Curating NASA's Past, Present, and Future Astromaterial Sample Collections

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NASA's Astromaterials Acquisition and Curation Office

Astromaterials Research & Exploration Science Division

NASA – Johnson Space Center

Overview

- Give you a general overview of the efforts involved with NASA's astromaterials curation:
  - The Collections and the Clean Rooms…
- Other aspects of Curation
  - Clean room monitoring
  - Physical Security (incl. remote storage)
  - Physical Infrastructure
  - Data Management
  - Instrumentation
  - Shipping and receiving
  - Tours and EPO
  - Future Mission Planning and Technique Development

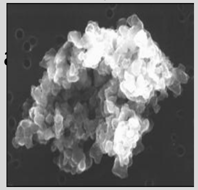
JSC's Astromaterials Acquisition & Curation Office

Our Past 50 years – planning for and curating multiple collections

Lunar
(1969)
Apollo program lunar rocks and soils; Luna samples

Meteorite
(1977)
Antarctic Search for Meteorites (ANSMET) program

Cosmic Dust
(1981)
Cosmic dust grains from Earth's stratosphere



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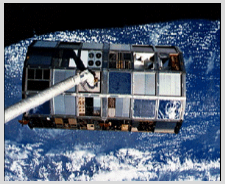
Space exposed hardware from spacecraft



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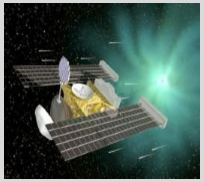
Cometary and interstellar samples from Comet Wild 2



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Samples collected from JAXA asteroid mission to Itokawa

Our Near Future . . .

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Subset of samples collected from JAXA asteroid mission to (162173) 1999

OSIRIS-REx
(2023)
Asteroid sample return from 101955 Bennu

OSIRIS-REx
ASTEROID SAMPLE RETURN MISSION

Authority from NPD 7100.10F + derivative NPR

Our More Distant Future . . .

Moon
(2020s)
Non-volatile-rich farside/polar sample return

Next New Frontiers Call

Comet
(2020s)
Cold curated (?) surface sample return from a comet

Next New Frontiers Call

Phobos
(2020s)
10% of a JAXA mission to bring back Phobos material

JAXA sample return mission

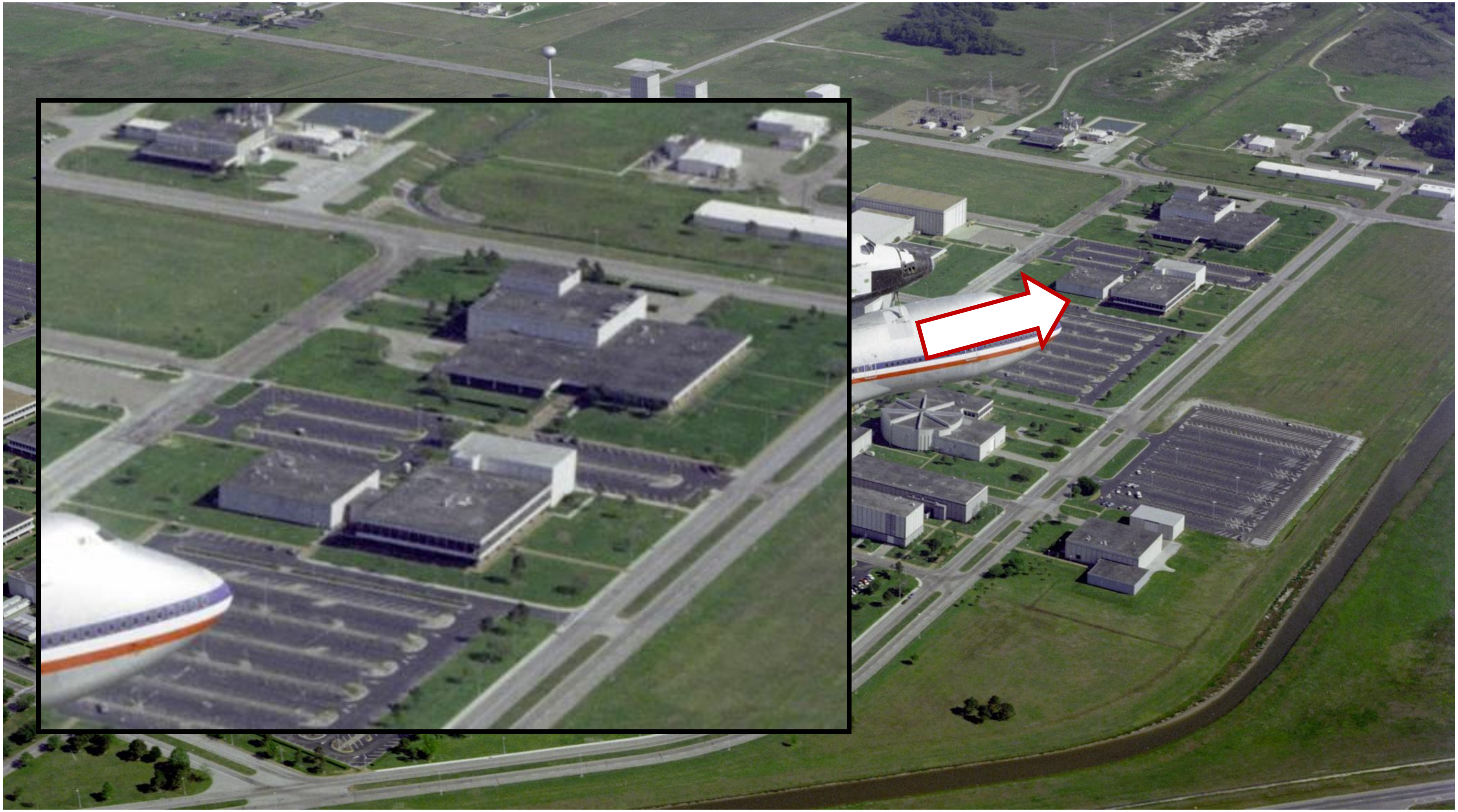
Mars
(~2030+)

