HERMES FALL 2025 PROGRESS REPORT

By: Emmett Leader, Samyak Mehta, Liba Snyder, Guru Teja

***CR**ashworthiness for **A**erospace **S**tructures and **H**ybrids Laboratory* (*The **CRASH** Lab*)|(c)
Department of Mechanical and Aerospace Engineering
University at Buffalo - The State University of New York

MISSION OVERVIEW

- HERMES - High Speed Extraction of Mercury Extraterrestrial Samples
- Collecting and returning ice samples from permanently shaded regions of Mercury's north pole
- Harsh conditions make a very quick mission ideal to minimize shielding requirements

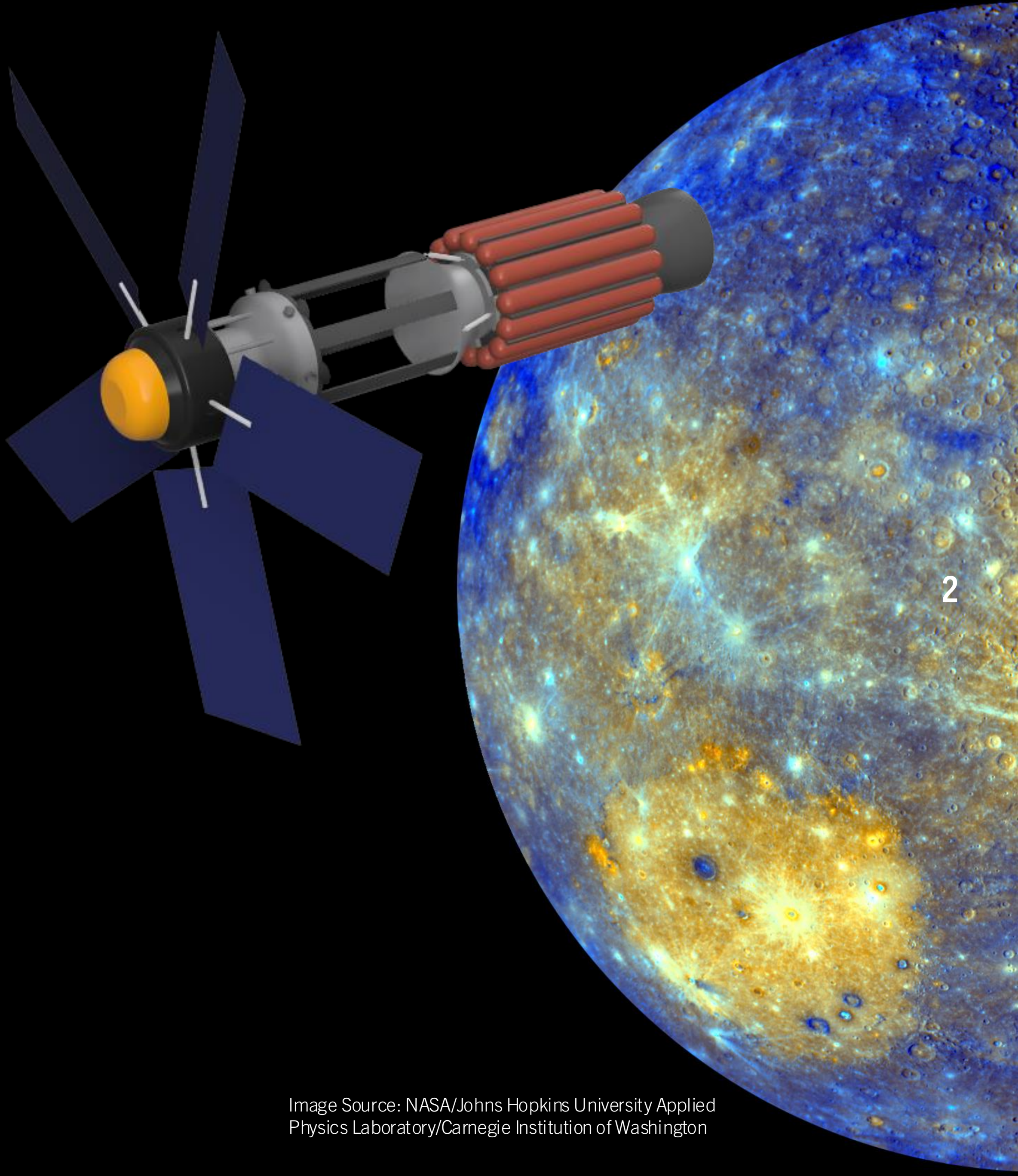
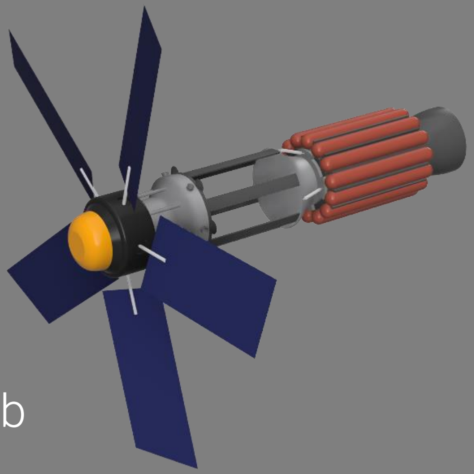


Image Source: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

COMPONENTS

Orbiter



- Transports equipment
- to Mercury
- Remains in orbit to collect data and act as command & control hub

Lander

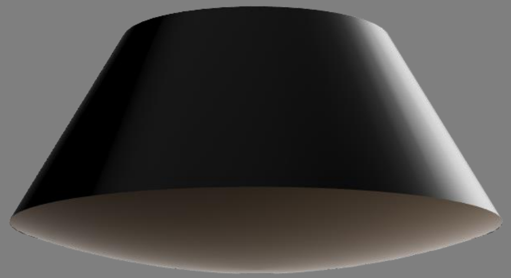
- Deorbits to deliver sample collection and secondary instruments safely to Mercury surface
- Houses robotic arm and ascent vehicle launch system

