Hermes

Asteroids on the ISS!

(A Microgravity Facility for Regolith Research)

Thursday, Oct 25th, 2018

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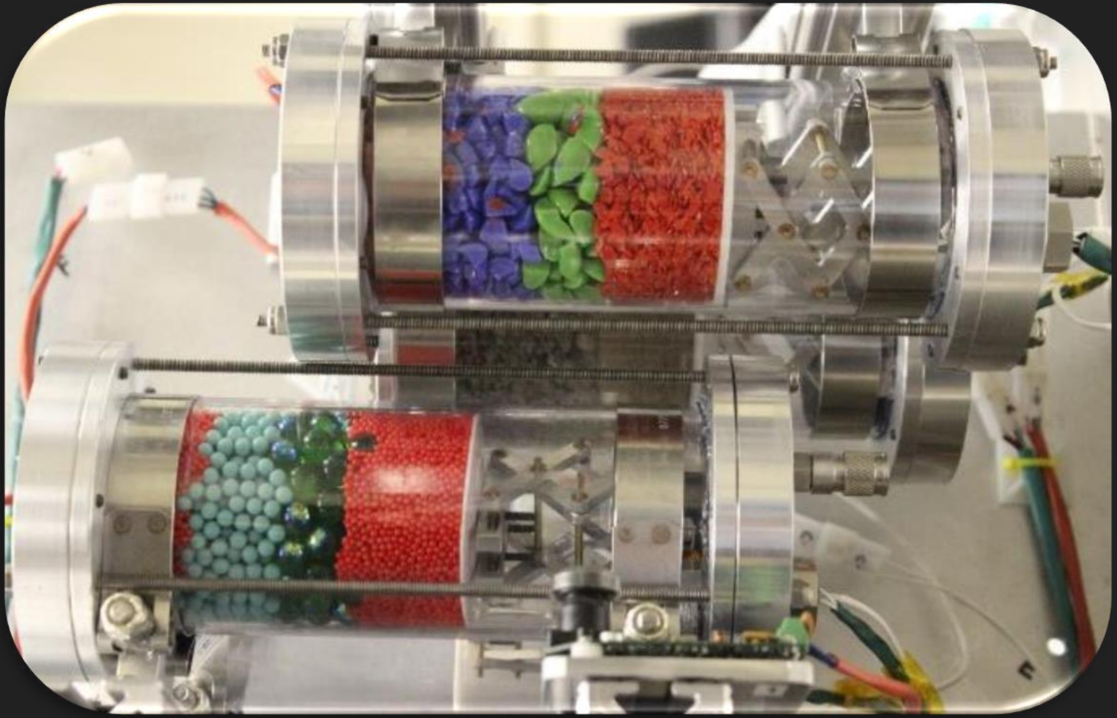
NASA JSC – Astromaterials Research & Exploration Science Division
Payload Developers: NASA JSC, Texas A&M, T STAR, UCF

Hermes in a Nutshell

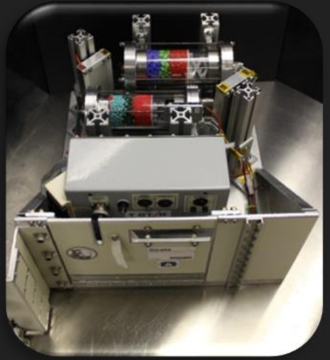
- A microgravity experimental facility launching to ISS
  - Jan 24, 2019 Hardware Delivery (NG-11 Launch)
- Reconfigurable on-orbit experiment facility
  - **4 experiments at a time** (Cassette)
  - Power & control provided by Hermes
- Focused on asteroid and small body investigations
- Express Rack Locker payload
- **Leveraging Strata-1 heritage**



Strata-1 Experiments

Class I-E

- Hermes is utilizing the JSC Class I-E paradigm
  - Development of experimental flight hardware in less time, less cost, and without compromising safety of the ISS
  - The intent of the life-cycle phases, gates and reviews remain, but oversight is minimized
- Hermes is the first Class I-E Facility
- Strata-1 served as Class I-E pathfinder, provided new information on regolith properties on small worlds



Strata-1

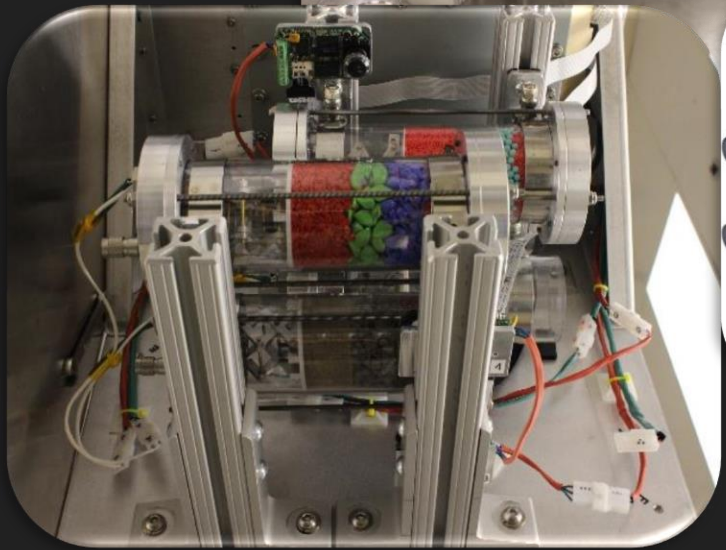
Biomolecule Sequencer

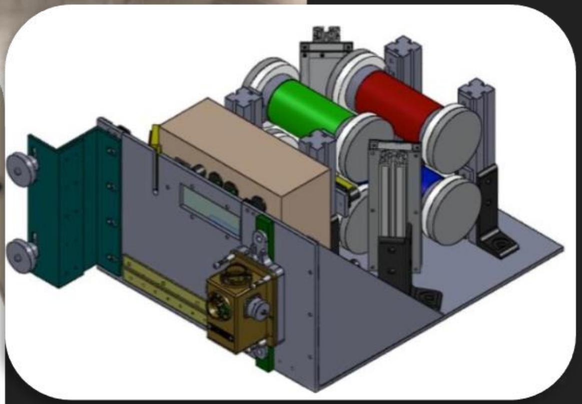
The ISS – The Perfect Place to Study Asteroids

- 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.*





Regolith

- Regolith is the layer of loose material covering bedrock
- Regolith covers all 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

