Presentation to the Planetary Science and Astrobiology Decadal Survey
Panel on Mercury and the Moon
November 03, 2020

Jacobs

Mercury Sample Return and Related Research and Analysis Activities

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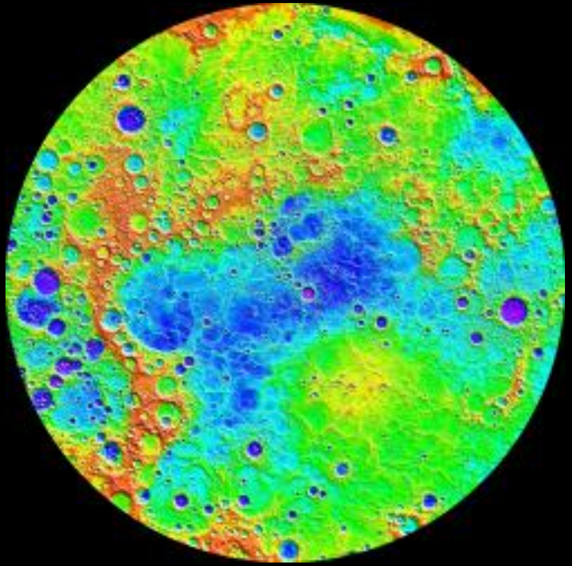
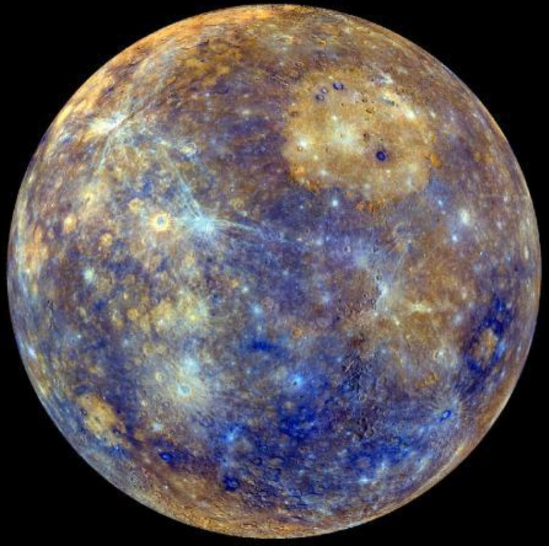
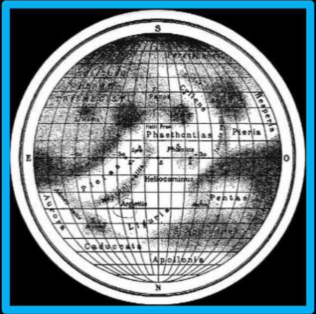


Ronald J. Vervack Jr., Michelle S. Thompson, Elizabeth B. Rampe, Gangkai Poh, Francis M. McCubbin, Christian Klimczak, Catherine L. Johnson, Suzie Imber, Steven A. Hauck II, Carolyn M. Ernst, Gina DiBraccio, Ariel N. Deutsch, Christopher J. Cline II, Nancy L. Chabot, Paul K. Byrne, and Brendan A. Anzures



Mercury Exploration



Telescopic Observations

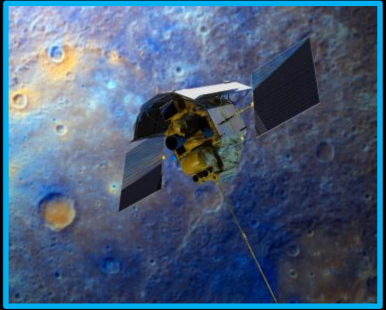
Progress

Ongoing Observations

Flyby

Progress

3 Flybys in 1970s



Orbiter

Progress

Orbited Mercury 2011 – 2015

Dual Orbiter

Progress

Launched in 2018 For 2025 arrival

Lander

Progress

Mission Concept Study Completed

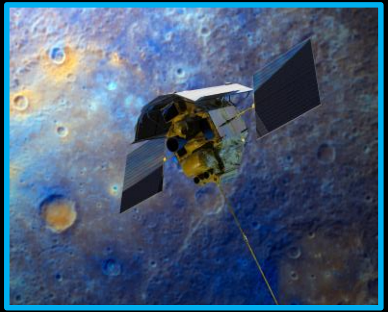
Sample Return

Progress

Brainstorming Underway

Telescopic observations of Mercury have occurred since the invention of the telescope in the seventeenth century and continue to occur today. Data from Mariner 10 flybys and MESSENGER orbiter are continuously being processed and utilized to conduct modern-day science. Knowledge gain from these observations will help to inform present and future missions to Mercury.

