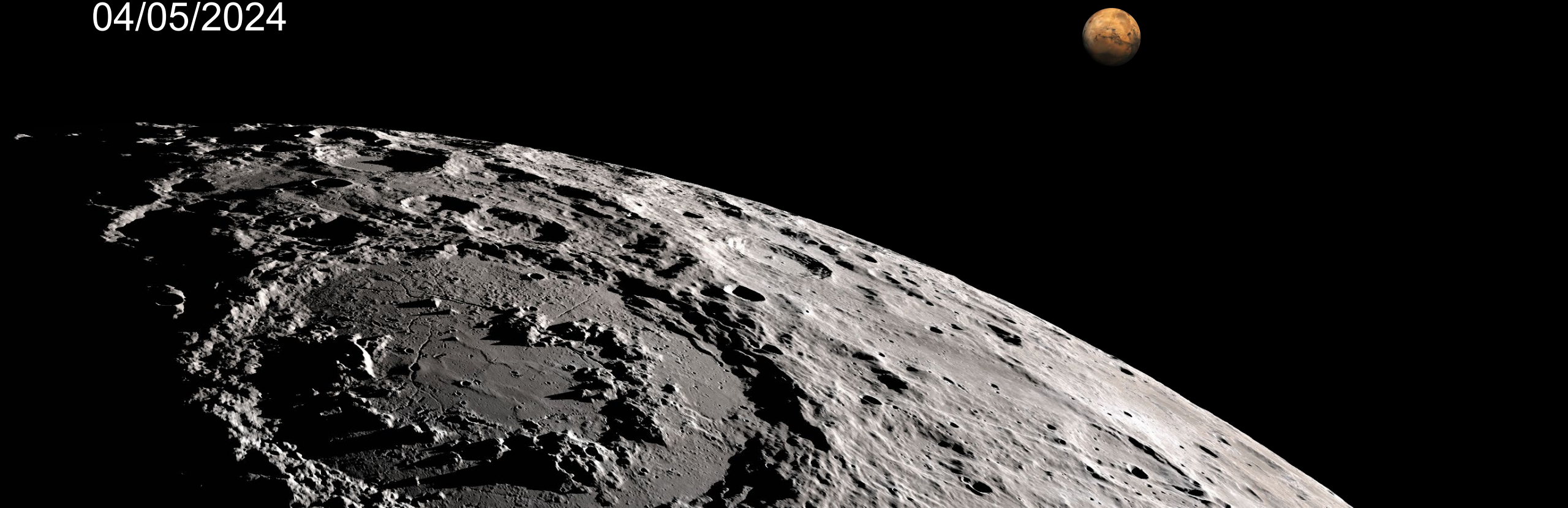
OSIRIS-REx: Curating Samples from the Carbon rich Asteroid Bennu

Aaron B. Regberg PhD.

04/05/2024

National Aeronautics and Space Administration



OUTLINE



- Introduction to ARES and Astromaterials Curation
- OSIRIS REx mission overview
- How the samples were collected
- Recovery Operations
- Curation Conditions
- What we've learned about Bennu… so far

Astromaterials Research and Exploration Science Division



- Scientists and engineers responsible for:
  - Collecting and Curating extraterrestrial samples
  - Studying extraterrestrial samples to understand the origins of earth and the solar system
  - Monitoring orbital debris and protecting spacecraft from hypervelocity impact
  - Remote sensing from The International Space Station and image analysis.

The Astromaterials Acquisition and Curation Office

Our Past 50 years – planning for and curating multiple collections

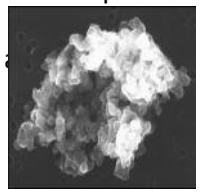
Lunar
(1969)
Apollo program lunar rocks and soils; Luna samples



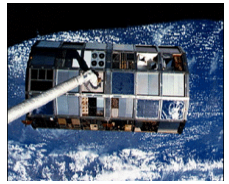
Meteorite
(1977)
Antarctic Search for Meteorites (ANSMET) program



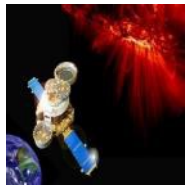
Cosmic Dust
(1981)
Cosmic dust grains from Earth's stratosphere



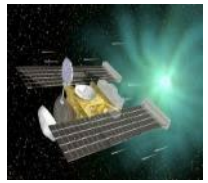
Micro-particle
(1985)
Space exposed hardware from spacecraft



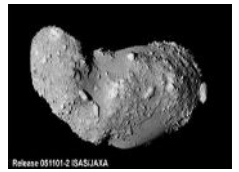
Genesis
(2004)
Genesis solar wind samples at Earth-Sun L1 point



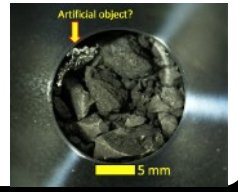
Stardust
(2006)
Cometary and interstellar samples from Comet Wild 2



Hayabusa
(2012)
Samples collected from JAXA asteroid mission to Itokawa



Hayabusa II
(2020)
Subset of samples collected from JAXA asteroid mission to 162173 Ryugu



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



Our Near Future . . .

Artemis
(2025)
Lunar South Pole. Cold Sample return?

ARTEMIS

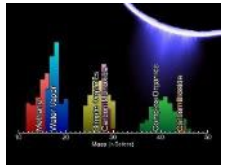
Our More Distant Future . . .

Mars
(~2030s)



(est. 1964)

Comet
Enceladus
Europa
Ceres

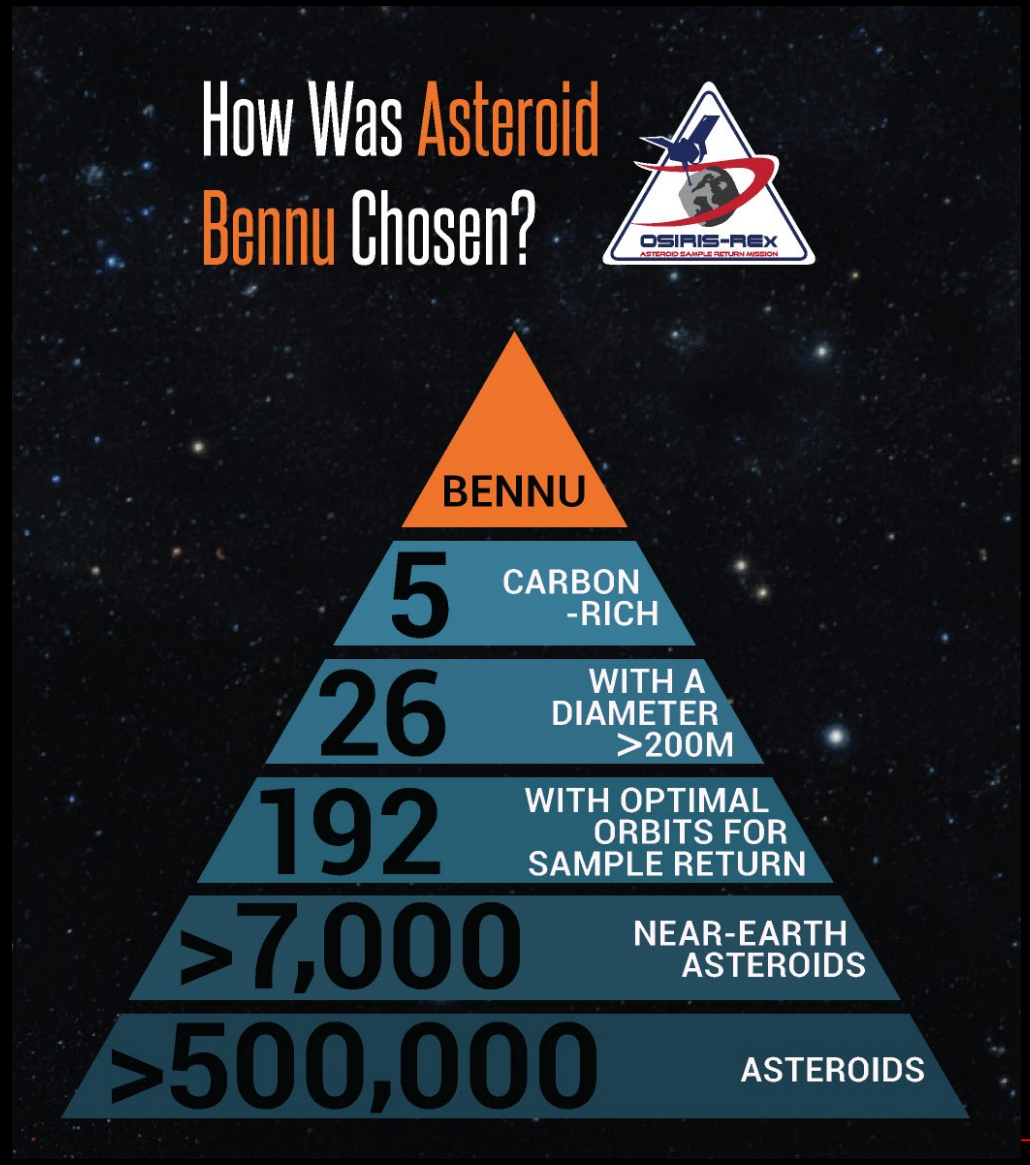


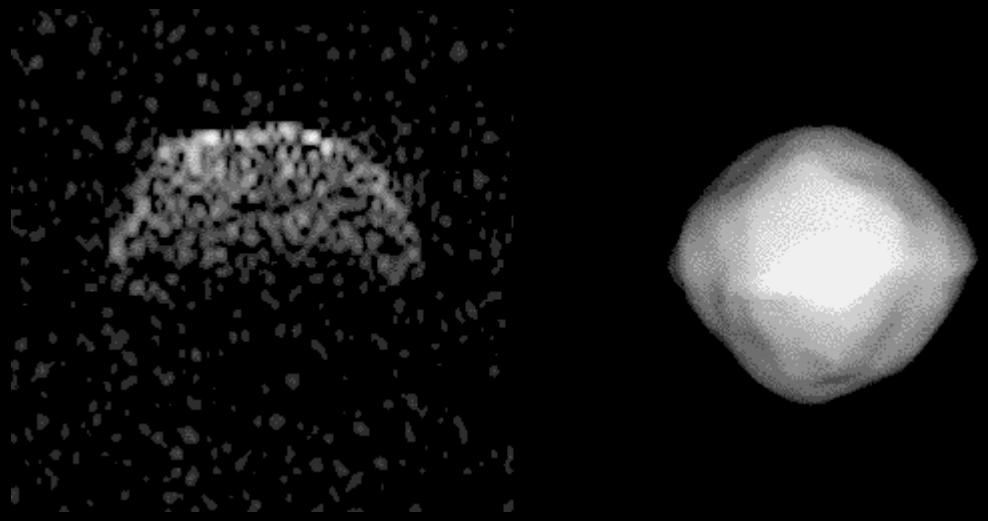
OSIRIS-REx (Origins Spectral Interpretation Research Identification and Security Regolith Explorer)



