Hayabusa Sample Curation Facility Visit

Presented to Planetary Protection Subcommittee

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INTRODUCTION

- Visit: May 11, 2010; Landing: June 13, 2010
- NASA Visitors: David Beaty (Mars Program Office, JPL), Karen Buxbaum (Mars Program Office, JPL), Carlton Allen (Astromaterials Curation, JSC), Perry Stabekis (Planetary Protection, HQ)
- JAXA Hosts: Masanao Abe (Curation Director), Akio Fujimura (Facility Director)
- Purpose of visit: first hand view of the facility before first use including contingency planning and capabilities, undistorted by success, failure, or anything in between
- Additional purpose: to understand the handling and analysis of the samples prior to 10% of sample being transferred to NASA/JSC

OVERVIEW

- Impressive laboratory designed to support
  - Entry capsule de-integration
  - Sample preliminary examination
  - Long-term sample curation
- First non-NASA facility for curation of samples returned from space
- Wide range of contingency capabilities
- Intended to preserve the maximum science value of whatever sample is collected

SPECIAL INTEREST RELATIVE TO POTENTIAL MSR

- Strategies and equipment for cleaning dirty incoming flight hardware, de-integrating the canister, measuring state of cleanliness
- Elaborate system for collection and analysis of gas in the sample container
- Innovative particle handling techniques
- Mix of manual and robotic systems
- Flexibility of approach

FACILITY OVERVIEW

- 6 rooms with total area of ~400 square meters
- 60% is cleanroom floor space
  - receiving room where the flight hardware exterior will be cleaned and the sample canister separated
  - a much cleaner sample processing room where the sample canister will be opened.
- Other 40% are rooms to provide support functions
- Facility cost $10M (not including the building) and took 3 years to build (not including design time ahead of that)

QUESTIONS POSED BEFORE THE VISIT

- We left for Sagamihara with a couple dozen questions in mind. Almost all questions tied directly back to our thinking about a possible future MSR and sample receiving facility.
- In our post-visit report, we answered most of those questions.
- But many questions deserve to be revisited to penetrate more deeply and take advantage of lessons learned.

FACILITY DESIGN REQUIREMENTS

- **What were the facility design requirements?**
  - Contractors designed and built the facility. We were not provided with a list of design requirements *per se*, but their handouts provide an extensive list of functional capabilities and flow charts.

FUNCTIONAL ELEMENTS OF FACILITY

- **What are the functional elements of the facility, and how much space does each require (and what is the total floor space)?**
  - Total floor space on the main level is ~400 square meters; additional facility space is required for air handlers and certain support equipment on the floors above and below.
    - Information room
    - Monitor room
    - Class 10K manufacturing and cleaning room
    - Class 1000 sample prep room
    - Class 1000 electron microscope room
    - And the large class 100-1000 sample handling room
    - Single locker room but 2 separate garmenting areas, air showers, and entry ways to the clean rooms

FACILITY CLEANING & CONTAMINATON AVOIDANCE

- **How did they test it without introducing contamination?**
  - During the 2009 rehearsal in the facility, no samples were in use. After their intermediate review in October 2009, they moved to more thorough rehearsal in which they used analog samples. The sample handling team is practicing in mockups and in the main chambers; they used small particles of unique compositions (stainless steel; Ni-rich olivine), which should be easily distinguishable from asteroid particles.

SAMPLE-CONTACT MATERIALS

- **What sample-contact materials choices did they make, and why?**
  - Solid samples will be in contact with quartz glass dishes and tubes, stainless steel surfaces (see more about surface finishes, below), and manipulators of carefully-specified metal chemistry. They will be exposed to clean nitrogen gas. The gas samples will be stored in metal cylinders, but we did not learn the composition. These materials are closely analogous to those used in NASA's curation laboratories.

PHYSICAL SECURITY

- **What provisions have been made for physical security?**
  - Perimeter security is provided as part of the entire JAXA complex, however, it is not strict—the campus has relatively open access. The lab security system consists of numerous levels of locked doorways (badge readers and cipher locks).

