Hermes Granular Material Research Material on the ISS

Thursday, January 16th, 2020

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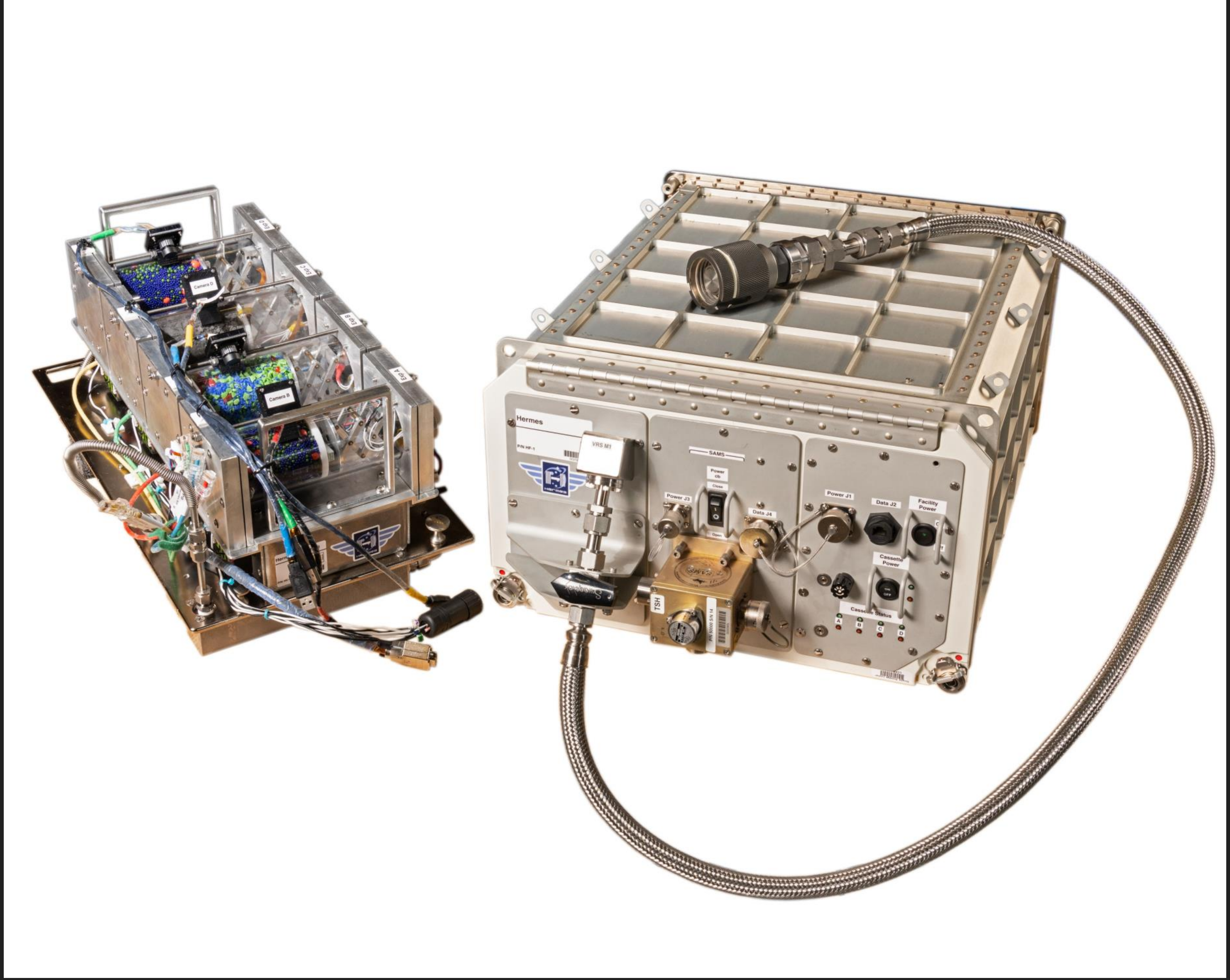
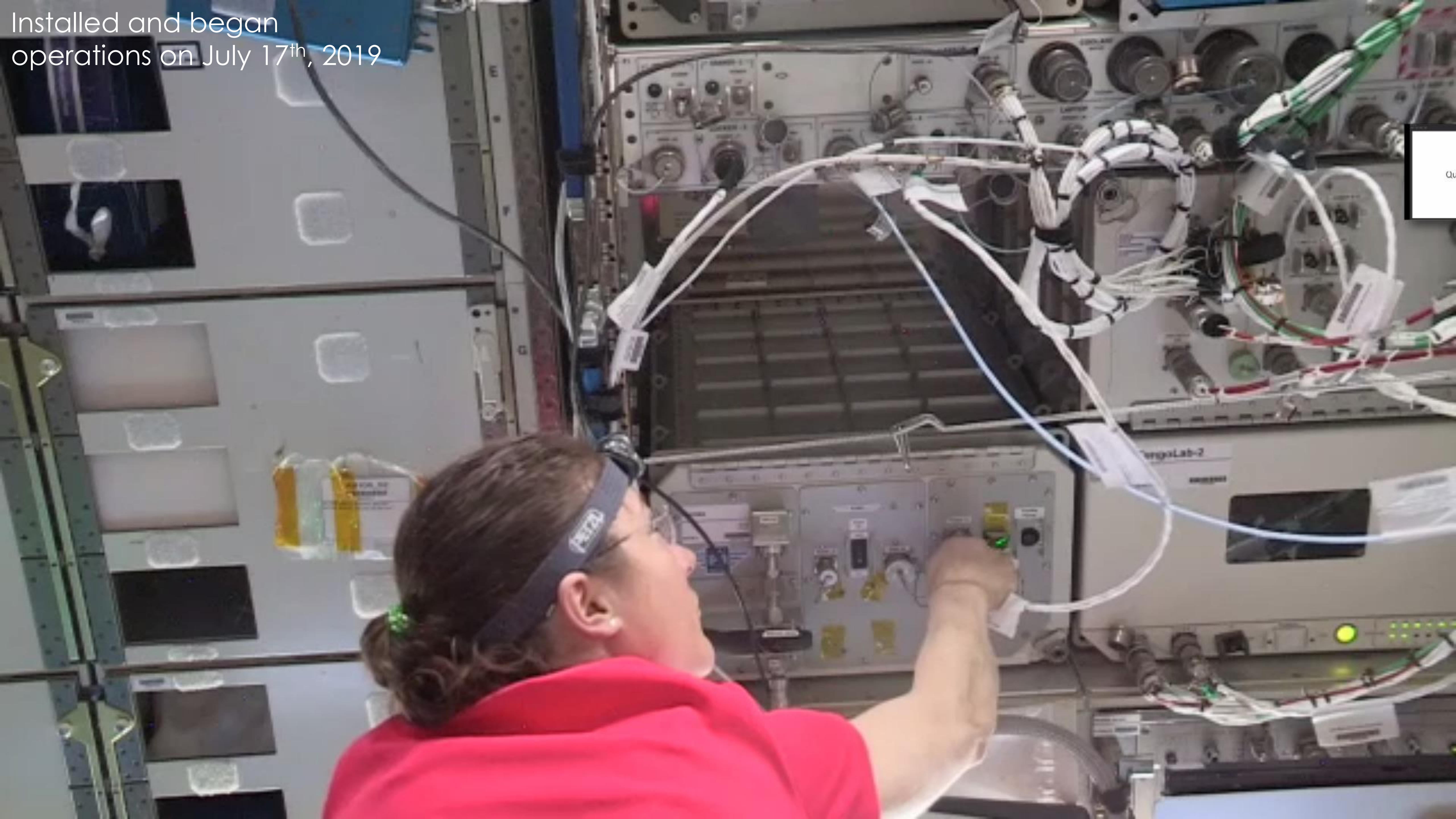
NASA JSC – Astromaterials Research & Exploration Science Division
Payload Developers: NASA JSC, Texas A&M, T STAR, UCF


Hermes
VRS M1
SAMS
Power J3
Data J4
Power J1
Data J2
Facility Power
Cassette Power
TSH
Camera B

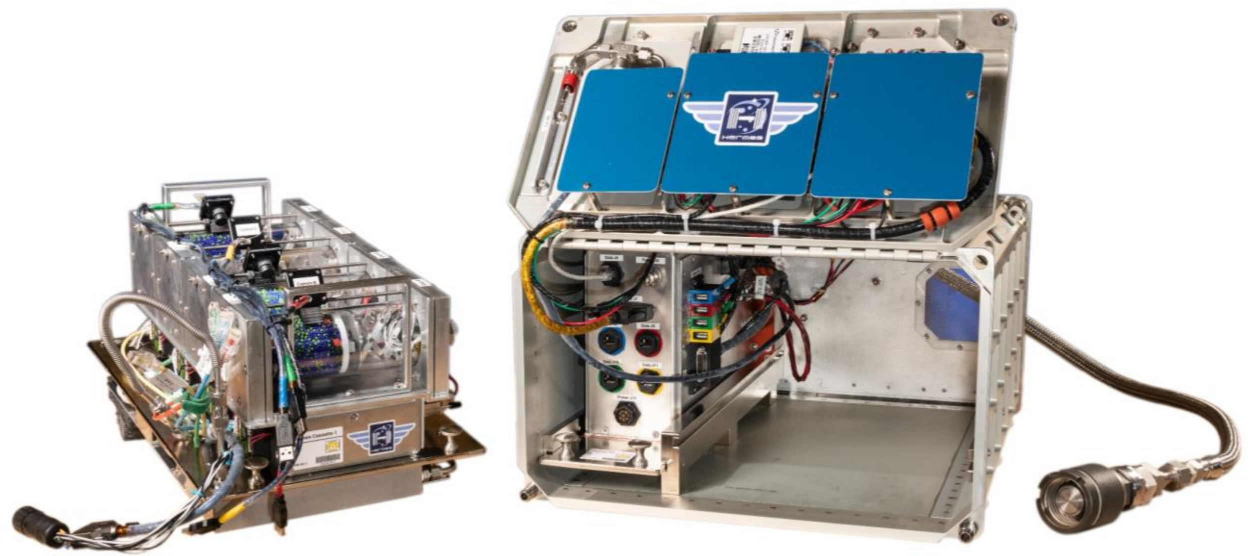
Launched May 3rd, 2019
from KSC to the ISS

