SAMPLE

Solar System Missions: Dawn

Vesta and Ceres

Aira Astralis

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Conclusion

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

Introduction

In the vast ring of rocky debris that circles the Sun between Mars and Jupiter, two worlds preserve the memory of what the solar system was like when it was young. One is Vesta, a rocky protoplanet that formed with a crust, a mantle, and an iron heart — a baby planet frozen in time, too small to grow up. The other is Ceres, a dwarf planet wrapped in ice and salt, hiding briny water beneath its surface — a relic of the ocean-bearing small worlds that once drifted through the outer system. For eleven years, one spacecraft explored them both.

That spacecraft was Dawn, and its name was chosen with care. Dawn did not visit Vesta and Ceres merely to photograph two large rocks. It went to read the record of the solar system's own dawn — the earliest era of planet formation, more than four and a half billion years ago, when small bodies like these were the raw material from which the planets assembled. Vesta and Ceres are survivors from that time: two protoplanets that never merged into anything bigger, preserved like museum pieces in the cold storage of the asteroid belt. Vesta kept its ancient rocky layers intact; Ceres kept its ice and, remarkably, traces of its water. Between the two of them, they bracket the story of how planets are built.

What made Dawn extraordinary, though, was not only its destinations but its engine. Dawn was propelled by ion propulsion — a system that pushes a spacecraft with a whisper of thrust generated by accelerating xenon gas with electric fields. Ion thrust is astonishingly gentle: about the weight of a sheet of paper resting on your hand. But an ion engine can sustain that whisper for years without stopping, steadily building up speeds that no chemical rocket could ever reach with the same amount of fuel. Dawn used its three ion engines to sail across the inner solar system, slow down into orbit around Vesta, climb out again, cross the belt, and settle into orbit around Ceres — the first spacecraft in history to orbit two worlds beyond the Earth-Moon system, and the first to orbit a dwarf planet.

This book tells the story of the Dawn mission. We will begin with the mission's origin in the ideas of planetary scientists who saw the asteroid belt not as a barrier but as a library of planetary formation. We will look at the spacecraft itself — its cameras, its spectrometers, its particle detectors, and its famous engines. We will follow the long voyage: launch in 2007, a gravity assist from Mars, arrival at Vesta in 2011, the crossing to Ceres, and arrival in 2015. We will tour the discoveries: Vesta's towering south polar mountain and the meteorites on Earth that can be traced to its surface; Ceres' glowing salt deposits, its lonely ice volcano, and the organic molecules tucked into its

craters.

And we will meet the challenges: reaction wheels that wore out one by one, forcing the team to fly the spacecraft in ways its designers had hoped to avoid, and a finite supply of hydrazine fuel that finally ended the mission in the autumn of 2018, with Dawn still healthy in orbit around Ceres, where it remains to this day.

The story of Dawn is a story about beginnings — of planets, of ocean worlds, and of a new era of spacecraft propulsion. It is also a demonstration of patient engineering: a mission that spent a decade in flight, changed course around two different worlds, and answered questions scientists had been asking since the 1800s. Welcome aboard.

Chapter 1: The Discovery of Dawn

The Dawn mission began not with a rocket but with a question. By the late twentieth century, planetary scientists had come to understand that the asteroid belt — once dismissed as the rubble left over from a broken planet — was actually the opposite: the residue of the solar system's construction site, the raw planetesimals that never got used. Two members of that residue stood out. Vesta, the second most massive body in the belt, is a rocky world that appears to have melted and differentiated — separated into layers like a tiny planet — within the first few million years of the solar system's existence. Ceres, the largest and most massive, is instead an ice-rich world, closer in nature to the outer solar system's icy moons. Between them, they held the two ends of the planet-formation story.

Scientists wanted to visit both. But the rules of orbital mechanics made this seem impossible. Vesta and Ceres are not close to each other: Vesta orbits the Sun nearer the inner edge of the belt, Ceres farther out near Jupiter's influence. A conventional mission, using chemical rockets for the big velocity changes of orbit insertion, could reach one of them with a reasonable budget — but not both. Slowing down into orbit around one world, then climbing out of its gravity to cross millions of kilometers, and then slowing into orbit around another demanded more fuel than any chemical propulsion system could practically carry.

