NEAR-EARTH ASTEROID SAMPLE CURATION. C. C. Allen and M. M, Lindstrom NASA Johnson Space Center, Houston, TX 77058 carlton.c.allen1@jsc.nasa.gov; marilyn.m.lindstrom1@jsc.nasa.gov

Introduction: Curation of Near-Earth Asteroid (NEA) samples returned by spacecraft will require careful planning to ensure that the samples are not contaminated prior to distribution to the research community. In addition, curation and distribution will be required to address a level of planetary protection concerns that depends on the asteroid type. Laboratories and procedures developed for curation of lunar samples and Antarctic meteorites have successfully preserved the integrity of these samples and supported research for decades. Planning for curation to support future asteroid, comet, and Mars sample return encompasses many of the concerns unique to a NEA mission.

Current Sample Curation:

Lunar Samples. NASA Johnson Space Center (JSC) preserves and distributes samples collected by the Apollo astronauts and by the Russian Luna 16, 20, and 24 spacecraft. The samples are packaged, stored, examined, subdivided, and prepared for distribution to approved investigators. All processing of pristine samples is conducted in positive-pressure nitrogen gloveboxes, operated in a class 1000 cleanroom environment at room temperature. Samples are segregated by mission in separate gloveboxes. Strict material controls are maintained to prevent inorganic contamination. Airborne particle counts in the laboratory and trace oxygen and water vapor in the cabinet nitrogen are regularly monitored. Cabinets and sample processing tools are precision cleaned with ultrapure water.

Antarctic Meteorites. JSC curates meteorites from Antarctica as part of a joint program run by the National Science Foundation (NSF), NASA, and the Smithsonian Institution (SI). NSF is responsible for annual collection expeditions, while NASA and SI share curation duties. Meteorites are returned frozen from Antarctica to JSC, and kept frozen until thawed in small groups in nitrogen gloveboxes in the Meteorite Processing Laboratory. This lab is a class 10,000 cleanroom which is currently being upgraded to class 1000 by the addition of HEPA filtered air. The meteorites are described, subdivided, and prepared for distribution at ambient temperature, either in nitrogen gloveboxes or on laminar flow benches. Samples are packaged and most are stored in nitrogen gloveboxes, however small ordinary chondrites are packaged in nitrogen and stored in air. Samples are segregated for processing by meteorite type – ordinary chondrite, carbonaceous chondrite, achondrite, and the rare martian meteorites. Strict material controls are maintained to prevent inorganic, and more recently organic and biological, contamination. Particle counts are taken routinely and the levels of organic/biological contamination are monitored periodically.

Future Sample Return Missions:

Asteroid Sample Return. The Japanese MUSES-C mission is currently scheduled to return several grams of material from asteroid 1998-SF36 in 2007. The sample canister will be opened and inspected at the Japanese Space Agency (ISAS) Curation Laboratory near Tokyo. The samples will be maintained in a nitrogen glovebox for preliminary examination, storage, and distribution. A portion of the asteroid sample will be transferred to the Curatorial Facility at JSC for curation, storage, and distribution.

Comet Sample Return. The NASA Stardust mission is currently enroute to a rendezvous with comet Wild 2 in 2004. Samples of dust from the comet's tail will be collected in silica aerogel and returned to Earth in 2006. The aerogel collectors will be scanned and mapped in a dedicated class 10 cleanroom at JSC. They will later be dissected and prepared for distribution in the cleanroom. Samples will be stored in positive pressure nitrogen gloveboxes. Processing and distribution will be done at room temperature.

NASA is also beginning to plan a comet nucleus sample return mission. Curation of comet nucleus samples will require stricter control of organic contaminants than is required for Stardust samples, and will most likely require a sub-freezing or cryogenic environment for processing and storage.

Mars Sample Return. Curation for a Mars sample return mission will involve the full range of inorganic contamination controls used for lunar samples, combined with organic and biological controls. The samples will be closely examined for evidence of present or past microbial life, as well as biological hazard. Planetary Protection concerns require that the terrestrial environment must be protected from possible biosafety hazards related to the samples [1]. Consequently, the sample receiving and curation laboratories must meet three main objectives: 1) protect the laboratory workers, 2) protect the environment (in this case the entire biosphere), and 3) protect the scientific integrity of the samples.

Preliminary planning for Mars sample curation envisions a multiple barrier approach. In these plans the samples are packaged, stored, examined, subdivided, and prepared for distribution in positive-pressure nitrogen cabinets. Sample manipulation may be done by humans in full protective suits, or remotely using ultraclean robots. The cabinets are operated in a Class 10 cleanroom environment. The cleanroom, in turn, is contained within a lab that meets the definition of biosafety level 4. Depending on mission design, sample curation at sub-freezing temperatures may be required.

Near-Earth Asteroid Sample Curation: Samples from a near-Earth asteroid will be collected from a surface that is in total vacuum and subjected to wide temperature variations over the course of the asteroid's orbit. The rocks and soils are exposed to solar and galactic radiation fluxes, as well as to meteorite and micrometeorite fluxes, characteristic of the inner solar system.

The elemental and mineralogical compositions of the NEA samples may span a broader range than those of lunar rocks and soils. The asteroids chosen for sample return could be primitive, fully differentiated, or somewhere in between. The range of classes among main belt asteroids are represented in the NEA population.

Some NEAs and some meteorites show evidence of hydrated minerals, which are totally absent from lunar samples. Carbonaceous chondrites also contain simple, and in some cases complex, organic molecules.

The planetary protection implications for an asteroid sample return mission were recently reviewed by the Space Studies Board of the National Research Council [2]. Their recommended approach for handling returned asteroid samples includes the following:

- For C-type asteroids, undifferentiated metamorphosed asteroids, and differentiated asteroids -- no special containment and handling are warranted beyond what is needed for scientific purposes.
- For P-type and D-type asteroids -- strict containment and handling is currently warranted, based upon uncertainties in the characteristics of those asteroids.

The combination of extensive experience with a wide variety of extraterrestrial samples, specific characteristics of some asteroids, and planetary protection considerations leads to the following strategy for NEA sample curation:

- Include curation as an essential element from the start of mission planning
- Include planetary protection concerns, particularly those related to P-type and D-type asteroids, in the choice of mission targets
- Plan for a dedicated asteroid sample curation laboratory, with the following characteristics, which may be used for samples collected by MUSES-C, NEA Sample Return, or future main belt missions:

  - Clean room environment of class 1000 or better

  - Ambient temperature in the laboratory, with the capability for sub-freezing storage and processing

  - Processing cabinets with positive-pressure nitrogen atmospheres

  - Dedicated processing cabinets for each parent body

  - Combination of human and robotic processing

  - Continuous monitoring of inorganic, organic, and biological contamination

Reference: [1] National Research Council (NRC). 1997. Mars Sample Return: Issues and Recommendations. Washington, D.C.: National Academy Press. [2] National Research Council (NRC). 1998. Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies. Washington, D.C.: National Academy Press.