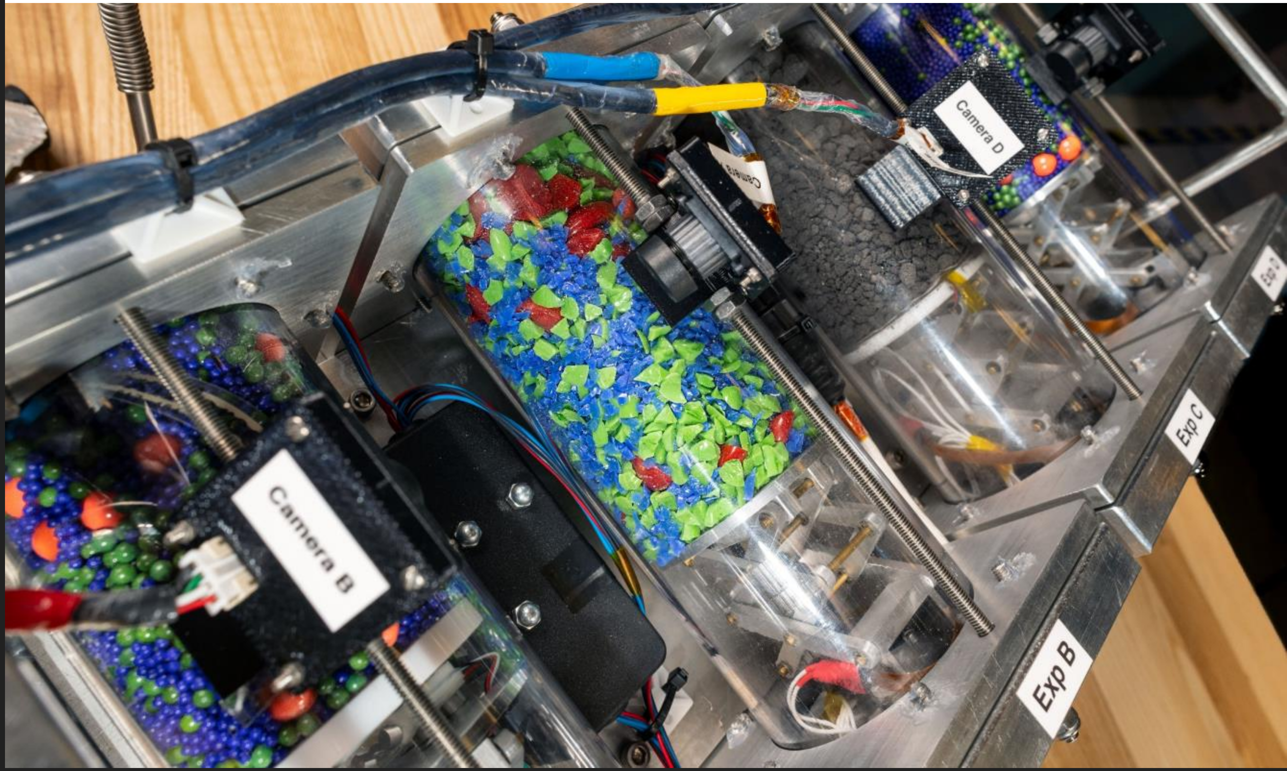
Installed and began
operations on July 17th, 2019



Hermes in a Nutshell

- A microgravity experimental facility on the ISS….
- Reconfigurable on-orbit experiment facility
  - **4 experiments at a time** (Cassette)
  - Power & control provided by Hermes
- Started as asteroid and small body investigations; also open to other investigations
- Express Rack Locker payload
- Leveraging Strata-1 heritage



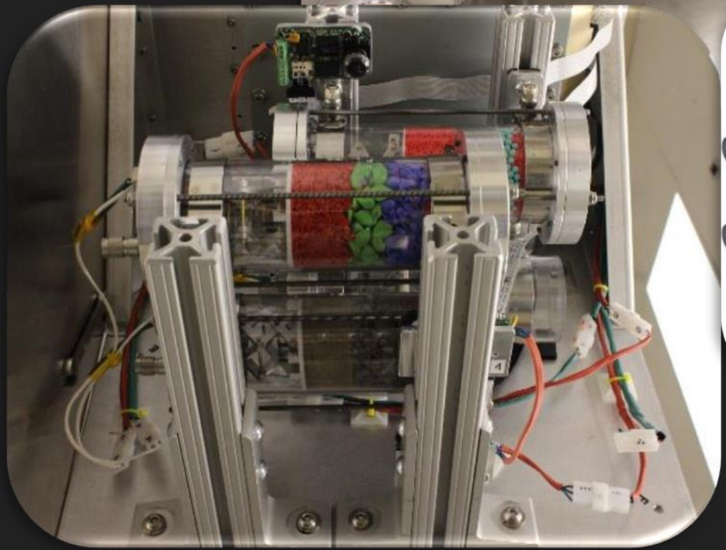


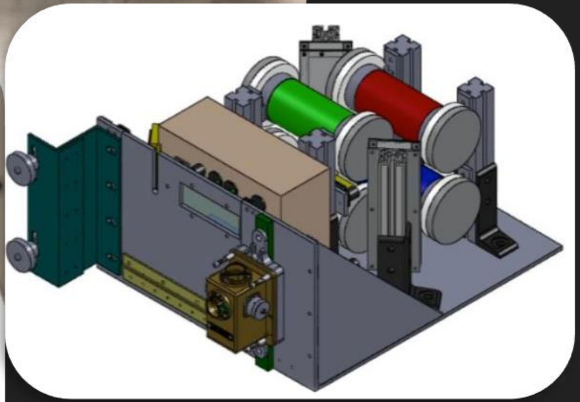
The ISS – The Perfect Place to Study Asteroids

- Microgravity
- Diurnal cycle
- Vacuum
- Impacts

Strata-1: A Study of Small Body Regolith

- Successful, one year asteroid regolith dynamics investigation on the ISS
- Four regolith simulants of increasing complexity
- Trapped in place on launch, released (within their evacuated tubes) upon installation on ISS
- Objective: Observe movement of particles in long-duration micro-g environment
- Hypothesis: *Current models accurately describe regolith evolution on small bodies.*
- Data analysis open to calls via NASA Planetary Data System (PDS)
  - pds.nasa.gov
  - Or contact Marc Fries, Paul Abell, or Kristen John at NASA





Regolith

- Regolith is the layer of loose material covering bedrock
- Regolith covers airless bodies
- On large (Moon, Mercury) bodies, regolith evolution is dominated by impact processing
- On small bodies (asteroids, comets), inter-grain forces (electrostatic, van der Waals, etc.) *should* dominate
  …but details are lacking

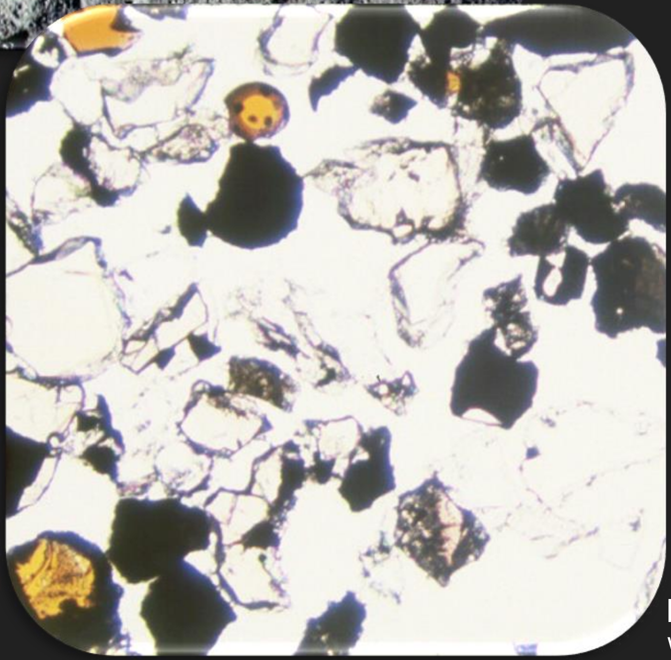
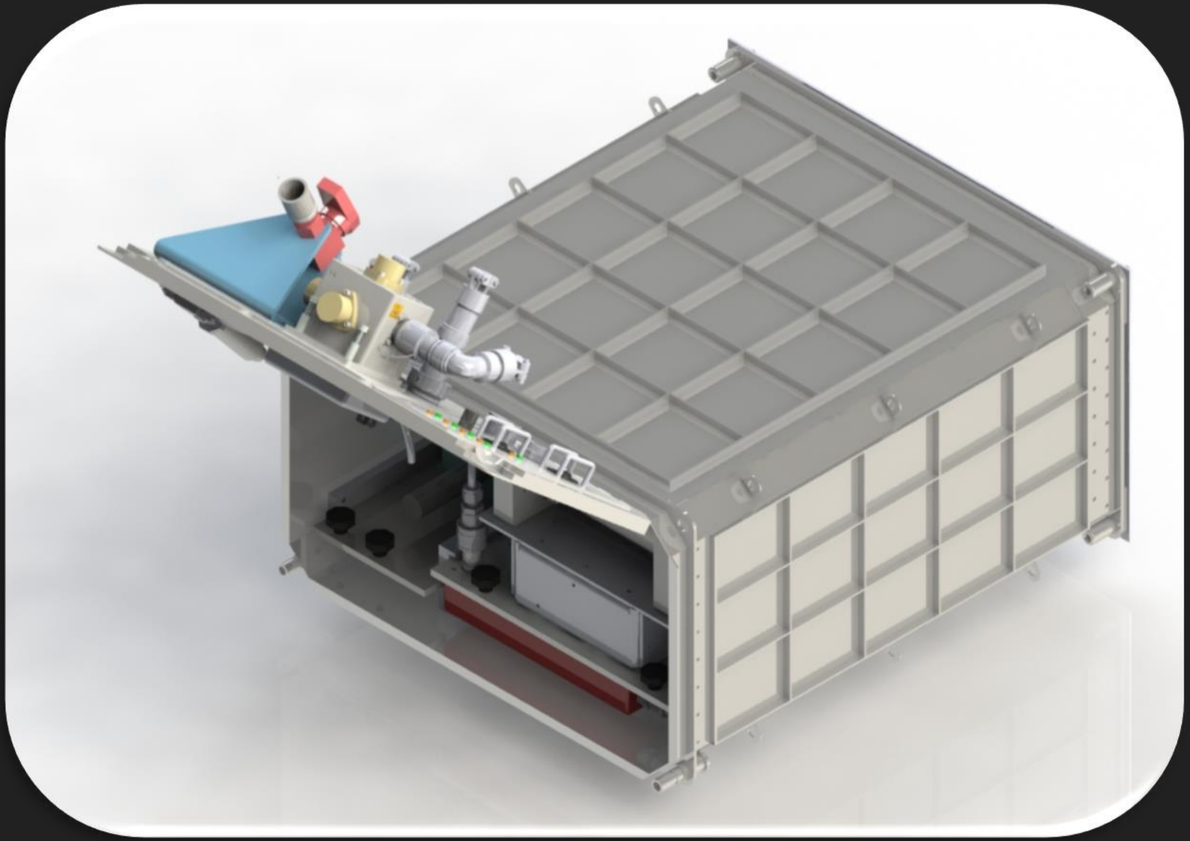


Image credit: WUSTL

Hermes System Objectives

- Long duration micro-g exposure
- Power
- Vacuum (at least 10^{-3} torr)
- Lighting/Cameras
- Environmental Acceleration Monitoring
- Experiment Tools
- Command and data handling
  - Downlink of data, access to data storage, autonomous monitoring, ground commanding