Various Mars Sample Return

Over 50 years in the planning (est. 1964)

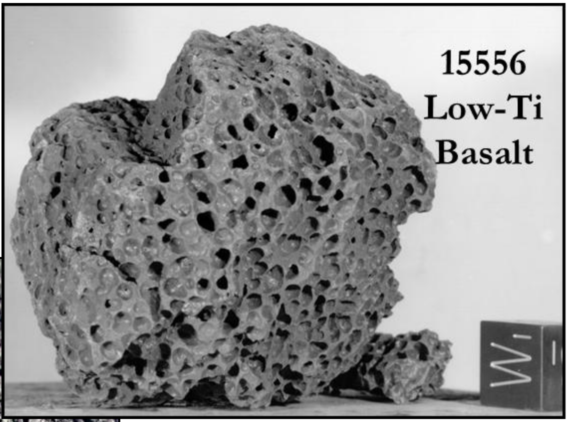
To Protect and Serve…

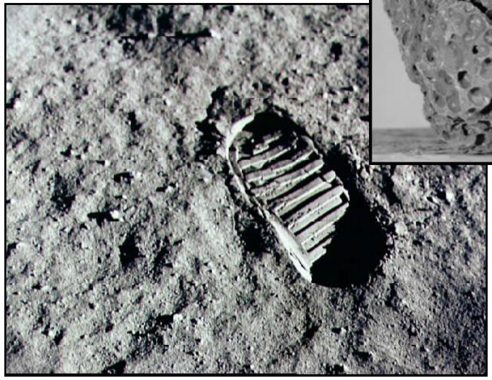
The JSC Astromaterials Facility

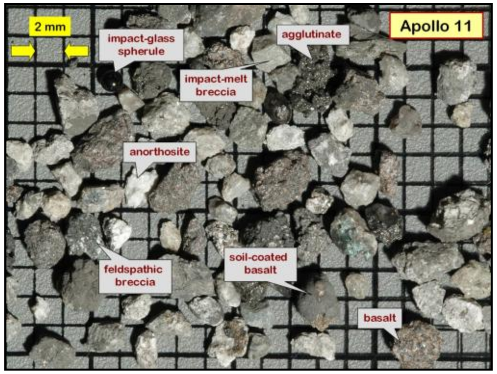


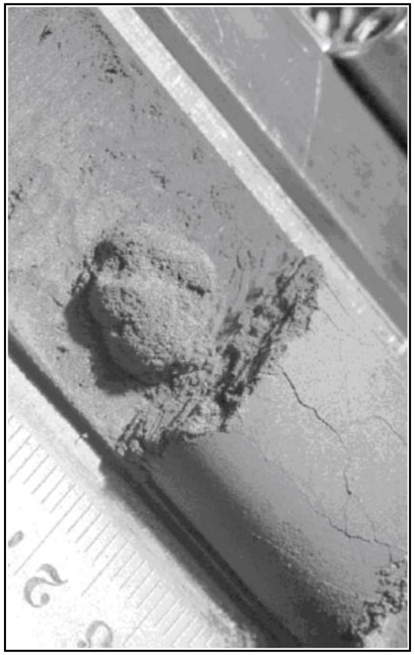
Apollo Sample Collection 1969-1972

- The Apollo missions collected 382 kg (2200 samples) of rock, soil, and cores from 6 geologically diverse locations on the Moon
- Only sample suite collected by astronauts, and the only suite collected with geologic context.
- Lunar lab complex is our largest suite of clean rooms and ancillary labs (ISO 6-7)
  - Clean room, storage and working areas designed to minimize contamination from the environment and other samples









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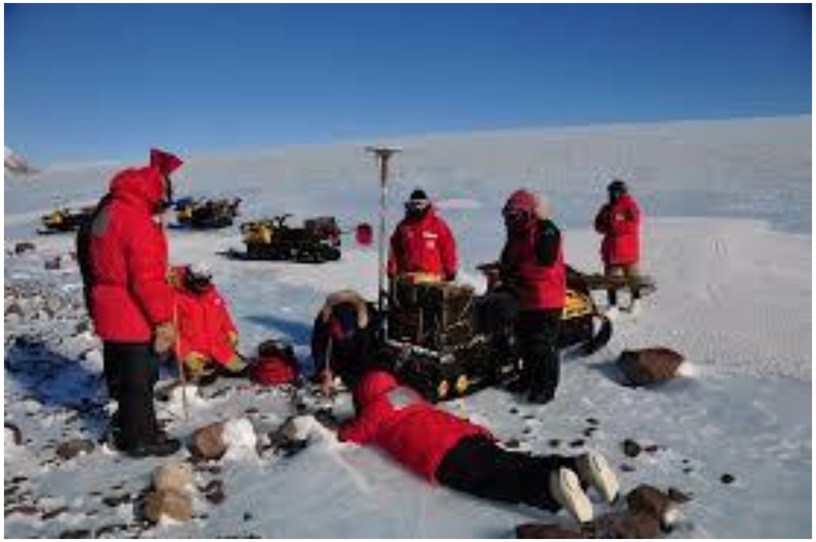
Antarctic Meteorite Collection 1977-Present

- For 40 years, teams of scientists have collected meteorites in the Trans-Antarctic Mountains
- Collection locations are blue ice fields where meteorites entrained in glaciers have been exposed by sublimation.
- Samples found by systematic searches of open ice fields and moraines.
- Meteorite lab complex is similar to the lunar labs (ISO 7), but only "special" meteorites are worked on in cabinets, others are processed in air.