Ascent Vehicle

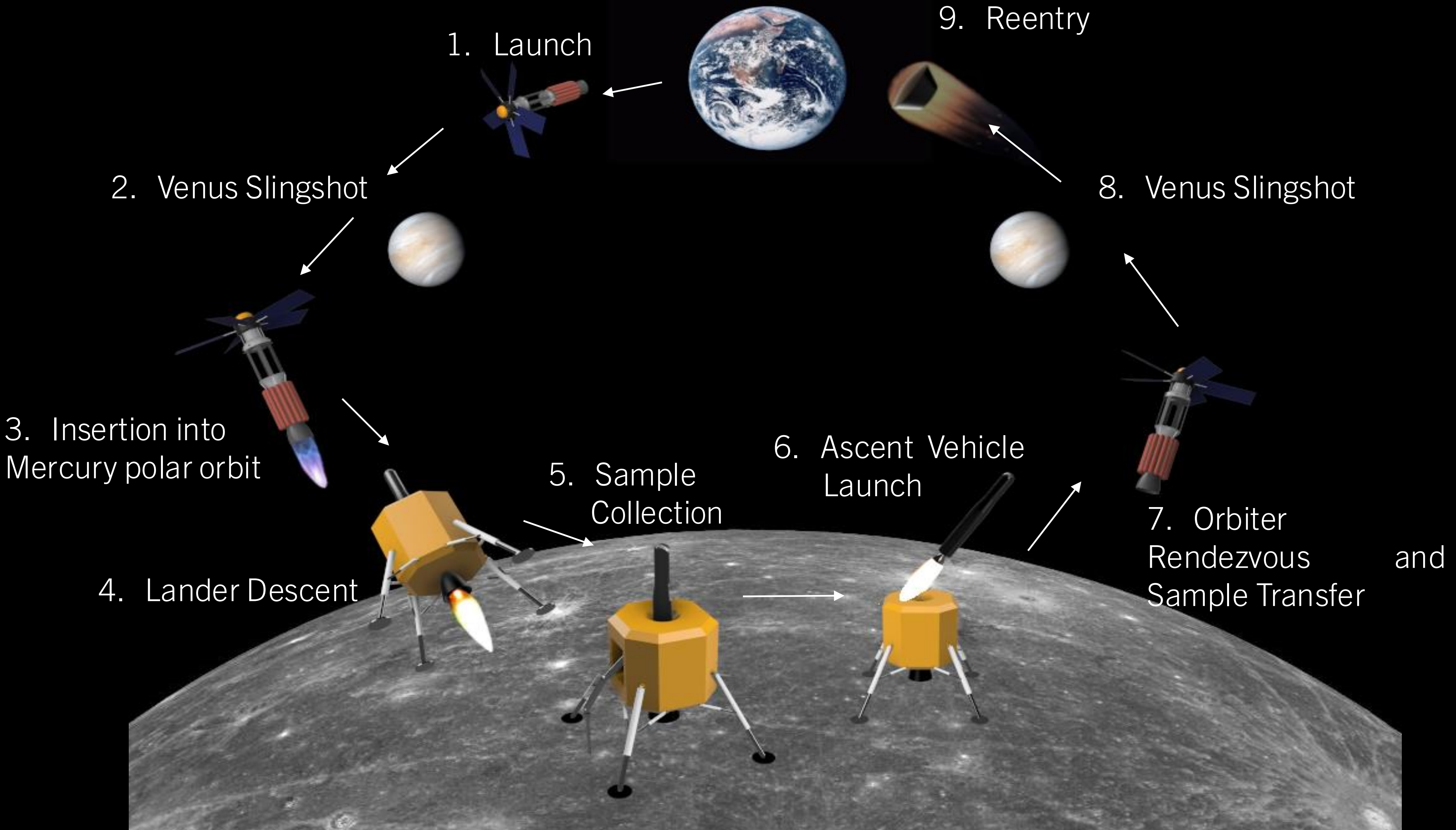
- Transports surface samples back to orbit to be loaded into return vehicle
- Cryocooler preserves sample collection conditions

Return Vehicle

- Returns Mercury samples to Earth
- Provides power and thermal shielding for cryocooler operation
- Facilitates reentry and sample retrieval



CONCEPT OF OPERATIONS



TRAJECTORY TO MERCURY

- BepiColombo Similar Launch Process [1]

  Earth Flyby around 2032

  Two Venus Flybys

  Two Mercury Flybys

  Dropping into Polar orbit around Mercury at 480km North Pole altitude (2.3 hr orbit)