- New Frontiers Mission
  - Medium sized, competed, PI lead planetary science mission
  - Dante Lauretta is the PI (University of Arizona)
  - Medium Sized ~ $1 Billion USD
  - Launched in 2016
  - Returned Sept. 2023

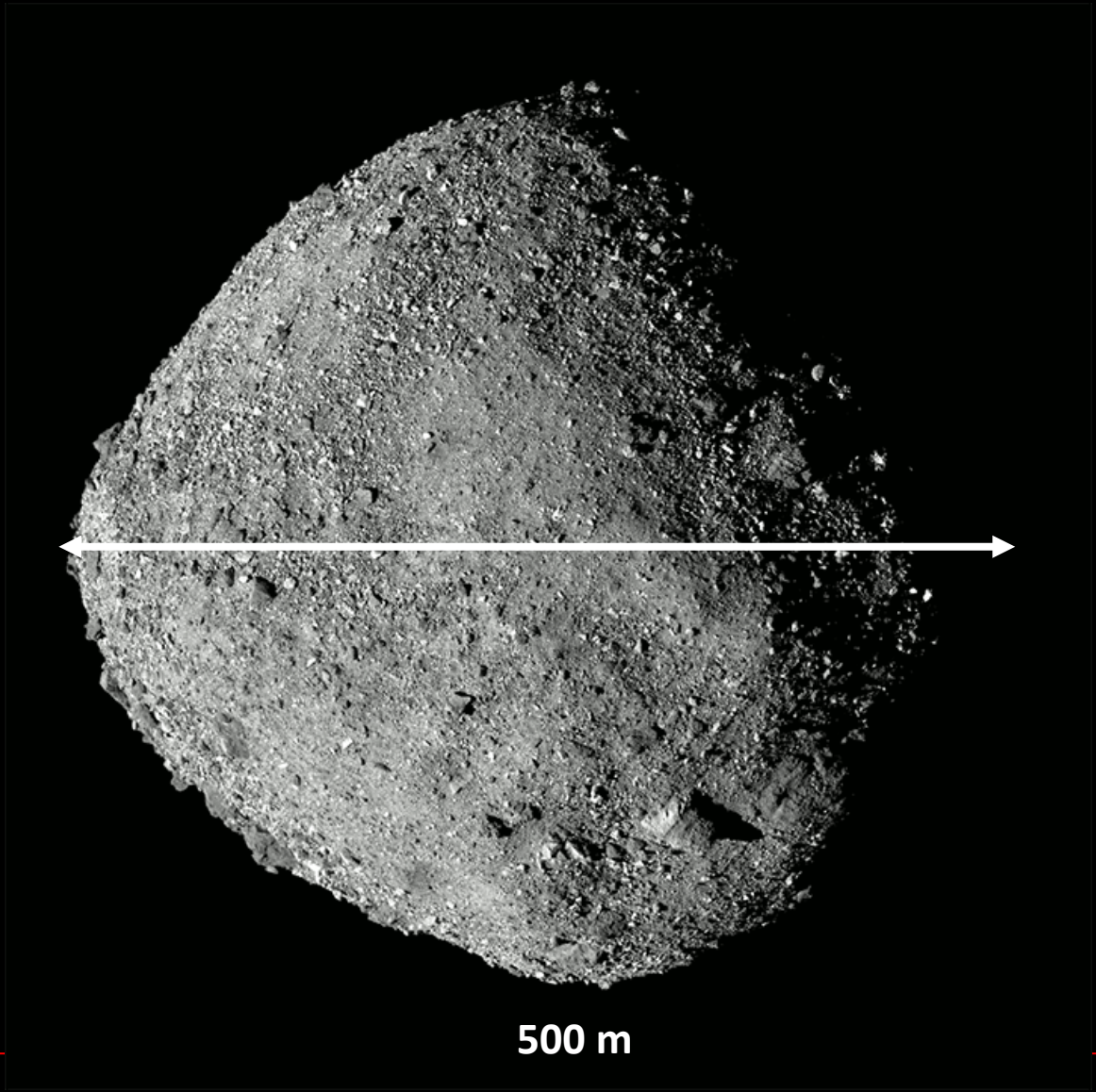
Choosing Bennu





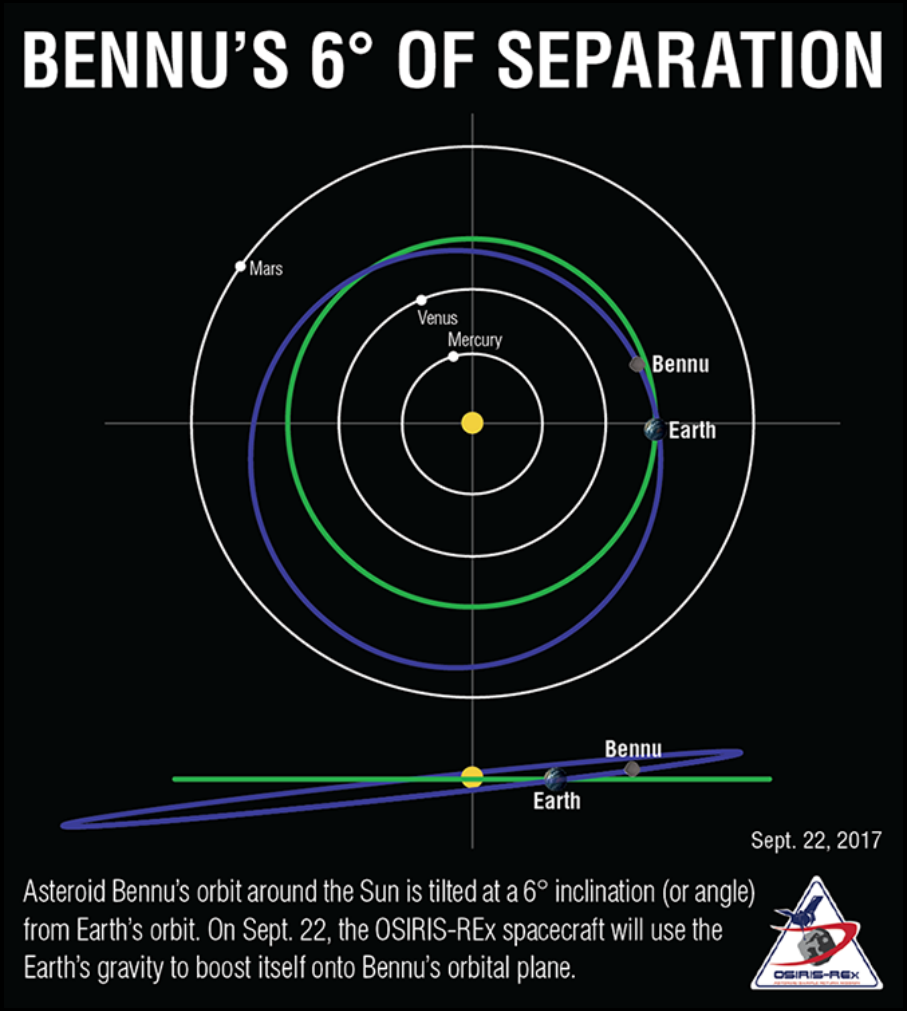
Michael C. Nolan / Arecibo Observatory / CC BY-NC-ND 3.0

The asteroid: Bennu



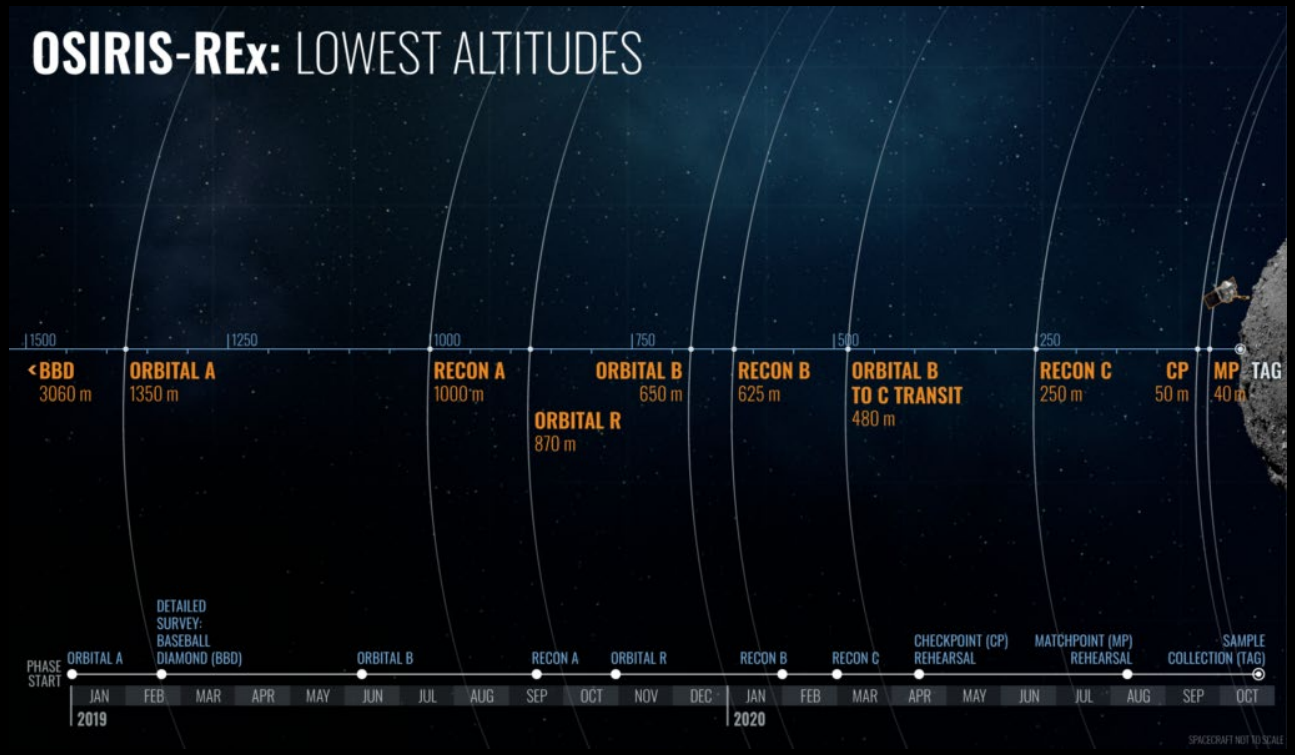
- Near Earth Asteroid
  - Rotation period 4.3 hours
  - Orbital period 1.2 years
  - Earth approach every 6 years
- Low Albedo B type asteroid
  - Dark and spectrally Blue
  - Carbon Rich
  - Rubble Pile
- Thought to represent primitive material from the early solar system
- Similar asteroids may have delivered most or all of the organic carbon to Earth