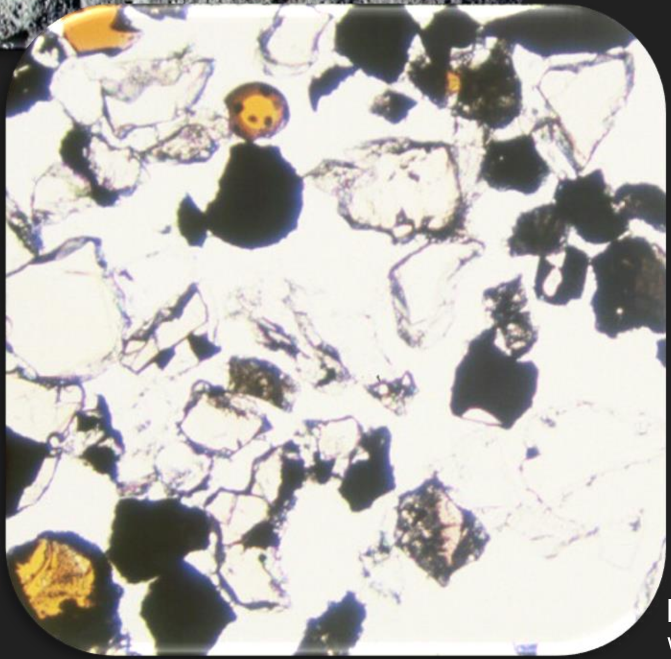


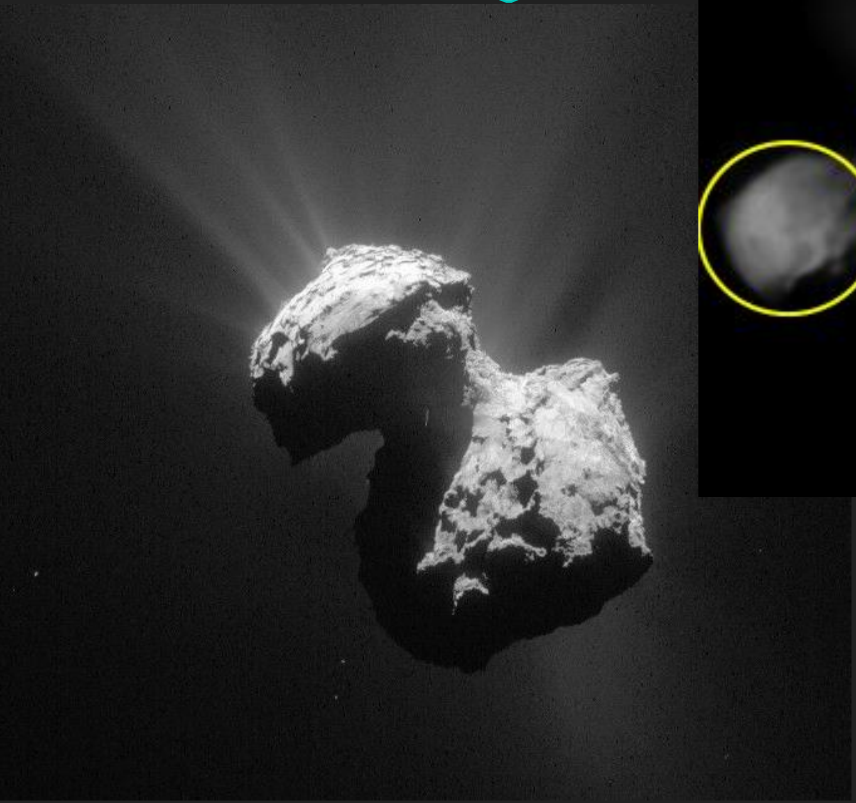
Image credit: WUSTL

Small Bodies Move. Great. Why Should We Care?

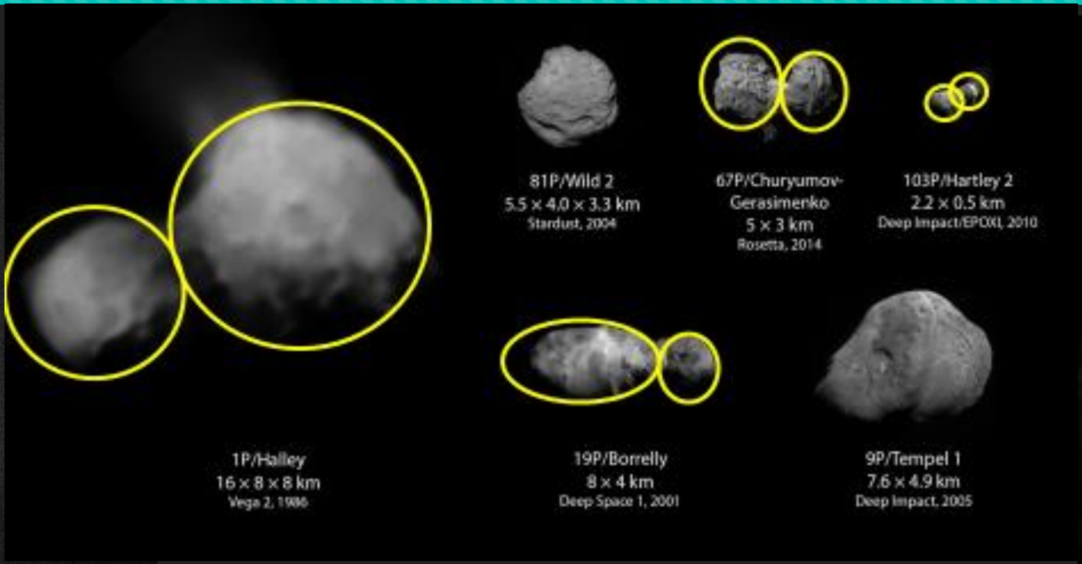
- Future missions, crewed and robotic, that visit small bodies should know how to interact with a loosely-aggregated surface
  - Best way to sample material?
  - How do you set anchors?
  - How do you safely move and process material for ISRU?
  - What materials properties should you expect for the surface? 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)

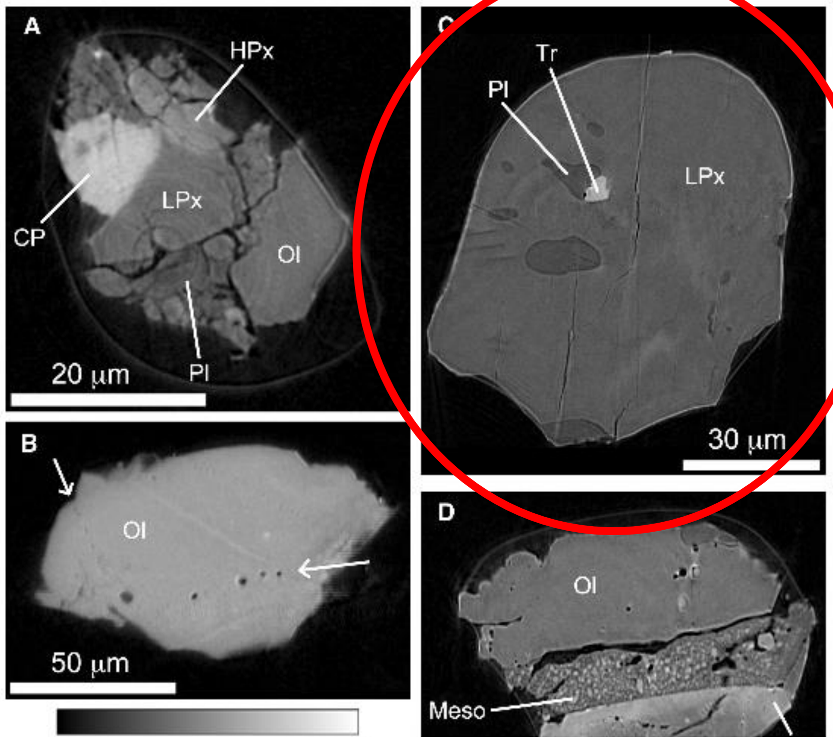


Most of the comets we have seen up close are bi-lobate, suggesting they have deformed significantly (Credit: M. Fries)