TECHNIQUES FOR SAMPLE HANDLING

- **What technical advances have they made in the handling of very small samples, most importantly, in the areas of sample manipulation and sample subdivision?**
  - The designers of this facility developed a unique sample manipulation system using electrostatic force. Very fine metal needles are threaded through the open tips of fine glass micropipettes, which are in turn held by the micromanipulators. Particles can be picked up and released by varying the charge on the wire. The micromanipulation system uses dual joystick controlled needles.

MAINTAINING SAMPLE QUALITY

- **What are their strategies for maintaining sample quality? How will they manage their pressure differentials within the facility to keep sample contamination within acceptable limits?**

  – It is only during the initial opening of the sample holder in Clean Chamber 1 that vacuum conditions were used. This was an integral aspect of the assessment of the seals and the opening of the holder. Clean Chamber #2 was designed to be operated under a slight positive gas pressure, using clean nitrogen.

PRELIMINARY EXAMINATION

- **Will any special steps be taken to assess the state of the capsule before it is opened?**
  - The sample container went through x-ray CT imaging at a separate facility prior to arrival at Sagamihara. We were told that they would be particularly interested in determining the state of the interior latches before the container was opened.

CLEANING OF SPACECRAFT EXTERIOR

- **In the receiving part of the facility, how will they clean the exterior of the spacecraft before opening it? How will they manage the transfer of the spacecraft from a dirty environment to a clean one?**
  - Multi-step cleaning process to get to the sample container
  - Class 10K manufacturing and cleaning room: several cleaning technologies in place
    - an acid and base cleaning compartment, an organic solvent cleaning compartment, and an ultrapure-water cleaning compartment
    - analytical equipment available for cleanliness evaluation (optical microscope, contact angle analyzer, FT-IR, surface roughness gauge).
  - The plan was for the sample container to move to the opening system after the removal of surface contamination and cleanliness was verified

SCIENTIFIC INSTRUMENT AT FACILITY

- **What kind of scientific instrumentation do they have in the Sagamihara facility? How much of that is in separate laboratories, how much is in the curation facility proper, and what subset is inside the isolation cabinets?**

  – Within the sample treating room, there is instrumentation to document the individually partitioned samples. Almost all of the scientific study of the Hayabusa samples will be performed at principal investigator (PI) institutions. The plan is to carry out only one formal scientific investigation in this facility (a spectroscopic investigation). Integrated into Clean Chamber #2 are two instruments—a long-focal length microscope and a balance.

SAMPLE ALLOCATION

- **What is their planned sample allocation process? Will there be a competition (or has a competition already taken place)?**
  - The baseline plans for sample allocation include 15% (by mass) for Preliminary Examination, 15% available for Japanese investigators through competed requests, 15% available for non-Japanese investigators through competed requests, 10% transferred to NASA for curation and allocation; and 45% held in reserve by JAXA.
  - Through a competitive process, an international committee will choose the investigators who will perform the sample analyses.
  - Only one PI instrument is located at the receiving facility. It is a custom-built NIR spectrometer that can be attached to a flange on Clean Chamber #2. Masanao Abe is the PI.

CURATION PROCESS

- **How do they envision the process of “curation”?**
  - Details of the curation process will depend strongly on the amount and physical condition of the samples. This will be determined during preliminary examination.
  - Clean Chamber 2 is equipped for photographing and weighing samples, and for placing them into individual glass containers. Samples can then be transferred to nitrogen-filled compartments for long-term storage.

TIMELINE

- **What does their timeline of movement of samples through the facility look like?**
  - The handouts provided to us described the flow through the facility. The timeline will be dependent on the physical condition and quantity of samples. Based on NASA experience with small particle curation, a one-year timescale for initial documentation and preliminary examination is reasonable.