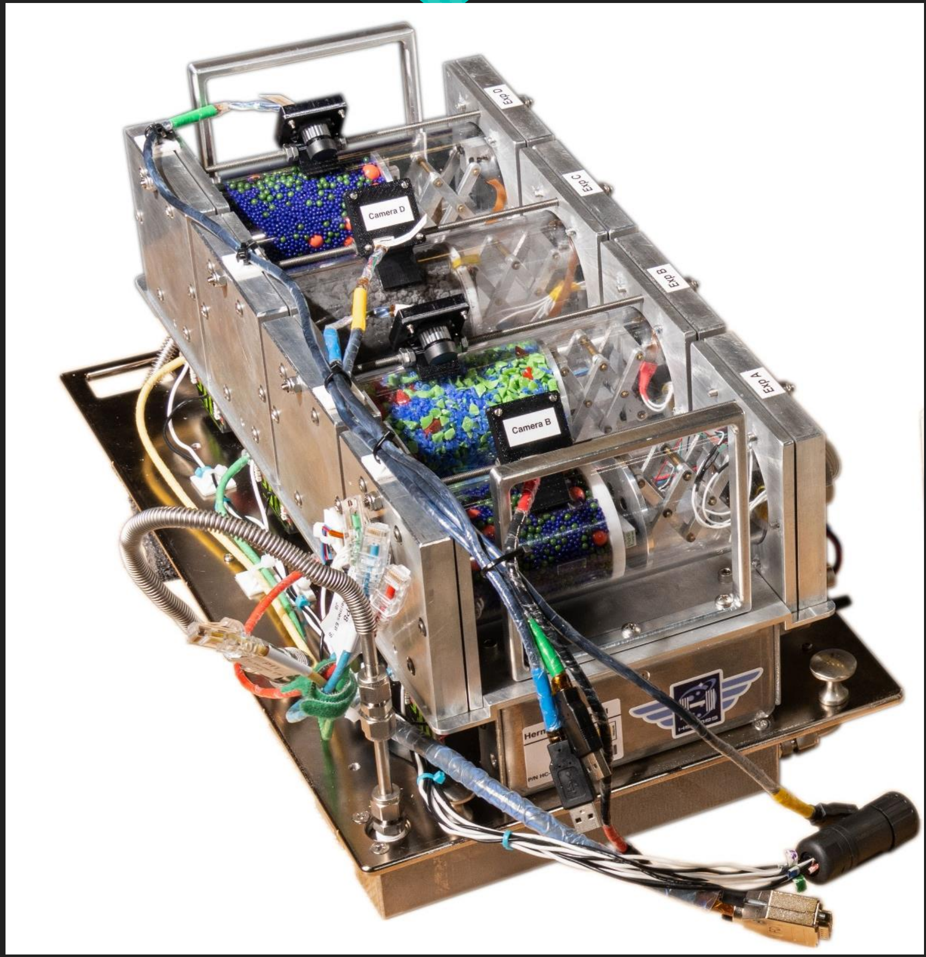


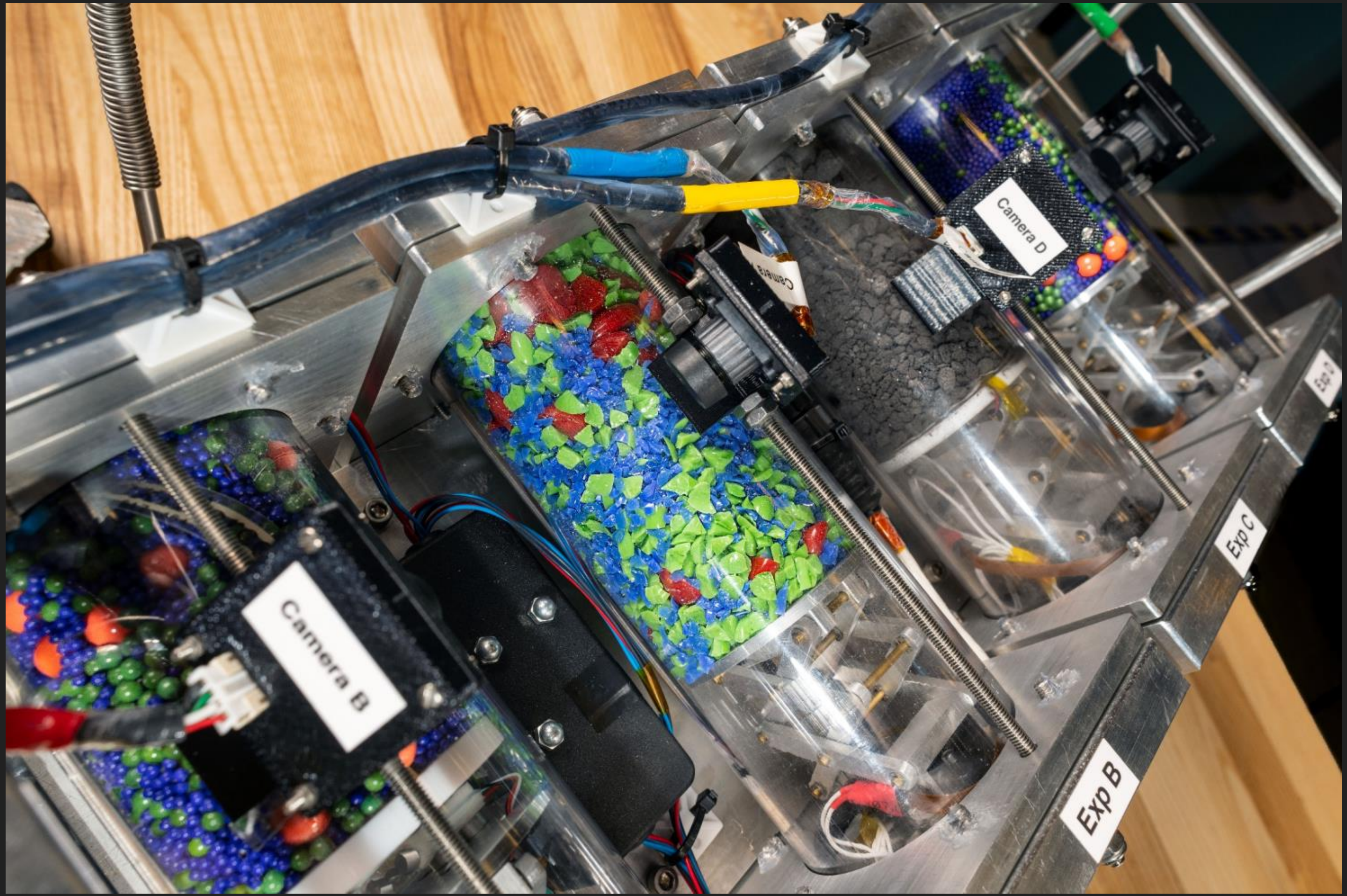
Flexible – Extendable – Robust – Minimal Crew Time

What is a Cassette?

- A Cassette will “plug in” to Hermes
  - Crew will remove and replace when complete
  - One Cassette at a time
- A Cassette is comprised of 4 experiments
  - Experiments can operate for hours, days, or months
  - Pre-integrated on the ground
- Control of Experiment “Tools”
  - All experiment activities will be commanded from the ground with no need for crew interaction
  - Adjustable settings (e.g. dim lights, actuate tool, change picture cadence)

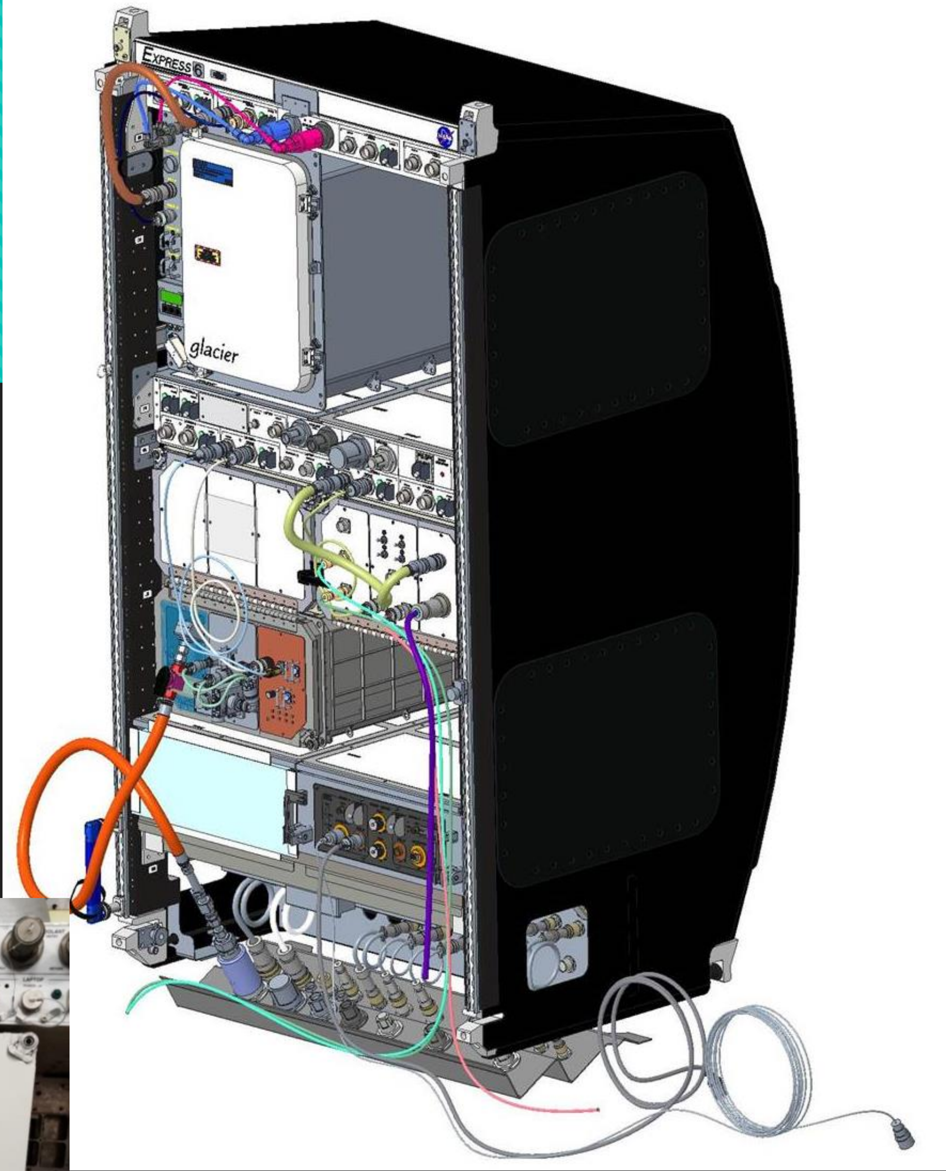
Hermes Cassettes & Tubes



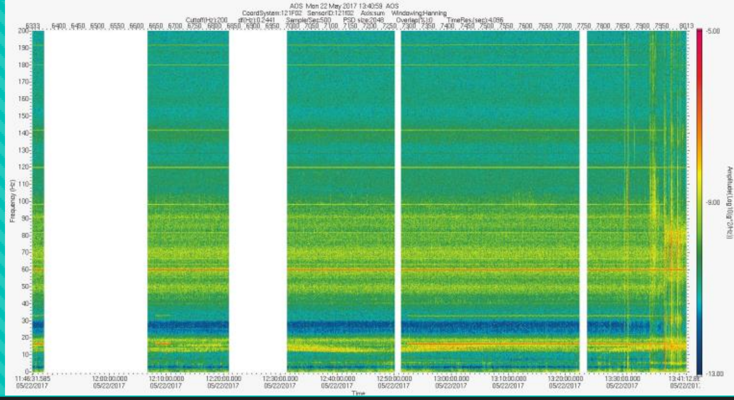


ISS Interfaces

- Topology: Locker Location, EXPRESS Rack 6, Locker Location 8
- Structural (Facility is Express Rack Locker, Cassette mounts to locker via rails)
- Hermes Door/Front Panel (connections to VRS, SAMS, data, power)
- Data (Ethernet RJ-45 plug for data connection)
- Power (ISS-provided 28 VDC Express Rack power cable)
- VRS (Vacuum Resource System)
- Thermal (fan/filter for AAA; facility component)
- SAMS / TSH-ES (using ISS-provided SAMS accelerometer sensor, facility component)
- Human Factors (covered by ICD/IRB)

