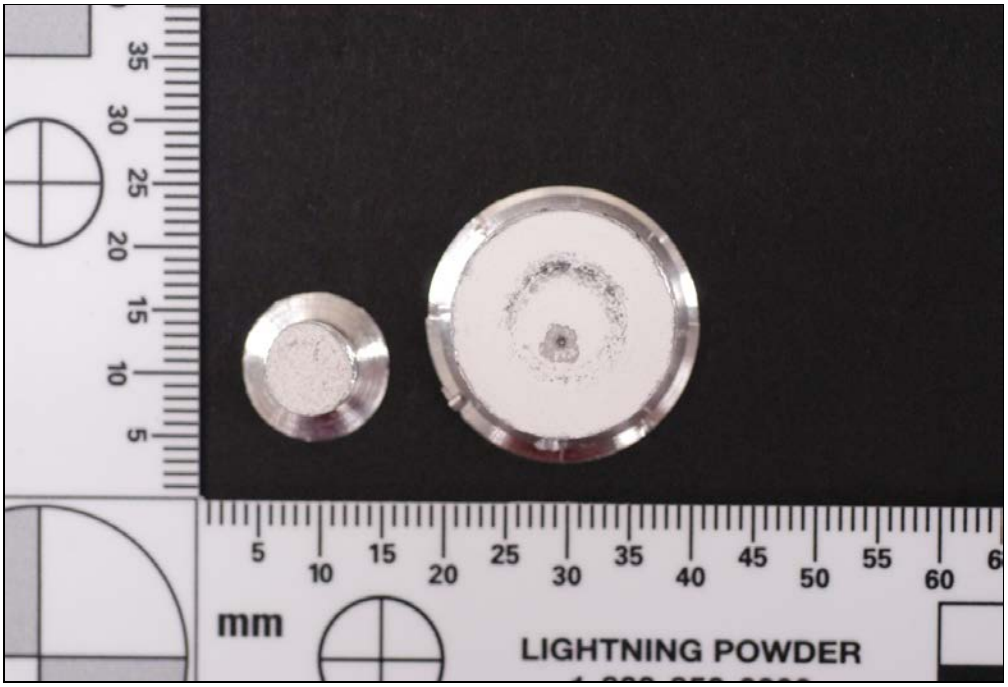

Figure 2.– Small (taken with the cutter portrayed in figure 1) and large cores collected using a larger, 1-1/16-in. diameter cutting tool. The small core is a "blank" taken as a standard reference for the YB-71 paint coating and Al substrate. Clearly visible on the surface of the large core is an impact crater displaying paint spallation. Also visible is an abrasion left by the large cutter's O-ring – this was later remedied by decreasing the cutter's spring constant.

Figures 3 and 4 illustrate the process by which cores are collected. The process begins with the identification of a feature to be cored. In figure 3, Orbital Debris Program Office team member Joe Caruana is aligning the core drill table roughly with a feature to be collected. The table allows 4 degrees of freedom in aligning the high-torque drill motor assembly with the feature. After a rough alignment, the assembly is rotated to enter the radiator's surface normally, and fine positioning is achieved with a laser alignment system.

In figure 4, the cutter is engaging the surface. As the feature is protected, so is the clean room environment – a vacuum shroud is visible around the cutter; dust generated by cutting is collected by a HEPA-filtered vacuum, while larger strands are collected by the shroud assembly itself.