Mission Objectives



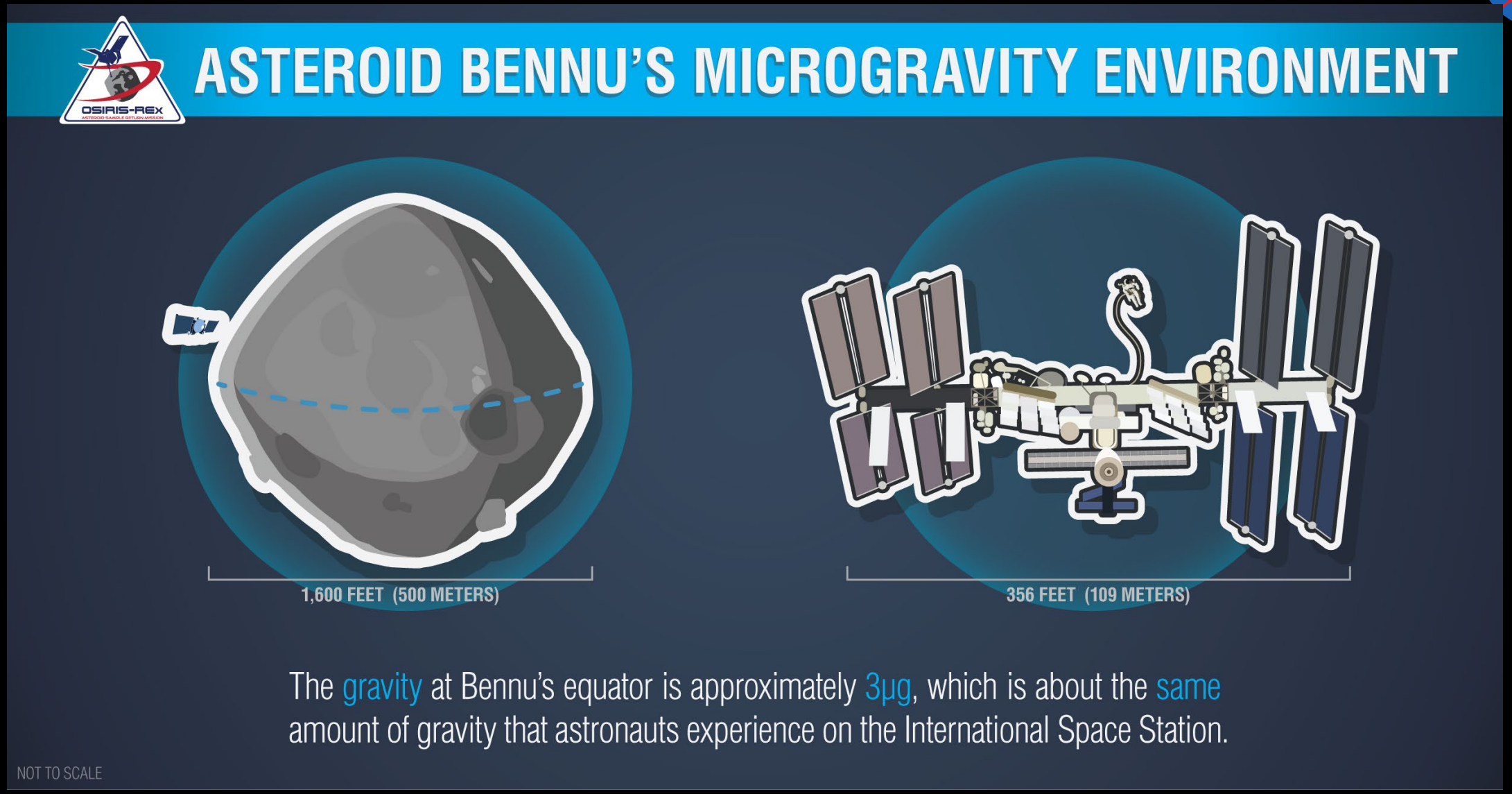
- Return and analyze a sample of Bennu's surface
- Map the asteroid
- Document the sample site
- Measure the orbit deviation caused by non-gravitational forces (the Yarkovsky effect)
  - Yarkovsky effect: sunlight induced orbital changes
- Compare observations at the asteroid to ground-based observation

TIMELINE



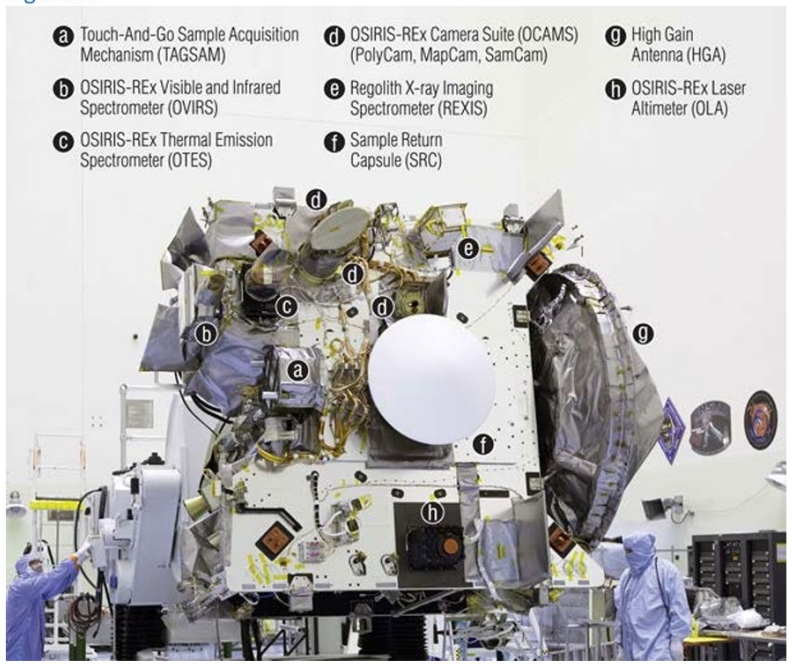
- Design and Construction 2011 – 2016
- Launch 2016
- **2018**
  - Arrival at Bennu and preliminary survey
  - Orbital A (r = 1.6 - 2.1 km) 2018 - 2019
- **2019**
  - Detailed Survey: baseball diamond, equatorial stations
  - Orbital B (altitude 650 m)
  - Orbital C (480 m)
  - Recon A (site selection)
    - Orbital R (r = 870 m)
  - Recon B (mapping primary and backup sample sites) ~625 m altitude
  - Recon C (250 m flyovers)
- **2020**
  - Rehearsal (125 m altitude)
  - Touch and go sampling (nightingale site)
  - Post sampling observation
- **2021**
  - Departure from Bennu
- **2023**
  - Return

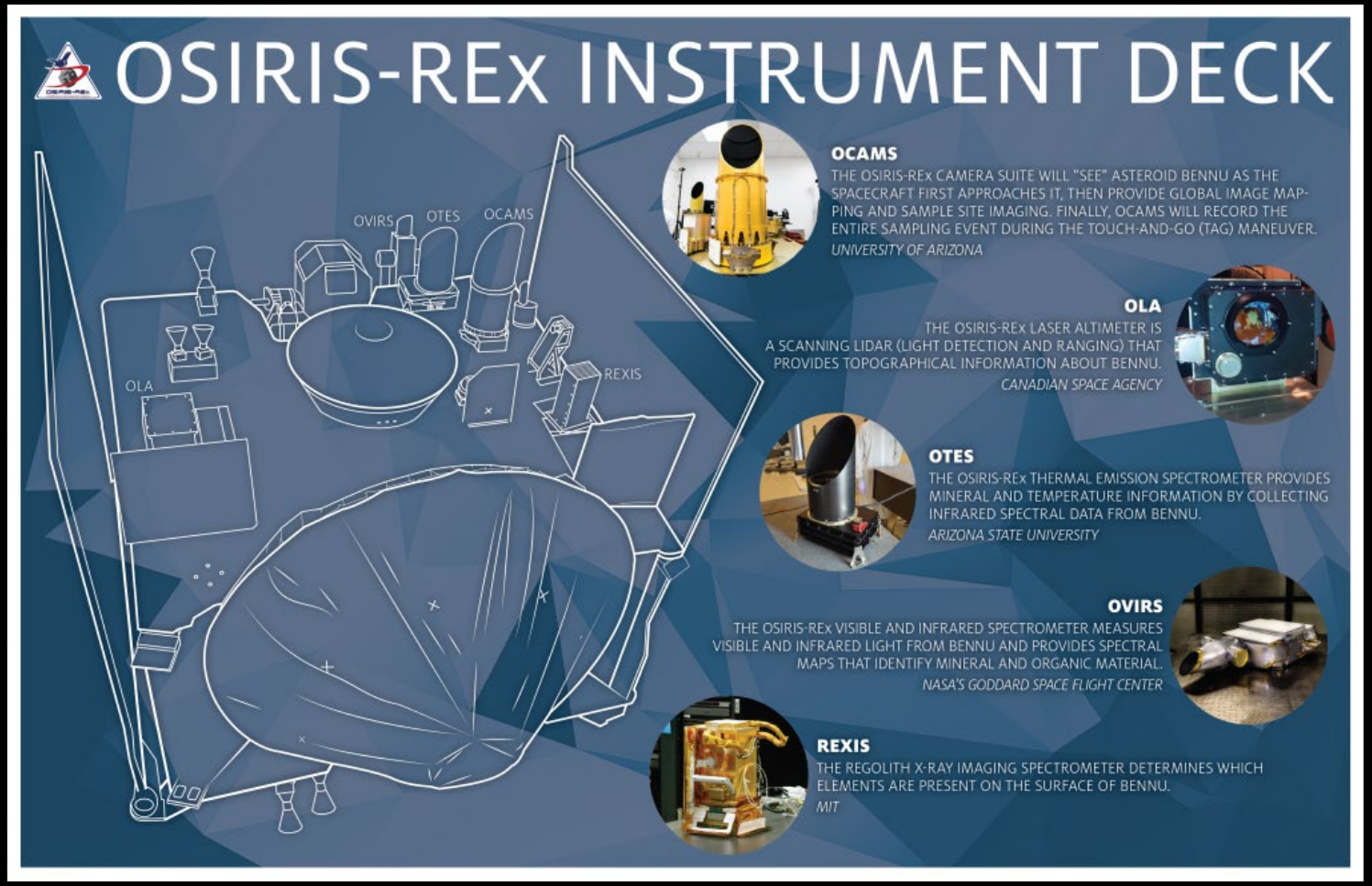
Orbital Mechanics at Bennu was Challenging