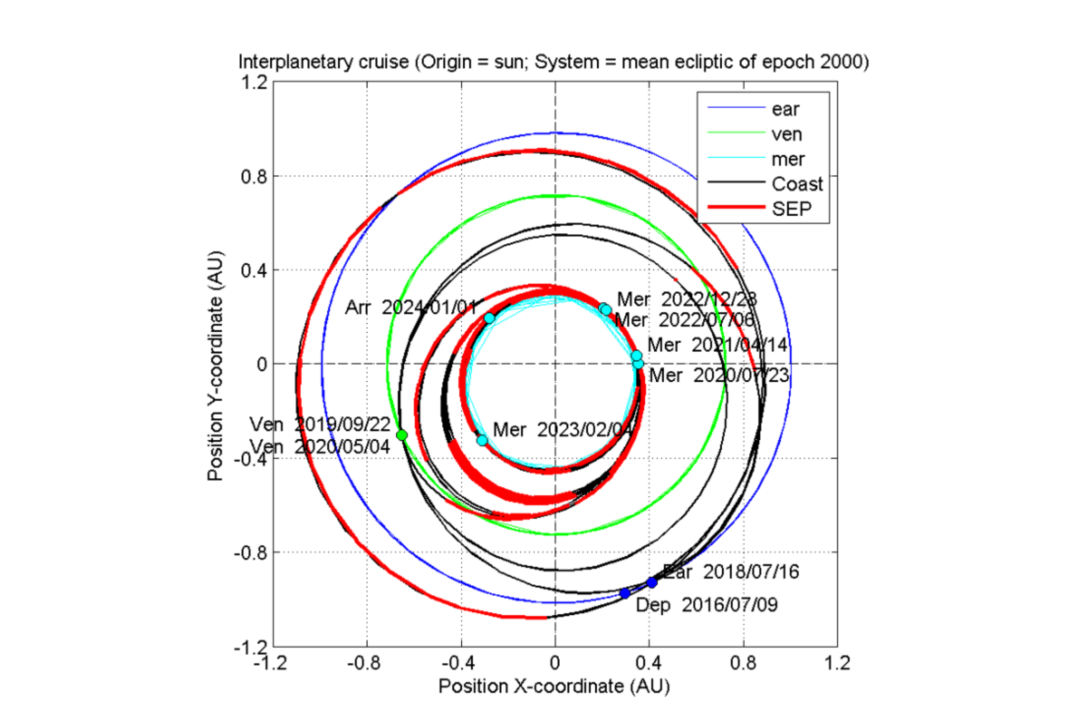
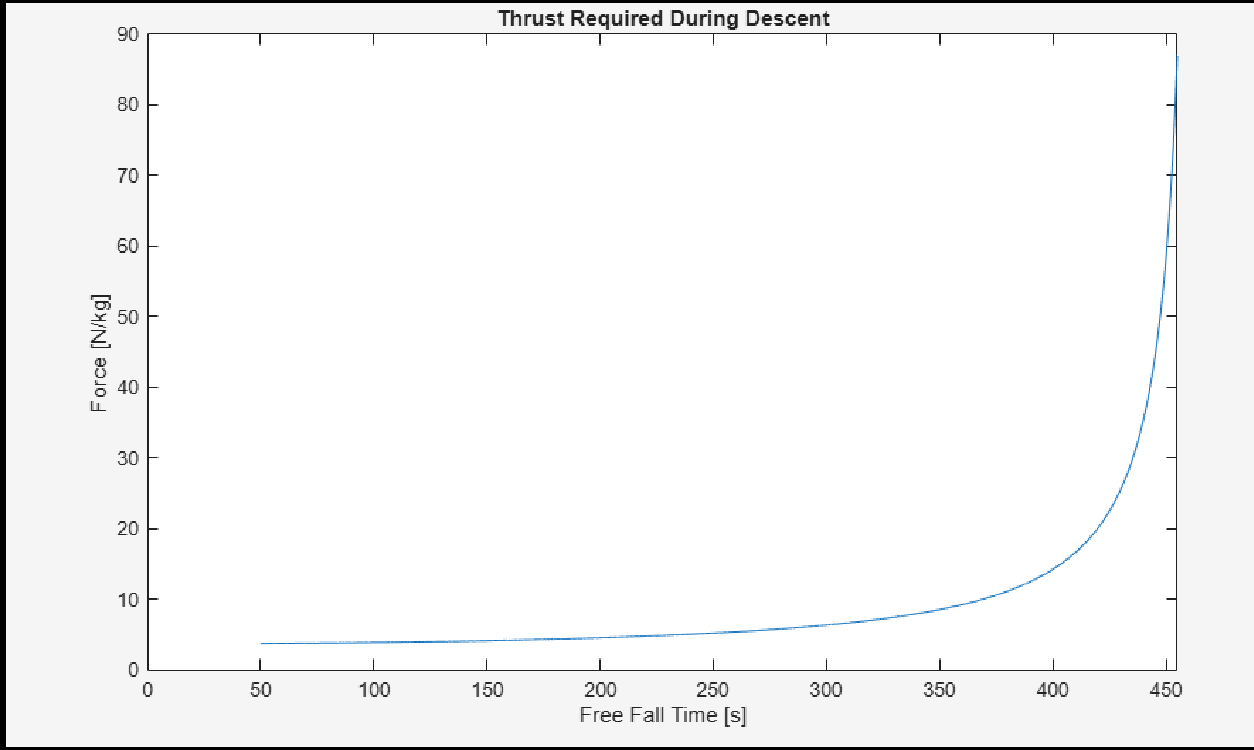