Mercury Exploration



Orbiter

Progress

Orbited Mercury 2011 – 2015

We are here!

Progress

Lab and Field Studies Underway

Dual Orbiter

Progress

Launched in 2018 For 2025 arrival

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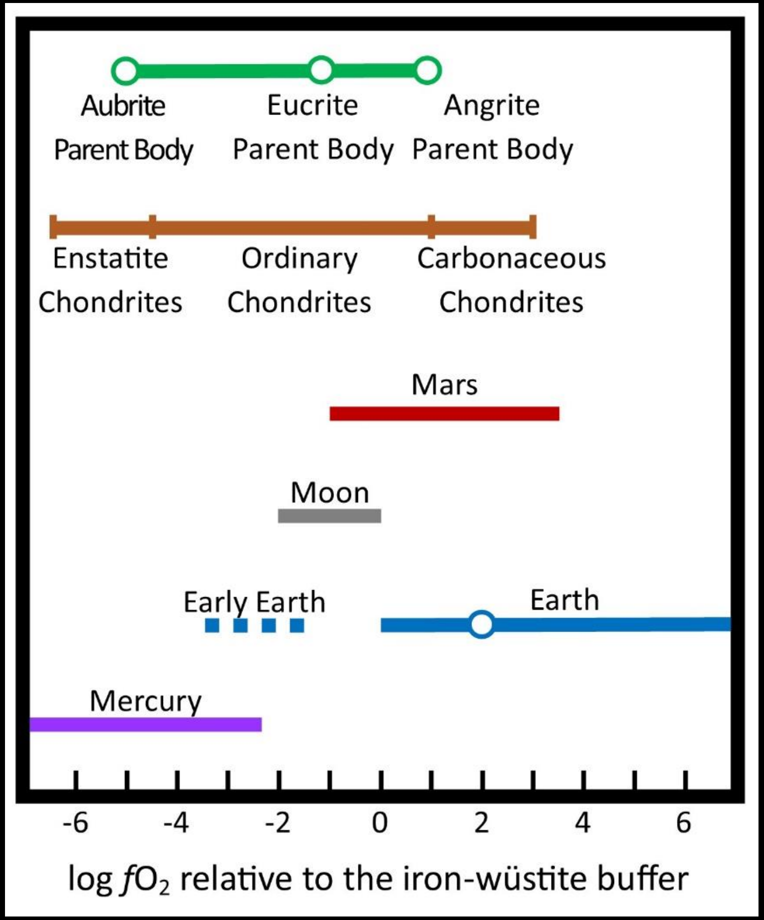
Brainstorming Underway

To enhance the scientific return of past, present, and future data collection at Mercury, it is imperative that laboratory and field-based studies be conducted over the next decade. Will present examples of studies related to *geochemistry*, *geology*, and the *space environment*, but this list is not exhaustive and extensive research related to *geophysics* and *other geosciences disciplines* is warranted.

How did Mercury form? How did Mercury differentiate and acquire its interior structure? What are the origin, history, and inventory of Mercury's volatiles?



Relative oxygen fugacity conditions for select rocky bodies in the solar system. Modified after Anzures et al. (2020).

- Currently do not have any recognized samples from Mercury in our collections
- Highest-resolution geochemical data from MESSENGER is of the N. hemisphere
- Much of the geochemical nature of Mercury is left to be inferred from laboratory-based experimental work
- Continuing to pursue laboratory-based work and testing new, top-of-the-line geochemical instruments, is crucial to prepare for the future exploration of Mercury