THE SPACECRAFT

Figure 11

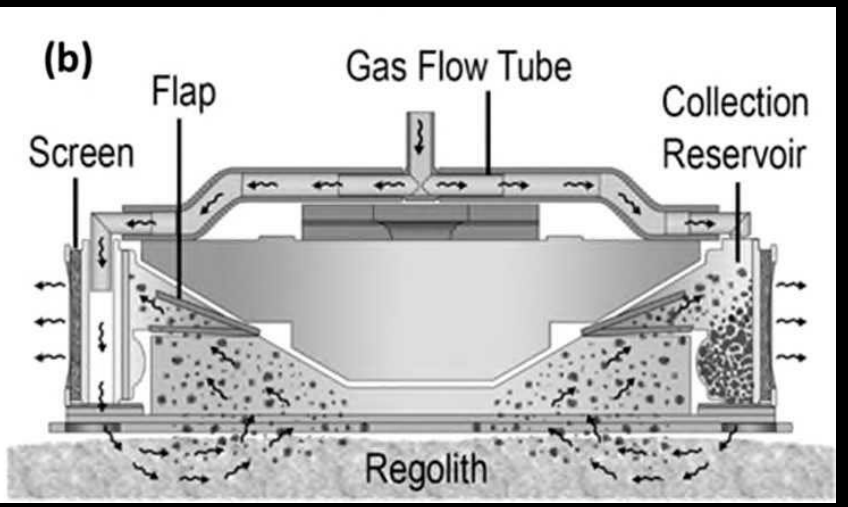




TOUCH AND GO SAMPLER

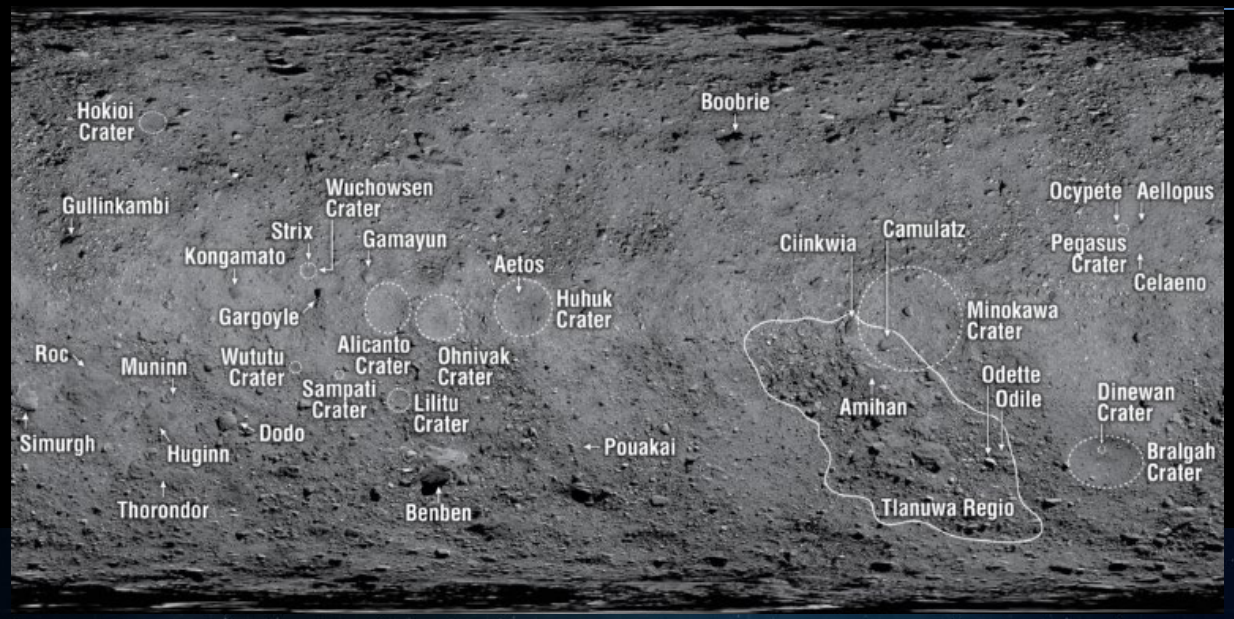


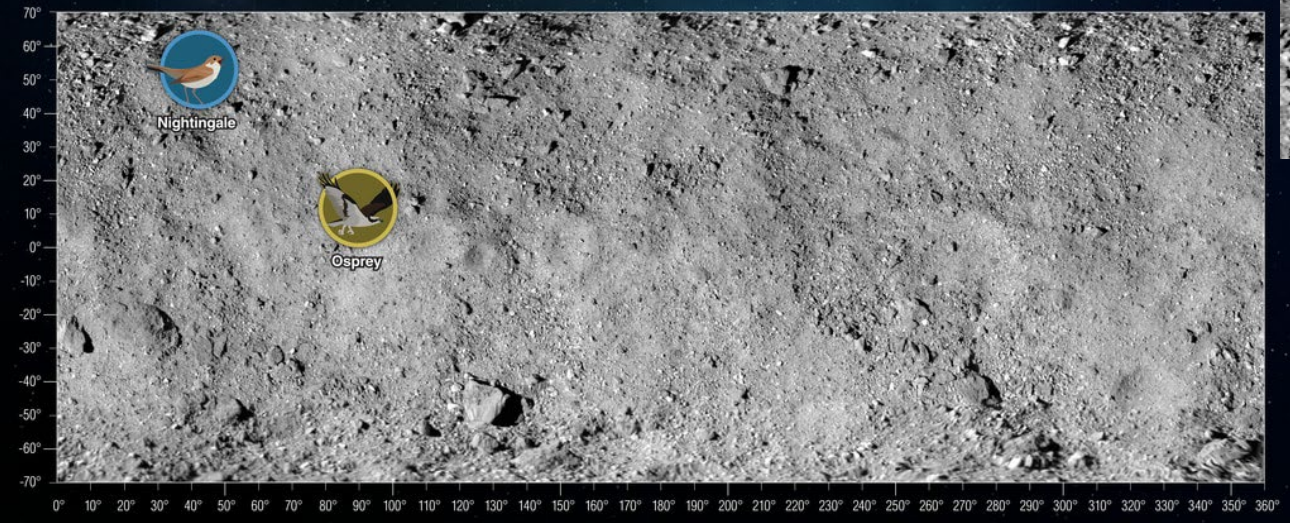




Bierhaus, E. B. *et al. (TAGSAM)*. *Space Science Reviews* vol. 214 (2018).

THE SAMPLE SITE: NIGHTINGALE

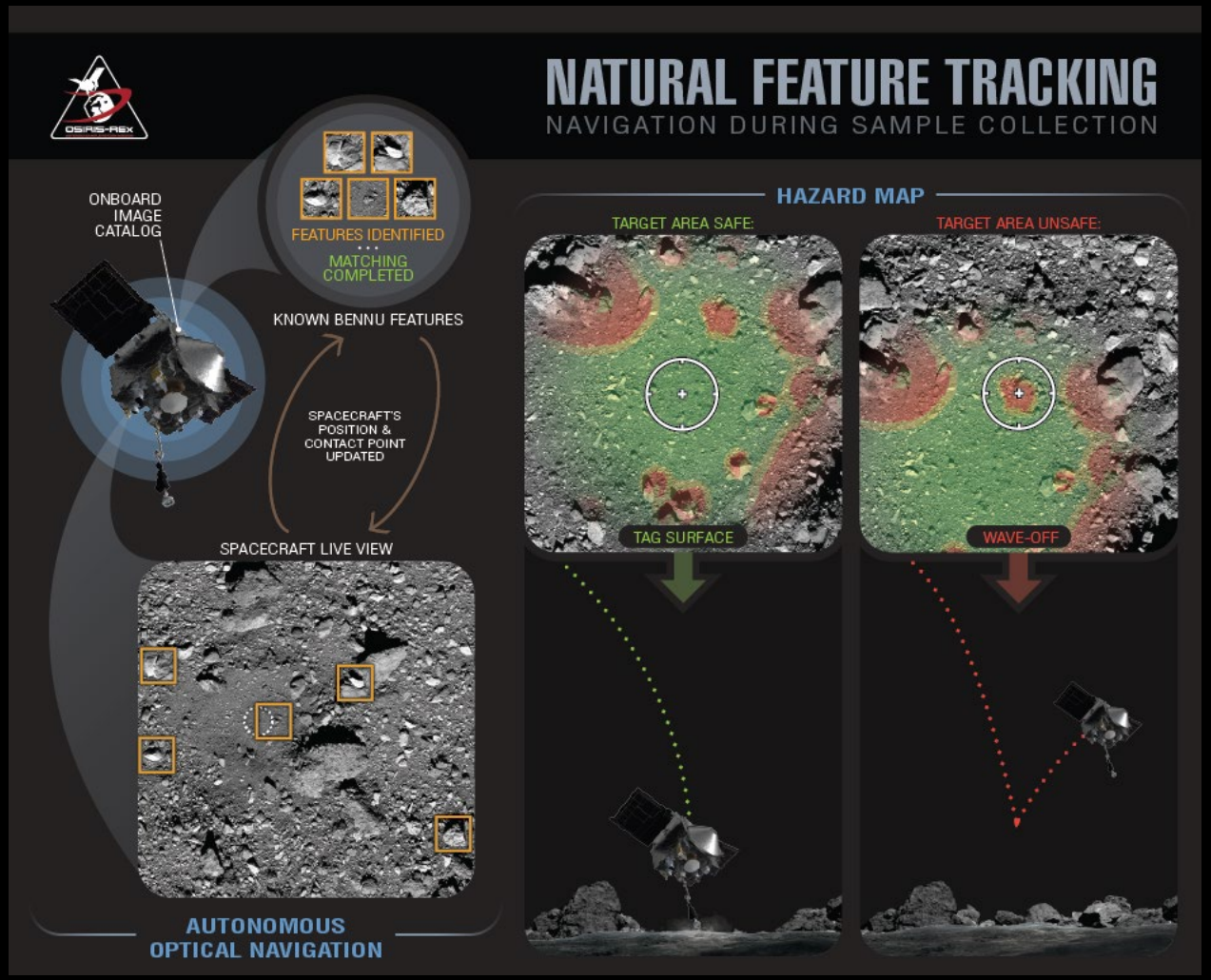






Original requirement was a 25 m. ellipse clear of obstacles

New Automated Sampling Technology was Developed to safely collect a sample





Brian May developed a method to collect 3D imagery without a stereo camera

~1.8 AU from earth at sampling (90 sec. comms delay one way)

Touch and Go Sampling





Landing and Recovery at UTTR (Utah Test and Training Range)