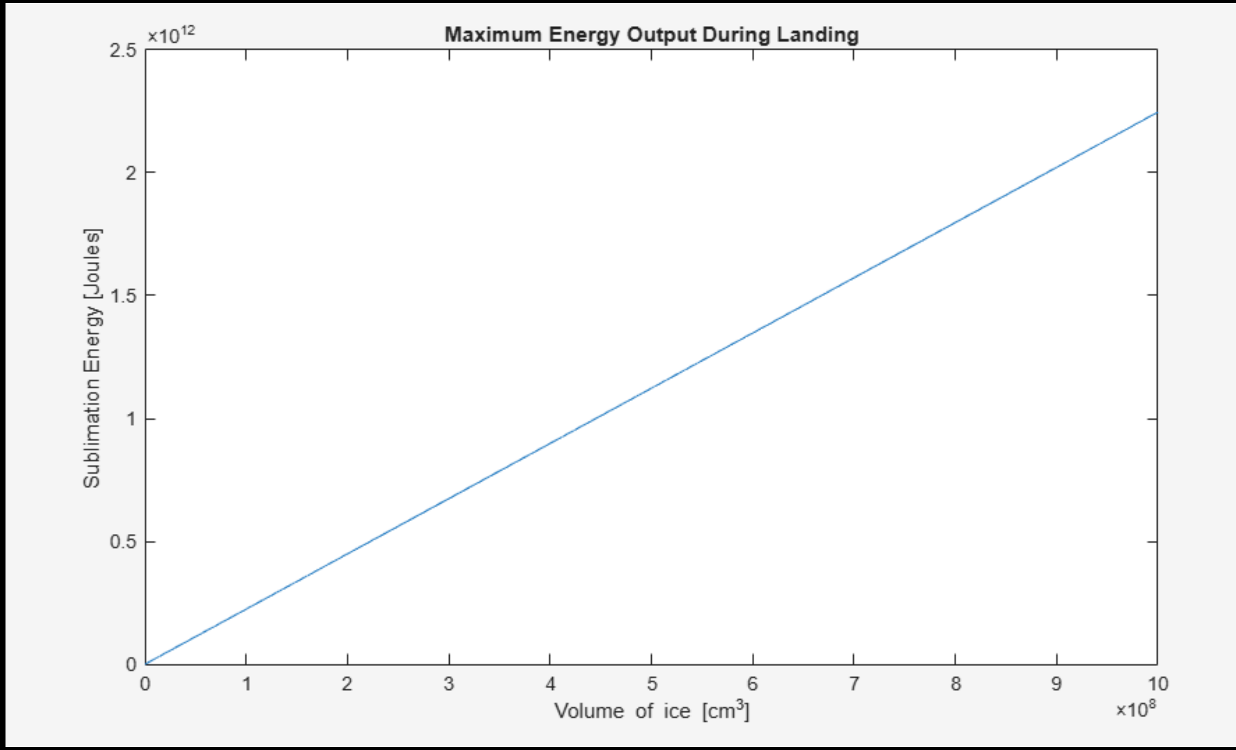
Figure 1: BepiColombo transfer trajectory with a launch on 9 July 2016 and arrival on 1 January 2024.

Orbital Visualization of BepiColombo [1].

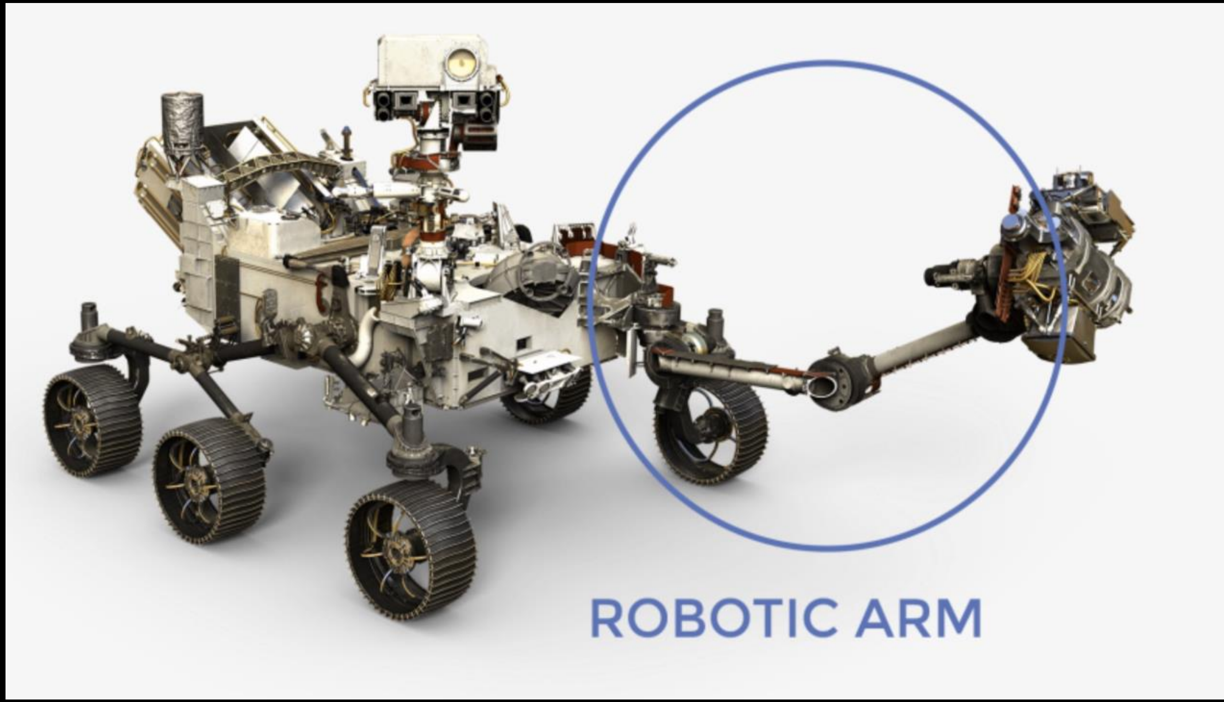
DESCENT PROPERTIES

- Two Figures for Landing Issues
- Lander will be designed based on ascent vehicle design