CURRENT STATUS

- According to JAXA announcements:

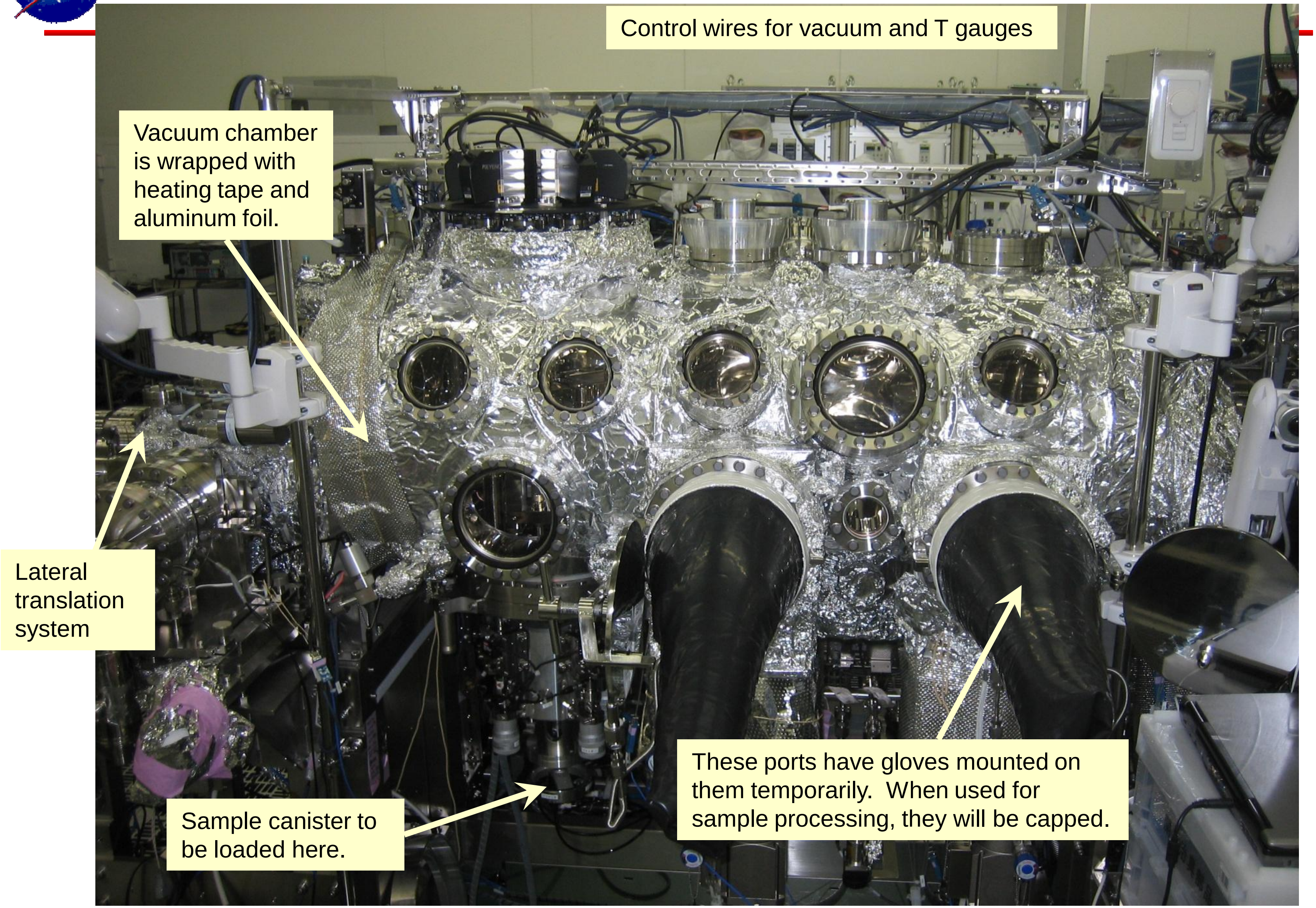
The spacecraft was successfully recovered with no apparent damage and transported to Japan. The sample canister was cleaned, assessed by CT, and successfully opened. A small number of particles was found in the canister, which is not surprising considering the reported problems with the sampling system. JAXA reports that the Preliminary Examination Team is currently examining those particles, and has made no announcement concerning their composition.