Landing and Recovery













Initial Disassembly AT UTTR



- Disarm NASA Standard Initiators
- Remove back shell and heat shield
- Purge science canister with Nitrogen
- Collect any errant / bonus sample material

TRANSPORT TO JSC





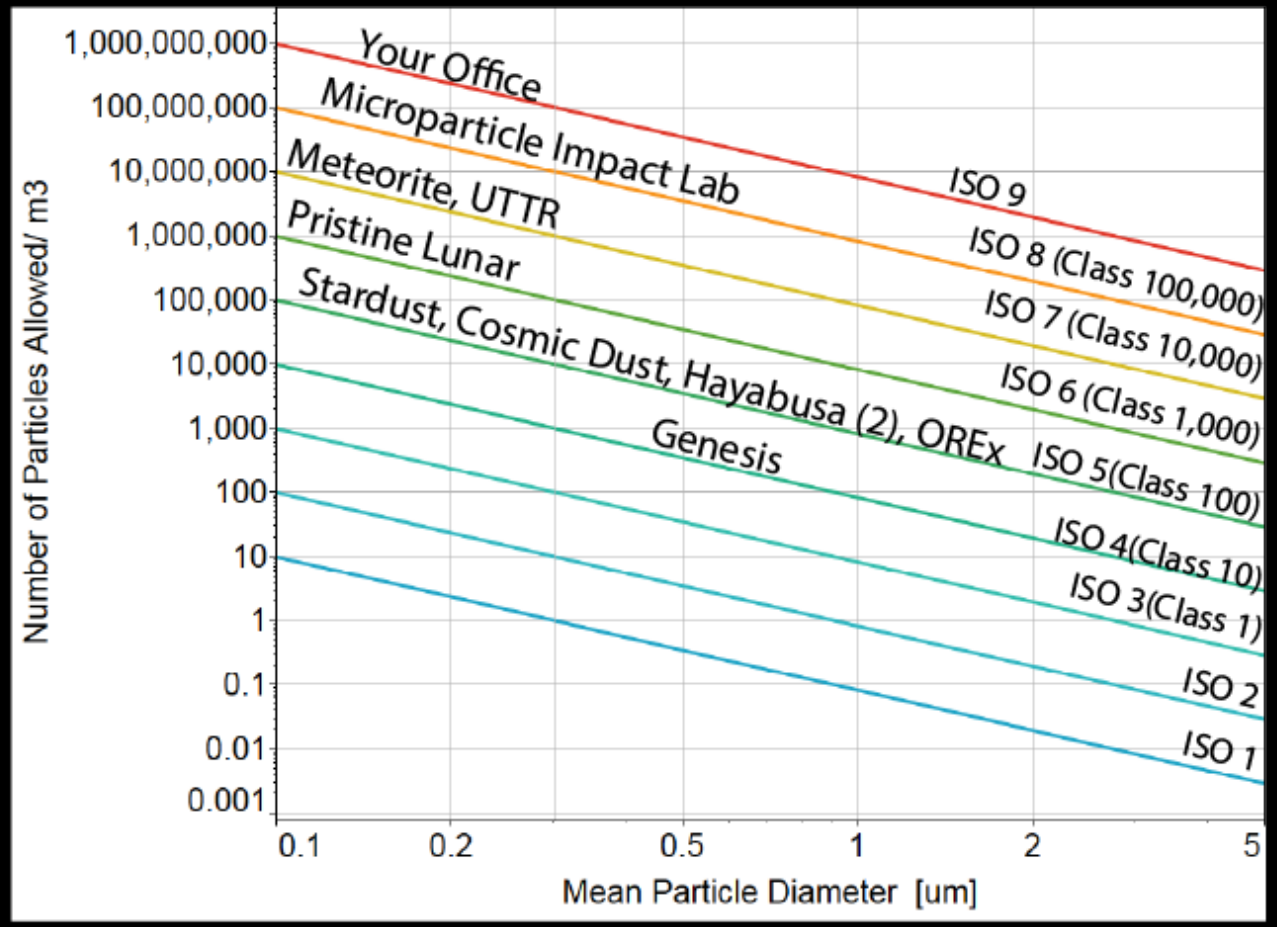






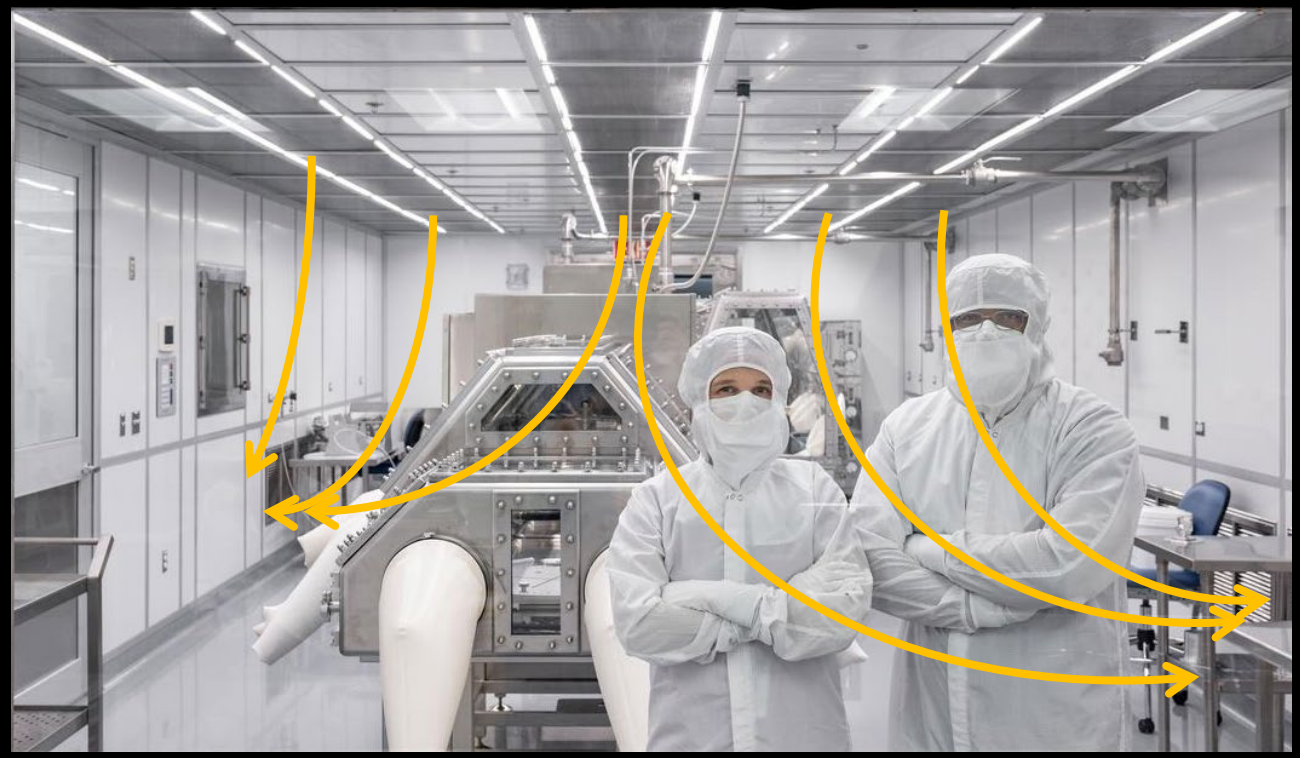


OSIRIS-REx Cleanroom operates at ISO 5 Equivalent Conditions



- <3,520 particles, ≥0.5 µm/ m^3 of air
  - (< 100 particles / ft^3 of air)
- Fan Filter Units create vertical laminar flow to push particles down towards exhaust grates mounted near the wall
  - 45 ULPA filters (MERV 20) capture 99.99997% of all particles 0.3-1.0 µm.
- Temperature and relative humidity are strictly controlled
  - Temp. ≤ 21.1 °C (70 °F)
  - Rh 40 – 60 %
- Particle counts are measured weekly
- Microbial monitoring occurs monthly

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  - (< 100 particles / ft^3 of air)
- Fan Filter Units create vertical laminar flow to push particles down towards exhaust grates mounted near the wall
  - 45 ULPA filters (MERV 17 or better) capture 99.99997% of all particles 0.3-1.0 µm.
- Temperature and relative humidity are strictly controlled
  - Temp. ≤ 21.1 °C (70 °F)
  - Rh 40 – 60 %
- Surfaces are cleaned with isopropyl alcohol daily
- Sensitive surfaces (glove box airlocks) are disinfected with hydrogen peroxide

Gowning Requirements Further Limit Contamination



- OSIRIS REx lab is an ISO 5 equivalent cleanroom
  - <3,5315 particles larger than 0.5 µm / m^3 of air
- Disposable Items
  - Booties
  - Hair cover
  - Beard cover
  - Facemask
  - Nitrile Gloves
- Cleanroom Garments
  - Bunny Suit
  - Hood
  - Shoe covers

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  - Bunny Suit
  - Hood
  - Shoe covers
- An additional smock is donned when operating the glovebox airlock

Material types in the lab are limited to minimize contamination



- **Approved Materials**
  - Metals (In order of preference):
    1. 6061 and 6063 Aluminum (Unfinished or Clear anodized)
    2. 316/316l Stainless Steel
    3. 304 Stainless Steel
    4. 2024 Aluminum (Clear anodized)
    5. 301, 302, 303 Stainless Steel
    6. Biodur 108 surgical stainless steel
  - Plastics (In order of preference):
    1. Polytetraflouroethylene (PTFE; Any metal with PTFE coating is acceptable w/approval)
    2. Flourinated Ethylene Propylene (FEP)
    3. Polyvinylidene Flouride (PVDF; For Tubing)
    4. Perflouroalkoxy Alkanes (PFA; For Tubing)
  - Glass:
    1. Schott Amiran Low Iron Laminated (glovebox windows)
    2. Pilkington OpticWhite (uncoated glovebox windows only)
    3. Fused Quartz/Fused Silica
    4. Borosilicate Crown Glass (BK7)
    5. Soda-Lime silicate glass (above without Boron)
    6. Sapphire/Sapphire Glass
  - Elastomers:
  - Viton (FKM)
  - Chlorosulfonated Polyethylene (CSM, Hypalon)
- Procedure for bringing approved materials into the cleanroom
  - Wipe with IPA (isopropyl alcohol) until item is visibly clean.