ROBOTIC ARM: HERITAGE & ADAPTATION PLAN



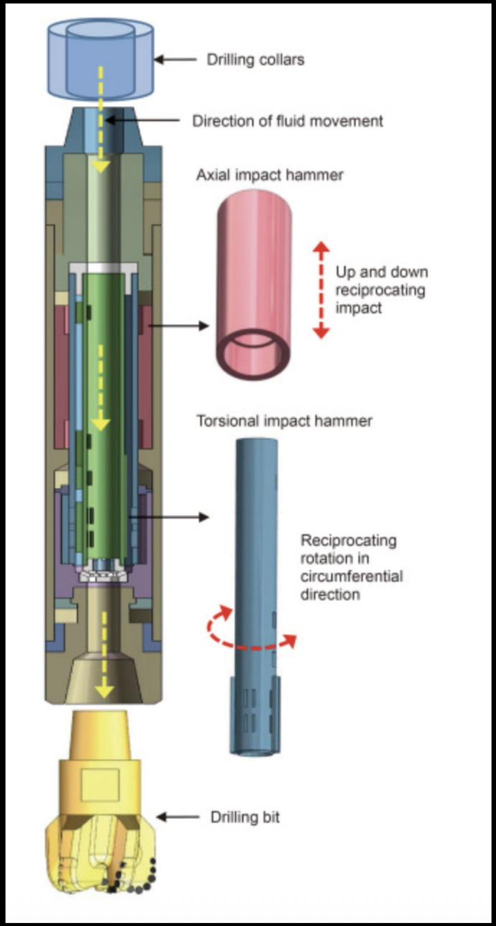
Feature / Parameter	Perseverance (NASA Tech Specs)	HERMES Planned Adaptation
Main Function	Assist in Mars surface investigation and sample collection	Support drilling, core retrieval, and tube transfer on Mercury
Arm Length	7 ft (2.1 meters)	Shorter arm (~1.2–1.5 m) sized for compact lander (consider ice conditions)
Degrees of Freedom	5 DOF (shoulder azimuth, shoulder elevation, elbow, wrist, turret)	6 DOF (adds wrist roll to align drill on uneven surfaces)
Actuation	Tiny rotary actuator motors enabling 5 DOF	Similar architecture; joints sized to support ~10 kg drill
End Effector (“Hand”)	Turret with sensors, analyzers, GDRT, drill	Simplified turret holding drill + tube-extraction interface

https://science.nasa.gov/mission/mars-2020-perseverance/rover-components/

DRILL SYSTEM: CONCEPT & DESIGN PATH

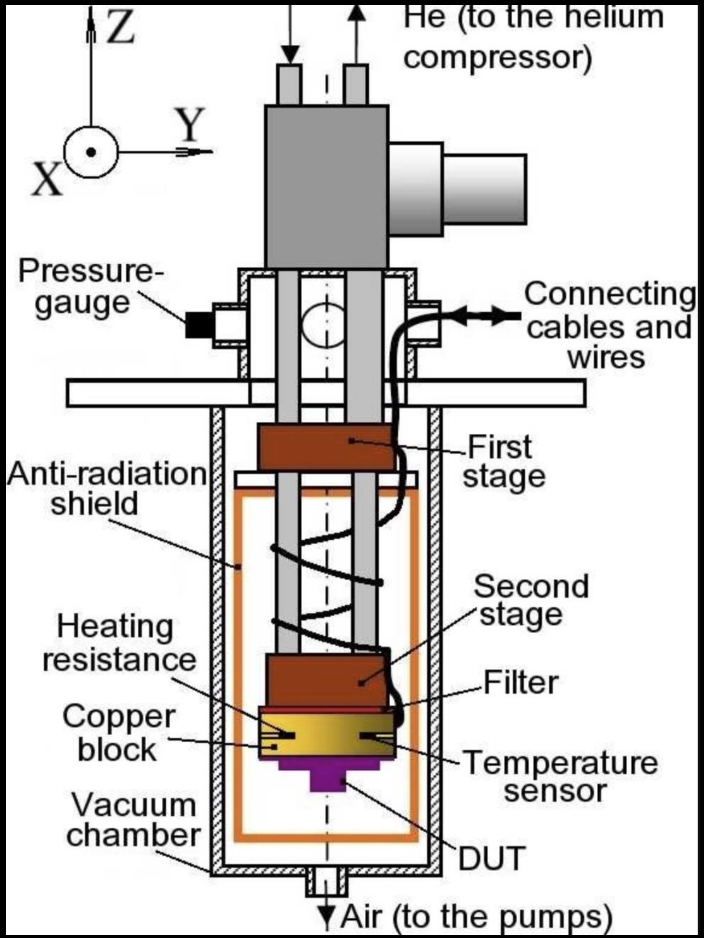
HERMES uses a **triple-tube coring system**: outer tube, cutting tube, removable sample tube.

- Drill type: rotary-percussive (Curiosity & Perseverance).
- Core diameter: **10–15 mm** (smaller than Perseverance for cryocooling).
- Breakoff mechanism: based on JPL Praying-Mantis / RANCOR.
- Next step: A completed customized CAD model