The answer to that problem had been taking shape since the 1990s: ion propulsion. Ion engines had been proven in space by NASA's Deep Space 1 mission in 1998-2001, which demonstrated that a small spacecraft could thrust almost continuously for months, using a tiny flow of ionized xenon gas accelerated by electric fields. Ion thrust is feeble in the moment but extraordinarily efficient over time — ten times more fuel- efficient than chemical rockets. A spacecraft with ion engines could, in principle, reshape its trajectory gradually, trading brute force for patience, and do what chemical missions could not: orbit one body, leave it, and orbit another.

Into this story came the planetary scientist Christopher Russell of the University of California, Los Angeles, who assembled the scientific case for a two-destination mission, and NASA's Discovery Program — the agency's class of lower-cost, tightly focused planetary missions, which had already flown Mars Pathfinder and the asteroid orbiter NEAR Shoemaker. The Discovery Program's format invited competing proposals from science teams, and the Dawn concept was born through that competition: a spacecraft that would use ion propulsion to visit both Vesta and Ceres, answering questions about the formation of the terrestrial planets and the icy bodies of the outer belt in a

single mission.

The proposal's road was bumpy. NASA selected Dawn as a Discovery mission in 2001, but development troubles — technical problems with the spacecraft and cost growth — led NASA to cancel the mission in March 2006. The decision caused an outcry: an independent review found the problems were not as severe as feared, and within weeks, in a rare reversal, NASA reinstated Dawn. The mission had come close to dying before it ever left Earth; instead, it got its name on the manifest and its hardware on the pad.

Even the launch was a cliffhanger. Dawn was assigned a tight planetary launch window: Vesta's position meant that if Dawn missed its opportunity in mid-2007, the next comparable window was more than a decade away. A launch attempt was scrubbed by weather and then, days later, again by a fueling problem at a nearby Delta rocket pad; engineers fixed the problems under enormous schedule pressure. Finally, on September 27, 2007, a Delta II rocket rose from Cape Canaveral carrying Dawn into space. The spacecraft, packed with instruments and propelled by the gentlest of engines, was on its way to the beginning of the solar system.

The mission had been named for its purpose. Just as dawn is the beginning of the day, Dawn would study the beginning of planetary history — the record preserved in the two largest survivors of the solar system's first generation of planetesimals. Vesta, the dry, rocky relic of the inner belt; Ceres, the icy world of the outer belt; and between them, threaded by a decade of ion thrust, the story of how worlds are made.

Dawn was also, from the beginning, an international mission. The Framing Cameras were developed and constructed by the Gottingen-based Max Planck Institute for Solar System Research together with the German Aerospace

Center and Berlin's Institute for Planetary Research; the Visible and Infrared Spectrometer was contributed by the Italian Space Agency through the Institute for Space Astrophysics and Planetology in Rome; the Gamma Ray and Neutron Detector came from Los Alamos National Laboratory. Science team members were drawn from across the United States and Europe, and the mission's data flowed to an international community. The scientific rationale, too, was built on decades of work by many hands: the classification of the HED meteorites, telescopic spectra of Vesta's surface taken since the 1970s, and the growing recognition — driven by theorists of early solar-system dynamics — that the belt preserves both native and immigrant worlds. Dawn's proposal did not invent the questions it answered; it inherited them, and gave them a spacecraft.

The mission's management structure deserves a final word in this chapter. NASA's Jet Propulsion Laboratory managed the project and supplied the navigators and operations teams; the University of California, Los Angeles, under principal investigator Christopher Russell, hosted the science operations center; Orbital Sciences built the spacecraft. That division of labor — one laboratory for the ship, one university for the science, one company for the hardware — was the organizational pattern of the Discovery Program, and it worked: for eleven years, across two worlds and dozens of orbit changes, the Dawn team held to the discipline of a cost-capped mission while delivering flagship-class results.

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.