Asteroid-meteorite connections: New Asteroid Curation Facilities and US Antarctic meteorite collection at JSC

Kevin Righter
NASA Johnson Space Center

SBAG, January 30, 2019, Houston, TX
Astromaterials Curation at NASA JSC

1969
6 Apollo Mission Lunar Rocks

1978
US Antarctic Meteorites

1981
Stratospheric Cosmic Dust

2004
GENESIS

2006
STARDUST

2011
HAYABUSA 1

2021
Hayabusa2

2023
OSIRIS-REx

Various sites on Moon
Asteroids/Moon/Mars
Comets/Asteroids
Solar wind @ L1 point
Comet Wild2
Asteroid Itokawa
Ryugu
Bennu

Hayabusa2 entry
microtomy
anterooms
OSIRIS-REx entry
Hayabusa 2

2021
Curation at NASA JSC

2023
### OSIRIS-REx Mission Operations Timeline

<table>
<thead>
<tr>
<th>LAUNCH</th>
<th>OUTBOUND CRUISE</th>
<th>EARTH GRAVITY ASSIST</th>
<th>APPROACH MANEUVER</th>
<th>NOMINAL SAMPLE COLLECTION</th>
<th>DEPARTURE MANEUVER</th>
<th>RETURN CRUISE</th>
<th>SAMPLE ANALYSIS</th>
<th>SAMPLE RETURN</th>
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</table>

- **Launch**
- **Outbound Cruise**
- **Earth Gravity Assist**
- **Approach Maneuver**
- **Nominal Sample Collection**
- **Departure Maneuver**
- **Return Cruise**
- **Sample Analysis**
- **Sample Return**

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**Earth Trojan Asteroid Search**
- **Launch**: Sept. 8, 2016
- **Earth Gravity Assist**: Sept. 20, 2017
- **Rendezvous**: June 2019
- **Earth**: Aug. 13, 2018

**OSIRIS-REx**
- **DSM-1**: Dec. 30, 2018
- **DSM-2**: June 19, 2018
- **Bennu**:
JSC Curation Role in OSIRIS-REx

1) Archiving for contamination control and knowledge

2) Establish new cleanroom (ISO5 / Class 100)

3) Sample Recovery

4) Preliminary Examination & 2 yrs Curation
Materials archive and witness plates for contamination knowledge

Rm 202 – SRC and TAGSAM

Thermal Vacuum Chamber

Shipping Container – Denver to KSC

PHSF to VIF (Lufkin)

VIF to launch pad (Pvan)

Space Science Bldng Hi-Bay

Reverberant Acoustic Lab

PHSF (Payload Hazardous Servicing Facility)
Materials archive - >400 items
Materials either in direct contact with sample, or line of sight

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<th>Lubricant</th>
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<th>Paint</th>
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Witness plates from cleanrooms
64 Al foils / 64 Si wafers

- Prepared at JSC /
- Hand carried to Denver or KSC
- Deployed for one month
- Hand carried to JSC

One of each immediately analyzed and the rest archived.

OMAC2

Materials now in Returned Sample Vault (RSV) in six dedicated desiccator GN2 cabinets
- Described in more detail in Dworkin et al. (2018) Space Science Reviews paper
Asteroid curation facility

- ISO 5 cleanrooms
- NASA and JAXA have agreed to exchange samples from OSIRIS-REx and Hayabusa2 missions: new Hayabusa 2 cleanroom will be adjacent to OSIRIS-REx
- Design phase completed in 2018
- Construction begins in Feb. 2019 – timing coordinated with return of Hayabusa2 / Ryugu so that cleanroom is complete and certified before samples arrive 2021
- OSIRIS-REx labs completed >1 year before samples are returned to allow for outfitting, rehearsals, monitoring, etc.
- Below the new cleanroom on 1st floor will be new advanced curation and cleaning labs supporting all collections
Curation facility - outfitting

Storage and handling

- TAGSAM de-integration and dis-assembly
- Bulk sample processing and storage
- Contact pad processing and storage
- Witness plate storage
- Return sample storage

Characterization

- Optical microscopy
- UV fluorescence
- FTIR and SEM (outside of cleanroom)
Materials curated at JSC

Bulk sample: From TAGSAM head
Contact pads: 24 pads on bottom of TAGSAM head
Witness plates: From inside canister and on TAGSAM head
Hardware: trapped gas or adhered dust
**Bulk sample**

**TAGSAM bulk sample collection**

- arm extends 2.8 meters from the spacecraft.
- releases jet of high-purity N2 gas that excites and “fluidizes” at least 60 g of regolith into the collection chamber.
- ground and “reduced-gravity” flight tests, using asteroid surface simulants, have routinely demonstrated collection of hundreds of g.
Contact Pad samples

Contact Pads
- Collect top layer of surface material
- Will be useful for space weathering, exposure, and regolith studies

2017-18 testing – Christopher Snead @ JSC
Witness Plates

TAGSAM and SRC Flight Witness Plates
Collect contamination knowledge of TAGSAM and SRC environment during flight operations.