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

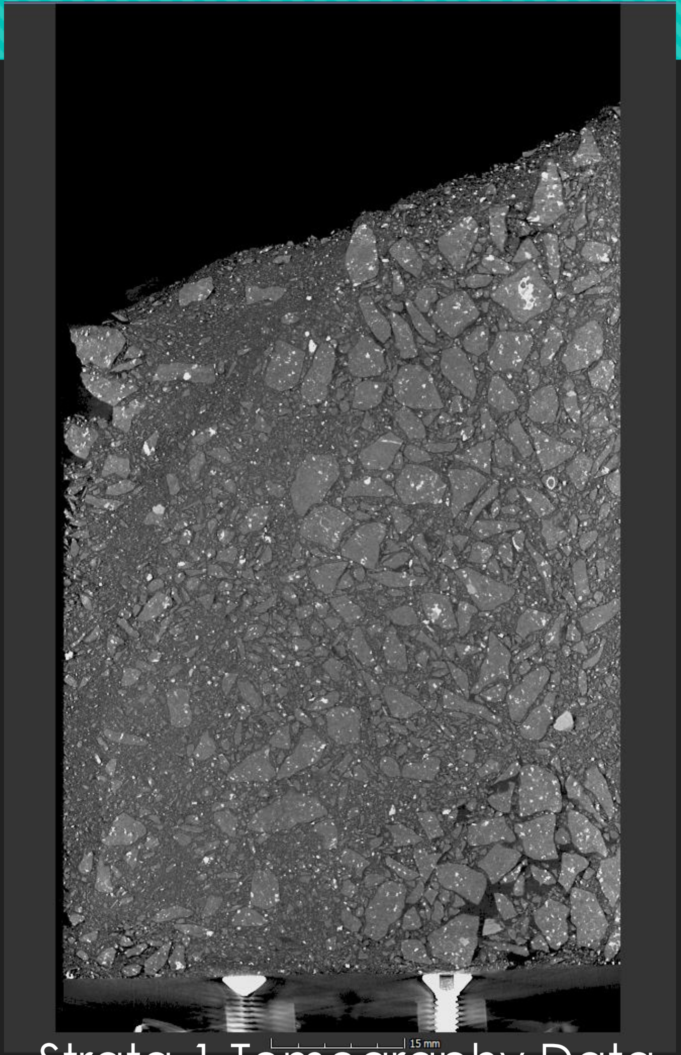
Akira Tsuchiyama,[1]* Masayuki Uesugi,[2] Takashi Matsushima,[3] Tatsuhiro Michikami,[4] Toshihiko Kadono,[5] Tomoki Nakamura,[6] Kentaro Uesugi,[7] Tsukasa Nakano,[8] Scott A. Sandford,[9] Ryo Noguchi,[1] Toru Matsumoto,[1] Junya Matsuno,[1] Takashi Nagano,[1] Yuta Imai,[1] Akihisa Takeuchi,[7] Yoshio 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.

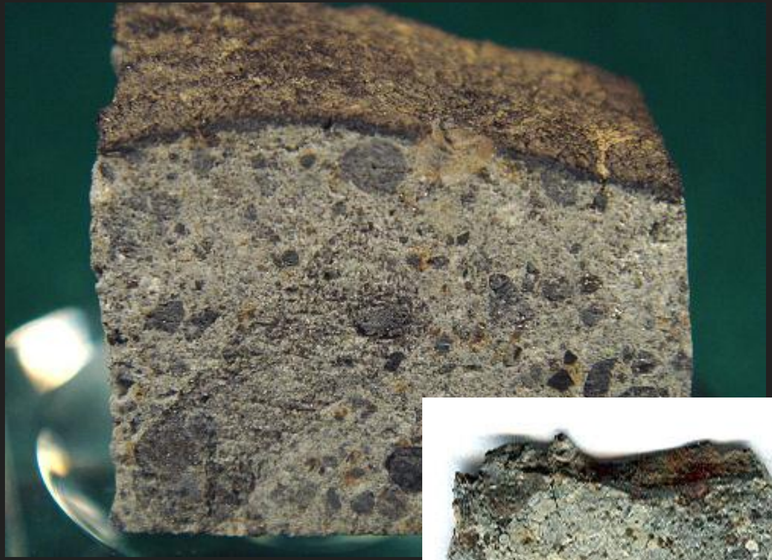
Look at bulk material behavior; "landslide" halfway through video; movement of material as acceleration vector changes

Tracking particles of different sizes; brazil nut effect; movement of material as acceleration vector changes

Similarities with Regolith Breccia Meteorites



Strata-1 Tomography Data



Adzhi Bogdo
LL3-6 breccia

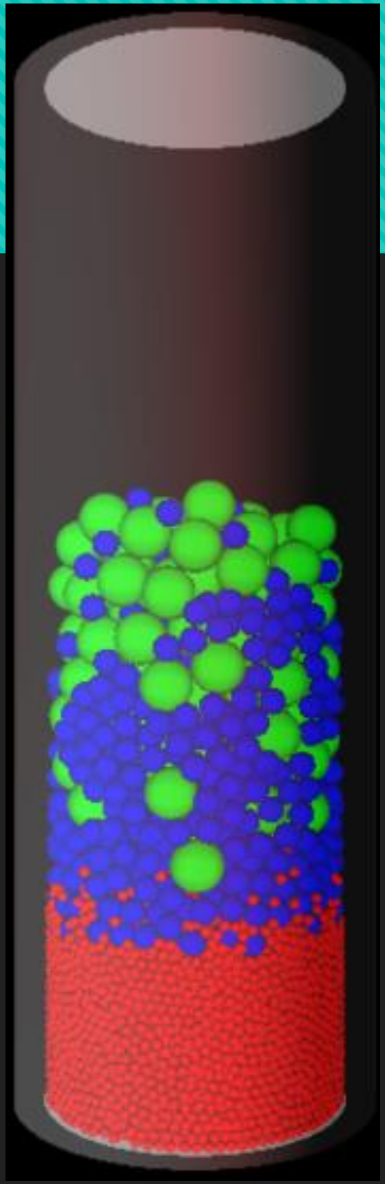
NWA
2791 LL3-4
breccia

Kendleton L4 breccia

Breccia - rock consisting of angular fragments cemented together

Data Analysis and Future Work

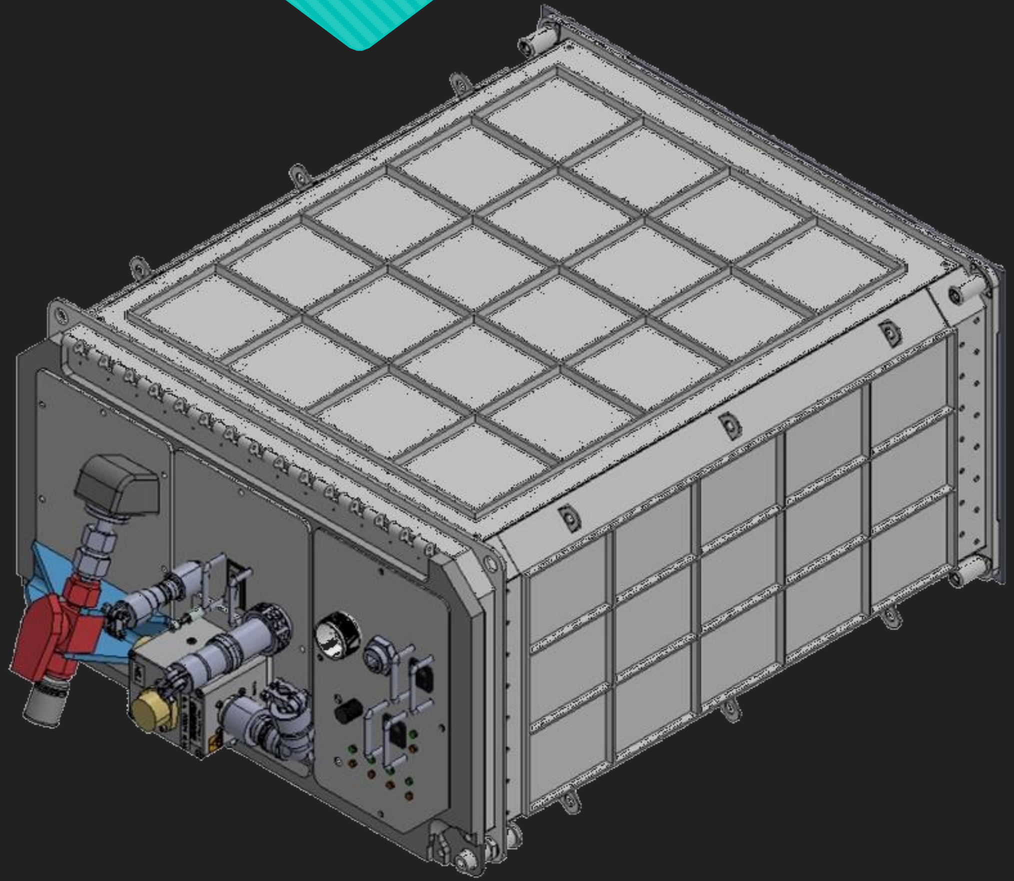
- Analysis of:
  - Imagery (100's of GBs, tens of thousands of pictures): Produce videos of particle perturbations over time scales analogous to small bodies; long-term, diurnal, and impact-driven
  - SAMS 3D accelerometer data reduction
  - Modeling of expected particle behavior given SAMS data
  - Comparison of modeled versus observed behavior
  - Conclusions on fidelity of existing models
- Tie observations in Strata-1 data to observations of small bodies
  - E.g. migrating regolith, Brazil-nut effect, size sorting, landslides
- Proposals are underway/submitted: NSF through U. Maryland, SMD ROSES through UCF, NASA PSI database