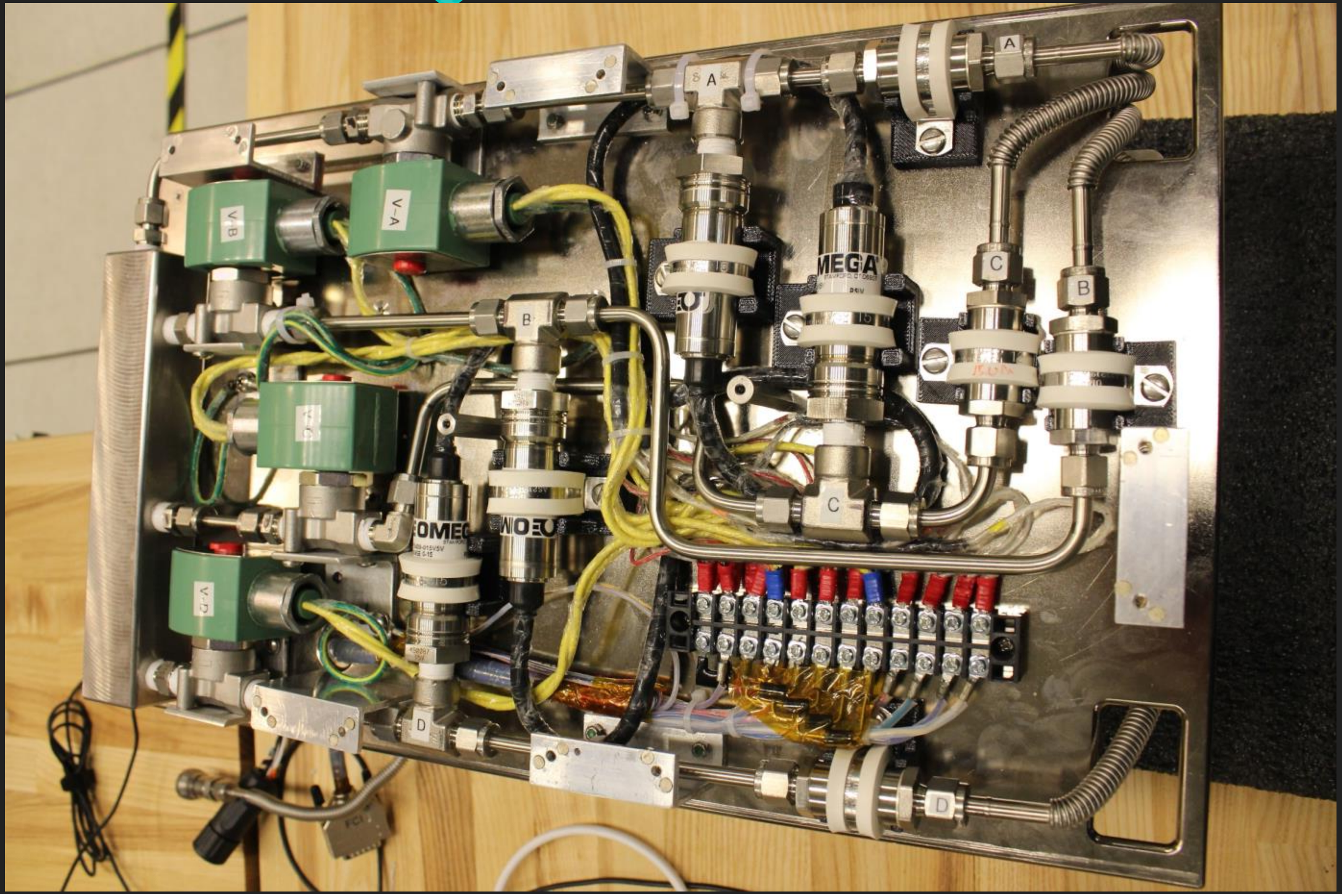


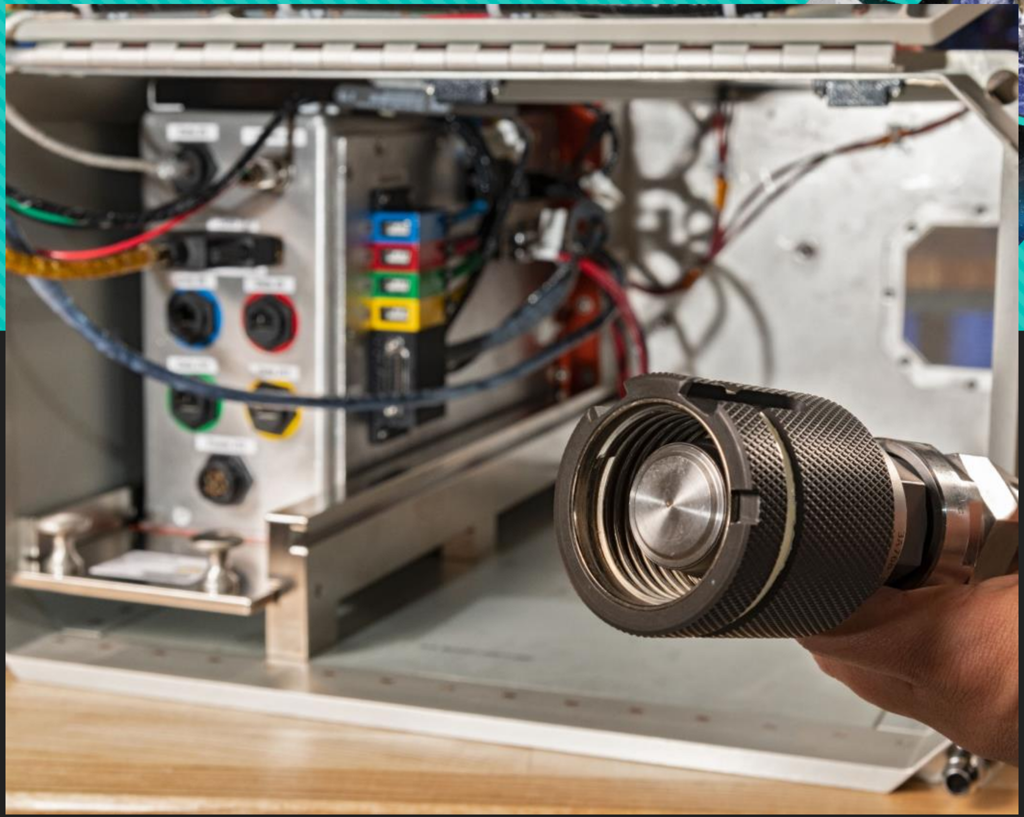
SAMS Data – A Vital Dataset



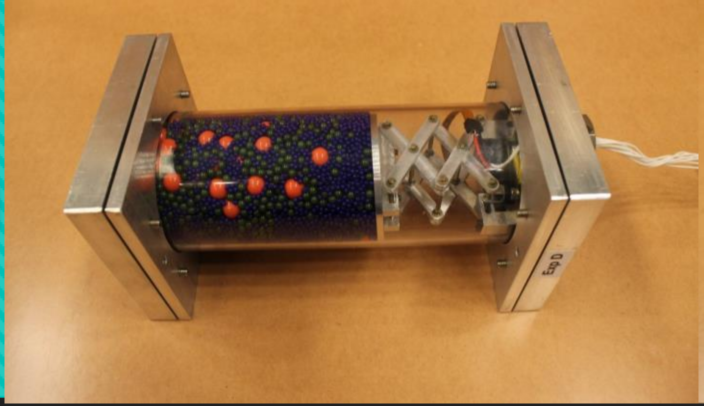
- The Space Acceleration Measurement System (SAMS) is an ongoing study of the small forces (vibrations and accelerations) on the International Space Station (ISS) resulting from the operation of hardware, crew activities, dockings and maneuvering
- *Background*, *diurnal cycling*, *transients* ("thumps") are all similar in duration and magnitude on small bodies
- Hermes is capable of utilizing SAMS or TSH-ES