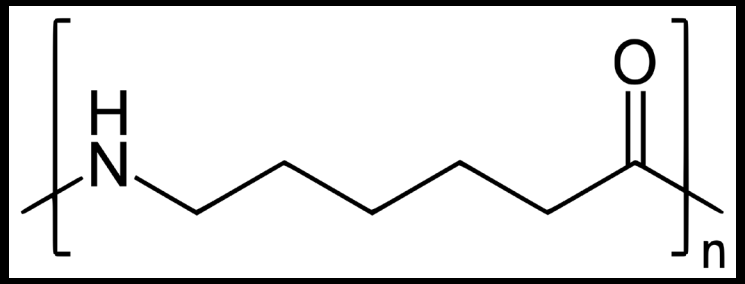
The use of Plastic in the Lab is strictly Controlled



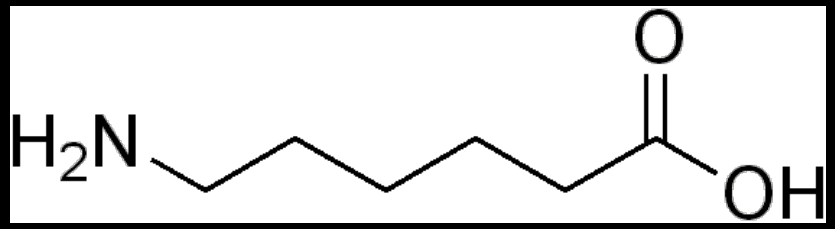
- **Prohibited Materials**
  - Latex, Nylon and polyamides
  - Open Solder
  - Magnetic materials
  - Silicones
  - Foams
  - Paints
  - Metal oxides
  - 3D printed material
  - Other astromaterials
- Procedure for bringing unapproved materials into the cleanroom
  - Obtain a waiver in writing from the OSIRIS-REx Curator

COMMON PLASTICS LIKE NYLON CAN DEGRADE AND RELEASE COMPOUNDS THAT ARE SIMILAR TO AMINO ACIDS

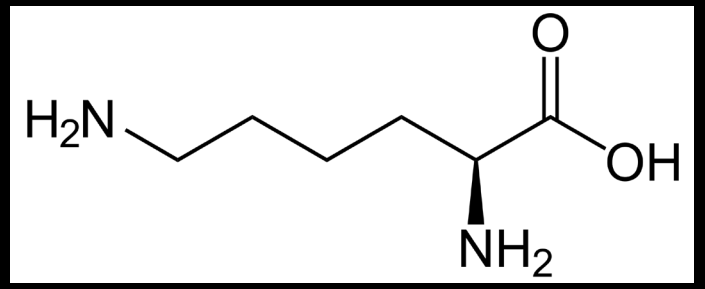
Nylon 6

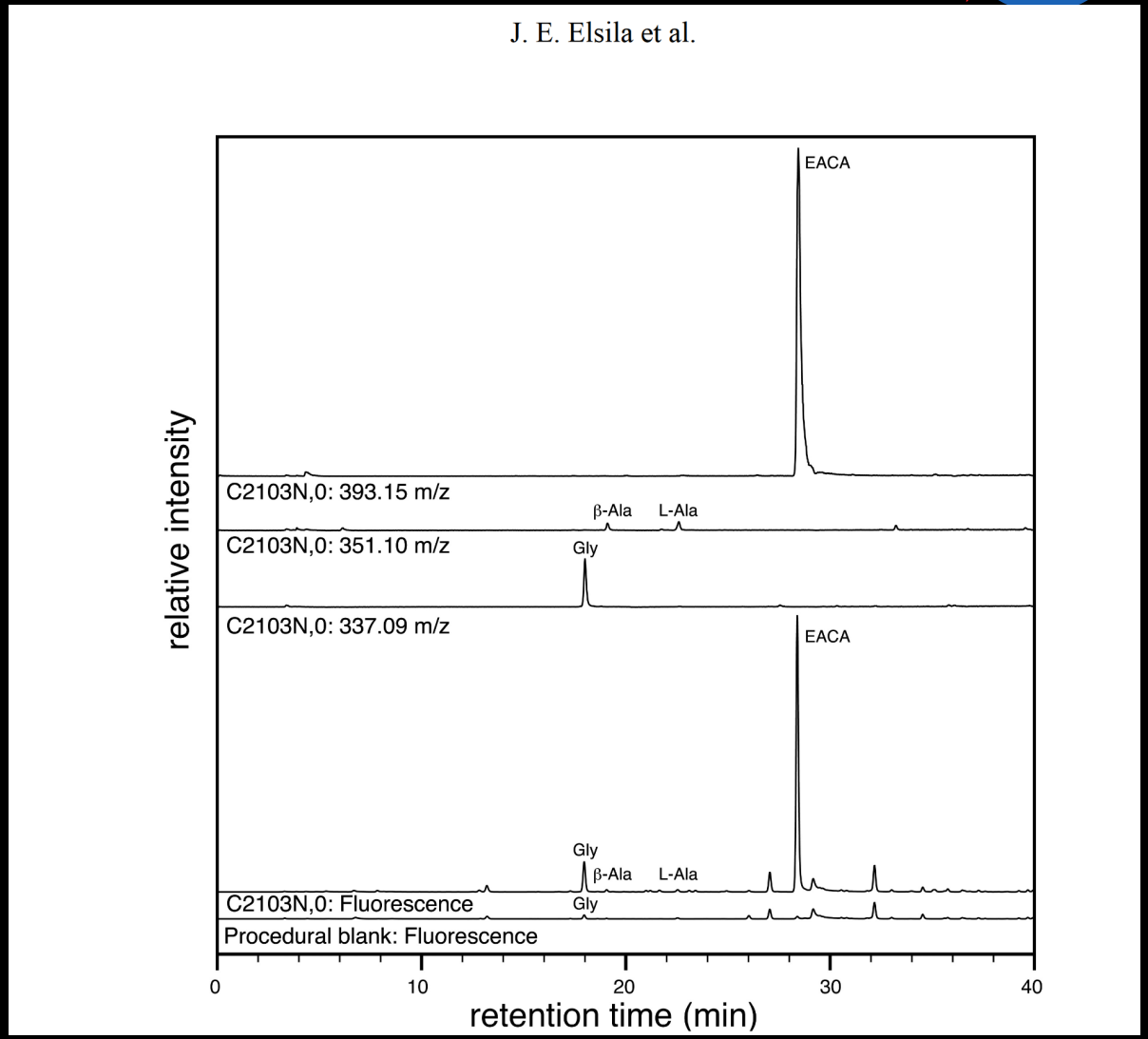


Aminocaproic acid (EACA)



L-lysine

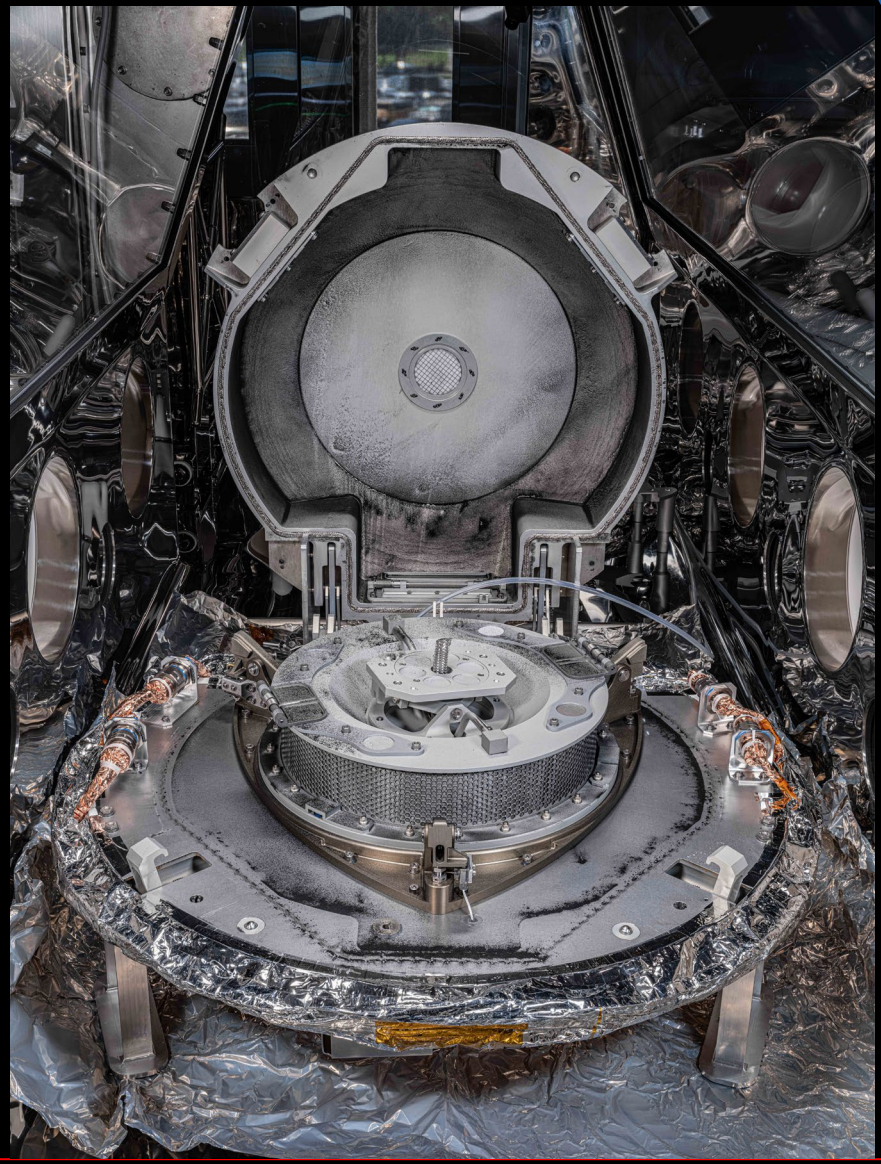




Elsila, J. E., Glavin, D. P. & Dworkin, J. P. *Meteoritics & Planetary Science* **44**, 1323–1330 (2009)

Samples are Opened in gloveboxes continuously purged with Nitrogen gas at 4.25 – 7.08 m^3/Hr (150 - 250 scf/ hr.)