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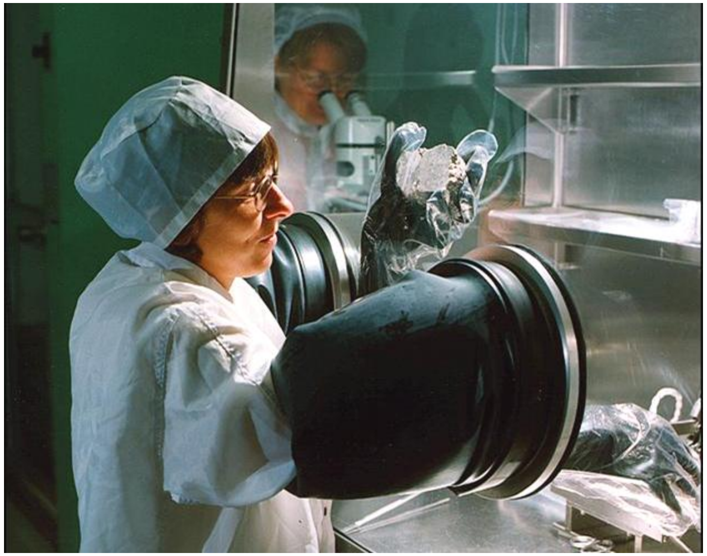

Cosmic Dust from the Stratosphere 1981-Present

- NASA collects atmospheric dust on collectors using high altitude reconnaissance aircraft.
- Most collections are with silicone oil collectors of random material
  - Dry collections attempts.
  - Target comet streams (Giabobini-Zinner).
  - Surface collection attempts
- Clean room (ISO 5) and specialized sample handling techniques allow isolation and preservation of micron scale samples from comets, asteroids, and interstellar dust.

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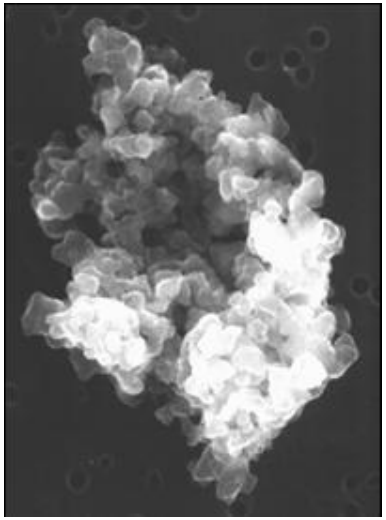
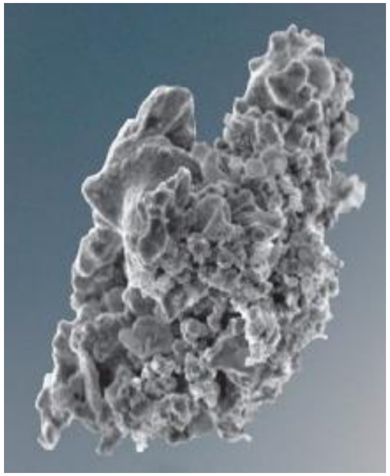
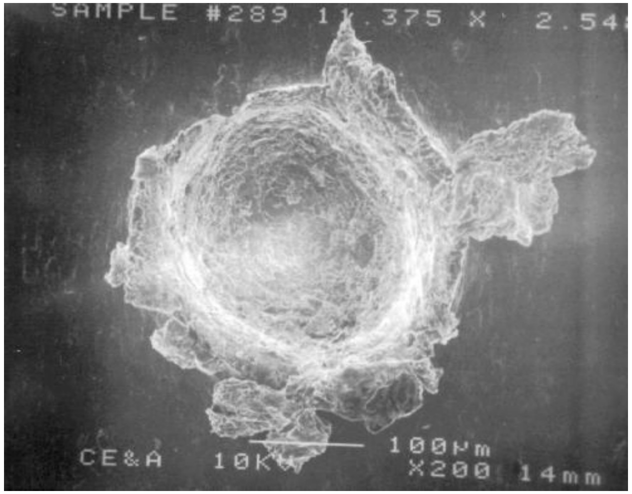




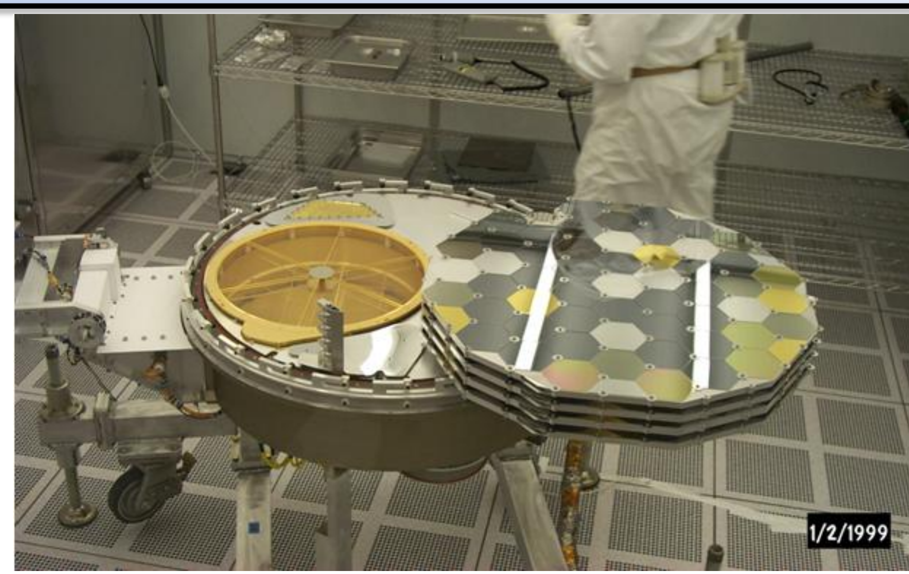
Microparticle Impact Collection 1985-present

