SAMPLE

Solar System Missions: Galileo

Jupiter and Its Moons

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Introduction

In October 1989, the space shuttle Atlantis lifted a spacecraft named Galileo into orbit and set it on a road to Jupiter so long that the mission outlasted the shuttle fleet that launched it. When the orbiter arrived, six years later, it became the first spacecraft to circle a giant planet, the first to drop a probe into a gas giant's atmosphere, and the only machine ever to orbit Jupiter for years on end, watching the planet's weather churn and its moons turn from unknown points of light into worlds. For eight years Galileo circled, and what it sent back rewrote the outer solar system: volcanoes erupting on Io from a source no one had seen clearly, an ocean of salt water inside Europa, a magnetic field around Ganymede, and a comet striking Jupiter while the world watched.

That story is the subject of this volume. It follows the spacecraft from its origins in the era after Voyager, through launch and the accident that crippled its main antenna, along the gravity-assist roads through the inner solar system, into arrival day with its two-front drama of orbital insertion and probe descent, and through the years of discovery, crisis, and improvisation that turned a two-phase mission into one of the most scientifically productive voyages ever flown. The story is one of engineering persistence as much as of discovery: the mission that lost its main antenna and its flight data path and still returned more science than anyone planned for is a case study in how exploration actually works, a lesson in what a small team on the ground can do with a spacecraft half a billion kilometers away.

The mission also matters as history, because it stands at a hinge of the space age. Galileo was designed in the era of the Voyagers and launched in the era of the shuttle; it operated through the decade in which the Deep Space Network's giant antennas were arrayed and the internet made planetary data public; and it ended just as its successor-generation, Cassini at Saturn, was hitting its stride. The missions that followed, Juno, Europa Clipper, JUICE, all inherited its engineering lessons, its scientific questions, and its data, and the outer-solar-system program of the present is, in a real sense, the extended mission of the spacecraft this book is about.

Chapter 1: Before Galileo — Jupiter from the Ground and the Flybys

Jupiter has been watched since antiquity, but until the twentieth century it was watched as a bright wanderer and a disk with stripes. The four large moons that the original Galileo found in 1610 were the first proof that not everything circles the Earth, and they made the Jovian system a permanent argument for the telescope; three and a half centuries later, the biggest open question about them was still what they were made of. Ground-based astronomy had measured the moons' sizes and orbits, photographed the Great Red Spot across generations, and inferred from Io's colors and Europa's cracked ice that something unusual might be happening at both places, but the resolution of any Earth-based image of Io was worse than the resolution of our moon seen with the naked eye.

The space age gave Jupiter four quick visits. Pioneer 10 crossed the asteroid belt in 1972 and swung past Jupiter in December 1973, the first spacecraft to visit any outer planet, returning the first close-up portraits and the first in-situ measurements of the planet's radiation belts and magnetic field; Pioneer 11 followed in 1974, using a Jupiter gravity assist to bend its trajectory toward Saturn and passing three times closer than its predecessor. The two Pioneers answered the questions that made a real Jupiter mission possible: how intense the radiation environment was, where the magnetosphere sat, and what a safe flyby geometry looked like.

Then, in 1979, the two Voyager spacecraft transformed the system in a matter of days. Voyager 1 and Voyager 2 photographed the Galilean moons with enough resolution to see surfaces, and the results were not what anyone ordered: Io's surface was sulfur-orange and volcanic, with at least nine actively erupting plumes, the first active volcanism found anywhere beyond the Earth; Europa was a shell of cracked ice with almost no craters, hinting at a young and possibly mobile surface; Ganymede and Callisto were mixes of ancient dark terrain and younger grooved or bright terrain, with a puzzle in Ganymede's light-vs-dark patterns. The Voyagers discovered Jupiter's rings, watched lightning in the clouds, charted the magnetosphere's structure, and left the planetary science community with a list of urgent questions that only an orbiting mission could answer. Galileo was conceived in exactly that moment of unfinished business: a Jupiter orbiter with a probe, proposed before the Voyagers even arrived and designed to build on whatever they found.

The scientific inheritance that the mission was designed to spend was assembled in the two decades before launch, and it came from instruments as

various as spectrographs and flyby radios. In the 1950s, radio studies of Jupiter's decametric bursts had revealed that the planet's radio voice was modulated by something, and the rotation of that source, a roughly ten-hour period, gave the planet's true spin; infrared observations in the 1960s found that Jupiter radiates more heat than it receives from the Sun, establishing the planet as a body cooled by its own interior rather than a mere reflector; and spectroscopy of the moons, crude as it was, had given surfaces of water ice for Europa and Ganymede, and something sulfur-tinged for Io.

The theoretical work kept pace: calculations of tidal heating, published in the same era as the first spacecraft plans, predicted that Io's interior should be hot, a prediction that Voyager confirmed with its plumes, and the pre-Galileo literature had already begun to argue that Europa's ice might hide a liquid layer.

There was also the practical problem that a Jupiter orbiter would have to survive in a place no spacecraft had lingered. The radiation environment, measured by the Pioneers and Voyagers, was fierce enough that the mission's designers were forced into a design war with it: electronic parts were selected for radiation tolerance, shielding was built around the most vulnerable boxes, and the flight plan itself was shaped to limit the time spent in the worst zones. The same studies defined the mission's other lasting constraint, the need for nuclear power: at five times the Earth's distance from the Sun, solar panels of the 1970s and 1980s would have been enormous and fragile, and the mission was designed around two radioisotope thermoelectric generators, the same plutonium-fueled sources that had powered the Pioneers and Voyagers, a choice that shaped the spacecraft's configuration, its politics, and its eventual end.

The human record of the planet ran just as deep as the instrumental one, and the mission inherited both. The Great Red Spot has been watched, on and off, since at least the 1830s, and the long ground-based record of its size and color was one of the datasets Galileo was sent to explain; the cloud belts had been charted by generations of amateur observers whose telescope sketches, compiled into longitude maps, were the only weather record of the planet that existed before the spacecraft era; and the atmospheric chemistry, worked out from spectroscopy in the 1960s and 1970s, had identified ammonia ice and ammonia hydrosulfide as the cloud-forming gases and hydrogen, helium, methane, and traces of water as the air they floated in, a composition so close to the Sun's own that the planet had already begun to look like a preserved sample of the solar system's starting material.

The mission's scientists arrived at Jupiter carrying two centuries of telescopic

weather diaries, and the orbiter's long watch was designed, in part, to give those diaries a modern continuation, a bridge from the age of sketching to the age of imaging that is still being used to test whether the giant planet's climate is changing.

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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.