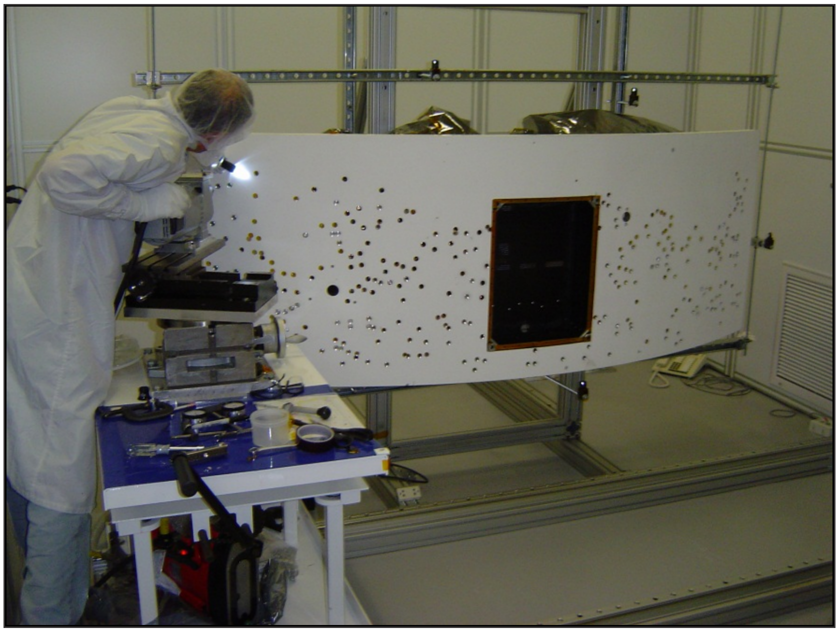

Figure 3.– Preparation for coring a feature.

Figure 4.– The system cores an impact feature.

Analysis

During project planning, it was agreed that the analysis would be shared by NASA and ESA. At JSC, the ARES SEM-EDX laboratory is charged with performing analyses to determine the elemental composition of impactors, and hence the source environment of the impactors, while the Ion Beam Center (IBC) of the United Kingdom's Natural History Museum (NHM) was chosen as ESA's agent. The cores were shared equally between NASA and ESA, becoming the laboratory sample property of each party. All core samples will be maintained in a state to allow future analyses on the cores, should superior techniques be developed and implemented for the analysis of returned surfaces.

The ARES and NHM IBC analytical teams are currently probing core samples to identify and record traces of impactor residue materials left in and about the impact features. Impactors from the MM and OD components have been identified, but analysis has yielded indeterminate results. In this latter case, a core can yield indeterminate results because no residues were present; no residues were identified; or, in the case of craters resident only in the YB-71 paint layer, the crater geometry complicated electron beam-based instrumentation, confounding the investigation. However, a full accounting of the three categories is premature pending completion of the ARES work as well as supporting analytical activities, such as the assessment of surface attitude compared to environment directionality.

Figure 5 depicts a small, so-called "paint crater," a conical impact feature resident entirely in the paint coating. Figures 6a and 6b depict a larger impact feature. The ARES and NHM IBC teams are concentrating their analytical efforts on characterizing the elemental constituents of the residue melts in both types of features.