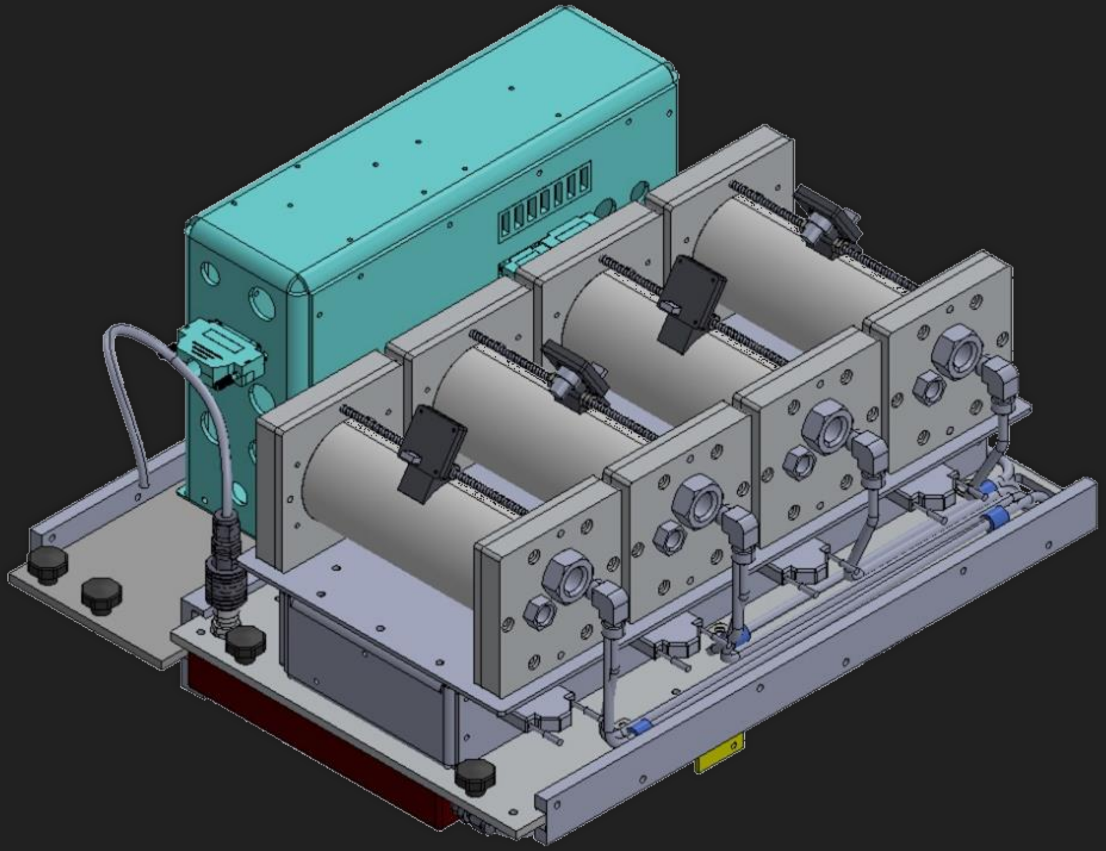
Why Hermes?

- In Greek mythology
  - Messenger
  - Moved freely between the worlds of the mortal and divine
- On the ISS
  - Messenger of data between space and scientists
  - Delivers new experiments to space

Hermes Configuration

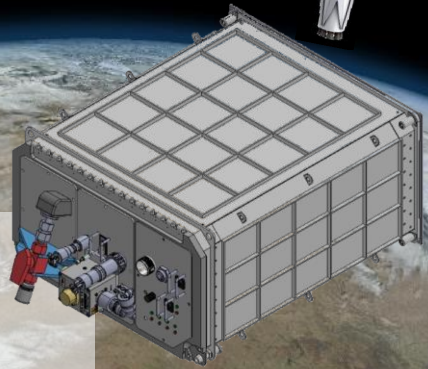


External View



Internal View

1. Construct Hermes facility: To consist of locker structure, fan, accelerometer, Electronics Box, vacuum hose, Vacuum Intelligence System, lighting, rails and space available for Cassette.



2. Construct Cassette-1: To consist of four clear, pre-integrated polycarbonate tubes (each filled with a different regolith simulant, as well active components), four HD cameras, and Cassette Intelligence System.

3. Launch Hermes; Launch Cassette-1

4. Install Facility in rack; Install Cassette-1

5. Crew to connect to power, data, and vacuum

6. Autonomous operations; activation of Experiment Tools; collect data; data downlink; commanding from ground; Maintaining vacuum

7. Meanwhile, Cassette-2 launches and arrives to ISS while Cassette-1 continues to operate

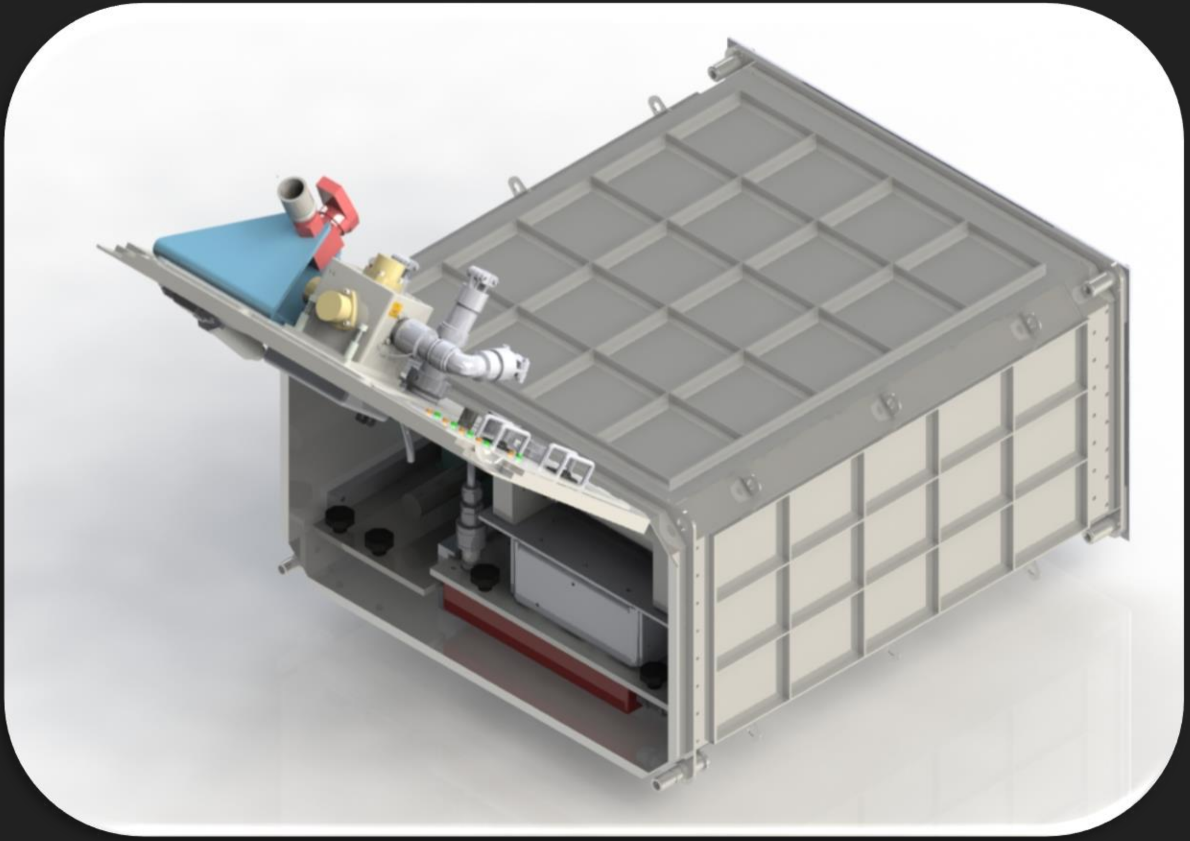
8. Completion of Cassette-1 mission; Power-off sequencing; Crew uninstalls