IN CONCLUSION

- JAXA's Sagamihara curation facility is currently devoted to the Hayabusa mission
- Designed to support preliminary examination and curation of potential future returned samples, too
- Based on experience with Hayabusa, JAXA should be able to provide valuable insights to other receiving facility planners in the future

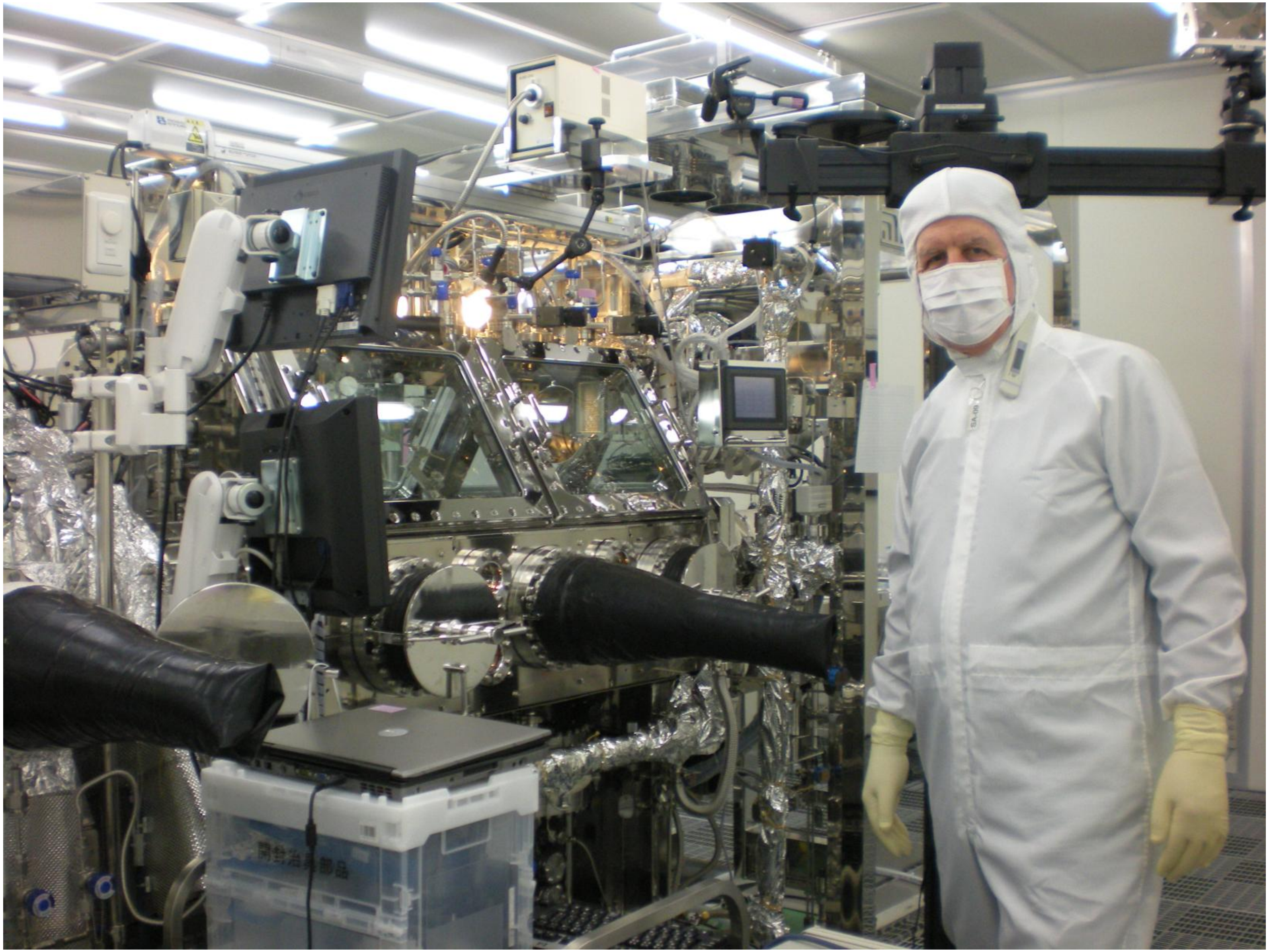
Clean Chamber #1 (front side)

Photograph by D. Beaty with permission to use by JAXA



Carl Allen next to Clean Chamber 2

Photograph by K. Buxbaum with permission to use by JAXA



Clean Chambers 1 and 2

Photograph by D. Beaty with permission to use by JAXA

ENTRY CAPSULE WITH PARACHUTE

NEXT MORNING AT THE LANDING SITE

Courtesy of JAXA

ENTRY CAPSULE

REMOVING PYRO DEVICE(S)