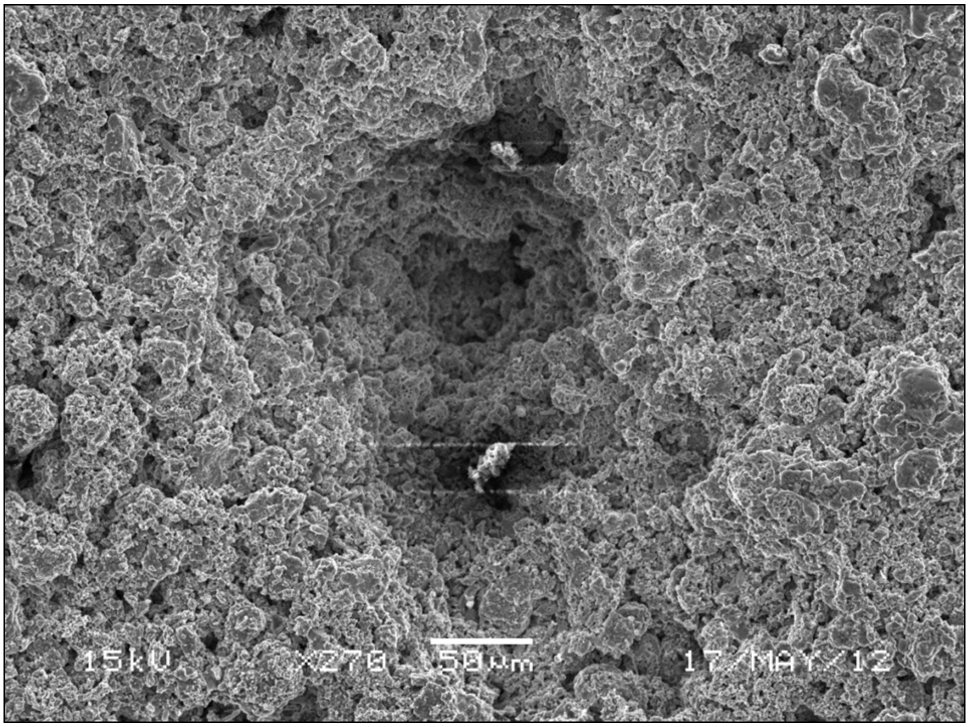

Figure 5.– Core sample 29, typical of the so-called "paint craters."

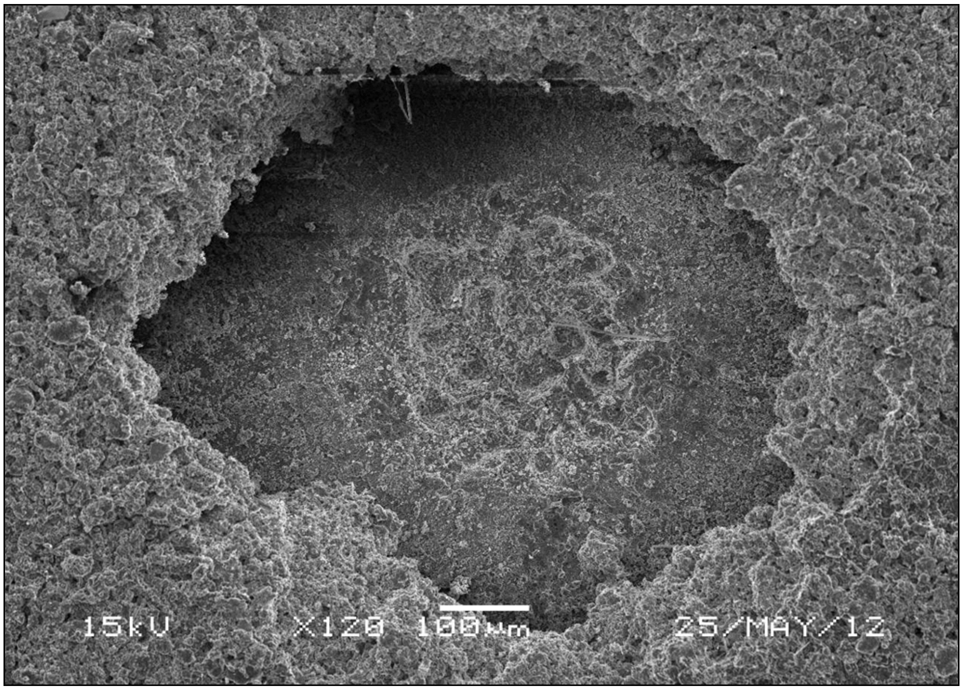

Figure 6a.– Core sample 29, typical of the larger impact features. Note the area of spalled paint and the relatively shallow impact feature on the revealed Al-6061 substrate surface.