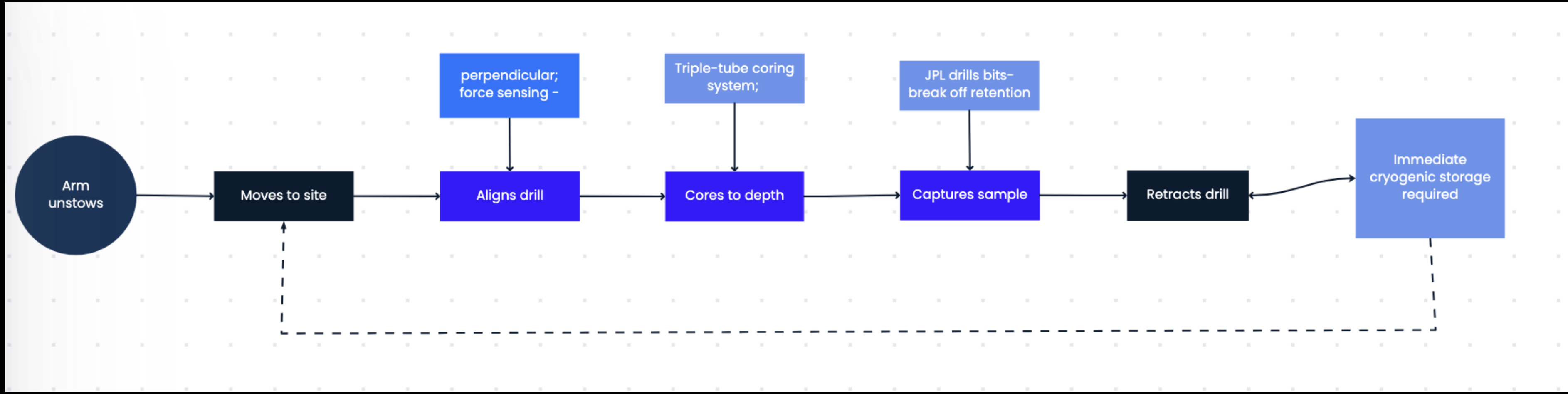
CRYOCOOLER

- Preserve temperature of ice samples at ~123 K
- Cryocooler regulates within 50–150 K
- Samples sealed in individual cryogenic canisters 10 m apart
- Multi-layer insulation reducing radiative heat load



Goryachev, Maxim (2011). ResearchGate

OPERATIONAL FLOW & PROGRESS STATUS



Completed:

- Selected heritage-based arm architecture
- Defined HERMES-specific modifications (6 DOF, simplified turret)
- Selected triple-tube coring mechanism for drill
- Developed first-version ConOps document
- Identified cryogenic storage requirements and tube transfer approach

Next steps:

- Begin CAD modeling of arm, drill head, and tube interface
- Define cryocooler → tube thermal contact geometry
- Perform joint torque and force-sensing requirement sizing
- Develop sample rack layout and insertion tolerances
- Continue research into ACA-style sample handling options

Mercury Ascent Vehicle (MAV)

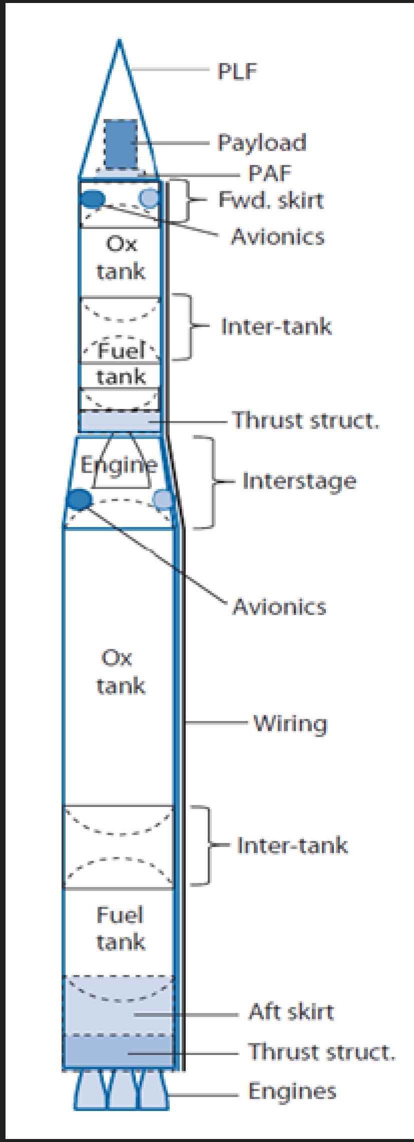
➔ Mercury Surface to Orbit at 480 km, from the Lander to the Orbiter.

Mission Parameters:

Gross Lift-Off Mass(GLOM) = 700 kgs.
ΔV_{total} = 4.72 km/s
Specific Impulse (I_{sp}) = 262 s
Payload Mass = 1 kg
Cryocooler Mass = 20 kg