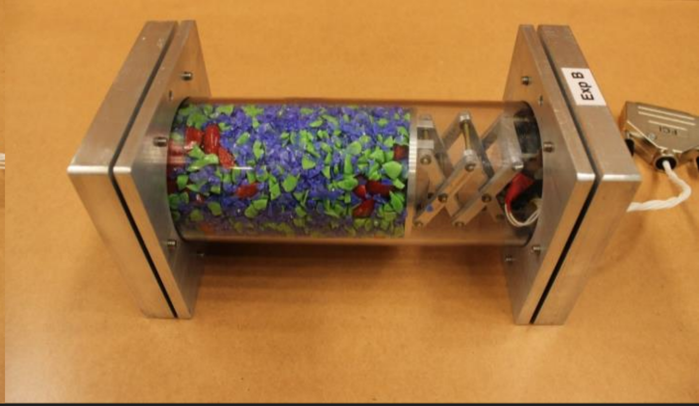
Vacuum System





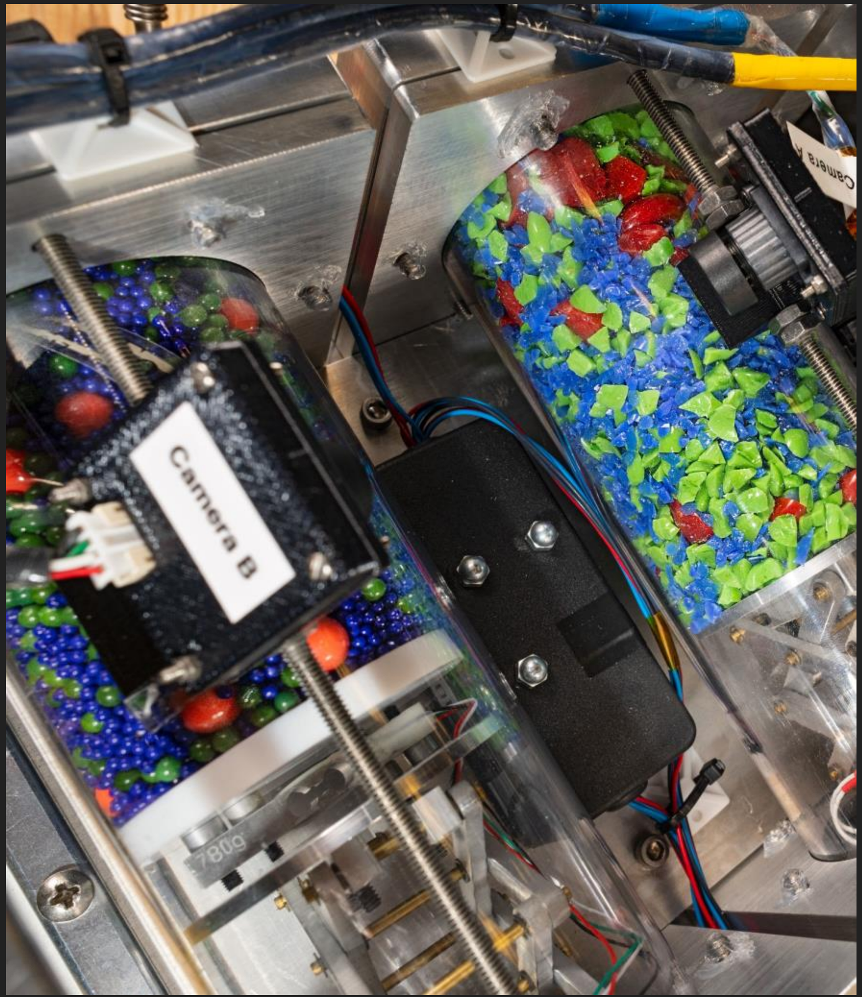
Cassette-1 Science Granular Segregation Experiments



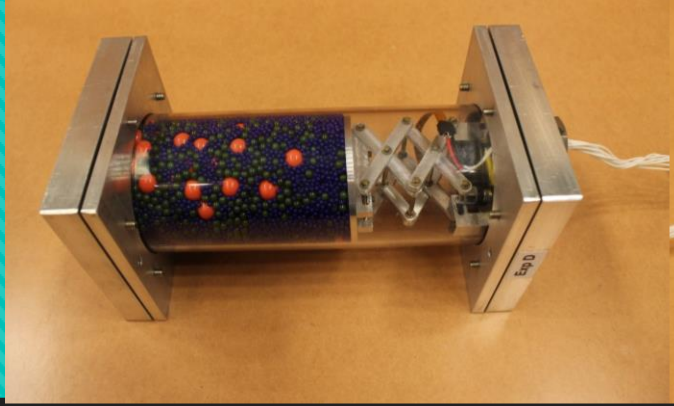


Two Granular Segregation Tubes

- Strata-1 Spherical Glass Bead and Angular Glass Bead Tubes
- Control size distribution
- Entrapulator 2.0
  - Control and use Entrapulator throughout experiment
- Glass beads only (for model validation)
- Science Objective 1: Determine role that grain size and shape play in regolith dynamics
- Science Objective 2: Validate and improve small body models
- Can compare these experiments to Strata-1; Compare these experiments to exploration experiments

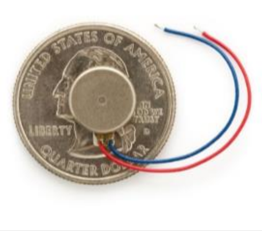


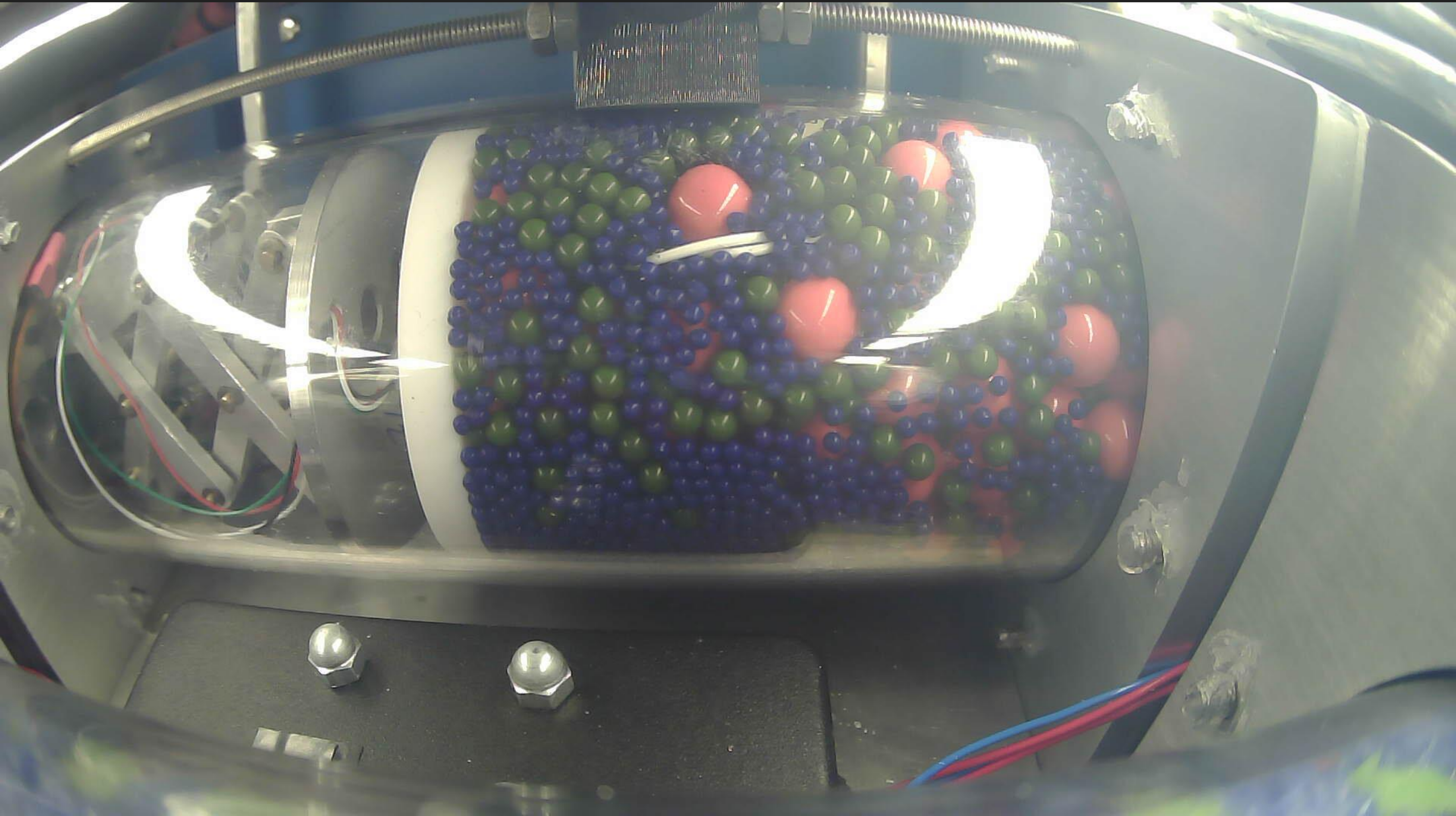
Cassette-1 Science Exploration Experiments