- JSC curates a variety of spacecraft and spacecraft components.
  - Surveyor III; LDEF; Solar Maximum satellite; Genesis/Stardust; and European Recoverable Carrier.
- Give the opportunity to study variety of effects: "**micro-meteoroid" impacts**, UV exposure, atmospheric oxygen erosion, radiation effects, etc.
- This lab also houses the coupons and witness materials for OSIRIS-REx



Genesis Solar Wind Samples 2004

- NASA mission that collected solar wind at Earth-Sun L1 location for 28 months.
  - Multiple detector arrays to sample different solar wind regimes
- Had an "off nominal" landing
  - Highlighted the importance of planning for worst case scenarios.
- Assembled and curated in JSC curation's best clean room (ISO 4), a vertical laminar flow modular cleanroom (a retrofit lunar lab).
  - Cleaning techniques developed
- Ultimately most of the science results were achieved



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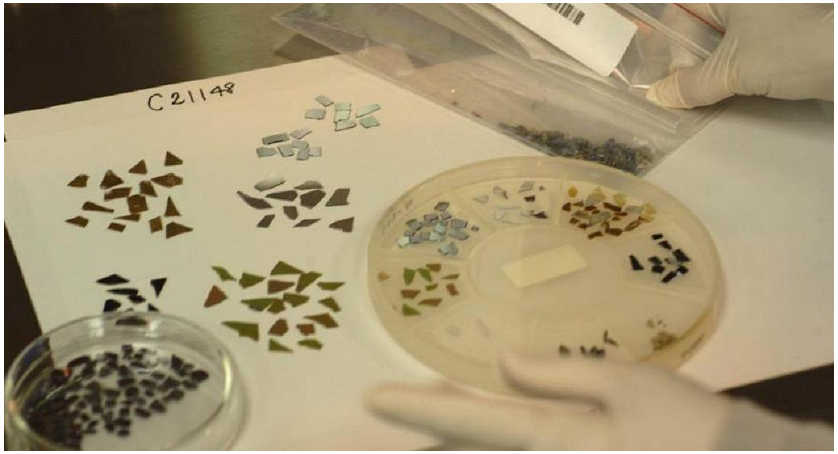

Stardust Comet + Interstellar Grains 2006

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  - Estimated that many 1000s of comet particles were collected; 100s of interstellar particles
- Particles were captured by impacts into aerogel.
- Stored in a dedicated ISO class 5 clean room.
- New sample handling techniques developed to extract the tracks.

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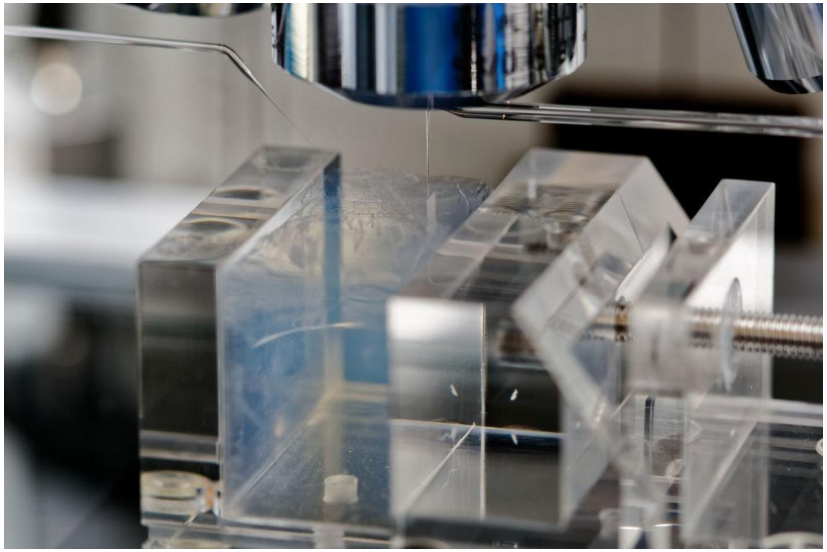
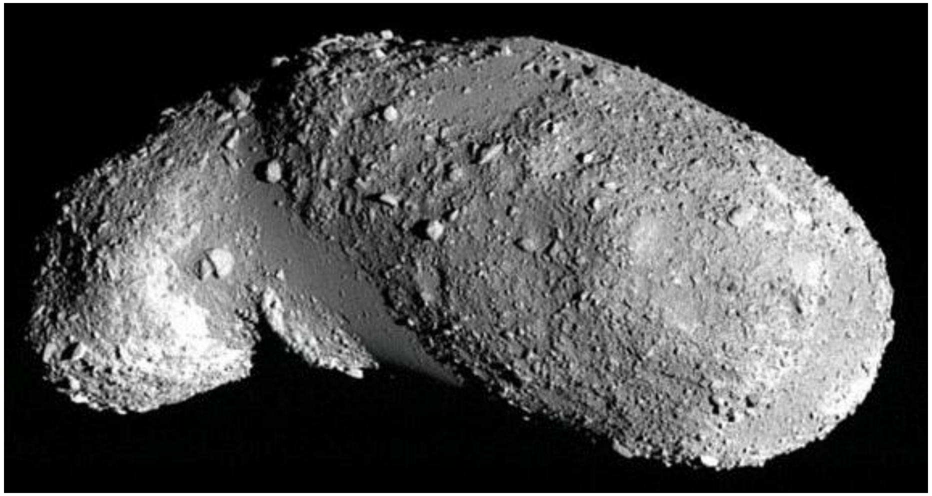
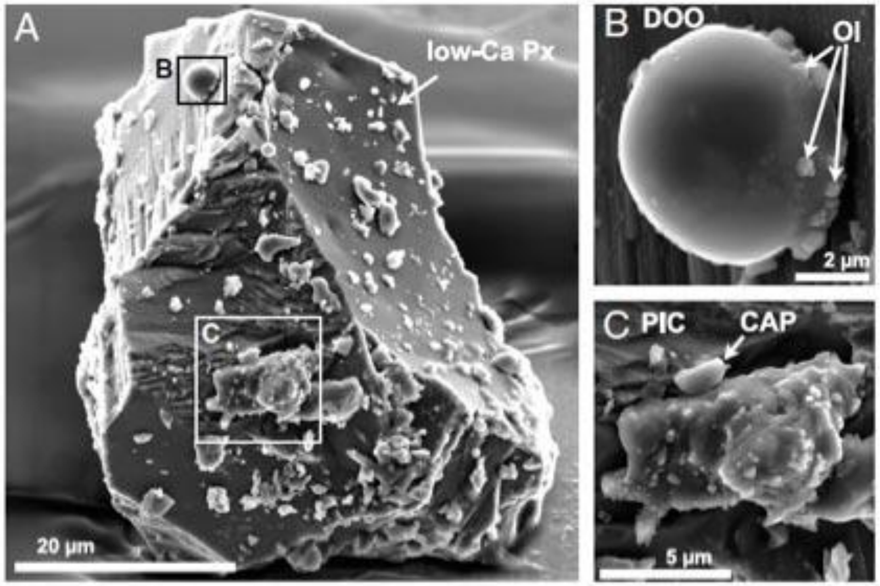