Engineers are dressed in protective gear in case of unexploded ordnance

POST-VISIT DETAILS OBTAINED DURING A JSC VISIT

- Assessment and cleaning
- Sample holder opening (clean chamber 1)
- Gas Sampling (Clean Chamber 1)
- Sample Removal (Clean Chamber 1 and 2)

Assessment and Cleaning

- The "instrumental module," consisting of the "sample holder" encased in an electric box and ablative materials, is removed from the re-entry capsule.
- The sample holder consists of two parts – the upper "Sample Catcher" and the lower "Sample Container" with viton O-ring seals between them, held together by latches.
- The instrument module is examined by X-ray CT scan to confirm the condition of the latches.
- The electric box and ablative materials are removed.
- The sample holder is examined by X-ray CT scan to confirm the condition of the O-ring seals (and perhaps image the samples).
- The sample holder is cleaned to remove surface contamination and cleanliness is verified. This step is critical to both gas and sample analysis. Several technologies are available to accomplish cleaning, including an ultrasonic cleaner, ultrapure water, UV/ozone, and atmospheric plasma.
- We did not learn the specifics concerning transportation of the instrumental module (and later the sample container) to and from the X-ray CT scanner nor the specific sequence of cleaning and cleaning-verification steps for the sample container.
- For the physical opening steps, they have set up a drill press and a mill in the receiving facility.

Sample Holder Opening (Clean Chamber 1)

- The sample holder is placed in the sample opening system, which presses the sample catcher in place on the sample container.
- The sample opening system is docked to **Clean Chamber 1**, which is under vacuum (manipulator operations; glove backup).
- The latches are removed; the sample holder is kept closed by pressure from the sample opening system.
- The sample opening system slowly releases pressure on the sample catcher, allowing it to rise on the O-rings. This rise, measured by laser displacement sensors, is proportional to the internal pressure. This pressure is between space vacuum and 1 atm, depending on the amount of leakage into the sample holder.
- Nitrogen is introduced into **Clean Chamber 1** to approximately match the internal pressure in the sample holder.
- The sample opening system is operated to remove the sample catcher from the sample container.

Gas Sampling (Clean Chamber 1)

- Prior to opening the sample holder, the pressure and composition of the nitrogen atmosphere is Clean Chamber 1 is measured.
- When the sample holder is opened, any gas contained in the sample holder is allowed to mix with the nitrogen in the full volume of Clean Chamber 1
- This gas in Clean Chamber 1 is analyzed, and the pressure and composition of the gas in the sample holder is calculated by difference.
- The emphasis on gas analysis is driven by interest in sealing integrity against gross leaks (in keeping with the engineering demonstration), rather than by interest in the trace of volatiles that might be released from the samples. Seen that way, their gas measurement strategy makes more sense.
- The pressure in Clean Chamber 1 can be manipulated to optimize the measurement. (It may be that they can learn a good deal about leaks, but perhaps very little about asteroid off-gassing with this system.)

Sample Removal (Clean Chamber 1 and 2)

- There may be regolith particles in the sample catcher, the sample container, or both.
- The sample catcher and sample container will be examined visually after opening.
- The sample container, with a small amount of sample, can be transferred directly from **Clean Chamber 1** to long-term storage under vacuum.
- The sample catcher, and the sample container if it contains a significant amount of sample, is transferred from **Clean Chamber 1** to **Clean Chamber 2** (nitrogen gas at atmospheric pressure; glove operations)
- Samples are poured into several quartz glass dishes; smaller samples are removed from the sample catcher and sample container using small hand tools.
- Individual small grains can be moved using the electrostatic manipulator; this instrument is operated using hand controls inside **Clean Chamber 2**.
- Samples in quartz glass dishes in **Clean Chamber 2** can be photographed, weighed, and analyzed with the UV-Vis spectrometer.
- Samples can be placed in nitrogen-filled containers and transferred from **Clean Chamber 2** to the SEM / EDX for analysis.
- Samples can be placed into quartz glass tubes, which are heat-sealed and transferred to other labs.