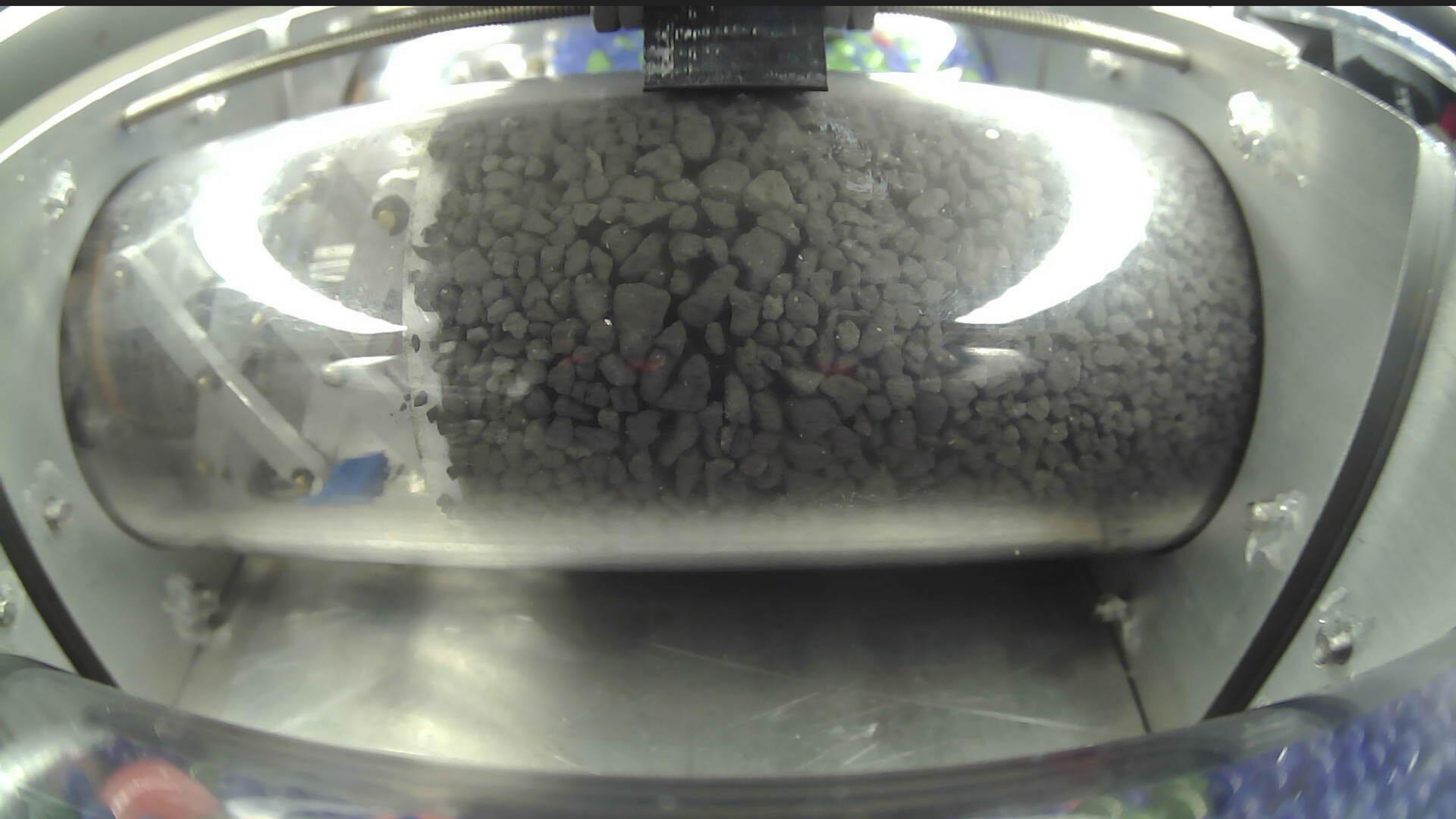


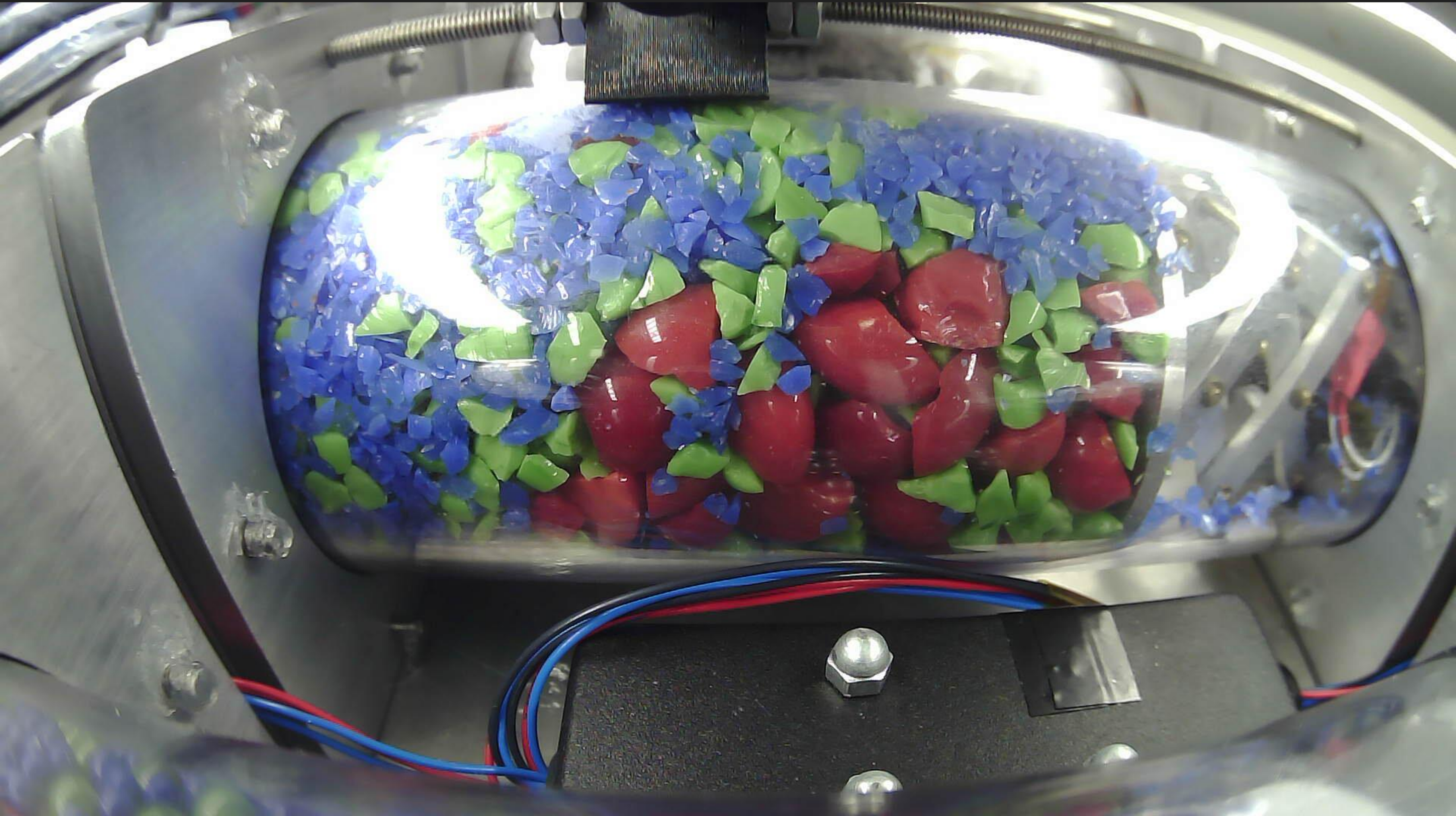
Two Exploration Tubes

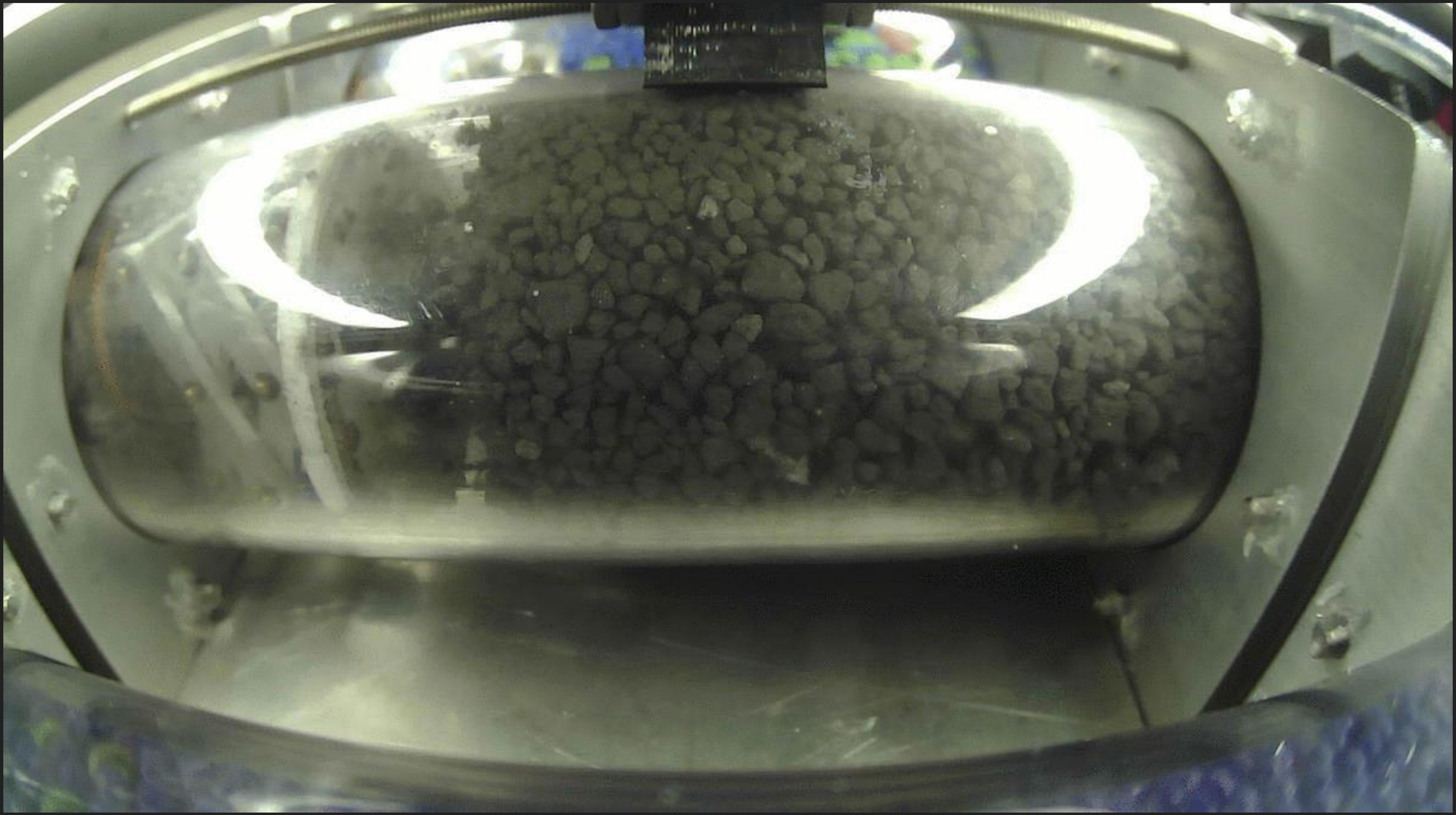
- Entrapulator, phone motor, load cell, force sensors
- Entrapulator has spacesuit material on it
- Phone motor is used to shake off regolith
- Simulant: Silica glass simulant and a meteorite simulant
- Science Objective 1: Cohesion Between Entrapulator Surface and Regolith (Press the entrapulator against the surface; see how vigorously we need to shake it; for various grain mixtures and materials)
- Science Objective 2: Adhesion of Regolith to Spacesuit Materials
- Science Objective 3: Force measurements (Load cell and force sensors allows for characterization of compression force; tie back to small body dynamics)









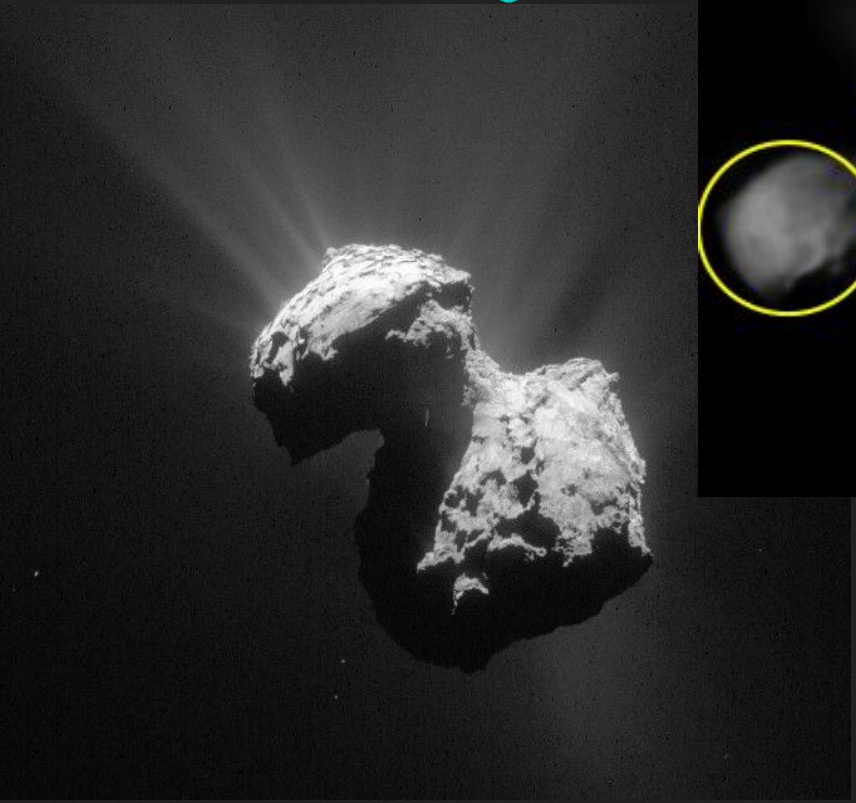


Small Bodies Move. Great. Why Should We Care?