Hayabusa Asteroid Samples 2012

- JAXA mission to study Itokawa, an S-type asteroid (535 meters long).
- Part of the mission Involved surface sample collection of small particles by firing a projectile at the surface and flying through the debris.
  - Collection mechanism didn't quite work as intended, but thousands of particles returned in the 10-100 micron size range.
- First samples returned from an asteroid and first samples returned from an airless body not named "The Moon"

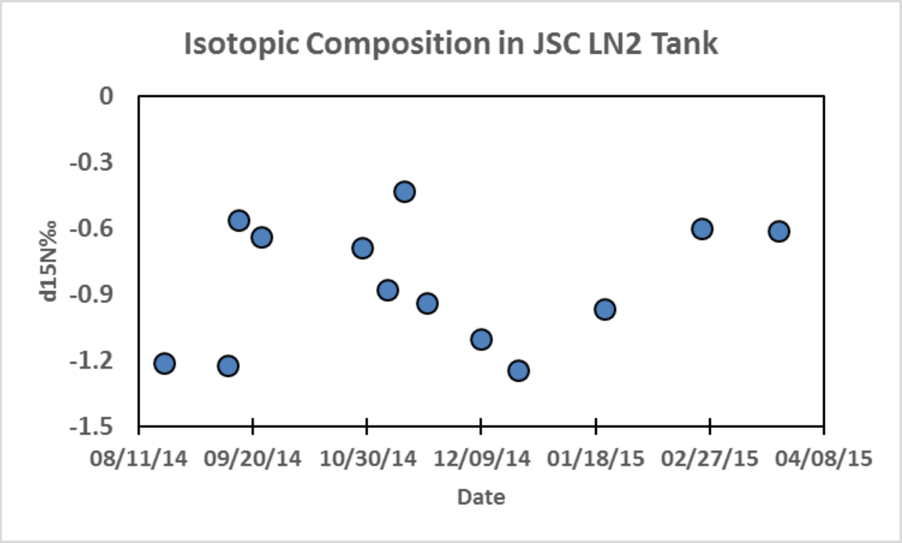




Quick Capabilities Summary

- Variety of different clean rooms (ISO 4-7), different sample storage and working conditions
  - Ultimately, the sample needs drive the lab capabilities, but cost, space, and time plays a factor
  - Colocation allows shared infrastructure and personnel
- Huge variety of sample types:
  - Large rocks, small rocks, bulk regolith, core samples, individual μm-particles, embedded μm-particles, solar wind atoms, and spacecraft parts.
- Requires a huge diversity of sample handling capabilities:
  - Processing in cabinets, processing on flow benches, band saws, wire saws, thin sections, micro-manipulation, microtome, FIB sectioning, keystoning (aerogel), etc.

Monitoring Laboratory Cleanliness



- Daily monitoring of the UPW sys.
- Weekly particle counts in labs.
- The composition of each delivery of N_2 is measured.
  - Delivery is refused if outside of spec.
- The $O_2 + H_2O$ in the lunar cabinets is measured 4x hour
  - Cycles through all cabinets.
- The isotopic composition of the N_2 gas is measured monthly.
- Periodically we analyze the composition of particles when the cabinets are cleaned.
- Periodically we measure the total organic hydrocarbons in the labs.