9. Crew installs Cassette-2; Power-On sequencing

10. Return Cassette-1; Scientific results & publications; Repeat the process for subsequent Cassettes

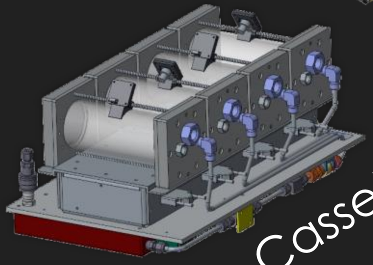
Hermes System Objectives

- 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

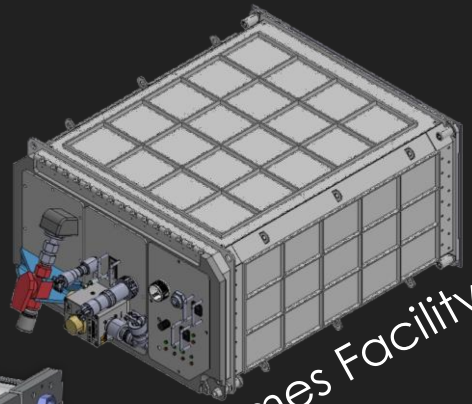


Flexible – Extendable – Robust – Minimal Crew Time

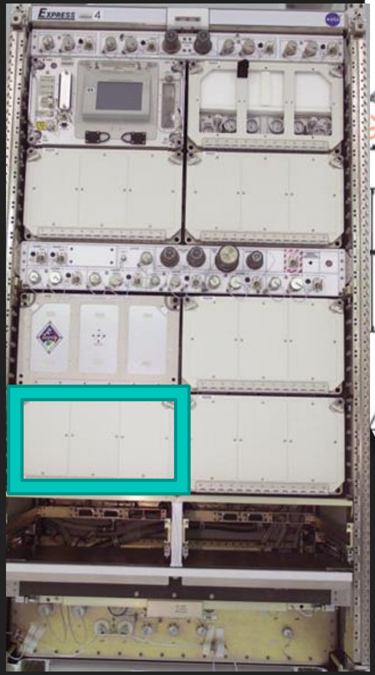
System Architecture



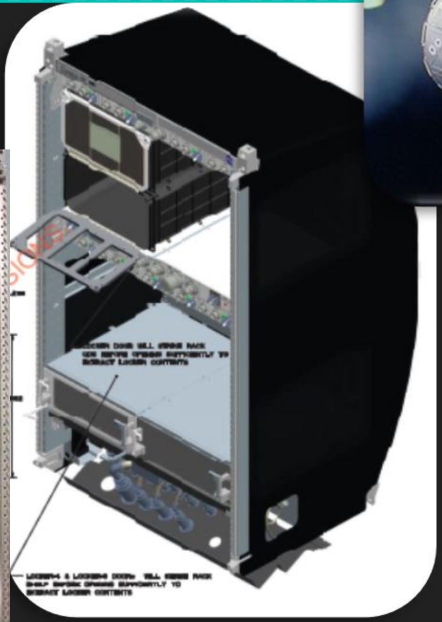
Cassette



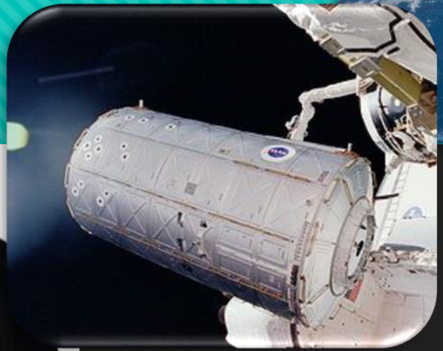
Hermes Facility



Locker Location 4



Express Rack 6



US Lab

ISS

System Architecture

Express Rack

SAMS mounted to Hermes, power and data provided by Hermes

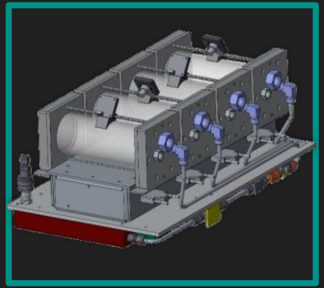
Express Rack Power & Data

ISS VRS

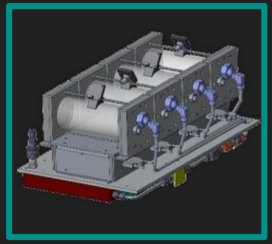
Hermes Facility

Cassettes integrated on the ground and launched separately; One Cassette loaded into Hermes at a time