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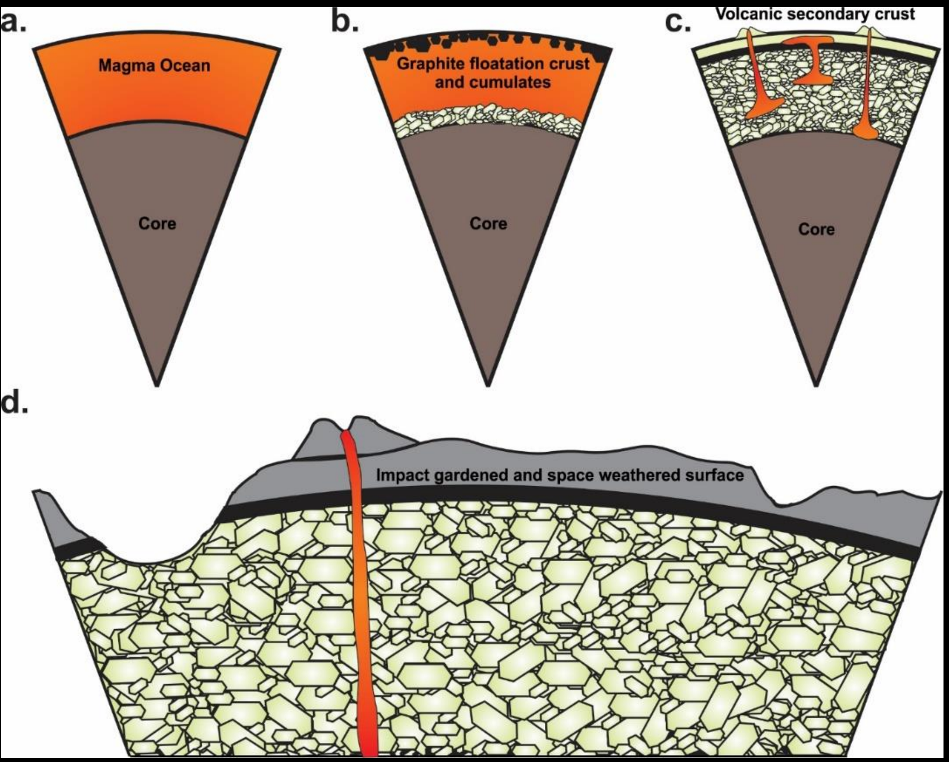

From Vander Kaaden and McCubbin (2015).

- Example laboratory studies
  - Crystallization of a mercurian magma ocean at varying pressure and temperature conditions
  - Geochemical affinity of major, minor, and trace elements in S-rich, reduced compositions via experiments and analytical studies
  - Experimental studies to place bounds on the upper limits of volatile elements the could be responsible for pyroclastic volcanism
  - Experiments at varying pressures to establish how much juvenile gas is released upon depressurization

How did Mercury form? How did Mercury differentiate and acquire its interior structure?

Artist rendition of lander on Mercury from Ernst et al. (2020).

- In addition to laboratory experiments to characterize the expected composition of the surface, it will be important to test geochemical and mineralogical instruments that may be used in future Mercury exploration.
- Geochemical and mineralogical instruments typically flown on planetary missions should be optimized to measure the composition of the mercurian surface
- Identify instruments → mature to flight-readiness → couple with experimental efforts

How did Mercury differentiate and acquire its interior structure? How do Mercury’s surface and interior reflect the evolution of the planet?

Example field site: Yakima Fold and Thrust Belt

A series of shortening landforms deforming flood-volcanic rock units on the Columbia Plateau analogous to shortening landforms in Mercury’s Borealis Planitia.

Image from nuari.net

- Fieldwork provides the basis not only for ground-truthing remotely sensed observations, but for acquiring samples of analogue materials that offer direct insight into the chemical and physical properties of rocks on other worlds.
- Mercury-focused studies → concentrate on volcanic deposits that have been subjected to tectonic deformation → most closely reflect the geological processes of the innermost planet
- Includes: geological relationships, geological field mapping, characterization of aeolian landforms, and measurement of tectonic strain can be carried out with standard geological field techniques, while also making use of emerging technologies such as remotely piloted aerial vehicles