Monitoring Laboratory Cleanliness

Lunar Glovebox SEM Particle Cleaning Anaylsis - Fine Filter				
Possible Identified Material Groups	Particle Count	Particle %	Size Range (µm)	Average Size (µm)
Aluminum	1	1.12%	25	25
Aluminum Oxide	1	1.12%	12	12
Iron Oxide	1	1.12%	5	5
Stainless Steel	23	25.84%	2 to 10	5
Lunar Geologic Material	24	26.97%	2 to 15	6
Lunar Geologic Ilmenite	7	7.87%	3 to 8	8
Organic Compound	27	30.34%	2 to 100	16
Hydrocarbon	1	1.12%	10	10
Silicone	4	4.49%	4 to 8	6

Lunar Curation Glovebox			
Hydrocarbons	Control Wafer (ng/cm²)	Vertical Exposure (ng/cm²)	Surface Exposure (ng/cm²)
Low boilers C7-C10	*	*	0.2
Medium boilers >C10-C20	*	1.8	2.5
High boilers >C20	*	0.1	0.2
Sum >= C7	*	1.9	2.9
Identified Compounds			
Diethylformamide	*	*	*
Diethylacetamide	*	*	*
Alkyl amine	*	*	*
2-Butoxyethyl acetate	*	*	*
Octafluoropentanal(m/z:51,69,100,131,151,181,200,231,281)	*	*	*
2-Cyclohexen-1-one, 3,5,5-trimethyl-	*	0.3	0.3
Dibutylformamide	*	0.2	0.2
Cyclo(Me2SiO)6	*	0.2	0.2
2,6-di-tert-Butylquinone	*	*	*
Cyclo(Me2SiO)7	*	*	*
Cyclo(Me2SiO)8	*	*	0.1
Cyclo(Me2SiO)9	*	0.2	0.3
Dibutyl phthalate	*	*	0.1
Cyclo(Me2SiO)10	*	0.1	0.2
Siloxane	*	0.1	0.1
* Recording Limit = < 0.1 ng/cm²			

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Physical Security of the Samples

- Building is designed to protect the samples from natural disasters; also from unnatural disasters

Physical Security of the Samples

Remote Storage Facility

- Store a subset of the collection at a remote location
- Static nitrogen storage
- Requires bi-annual maintenance visits.

Physical Infrastructure

- The clean rooms themselves are just a part of the picture, numerous infrastructure systems must be maintained
- Stable power supply
  - Emergency backup
- HEPA-filtered HVAC air for the labs
  - We have >10 units
- Liquid/gaseous N_2 system
- Ultrapure water system
  - Important to integrate these

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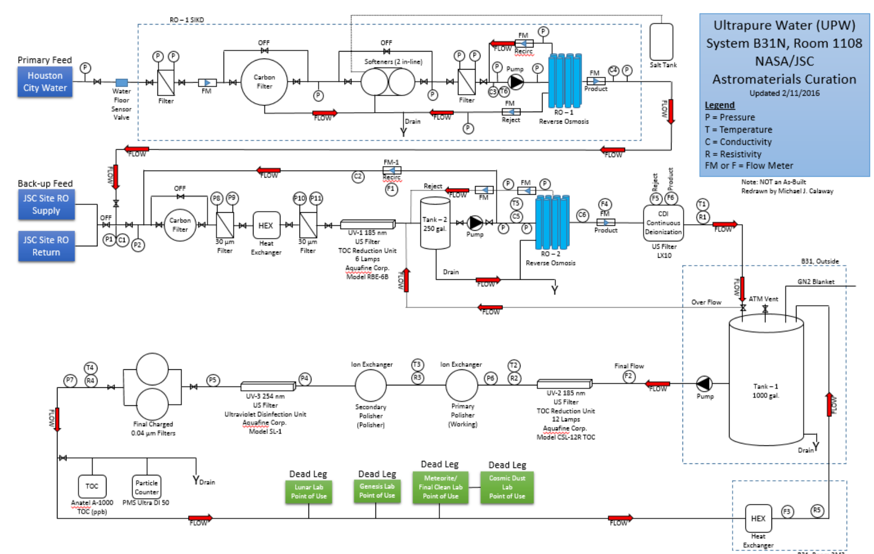
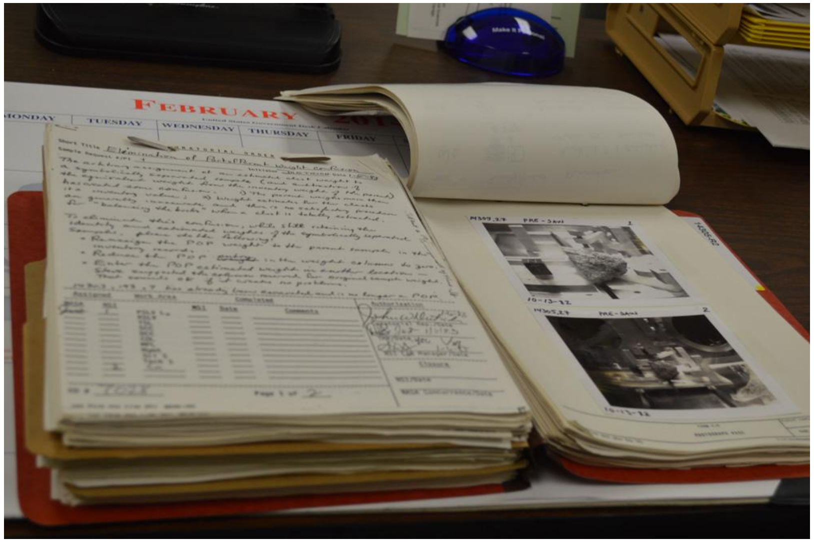
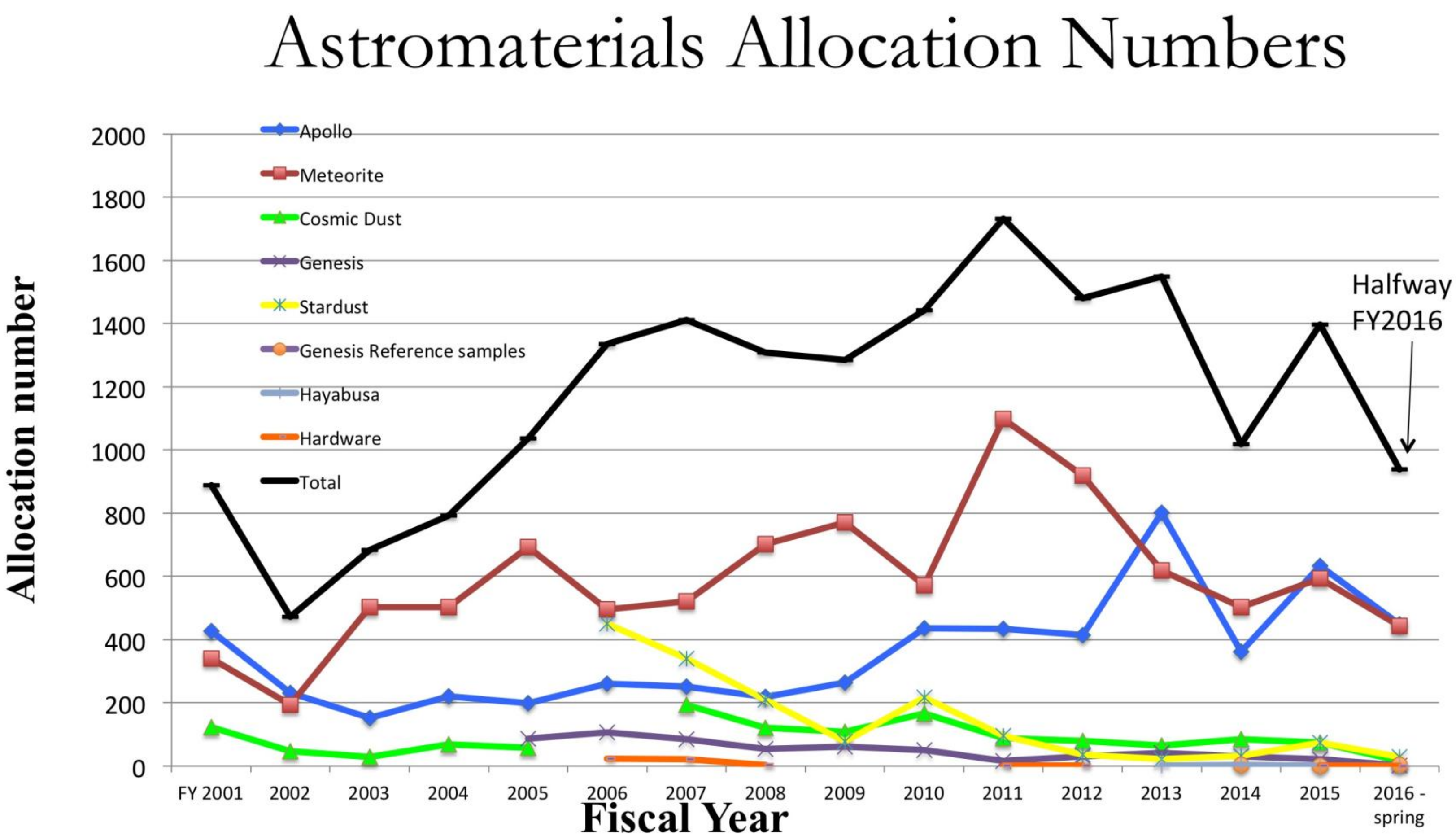