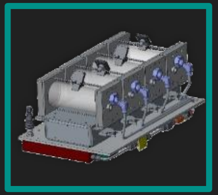
Cassette-1



Cassette-2

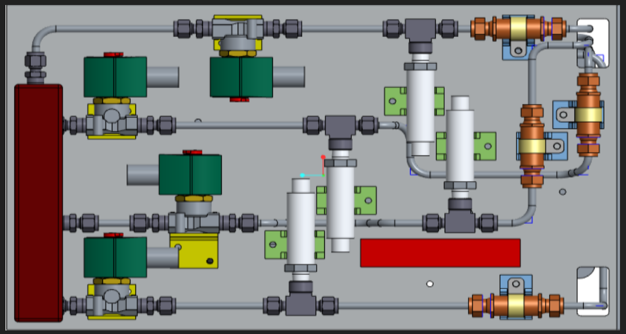


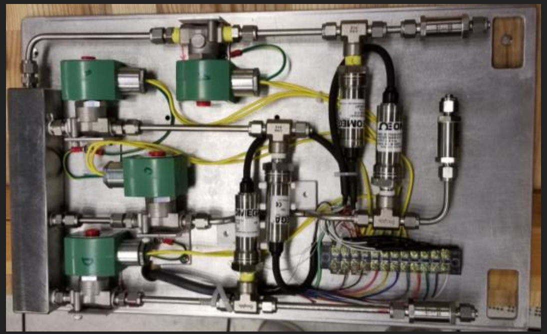
Cassette-3…

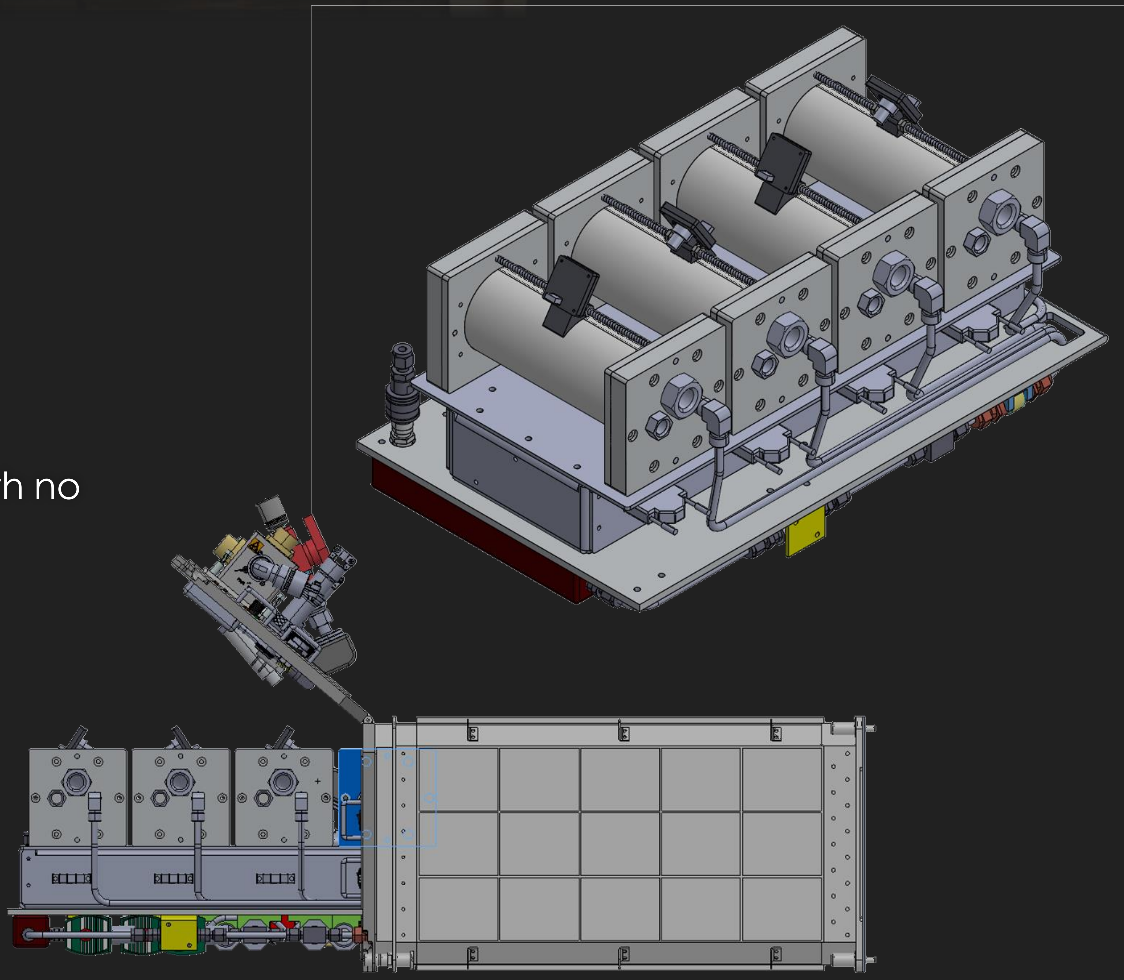


What is a Cassette?

- 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)