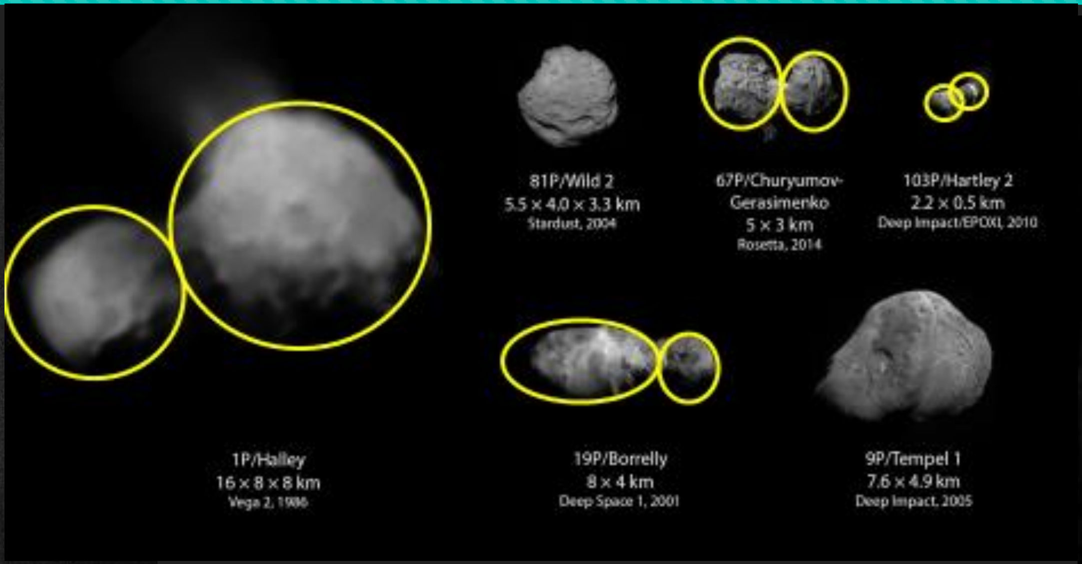
- Future missions, crewed and robotic, that visit small bodies should know how to interact with a loosely-aggregated surface
  - Best way to sample material?
  - How do you set anchors?
  - How do you safely move and process material for ISRU?
  - What materials properties should you expect for the surface? How much will fly free when disturbed?
- Sample return missions (CAESAR, OSIRIS-Rex, ARM, Hayabusa-1, Hayabusa-2, etc.)
  - When you examine material collected from the surface, is it representative of the bulk asteroid or comet? Or is it the product of a particle size/density segregation process?

Graphic: ESA/Rosetta

Bi-lobate Bodies



Comet 67P/Churyumov-Gerasimenko, ESA Rosetta Target, Bilobate body, Target for NASA CAESAR Sample Return Mission (Credit: ESA Rosetta)

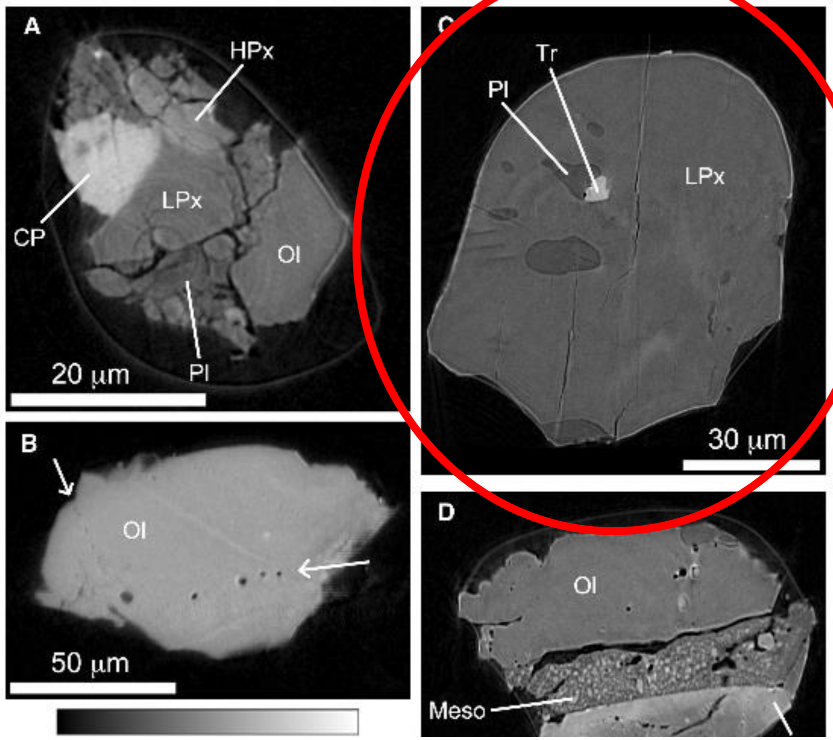


Most of the comets we have seen up close are bi-lobate, suggesting they have deformed significantly (Credit: M. Fries)

Asteroid 2014 JO25
Near-Earth Object (NEO); Radar imagery shows a bilobate structure; Bilobate bodies are common – why?
~650m diameter (Credit: Arecibo/Goldstone)

Small Bodies *Flow*

- JAXA's Hayabusa-1 mission to asteroid Itokawa returned small grains
  - Some of those grains are *rounded*
  - On Earth, rounded grains arise from water or wind action
  - On Itokawa, the only explanation is that the body is actively moving and abrading grains

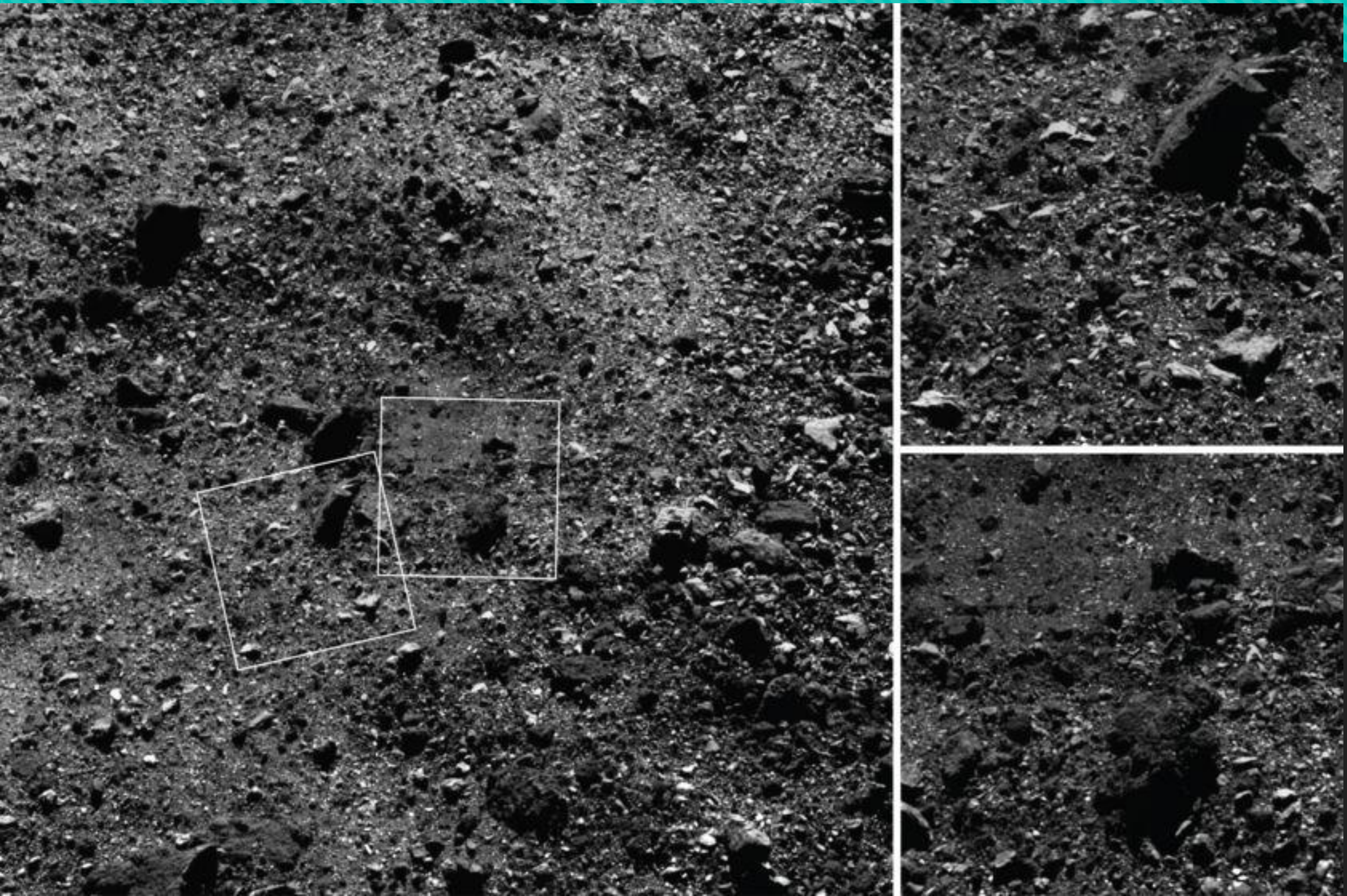


Three-Dimensional Structure of Hayabusa Samples: Origin and Evolution of Itokawa Regolith

Akira Tsuchiyama,[1]* Masayuki Uesugi,[2] Takashi Matsushima,[3] Tatsuhiro Michikami,[4] Toshihiko Kadono,[5] Tomoki Nakamura,[6] Kentaro Uesugi,[7] Tsukasa Nakano,[8] Scott A. Sandford,[9] Ryo Noguchi,[1] Toru Matsumoto,[1] Junya Matsuno,[1] Takashi Nagano,[1] Yuta Imai,[1] Akihisa Takeuchi,[7] Yoshio Suzuki,[7] Toshihiro Ogami,[6] Jun Katagiri,[3] Mitsuru Ebihara,[10] Trevor R. Ireland,[11] Fumio Kitajima,[12] Keisuke Nagao,[13] Hiroshi Naraoka,[12] Takaaki Noguchi,[14] Ryuji Okazaki,[12] Hisayoshi Yurimoto,[15] Michael E. Zolensky,[16] Toshifumi Mukai,[2] Masanao Abe,[2] Toru Yada,[2] Akio Fujimura,[2] Makoto Yoshikawa,[2] Junichiro Kawaguchi[2]

Regolith particles on the asteroid Itokawa were recovered by the Hayabusa mission. Their three-dimensional (3D) structure and other properties, revealed by x-ray microtomography, provide information on regolith formation. Modal abundances of minerals, bulk density (3.4 grams per cubic centimeter), and the 3D textures indicate that the particles represent a mixture of equilibrated and less-equilibrated LL chondrite materials. Evidence for melting was not seen on any of the particles. Some particles have rounded edges. Overall, the particles' size and shape are different from those seen in particles from the lunar regolith. These features suggest that meteoroid impacts on the asteroid surface primarily form much of the regolith particle, and that seismic-induced grain motion in the smooth terrain abrades them over time.