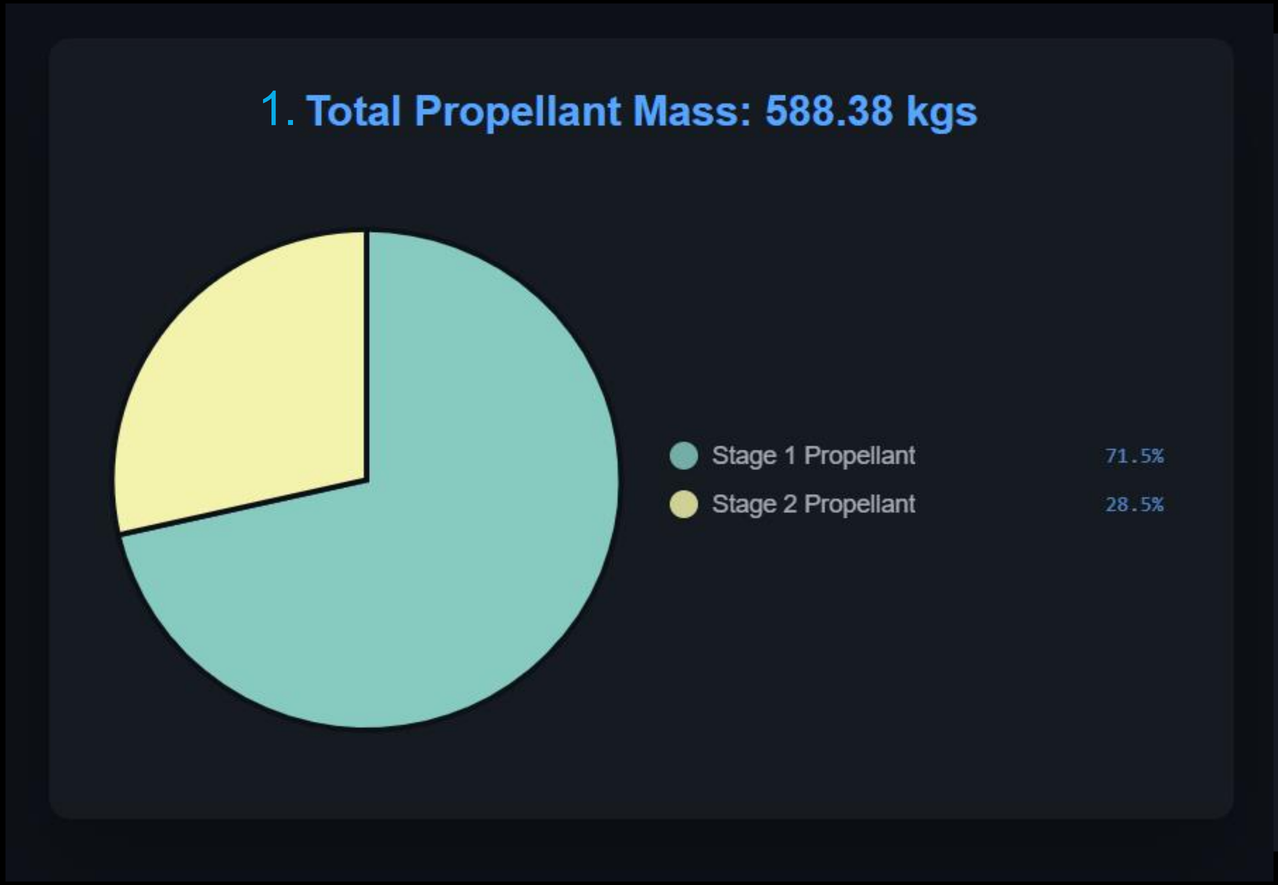
Ascent Vehicle building steps

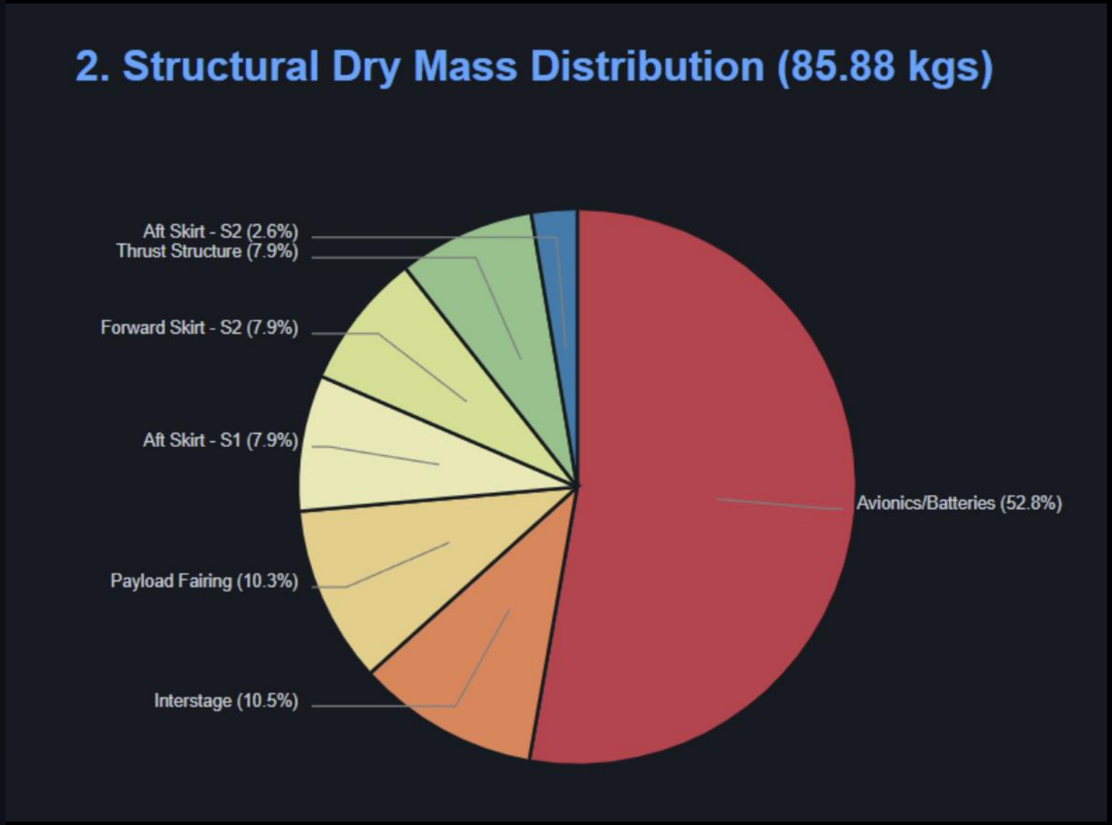
- **Δ**V allocation for stages.
- Mass estimates for Propellant
- Mass estimates for Structural Dry Mass
- Vehicle Sizing
- Mass Budget allocation for Structure (Dry)
- Nose Cone selection



Profile of a Launch Vehicle [4]