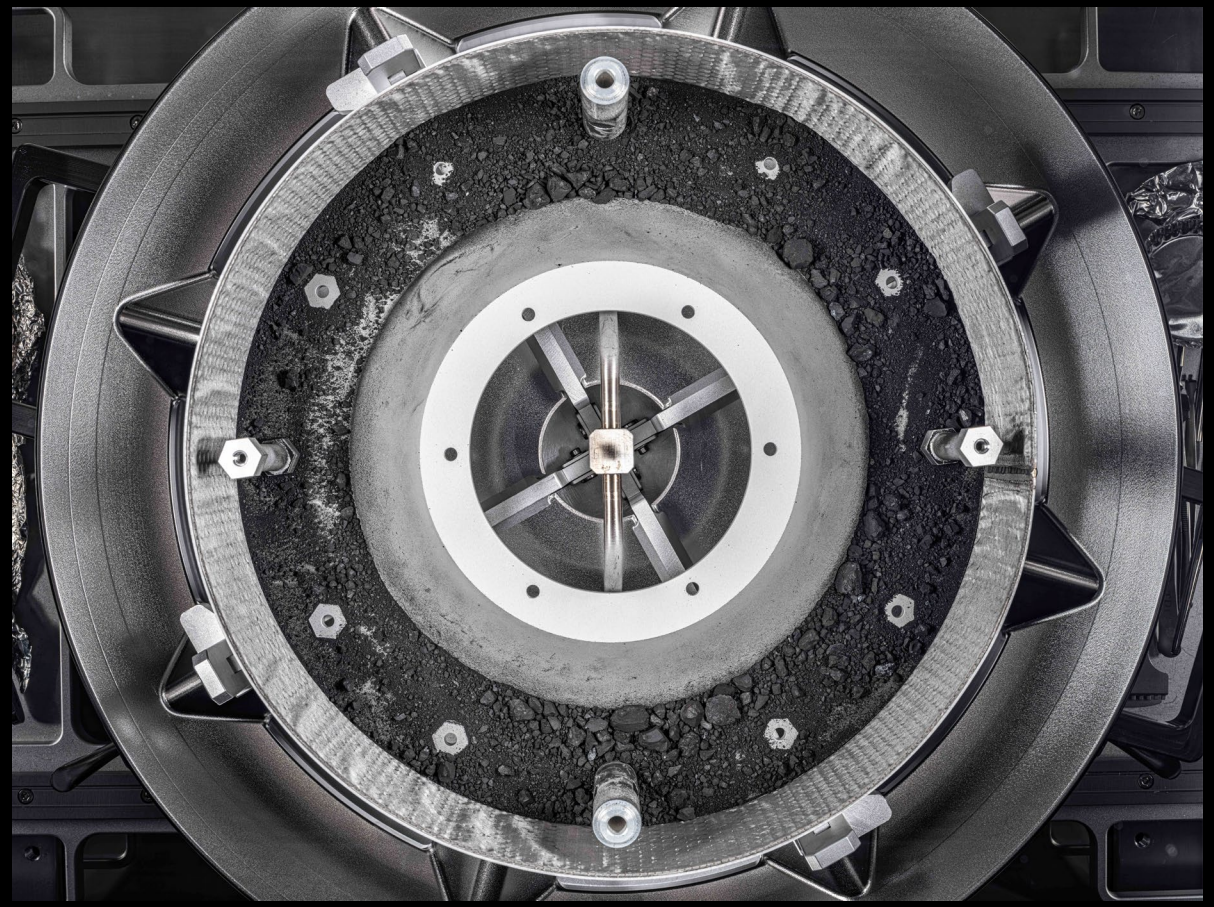


TAGSAM Transfer to the Processing Cabinet



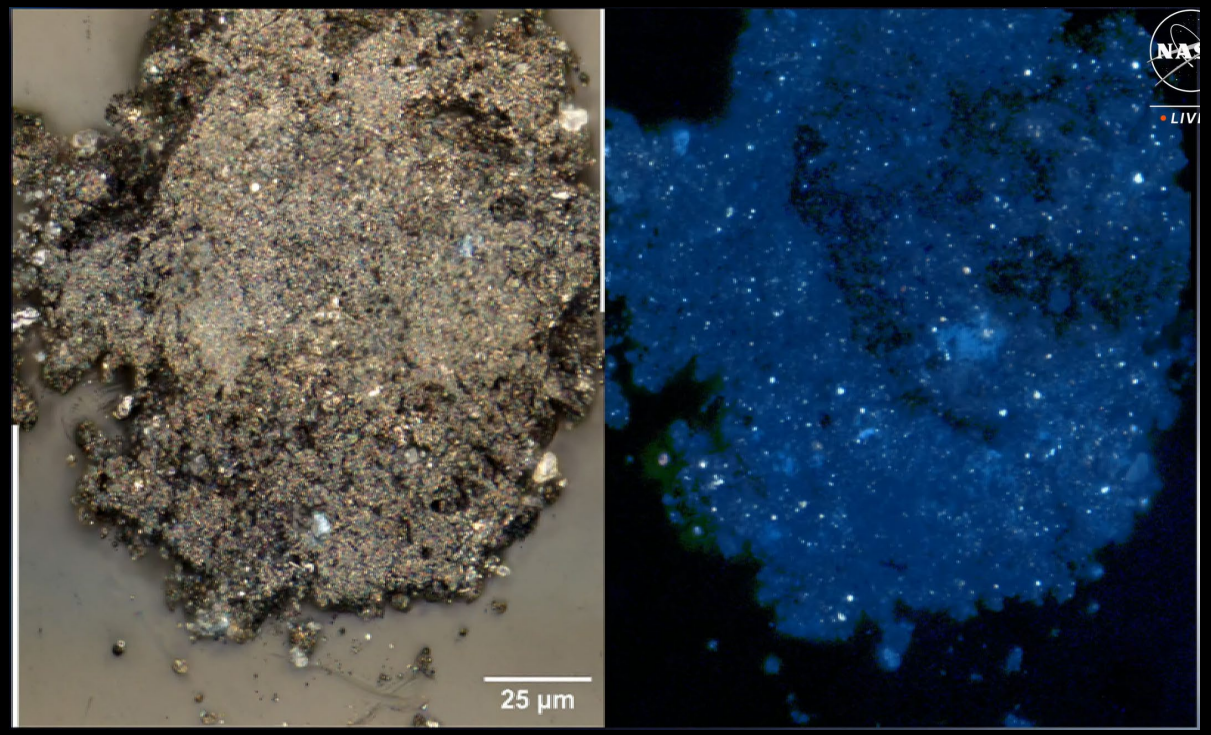


Preliminary Results



- We collected 121 g. of material
- Bennu is similar to the Ivuna meteorite
  - Probably more clay minerals
  - Probably better preserved organics
  - 4.7 wt% total organic carbon
- Quick Look Measurements
  - Optical Microscopy
  - Electron microscopy
  - X-ray diffraction for mineralogy
  - X-ray CT scan
  - Mass spectrometry to characterize organic molecules (RNA base pairs?)
  - Nano SIMS to determine isotopic composition
- The sample catalog published in March
- Curation will start allocating material to the wider community later this year.

Preliminary Results

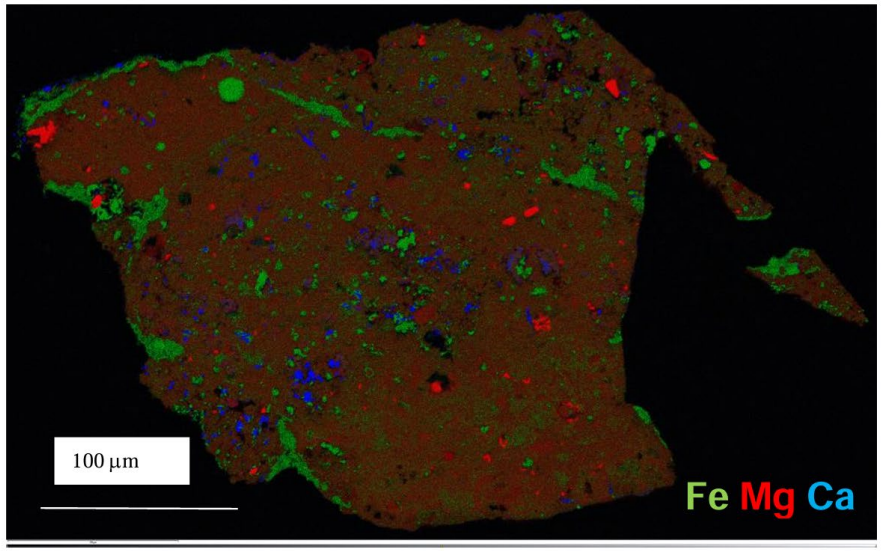


Fluorescent organic matter

- Bennu is similar to the Ivuna meteorite
  - Probably more clay minerals
  - Probably better preserved organics
  - 4.7 wt% total carbon
- Quick Look Measurements
  - **Optical Microscopy**
  - Electron microscopy
  - X-ray diffraction for mineralogy
  - X-ray CT scan
  - Mass spectrometry to characterize organic molecules (RNA base pairs?)
  - Nano SIMS to determine isotopic composition
- Sample catalog published in March
- Curation will start allocating material to the wider community later this year.

Preliminary Results

Figure 1. False color element map of OREX-501054-0. Phyllosilicates appear as dull red/brown; magnetite and sulfides as green; carbonates as blue; olivine and pyroxene as bright red.



Phyllosilicates, sulfides, carbonates, olivine and pyroxene

- Bennu is similar to the Ivuna meteorite
  - Probably more clay minerals
  - Probably better preserved organics
  - 4.7 wt% total carbon
- Quick Look Measurements
  - **Electron microscopy**
  - X-ray diffraction for mineralogy
  - X-ray CT scan
  - Mass spectrometry to characterize organic molecules (RNA base pairs?)
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- Sample catalog published in March
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Russel, S. S. *et al.* in *55th Lunar Planetary Science Conference 1197* (2024).

Preliminary Results

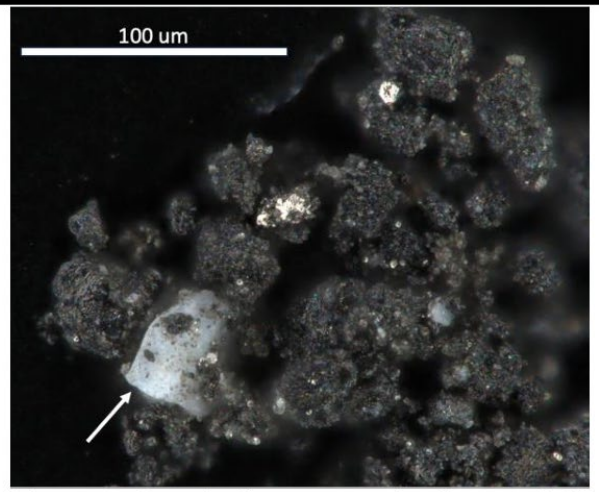


Figure 1. Optical photomicrograph of area of QL sample OREX-501050-0. Mg-phosphate is the white particle denoted with a white arrow.