Data Management



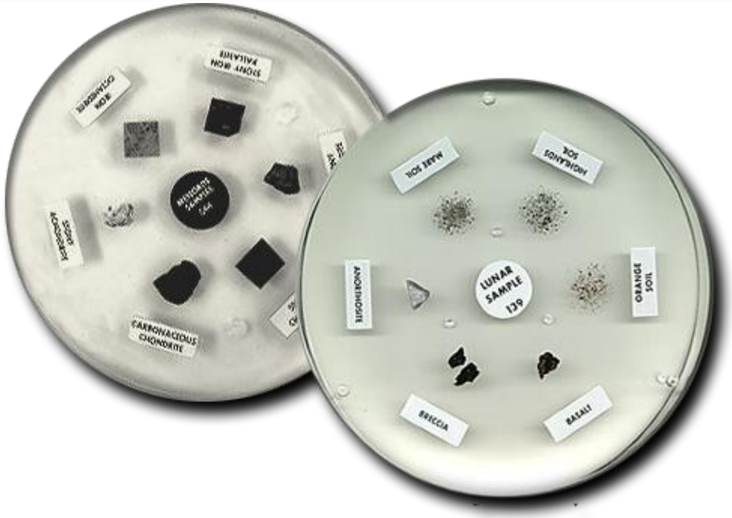
- Need a database to track your samples – we track >250k over the different collections.
  - Need to be able to create relationships among samples, change weights, etc.
  - Different collections have diff. needs
  - Level of accountability is key
- Other data important to the samples needs to be archived
  - >100k sample images
  - > 125 meters of shelving w/ processing notes
  - ~50,000 return sample histories
  - Countless information about geologic context, spacecraft data, or catalogs need to be included.
- Need an external website to advertise your wares.
- Data issues are going to get worse!

Shipping and Receiving



EPO and Tours

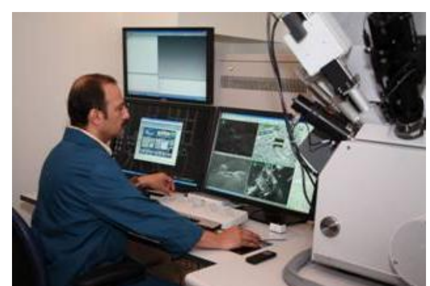
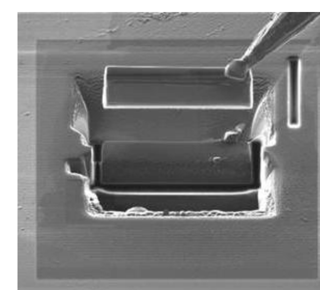
- We ship out about 600 lunar and meteorite education packages a year
  - Reaches >50,000 students
- We also support numerous other EPO and PAOevents
- 80 long term lunar displays
- In the past year, we did nearly 200 tours for nearly 1,000 people (just for lunar).
  - There will be tours that you just can’t say no to.
  - Important for funding.