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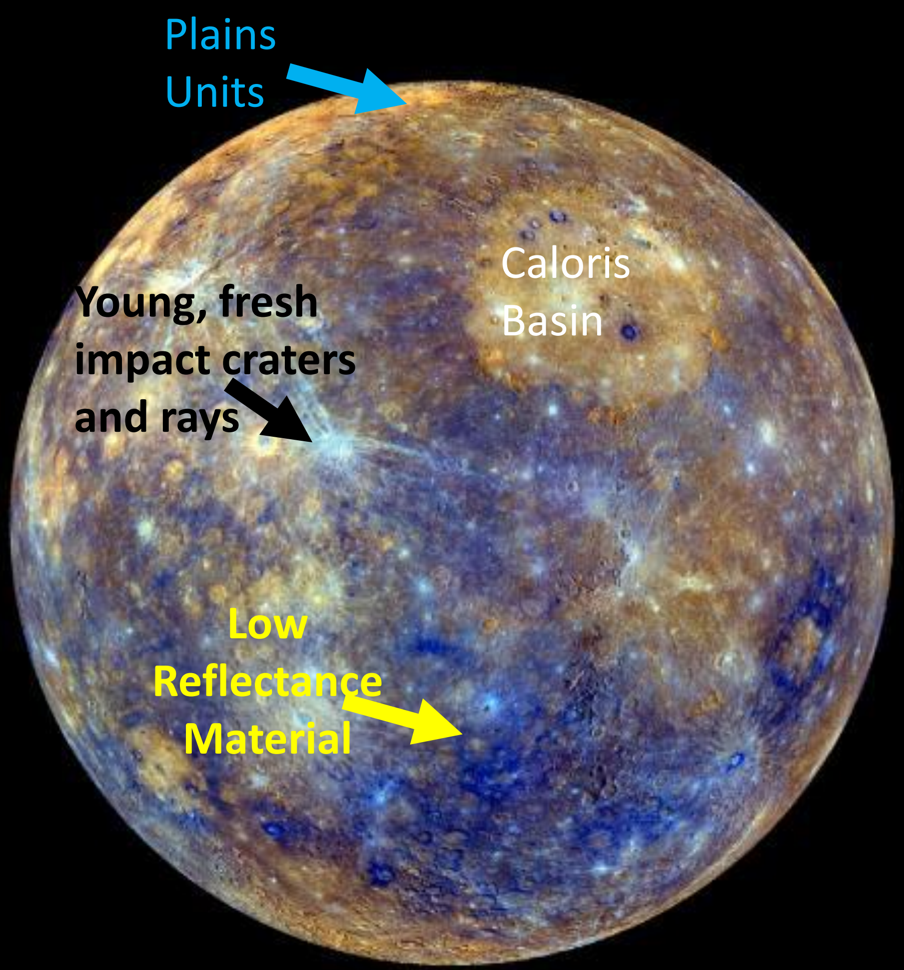
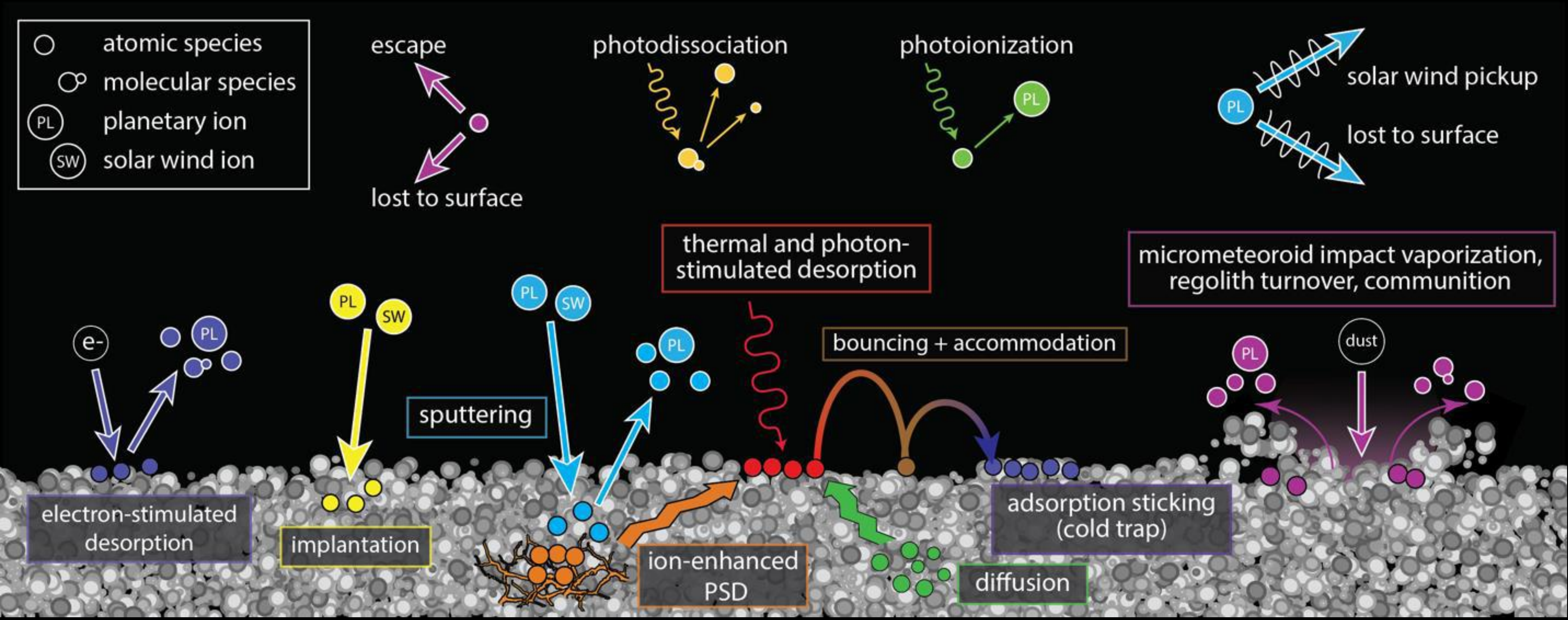