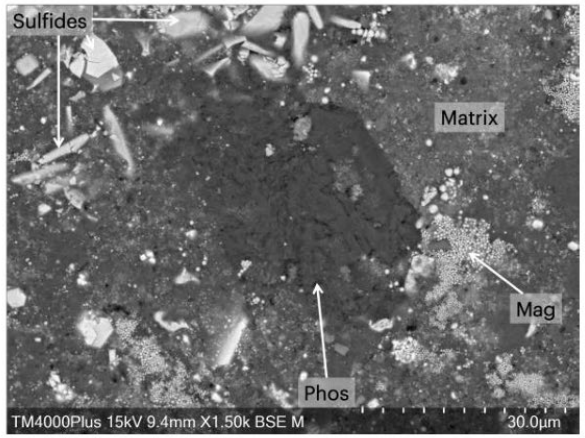
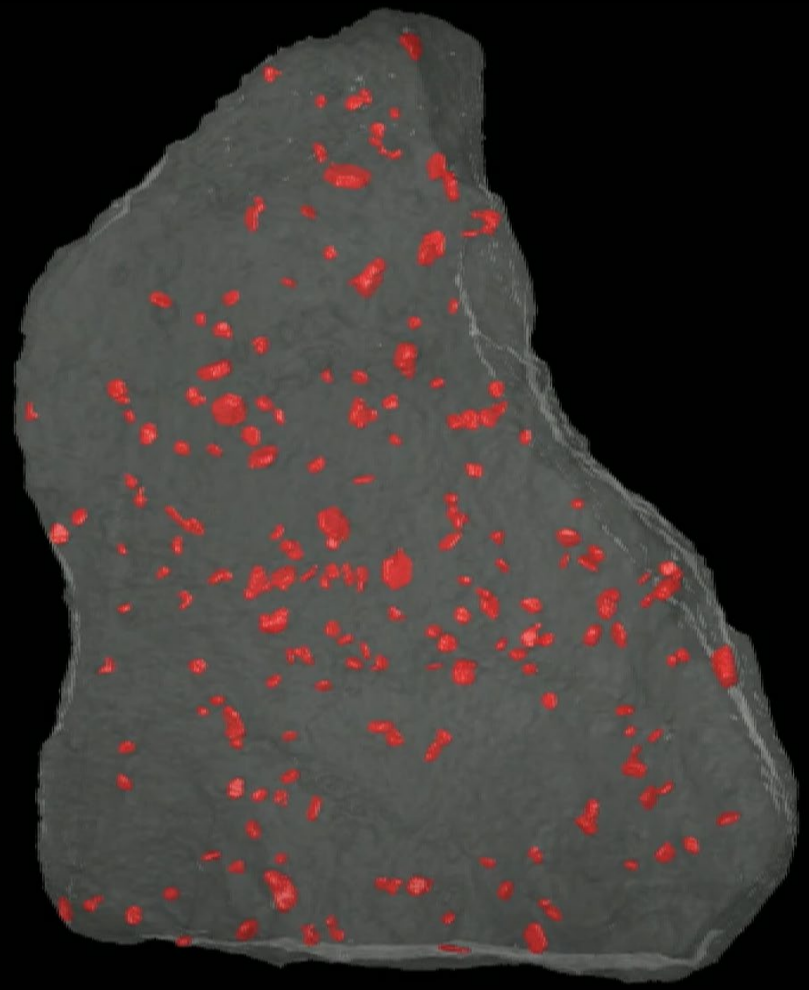


Figure 2. Backscattered electron image of an area of matrix in QL sample OREX-501049-0. Mg-phosphate is denoted with 'phos', and 'mag' is magnetite.

- Bennu is similar to the Ivuna meteorite
  - Probably more clay minerals
  - Probably better preserved organics
  - 4.7 wt% total carbon
- Quick Look Measurements
  - **Electron microscopy**
  - X-ray diffraction for mineralogy
  - X-ray CT scan
  - Mass spectrometry to characterize organic molecules (RNA base pairs?)
  - Nano SIMS to determine isotopic composition
- Sample catalog published in March
- Curation will start allocating material to the wider community later this year.

Barnes, J. J. *et al* in *55th Lunar Planetary Science Conference* 1532 (2024).

Preliminary Results



Sulfide bearing minerals

- Bennu is similar to the Ivuna meteorite
  - Probably more clay minerals
  - Probably better preserved organics
  - 4.7 wt% total carbon
- Quick Look Measurements
  - Electron microscopy
  - X-ray diffraction for mineralogy
  - **X-ray CT scan**
  - Mass spectrometry to characterize organic molecules (RNA base pairs?)
  - Nano SIMS to determine isotopic composition
- Sample catalog published in March
- Science team gets two years to study the samples and then curation will start allocating material to the wider community

Preliminary Results

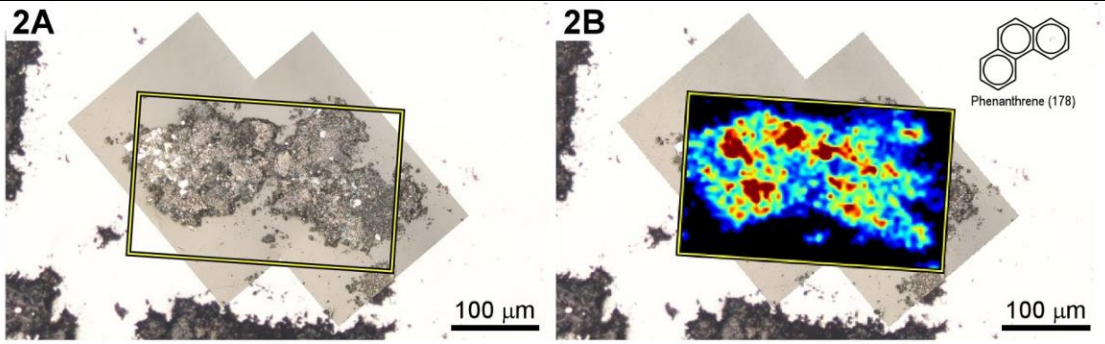


Figure 2: (**A**) Optical image of Bennu grain pressed on KBr window. (**B**) μ-L^{2}MS spatial map showing distribution of phenanthrene.

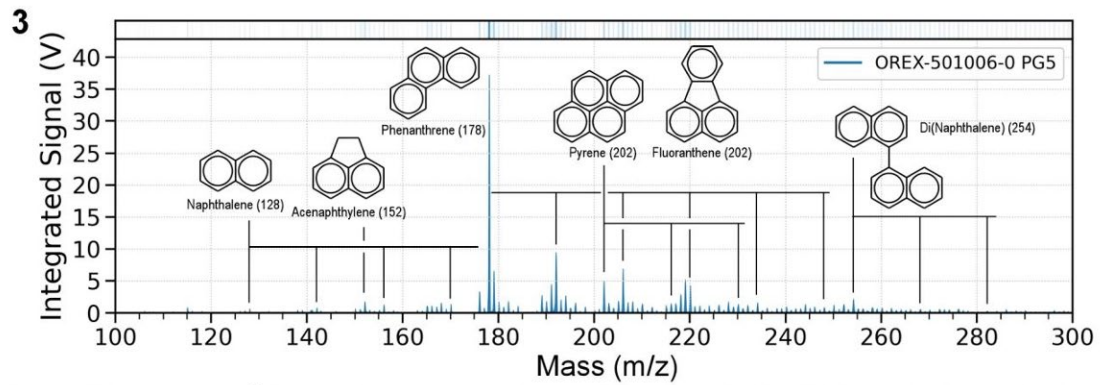


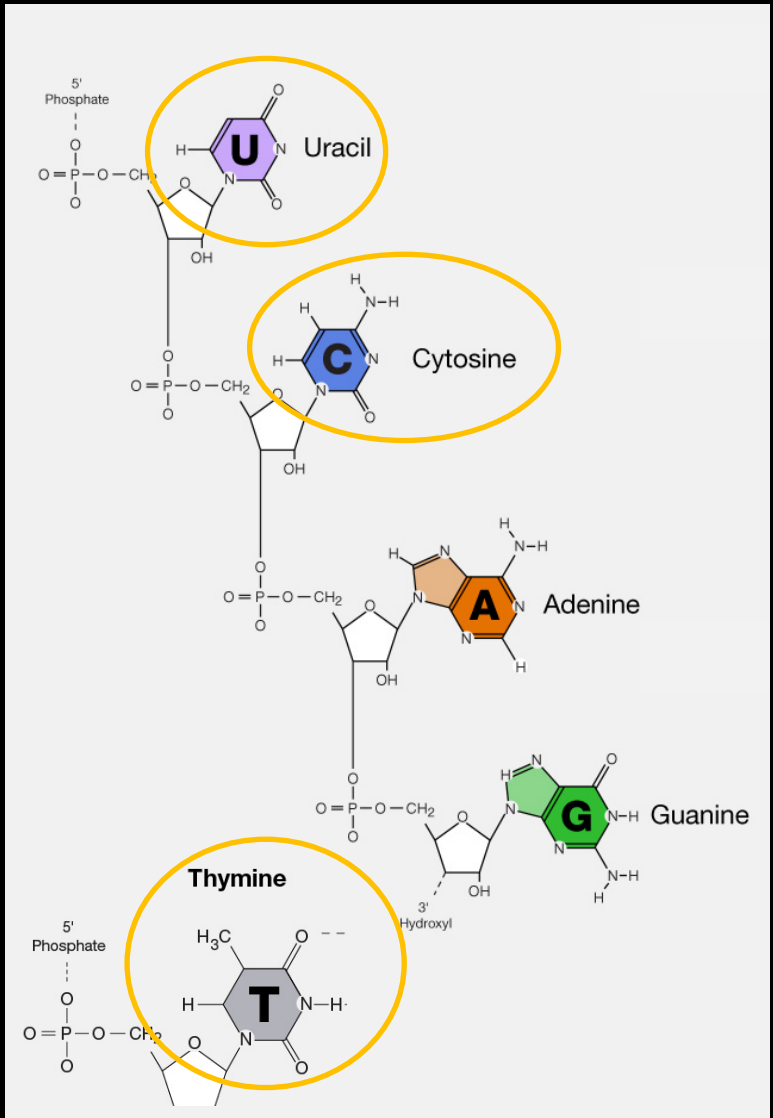
Figure 3: Summed μ-L^{2}MS spectrum acquired from particle shown in Fig. 2B. The structures of primary PAHs, along with their associated alkylation series, are overlaid.

Polyaromatic hydrocarbons detected

- Bennu is similar to the Ivuna meteorite
  - Probably more clay minerals
  - Probably better preserved organics
  - 4.7 wt% total carbon
- Quick Look Measurements
  - Electron microscopy
  - X-ray diffraction for mineralogy
  - X-ray CT scan
  - **Mass spectrometry to characterize organic molecules**
  - Nano SIMS to determine isotopic composition
- Sample catalog published in March
- Curation will start allocating material to the wider community later this year.

Clemett, S. J. et al. in 55th Lunar Planetary Science Conference 1484 (2024).

Preliminary Results



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Building blocks of DNA and RNA detected

Mojarro, A. *et al. 55th Lunar Planetary Science Conference* 1219 (2024).

QUESTIONS?