Witness locations by exposure timeline
a) Launch to Pre-sample collection
b) Post-Sample collection to earth return
c) Whole mission (screen coverage on ½ of the locations)

Material and Finish
Pure Aluminum - Exposed side roughened to matte finish
Monocrystalline Sapphire - Exposed side roughened to matte finish
Prevent gas phase and particulate contaminants from entering the sample canister when it is closed, during atmospheric reentry and recovery, and during launch.

Capture asteroidal volatiles and dust particles trapped in canister - after reentry and recovery of the capsule and extraction of the sample canister at UTTR, an N2 gas purge of the canister will be started through the canister septum. The resulting flow of air will exit through the canister air filter and this will encourage any volatiles located in the canister into the filter.

Thus, if the TAGSAM contains volatiles that can outgas from the collected samples and cold trap within the canister, it is in the air filter where there is the best chance of detecting them.
Preliminary testing of techniques
Contact pad grain handling

Basalt simulant results

The basalt captured by the contact pad simulant appeared more dominated by larger (>100 µm) particles. This may be due to a lack of fine particles in the simulant, or it may be due to a reduced organic component to the dust.

Small particle handling with micromanipulators

Courtesy of C. Snead, Jacobs, NASA-JSC, Advanced Curation
Preliminary examination - Phase E rehearsals

- Goals of Phase E curation rehearsals
  - Use real hardware, tools, environment
  - End-to-end curation operational simulations
In the 41 US expeditions since 1977, **22,835** meteorites have been collected.

As of Oct. 2018, **21,384** of these meteorites have been classified and are available to researchers worldwide.

The ANSMET collection is the largest research collection of meteorites in the world, **2×** larger than any other, measured by the number of classified, available specimens.
1995
29 DCA

1993-1994 field team

2018-19 field team

12.22.2018 18:15

2019
52 DCA

865 new meteorites
Chondrites (n=19652)

- ungrouped
- R
- enstatite
- carbonaceous
- H
- L
- LL

Achondrites (n=701)

- angrites
- acapulcoites
- acap/lodr
- aubrites
- brachinites
- diogenites
- eucrites
- howardites
- lodranites
- mesosiderites
- irons
- pallasites
- ureilites
- winonaites
- lunar
- martian
- ungrouped

US Antarctic chondrites: helped establish CK, CH, CB, CR, EL3 + EH3, and R groups
US Antarctic meteorites integral to systematic studies of spectral features and aqueous alteration.

Reflectance IR: Takir et al. (2013)

XRD: Howard et al. (2015)

Reflectance: Garenne et al. (2015)

Transmission IR: Beck et al. (2014)
Bennu and Ryugu spectral matches to carbonaceous chondrites

Bennu:
Hydrated – similar to CI, CM 2.0-2.2

Garenne et al. (2016)
Bennu analogues - CM 1 to CM 2.2:

- LAP 02277
- ALH 83100
- LEW 90500
- ALH 85013
- MET 00639

Rubin et al. 2007
Howard et al. 2015
Bennu and Ryugu spectral matches to carbonaceous chondrites

Ryugu:
Weak hydration – similar to heated CM?

Garenne et al. (2016) show Links between 2.7 micron band depth and H and C contents and reflectance.
Ryugu analogues – anomalous CM:

**WIS 91600**
- 14% Oliv; 78% Phyllo; px, mgt, sulf
- Mostly oliv and phyllo; px, mgt, sulf
- Howard et al. 2015

**PCA 02010**

**PCA 91008**
- Mostly oliv and phyllo; px, mgt, sulf
- Tonui et al. 2014
New curation facilities being developed that will be dedicated to asteroid samples from carbonaceous asteroids

- Ryugu (Hayabusa2) – 2021
- Bennu (OSIRIS-REx) - 2023

Dust and meteorite collections linking samples and remote sensing / observations

- Moon (Apollo, Prospector, Kaguya, Luna, SMART-1, Chang’e’, Chandrayaan)
- Mars (Viking, MO, MGS, Pathfinder, MER, MRO, Phoenix)
- Asteroids (Dawn, Hayabusa, Rosetta fly-bys)
- Comets (Stardust, Rosetta)
- Sun (Genesis)
- Current missions OSIRIS-REx, Hayabusa 2 – looking forward to making links between collection and asteroids