SAMPLE

Solar System Missions: BepiColombo

Journey to Mercury

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This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Of all the worlds that spacecraft have been sent to visit, the one closest to the Sun has been visited the least, and the reason is a fine joke of orbital mechanics: the planet Mercury, the nearest neighbor to the Sun, is the hardest of the inner worlds to reach. Falling toward the Sun means falling into a gravity well, and a spacecraft dropping into that well arrives with too much speed to stop; the Sun's grip must be fought all the way down, the energy shed in slow spirals and careful passes, and the planet at the bottom, small and fast on its orbit, must be caught by a craft that has to brake harder than for any other destination.

It took humanity a quarter of a century to send a single mission there, half a century for the second, and a joint fleet of two orbiters, the subject of this book, took nearly two decades from approval to launch and has spent most of a decade simply falling the right way.

The mission's name carries a story of its own. BepiColombo is named for an Italian scientist with a billiard player's intuition, whose insight into the rhythms of Mercury's orbit made the first mission there possible, and the double name, familiar and formal, suits the double vehicle it carries: a European planetary orbiter and a Japanese magnetospheric orbiter, stacked with their transport and a sunshield for the years-long cruise, launched together in 2018 as the most complex object ever sent inward. Built by the European and Japanese space agencies as their first joint interplanetary mission, it is designed to answer questions that fifty years of planetary science have left standing: why the smallest planet has a magnetic field, why its metal core takes up nearly its whole volume, why its scorched surface holds ice, and what its strange tenuous atmosphere is made of, questions that connect Mercury to the earliest era of the solar system's formation.

This book tells the story for a general reader. The opening chapters set the paradox of the hardest planet and the questions its half-known face raises, honor the lone orbiter that first circled it and the professor whose trick made the journey possible, and lay out the four-craft stack and the long fall sunward; the middle chapters carry the furnace's engineering, the two orbiters' cargo, the crooked field and the fast coupling of wind and field, the shrunken planet's bones, and the great basin's face; the closing chapters follow the ghost ocean of atoms, the relativity dividend of the star's near shadow, the arrival, and the campaign the arrival opens.

The account asks no mathematics of the reader, names no mission by the flight logs' acronyms, and gives every number plainly, in the scales of common

things; and the reader who finishes it will understand why the planet nearest the Sun was the last of the old planets to be orbited, and what two decades of patience were spent to earn.

A note on companions: this mission is part of a series, and the shelves around this volume carry the other Mercury stories: the account of the pioneering flyby mission of the 1970s and the orbital mission that mapped the planet in the last decade belongs in its companion volume, and this book touches those missions only where the science demands context. Here the subject is the joint mission itself: the fall into the gravity well, the two orbiters it carries, and the answers they are built to find. No equations follow, the engineering is explained in plain words, and the reader is asked only for an appetite for the strangest planet in the neighborhood.

Chapter 1: Why Mercury Is the Hardest Planet to Reach

The paradox deserves a careful first statement, because the rest of the book stands on it. A spacecraft going outward, to Mars or Jupiter, climbs out of the Sun's gravity well and spends energy doing so; a spacecraft going inward, to Mercury, falls into the well and must somehow arrive at the bottom without crashing. The falling adds speed continuously, and near Mercury the orbital velocity is ferocious, so a craft launched from Earth arrives at Mercury's neighborhood moving far too fast to stay: the naive trajectory, a straight dive, ends with the spacecraft whipping past the planet and back out of the well, or through it. Reaching Mercury is not a problem of getting there; it is a problem of arriving slowly, and the solution has consumed more mission-design ingenuity than any destination short of the Sun itself.