Analytical Capabilites

- There are several different categories here:
- In lab curation techniques – optical microscopy, FTIR
- In Curation techniques (separate labs, but curation controlled) – Raman, XCT, XRF (future)
- We are collocated with the JSC astromaterials research group, giving us access to advanced instrumentation
  - SEM, EPMA, SIMS, TEM, TIMS, ICPMS, FIB, FTIR, XRD
  - Used in both sample characterization and contamination knowledge/control



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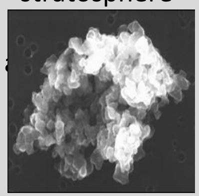

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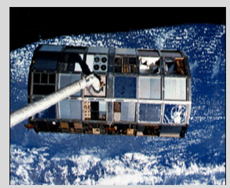

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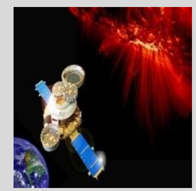

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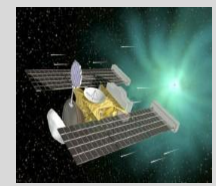

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Non-volatile-rich farside/polar sample return

Next New Frontiers Call

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Cold curated (?) surface sample return from a comet

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10% of a JAXA mission to bring back Phobos material

JAXA sample return mission

Mars
(~2030+)

Various Mars Sample Return

Over 50 years in the planning (est. 1964)

To Protect and Serve…

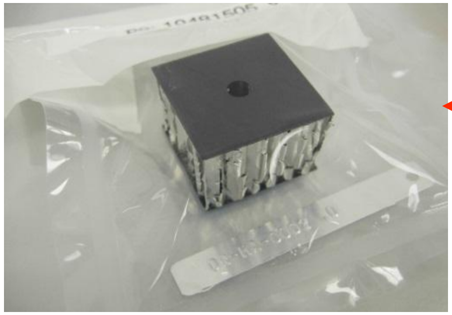
Curation of Future Sample Missions

- The curation of samples should not begin when they arrive at JSC (though this is important).
- The curation of samples should not begin when they arrive on Earth (though this is important).
- The curation of samples should not begin while you are building the spacecraft (though this is important).
- The curation of samples should begin with the initial planning and design of the mission, and be carried through every aspect of the mission.
  - This is the only way to ensure that you maximize the science return of your samples, particularly if something unexpected happens

OSIRIS REx

- Materials Coupons – Examples of materials used in the spacecraft that are possible sources of contamination.
  - Several hundred materials in total.
  - Some analyzed now, most archived for posterity in a dedicated cabinet in an ISO 7 cleanroom.
- Witness Plates – High purity materials continuously exposed during spacecraft ATLO
  - Ultrapure Al-foil and Si-wafers are exposed during spacecraft assembly.
  - They are analyzed by SEM each month (while others are archived) for near real-time feedback on the contamination environment that the spacecraft is exposed to.

OSIRIS-REx coupon storage cabinet at JSC



Solar array panel assembly + Honeycomb composite

Perfluorinated polyether Braycote 601

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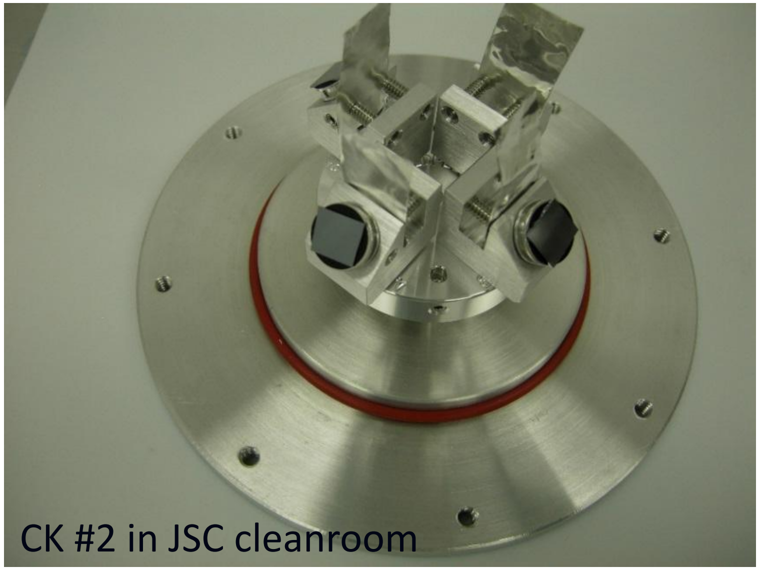

CK #2 in JSC cleanroom

OR-CKP-01-2-Si, -3-Si, and -4-Si (archived)

Advanced Curation Efforts

- Always thinking ahead and planning for the next few missions.
- Active areas of curation research:
  1. Precision Organic Contamination Control
  2. Cold Curation
  3. Next Generation Sample Handling
  4. Precision Inorganic Contamination Control
  5. Robotics and Next Generation Processing Techniques
- By the time a mission is ready to fly us likely too late to begin the learning curve for curating the samples.

Summary

- Much more to the curation of astromaterials than simply building clean rooms.
- People are as important as the facilities:
  - Curators – one per collection
  - Processors and Technical staff
- Colocation with analytical facilities will greatly enhance curation capabilities
- Everything Takes longer (balances)
- Careful forethought is a key for future flexibility