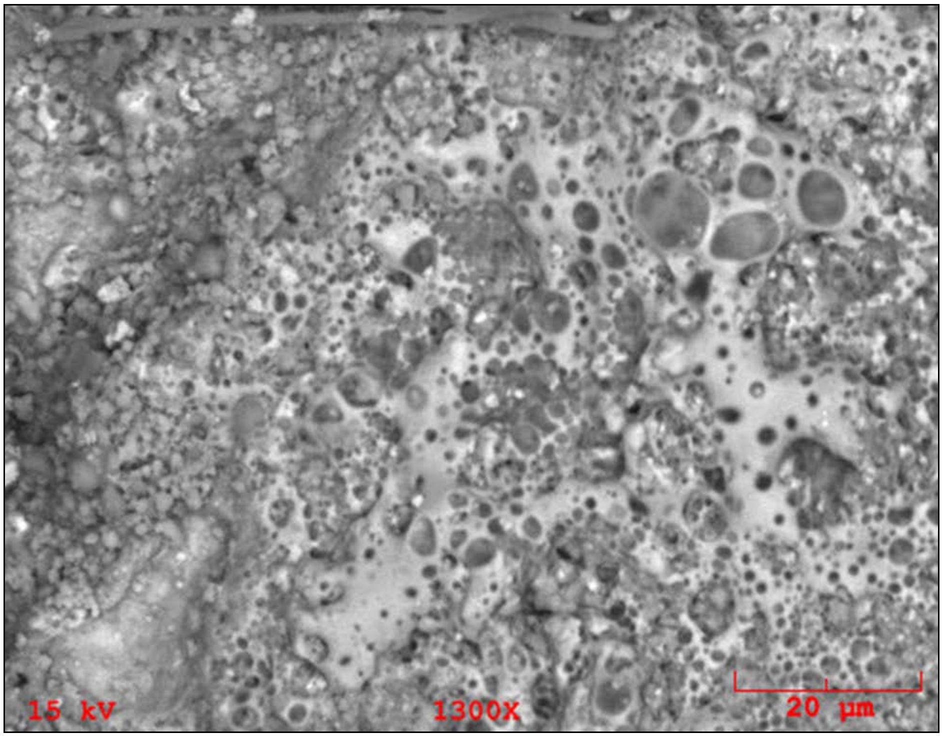

Figure 6b.– Projectile and target residue melt on the floor of the sample 29's impact feature. Note the frothy appearance and large number of vesicles in the melt.

After the two impactor populations are identified, along with the indeterminate cases, population characteristics (density, relative velocity, and directional distributions) will be used in conjunction with damage equations to estimate the impactor's characteristic size. At that point, cumulative number or flux distributions of the MM and OD components begin to serve the space environment modeling community.

Multi-Purpose Crew Vehicle Camera Asset Planning: Imagery Previsualization

K. Beaulieu

Using JSC-developed and other industry-standard off-the-shelf 3D modeling, animation, and rendering software packages, the Image Science Analysis Group (ISAG) supports Orion Project imagery planning efforts through dynamic 3D simulation and realistic previsualization of ground-, vehicle-, and air-based camera output.

A total of 11 cameras will be onboard the Multi-Purpose Crew Vehicle (MPCV) and Service Module during Exploration Flight Test 1 (EFT-1), the first test flight of Orion, scheduled to launch in September 2014. These 11 cameras will collect imagery data essential to the fulfillment of EFT-1 flight-test objectives defined by Lockheed Martin and NASA. The optimization of the onboard camera suite – the evaluation of proposed camera and lens hardware options and definition of settings, position, and orientation parameters – has been achieved using imagery previsualization techniques.

Provided simulation data for a dynamic event; camera sensor and lens specifications; and industry-standard modeling, animation, and rendering software are used to produce high-quality, accurate previsualization imagery. EFT-1 dynamic events that have been modeled using simulation data provided by Lockheed Martin include the Launch Abort System (LAS) jettison, Crew Module/Service Module separation, and the Crew Module forward bay cover (FBC) jettison.

LAS-jettison imagery will be captured by three cameras mounted inside and pointed out of Crew Module windows. Lockheed Martin and NASA require this imagery to verify a successful LAS jettison without recontact during nominal ascent. Previsualization imagery of the LAS jettison, captured by the overhead docking hatch window, is shown in figure 1.