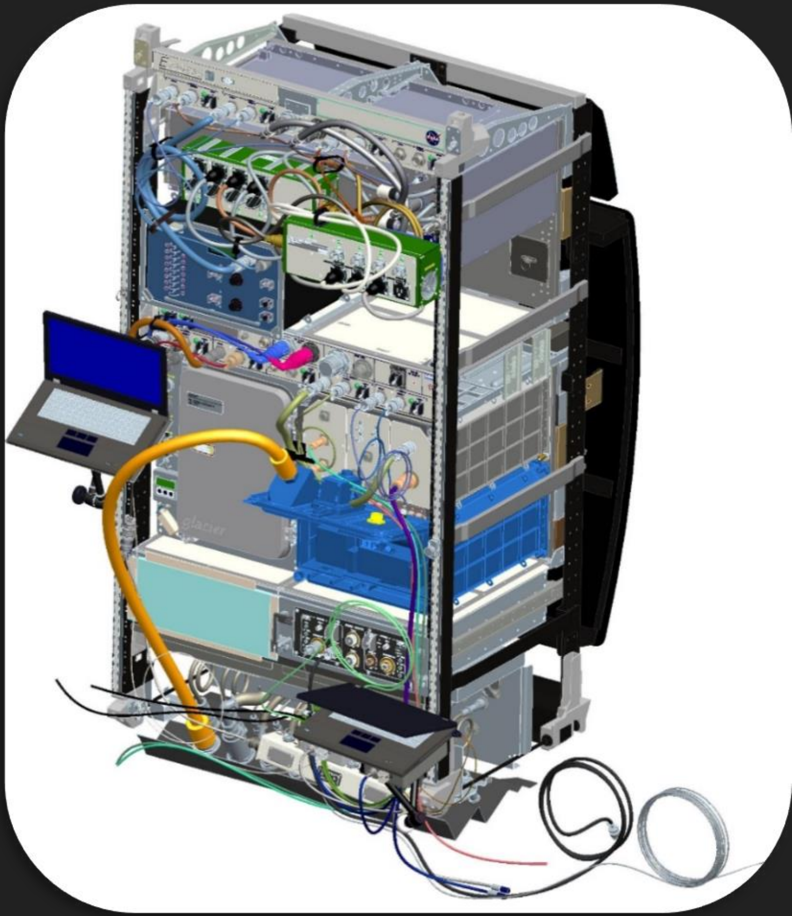




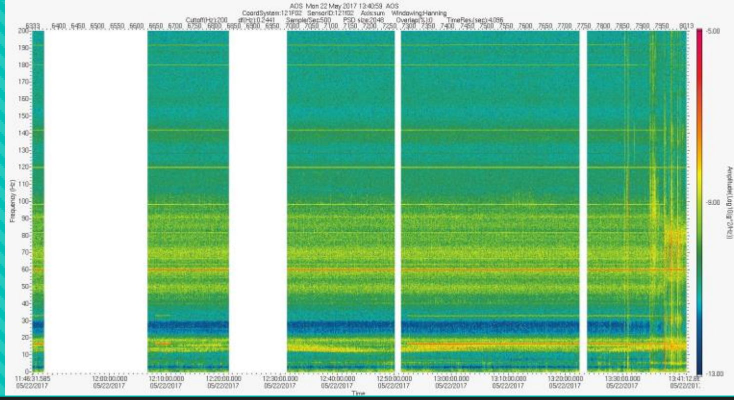


ISS Interfaces

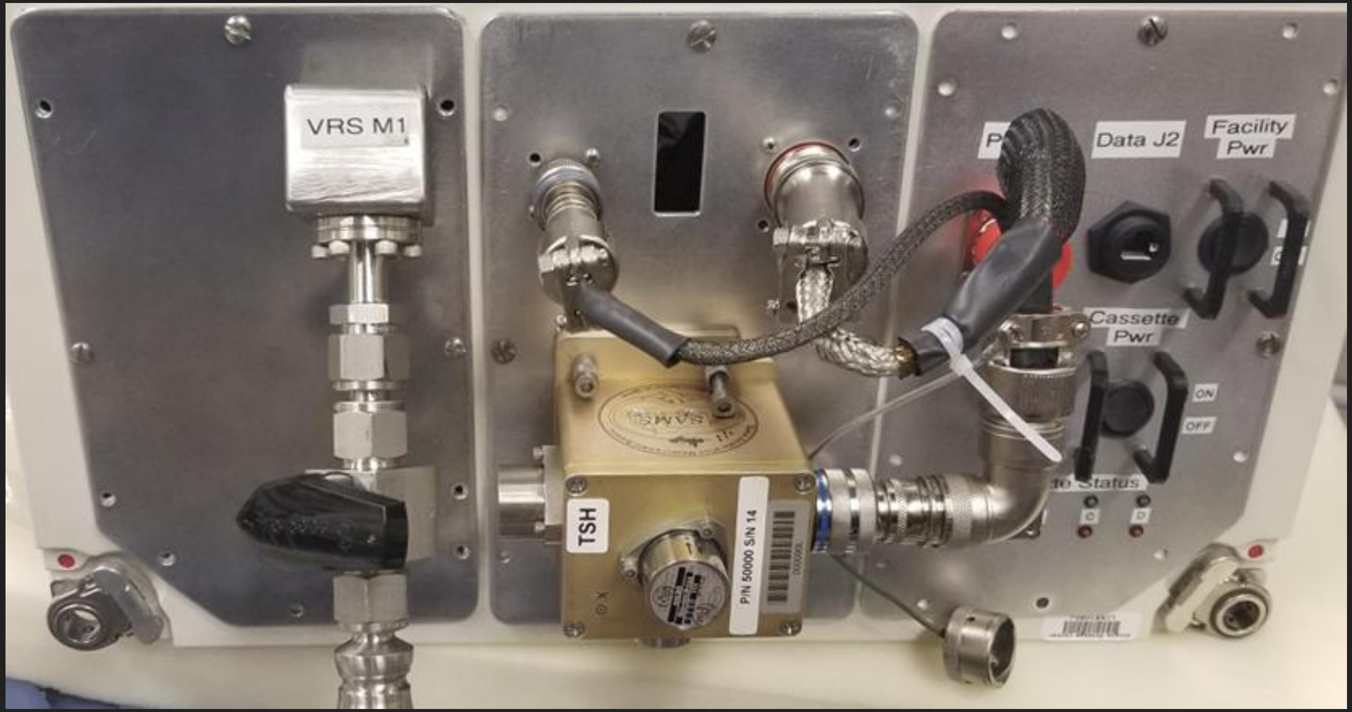
- Express Rack Locker
  - Express Rack 6, Locker Location 4
- Hermes Door/Front Panel (connections to VRS, SAMS, data, power)
- Data (Ethernet RJ-45 plug for data connection)
- Power (ISS-provided 28 VDC Express Rack power cable)
- SAMS accelerometer sensor
- SAMS / TSH-ES (using ISS-provided accelerometer sensor)
- Thermal (fan for AAA)
- Human Factors
- Vacuum
  - A series of filters, transducers, valves, and a connection to the ISS Vacuum Resource System (VRS) enable vacuum in each experiment (at least 10-3 torr)
- C&DH
  - Hermes Facility internal storage, ISS onboard storage, health and status monitoring, ground commanding of experiments, minimal crew interaction; utilizing TrEK, CFDP over DTN, NAS, QSync



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



ISS Location: US Lab

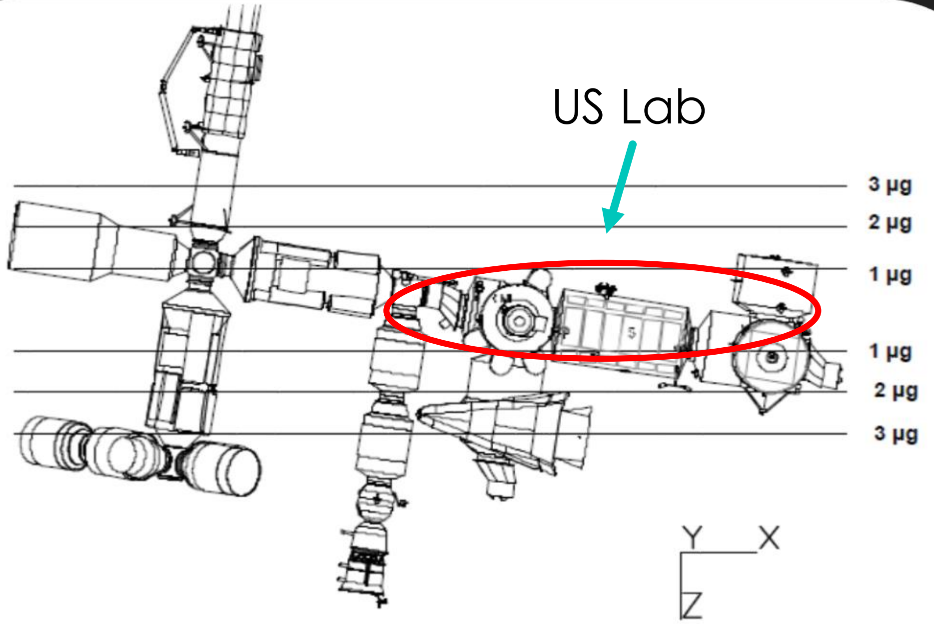
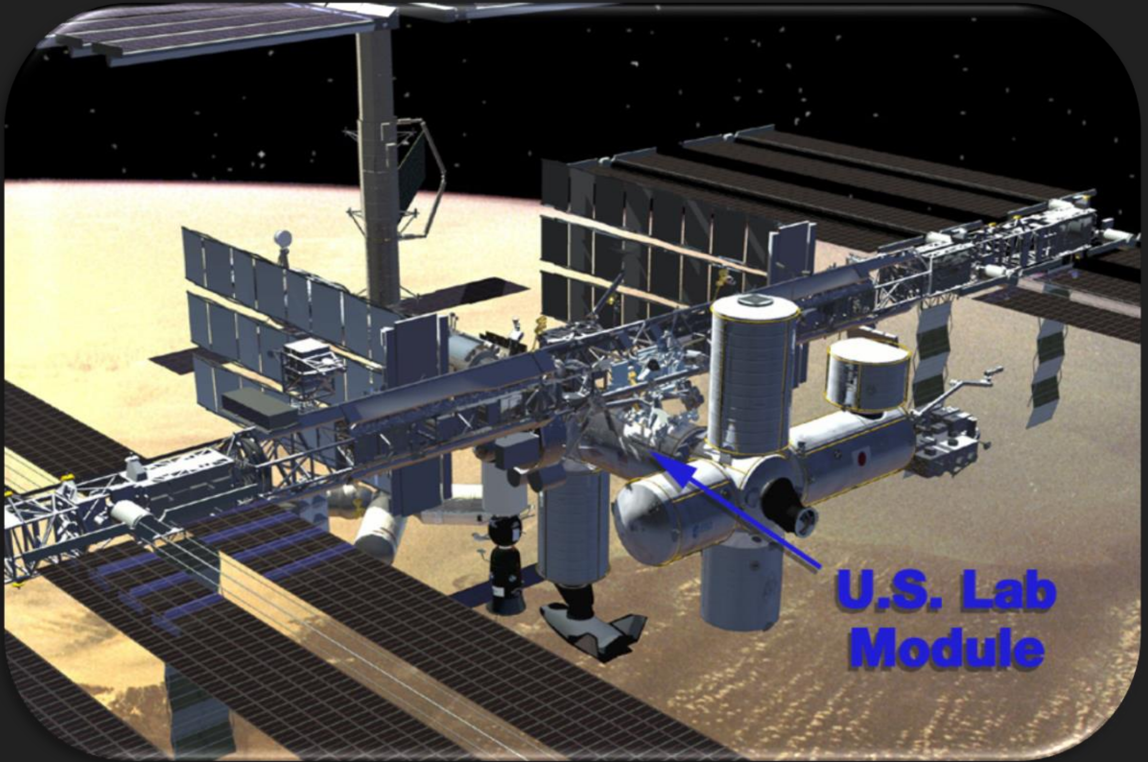