Image Credit: NASA/JHUAPL/CIW

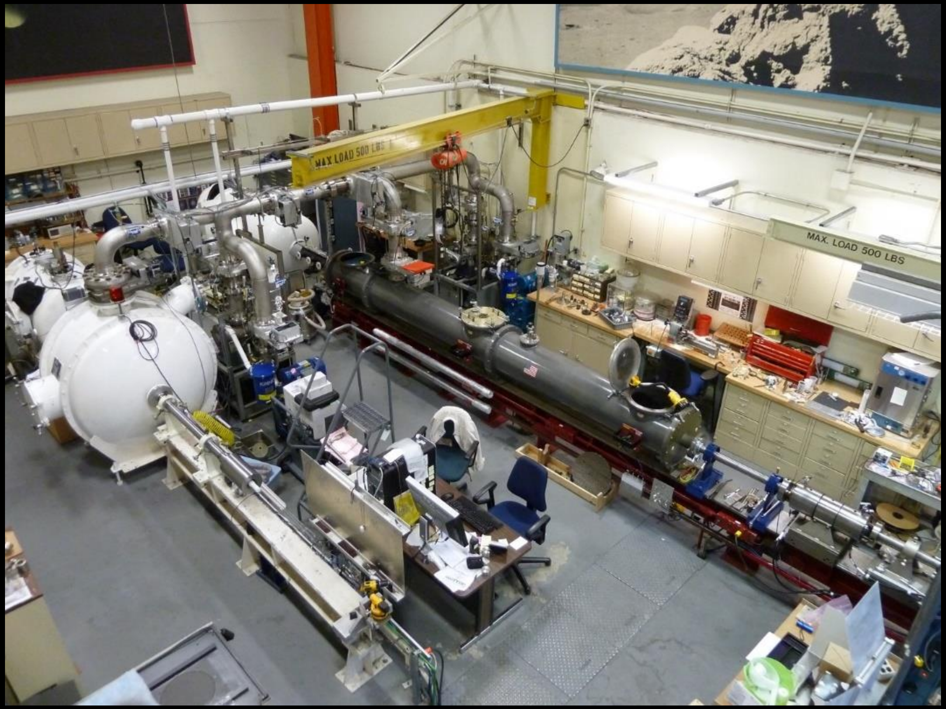
- The Mercury surface likely features a thick layer of regolith.
- Physical processes including meteoroid bombardment, thermal stresses from diurnal insolation variations, and even interactions with solar and cosmic particles can degrade rocks to form regolith.
- Geological laboratory studies should include assessment of the mechanical characteristics of rock (e.g., compressibility, fracture density, porosity, permeability, etc.), and employ a wide variety of techniques including conventional microscopy of samples and thin sections, scanning and transmission electron microscopy, X-ray diffraction, fluorescence, and tomography, and well as cathodoluminescence and optically stimulated luminescence.