ASCENT VEHICLE MASS BUDGET





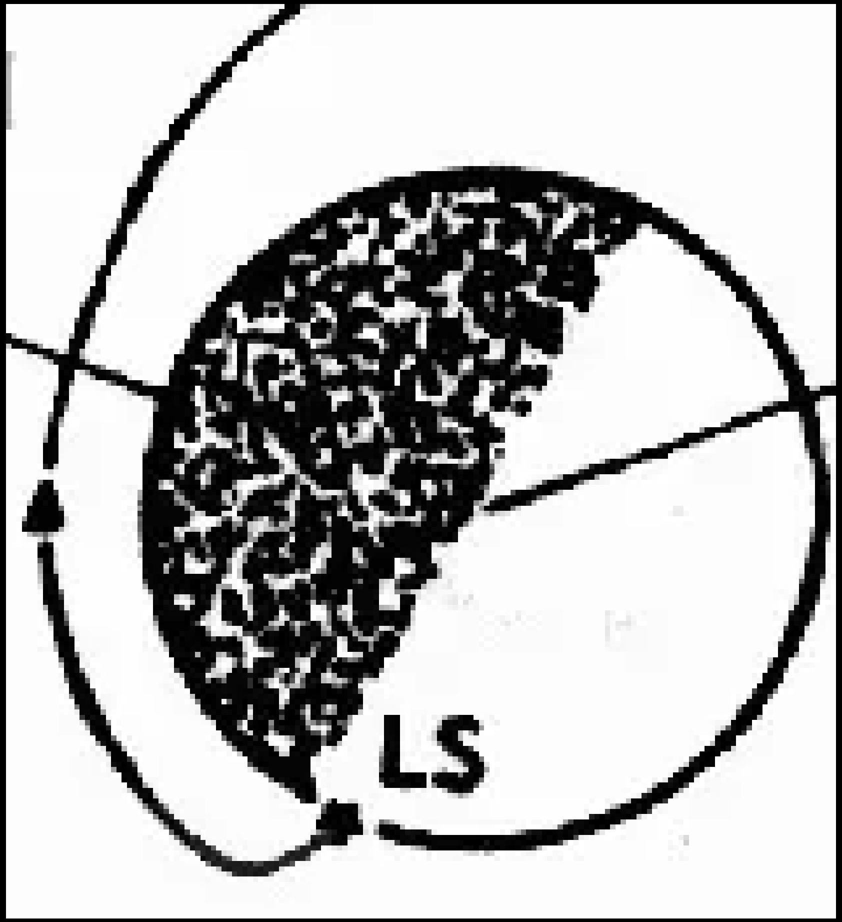
ASCENT

- Two main phases for ascent [3]

  Vertical Launch (1.721 km/s)

  Orbital Insertion (2.996 km/s)

- Dock ascent module to main orbiter
- Send sample back to Earth using return trajectory



Lunar Orbital Rendezvous [3]

RETURN TO EARTH

- Return Launch Process

  Mercury to Venus Trajectory

  Two Venus Flybys

  One Earth Flybys

  Earth Parking Orbit

  Earth Orbital Exit

  Earth Landing

Artist Rendering of BepiColombo [2].

REFERENCES

[1] Bepicolombo Trajectory Options To Mercury in 2016 and 2017, European Space Operations Centre, ESA/ESOC, Robert-Bosch-Str. 5,64289Darmstadt, Germany. Retrieved October 16, 2021, from https://issfd.org/ISSFD_2014/ISSFD24_Paper_S6-5_jehn.pdf

[2] https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Hot_stuff_the_making_of_BepiColombo

[3] The Apollo Flight Journal - Lunar Orbit Rendezvous

[4] Design of Rockets and Space Launch Vehicles - Don Edberg, Willie Costa

DRILL SYSTEM: CONCEPT & DESIGN PATH

HERMES uses a **triple-tube coring system**: outer tube, cutting tube, removable sample tube.

- RANCOR: outer auger, breakoff tube, sample tube → closest to our architecture
- Praying Mantis: bend-break + retention → breakoff method for HERMES
- Designed for low-heat volatile preservation (important for polar ice sampling)

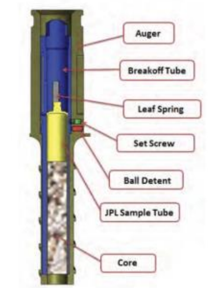


Figure 3. CAD image of the drill bit with its components labeled

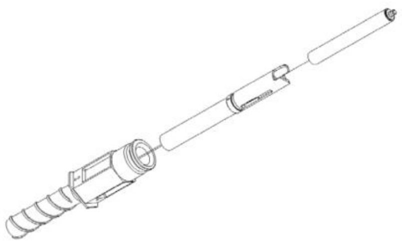
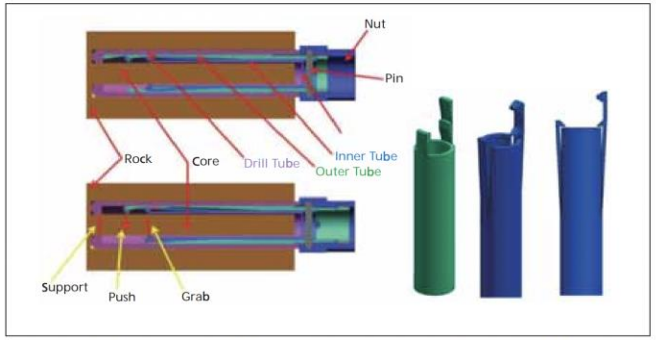


Figure 4. Picture of the drill bit in an exploded drawing view, Auger, Breakoff Tube and JPL Sample Tube Visible



The **Praying Mantis Core Breakoff Mechanism** design assembly (left), and (right) the outer (green) and inner tubes (blue).

Design plan:

- Drill type: rotary-percussive (Curiosity & Perseverance).
- Core diameter: **10–15 mm** (smaller than Perseverance for cryocooling).
- Breakoff mechanism: based on JPL Praying-Mantis / RANCOR.
- Sequential cores at 10, 50, 100 cm
- Next step: A completed customized CAD model

SAMPLE HANDLING + STORAGE: OPTIONS & NEXT STEPS

- HERMES will use a **fixed tube-catcher mechanism** instead of a full rotating carousel.
- The robotic arm will insert the drill into the catcher to unload tubes.
- Tubes will slide into a **3-slot cryocooled rack**, each thermally anchored to the cryocooler.
- Gripper or a passive catcher?