Figure 4.2.1-1. ISS quasi-steady micrograv-ity environment

ISS Microgravity Optimum Location



Testing at JSC & MSFC

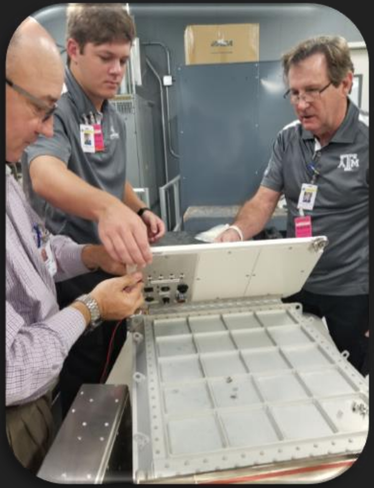
Thermal Testing

Acoustics Testing

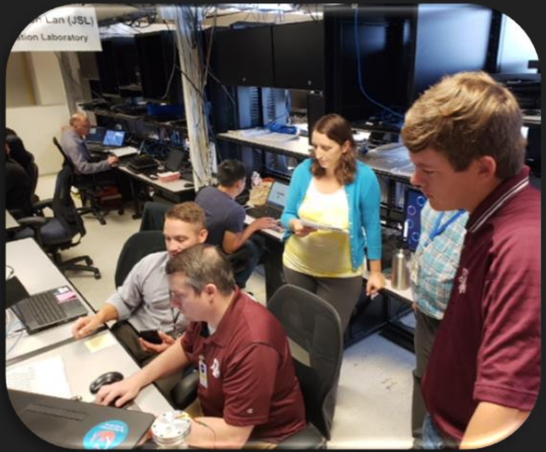
Vacuum Development Testing

EMI Testing

Integrated Testing at MSFC
Power Test (PRCU), Vacuum Test,
HOSC Connection, C&DH End to End



In-rush Testing



JSL Testing

C&DH Development Testing at A&M

Cassette-1 Science
Granular Segregation Experiments

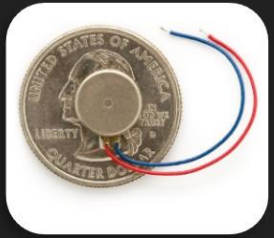
Two Granular Segregation Tubes

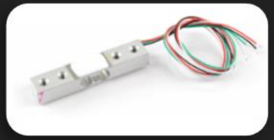
- Strata-1 Spherical Glass Bead and Angular Glass Bead Tubes
- Control size distribution
- Entrapulator 2.0
  - Control and use Entrapulator throughout experiment
- Glass beads only (for model validation)
- Science Objective 1: Determine role that grain size and shape play in regolith dynamics
- Science 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)

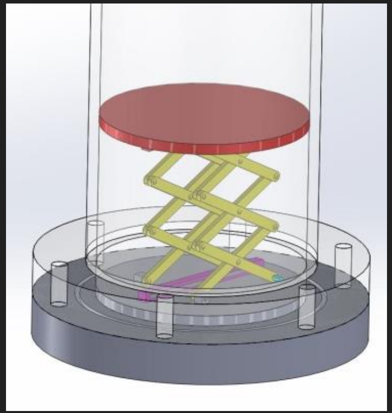




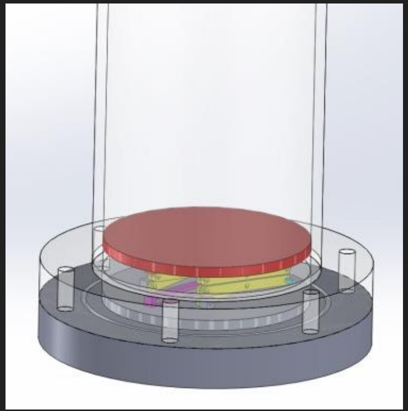
Regolith Retention Design
"The Entrapulator"

Strata-1 Entrapulator

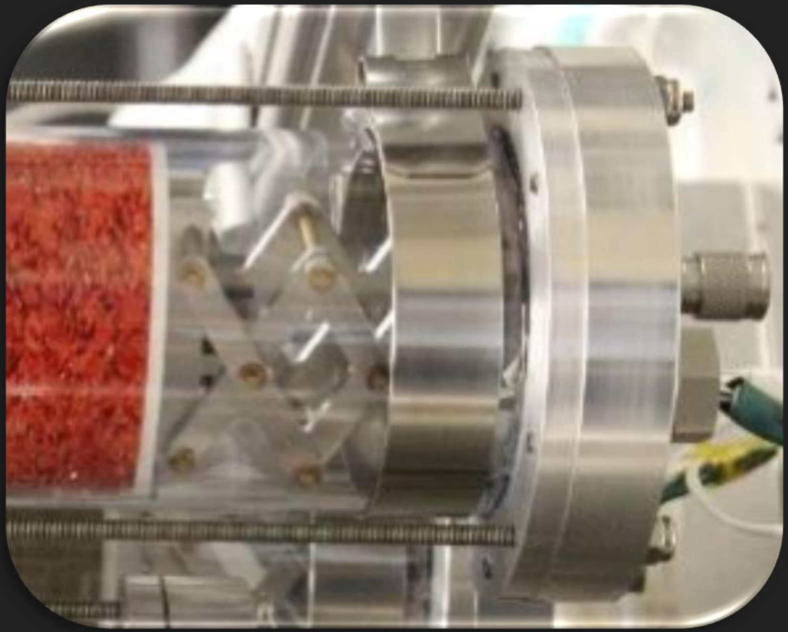
- Linear actuator, plate, and scissor retractor device
- Entrapulator 2.0
- Built at UCF



Extended Configuration

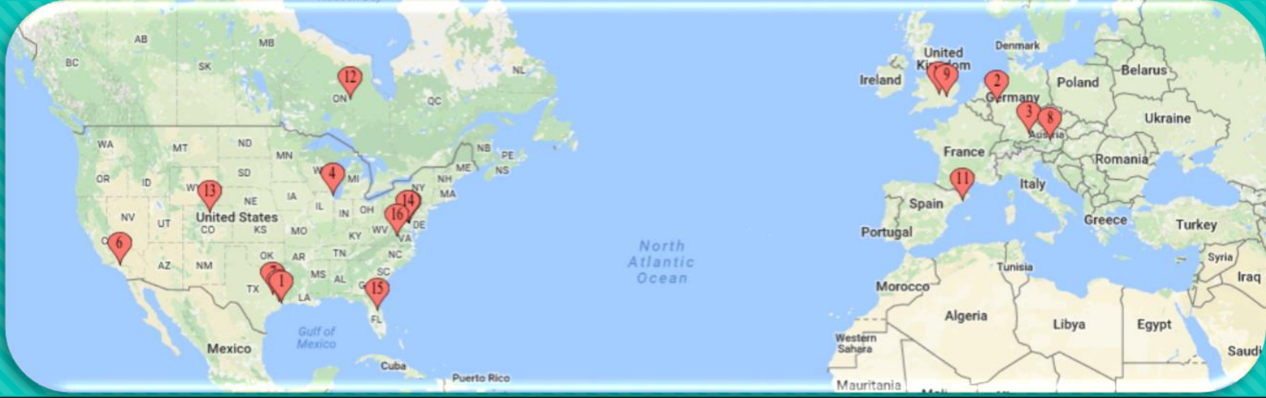


Retracted Configuration



Strata-1 Entrapulator

Who will use Hermes?



- Collected ideas for experiments in May/June 2017
- Advertised to **small body community**, CubeSat community, and beyond
- Helped inform the design of Hermes
- 44 responses from universities, companies, international space agencies, and 4 NASA Centers

How can you use Hermes?

- Experiment Solicitation Process being defined now
- Hermes website will be available for instructions on how to fly an experiment, interface requirements, and experiment data

Thank you!

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