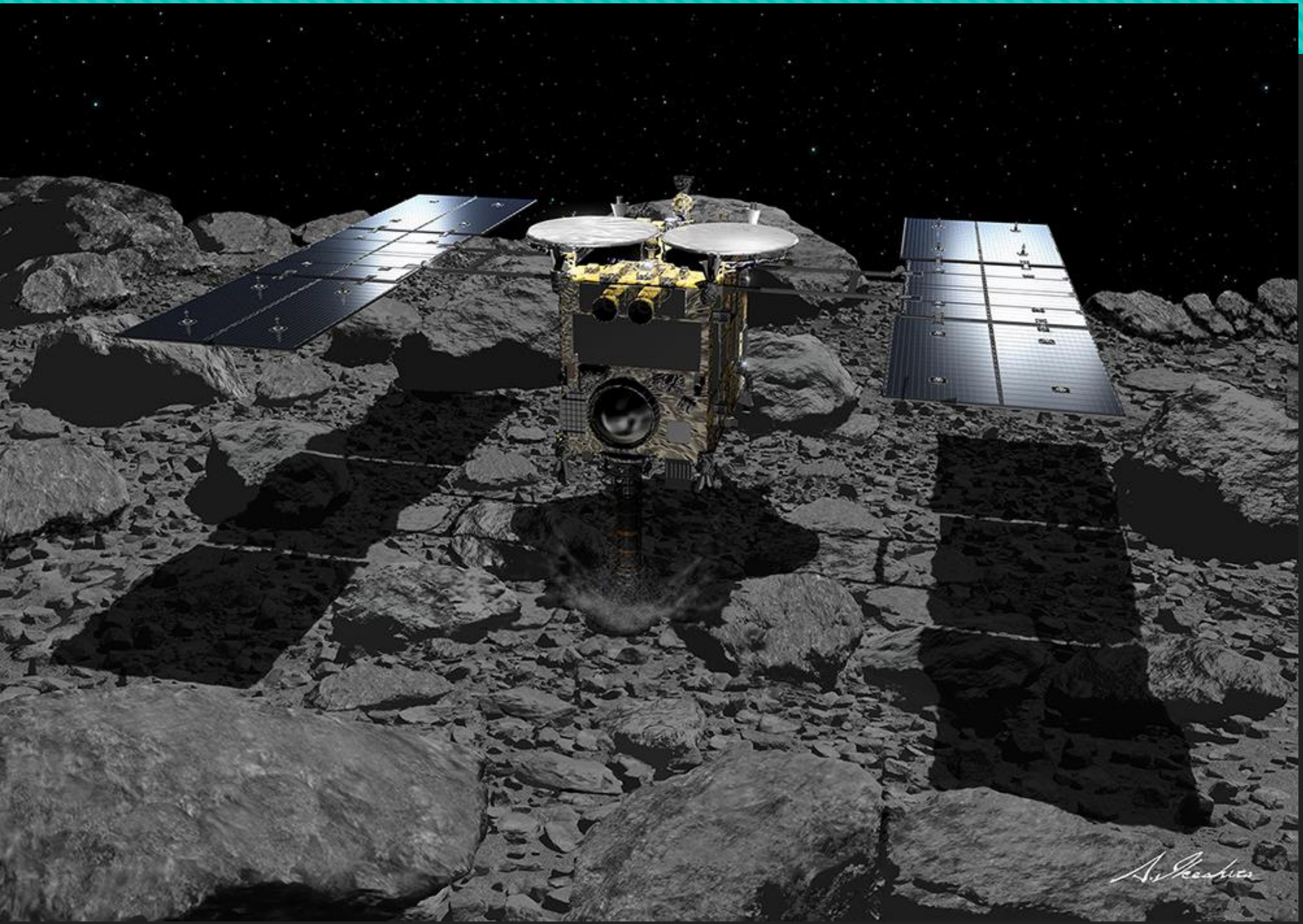
Bennu's Regolith



REGOLITH POND ON BENNU

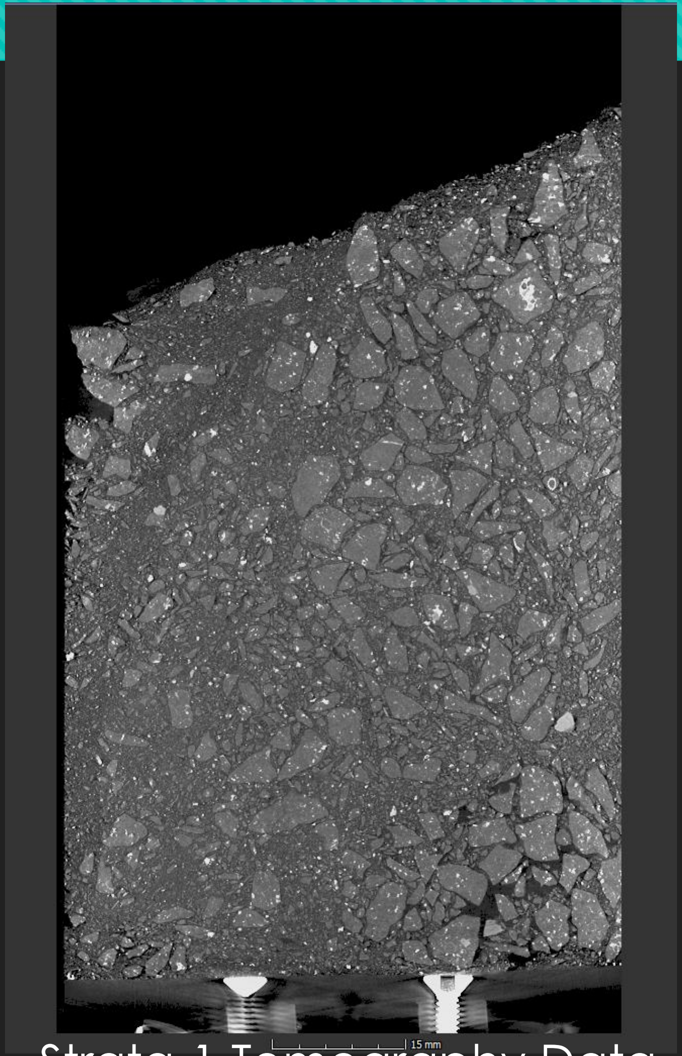
"This trio of images acquired by NASA's OSIRIS-REx spacecraft on 25 February approximately 1.8 kilometers from the surface shows a wide shot and two close-ups of a region in Bennu's northern hemisphere. The wide-angle image (left), obtained by the spacecraft's MapCam camera, shows a 180-meter-wide area with many rocks, including some large boulders, and a "pond" of regolith that is mostly devoid of large rocks. The two closer images, obtained by the high-resolution PolyCam camera, show details of areas in the MapCam image, specifically a 15-meter boulder (top) and the regolith pond (bottom). The PolyCam frames are 31 meters across." – From Planetary Society

Ryugu's Crater

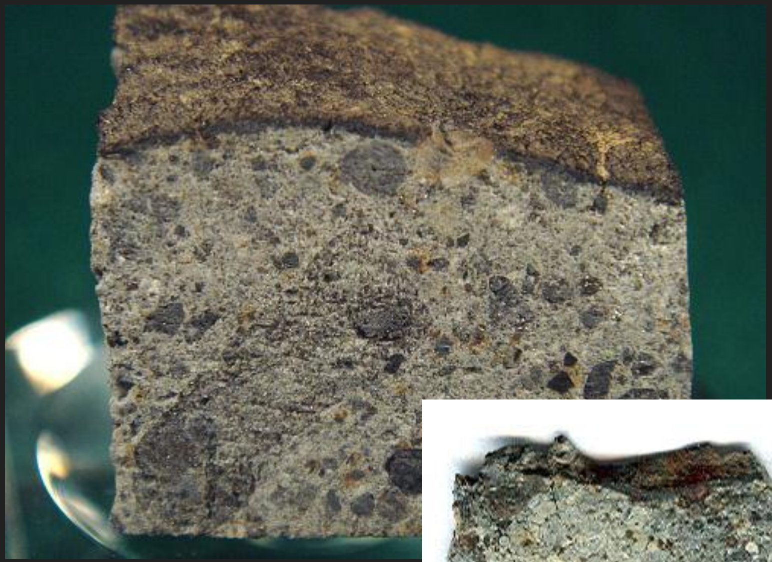


- "As part of its mission to explore the Near-Earth Asteroid (NEA) 162173 Ryugu, the Japan Aerospace Exploration Agency's (JAXA) *Hayabusa2* spacecraft recently dropped a "bomb" on the asteroid's surface. This explosive package, known as the Small Carry-on Impactor (SCI), was specifically designed to create a crater in the surface, thus exposing the interior for analysis.
- The deployment of the SCI took place on April 5th, exactly six weeks after the spacecraft collected its first sample from the surface. Last Sunday, (April 21st, 2019), JAXA provided the video of the "bombing run" via the mission's official twitter account. This was followed four days later by images of the crater that resulted, which revealed darker material from the interior that was now exposed to space.
- The SCI operation consisted of a 2.5 kg (5.5 lbs) copper plate being accelerated by a shaped-charge of 4.5 kg (~10 lbs) of plasticized HMX explosive (aka. octogen) – used in military-grade weapons and munitions. The plate then collided with the surface, releasing a cloud of regolith that was then photographed by the spacecraft's deployable camera (DCAM3) – which was destroyed in the process." – From Universe Today

Similarities with Regolith Breccia Meteorites



Strata-1 Tomography Data



Adzhi Bogdo
LL3-6 breccia

NWA
2791 LL3-4
breccia

Kendleton L4 breccia

Breccia - rock consisting of angular fragments cemented together

How do I use Hermes?

- Hermes is currently operated by NASA JSC ARES
- Interested users should reach out to Paul Abell, Kristen John, Marc Fries, Kenton Fisher, Will Stefanov, Dan Garrison, or Paul Niles at NASA JSC
- Users will have to fund:
  - Development of the experiments (Cassette)
  - Ground integration costs (to be performed by ARES or user)
  - Ground support costs (to be performed by ARES or user)
  - Analysis and future work with data
- ISS will provide:
  - Launch
  - ISS integration services
  - On-orbit installation and support

Hermes Team

- **JSC**
  - PI: Kristen John
  - PM: Veronica Saucedo
  - SE&I: Pedro Curiel
  - Vacuum: Kenton Fisher
  - PRCU Integration: Gaschen Geissen
  - Structures: Matt Hernandez, Peter Taylor
  - Thermal: Scott Coughlin
  - Manufacturing: James Brown
  - Manufacturing Intern: Alissa Chavalithumrong
  - Technical Advisor: Paul Abell
  - Technical Advisor: Marc Fries
  - Technical Advisor: Lee Graham
  - Operators: Kristen John, Kenton Fisher, Angela Garcia
- **T STAR and Texas A&M**
  - C&DH: Matt Leonard
  - C&DH: Joseph Morgan
  - C&DH Hermites Team: Dustin Tish, Jeremy Coffelt, Luis Orozco
  - C&DH MARS Team: Colby Ryan, Alexis Crandall, Mitch Martinez, David Kennedy, Kristian Ecolango
- **University of Central Florida**
  - Experiments: Adrienne Dove
  - Experiments: Josh Colwell
  - Data Analysis: Gillian Gomer
  - Electrical: Jacob Anthony
  - Mechanical Design: Alex Heise, Anna Metke, and Sean Shefferman

ISS Integration Team

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Thank you!

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