The numbers behind the paradox are worth a paragraph. Every change a spacecraft's trajectory requires has a cost in velocity, the currency mission designers spend their fuel buying, and the bill for a direct Mercury flight is larger than the bill for a flight to Pluto, which is the joke in its plainest form: the nearest planet is more expensive to reach, in the designer's currency, than the farthest. The bill is paid in two ways: by burning fuel with the craft's own engines, which is limited by the fuel a rocket can lift, or by borrowing the gravity of the planets themselves, flying close to a moving body and letting its momentum do the pushing, the technique of the gravity assist, which this book's cruise chapter treats as its own adventure. A Mercury mission's design is a long exercise in borrowing: every planet on the way inward, Earth included, and Mercury itself, passed repeatedly before the final capture, each pass trimming the speed the Sun's well has added.

The Sun's presence at the destination adds a second design problem, nearly as severe: heat. A craft at Mercury's distance receives ten times the sunlight Earth does, and the light that does not burn the instruments blinds them, so the craft must survive both a flood and a glare, with a temperature swing between day and night sides more extreme than any other planet offers. Electronics, optics, adhesives, lubricants, and the solar cells that power the craft all degrade in fierce light, and the design answer is a machine built like a parade float in a furnace: shaded, mirrored, wrapped, and wrapped again, with nearly every instrument peering out from behind a shield, described in the thermal chapter.

The planet itself is a small target on a fast orbit. Mercury races around the Sun in eighty-eight days, and its orbit is eccentric, its distance from the Sun

varying markedly, so the geometry of arrival is a moving problem: the spacecraft must not only reach the planet's orbital path but arrive when the planet is there, with its velocity matched, at a moment when the geometry allows the braking. The launch windows for efficient trajectories are rare, occurring years apart, and a missed window means a missed mission, one reason the planning horizons of Mercury missions are measured in decades.

The final difficulty is the planet's own weak but real gravity, which offers only a shallow well of its own for capture. Arriving at Mercury, the craft cannot simply fall into orbit; it must brake precisely at the right point, using engines and the Sun's tidal help, to settle into capture. Every one of these difficulties, the speed, the heat, the timing, the capture, has shaped the mission this book describes, and the history of Mercury flight, told in the next chapter, is the history of each difficulty being solved in turn.

A note on why the brakes cannot be borrowed. At Mars or Venus, a spacecraft arriving too fast can save fuel by dipping into the atmosphere, using drag to slow down, the technique of aerobraking that has trimmed many a mission's budget; Mercury has no atmosphere worth the name, and so no brake exists to borrow: every unit of speed must be shed by the craft's own engines or the planets' gravity, and the difference explains a good deal of the design. The absence also works the other way, and harshly: the mission's orbiters, once at Mercury, feel no drag at all, so their orbits are stable without the maintenance other low orbiters need, but they also cannot dispose of a bad orbit by patience, and the arrival choreography must be right the first time.

The planet's calendar is the strangest in the neighborhood, and a mission must live by it. Mercury turns on its axis once every fifty-nine Earth-days and orbits the Sun in eighty-eight, and the two rhythms, locked in a resonance of three rotations to every two orbits, give the planet a day-night cycle of one hundred seventy-six Earth-days from noon to noon: a single Mercurian day spans two of its years, with sunrise to sunrise longer than the planet's own year twice over. A surface point endures months of daylight, then months of dark, and the temperature between the two runs through the widest range of any solid surface in the solar system, baking far past the point of melting lead at noon and falling below the point of freezing oxygen at night. The mission's polar orbit, crossing the planet every few hours, samples the whole slow day, and the orbiters' year of operations, spanning two Mercurian years, watches every season twice.

One more framing fact completes the paradox's picture: Mercury is not merely expensive to reach but awkward to see. Hugging the Sun in Earth's sky, it never rises far from the glare, visible only in the twilight bands of morning and

evening, a low, hurried spark that most people live and die without noticing; the astronomers of antiquity logged it, the telescope era mapped its phases poorly, and the ground-based understanding of the planet, even after the flyby era, remained coarser than for any other rocky world. What cannot easily be seen cannot easily be loved, and the planet's obscurity, as much as the difficulty of its orbit, explains its long wait for visitors: the mission this book describes was, through its whole life, the only one on anyone's ledger.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.