What is the nature of the complex interactions among Mercury's external drivers and the planet's magnetosphere, exosphere, surface, and interior?



Processes that act on Mercury's surface to generate and maintain the exosphere and contribute to space weathering of the regolith. From Ernst et al. (2020)

How did Mercury differentiate and acquire its interior structure? How do Mercury’s surface and interior reflect the evolution of the planet?

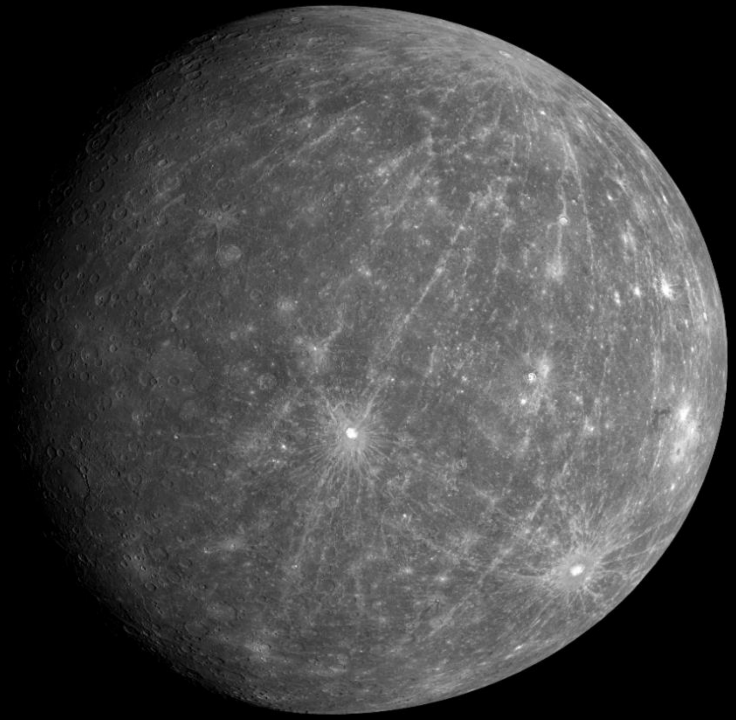


Experimental Impact Laboratory at NASA Johnson Space Center showing the flat-plate accelerator (left) and the light-gas gun (right)

Image from ares.jsc.nasa.gov

- Example laboratory studies
  - Place better constraints on the release processes for O at Mercury
  - Place better constraints on the release of ions such as O^+, OH^+, H_2O^+ and combinations thereof
  - Identify what species are released during meteoroid impact vaporization and what the associated energy distributions are
  - Confirm theoretical studies about exospheric generation processes with laboratory studies
  - Understand how the mechanism of micrometeoroid impacts plays a role in space weathering under the unique conditions present on Mercury’s surface

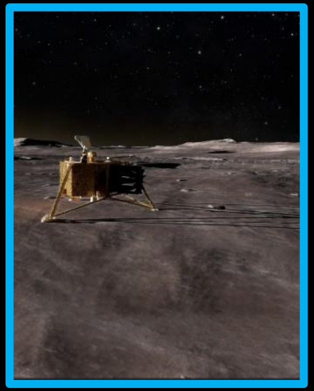
Implementation over the next decade



- To maximize the scientific return of data from current and future exploration efforts of Mercury, it is critical that laboratory- and field-based research be conducted over the coming decade to shed light on the origin and evolution of this geochemical endmember of terrestrial planet formation.
- Any delay in future exploration efforts could have detrimental impacts on the continued exploration of Mercury and, with it, our understanding of our solar system at large.

Image Credit: NASA/JHUAPL/CIW

Implementation over the next decade



- Increase funding selection rates for R&A programs
- Include funding opportunities for education and public outreach of Mercury science
- Support future opportunities for additional IDS and GI positions on BepiColombo
- Expand the DDAP call to include data from BepiColombo or create and additional call for a BepiColombo Data Analysis Program
- Add NASA-led missions to Mercury to the New Frontiers call (e.g., a Mercury Lander)
- Consider the critical role of team dynamics, equity, diversity, inclusion, and accessibility not just in the continued exploration of Mercury, but across the field of planetary science.