SAMPLE

Solar System Missions: Stardust

Capturing Comet Dust

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

Introduction

On February 7, 1999, a Delta II lifted off from Cape Canaveral with a spacecraft whose cargo hold was unlike any before it: a grid of glass-like tiles designed to catch dust, gently, one grain at a time, and bring it home. The spacecraft was Stardust, and over the next seven years it would cross the solar system three and a half times, pass through the coma of a comet at six times the speed of a rifle bullet, and return to Earth carrying the first samples of comet material, and of the dust that drifts between the stars, ever delivered by any mission to any laboratory.

The idea the mission served is older than the space age. Comets are widely understood to be leftover building blocks from the formation of the solar system, ice-rich bodies put together four and a half billion years ago, held ever since in cold storage, and the dust they shed is thought to preserve a record of the materials, chemistry, and conditions of the disk of gas and debris from which the planets formed. But studying a comet across hundreds of millions of kilometers of vacuum limits what can be learned; remote instruments report chemistry that arrives scrambled, and a flyby spacecraft can only guess at what its dust is made of from the ways it scatters light and shatters on impact. To read the record, the record must be brought back. Stardust was the mission built to do it.

The engineering heart of the mission was a substance as strange as its task. The collector was packed with aerogel, a silica foam so tenuous it is mostly emptiness, sometimes described as frozen smoke: the lightest solid material then known. Comet dust arriving at six kilometers per second does not survive a landing on any ordinary surface, but in aerogel a particle burrows a centimeter or two into near-nothingness, slowing over a long and gentle distance like a car eased to rest by an infinitely long cushion, its structure preserved. Track by track, the grains wrote themselves into the collector, and the collector kept them for the journey home.

The mission's plan had three acts. In cruise, the spacecraft opened one side of its collector to the thin, steady drift of interstellar dust, grains that originate in other stars' winds and pass through our solar neighborhood; by mission's end, volunteers scanning microscope images would find the faint tracks they left. Then, on January 2, 2004, Stardust flew within roughly two hundred forty kilometers of the nucleus of Comet 81P/Wild 2, swinging its collector around so the comet-facing side caught the storm of particles streaming from the ice, while shields on the spacecraft body absorbed the ones that would otherwise shred it. Finally, on January 15, 2006, the sample return capsule hit the atmosphere over Utah at nearly thirteen kilometers per second, the fastest

human-made object ever to reenter, and landed intact under parachute in the desert.

That landing closed the loop that the mission's scientists, led by principal investigator Donald Brownlee of the University of Washington, had opened a decade earlier, when Stardust was selected in 1995 as the fourth mission of NASA's Discovery Program of faster, cheaper, focused planetary missions. The chapters that follow tell the story in order: how the mission came to be, how it was built and flown, the science that drove it, the flyby it survived, the firestorm of reentry it endured, and, above all, what the thousands of grains it carried back have told us about where comets, and the solar system itself, actually came from.

Chapter 1: The Discovery of Stardust

The discovery of Stardust is a story about a class of mission rather than a single flash of insight. In the early 1990s, NASA confronted a problem of scale: planetary exploration was becoming so expensive that each flagship mission consumed a decade of budget, and the pace of discovery had slowed to match. The answer, proposed by NASA leadership and accepted by Congress, was the Discovery Program, a standing series of small, focused missions with a fixed cost ceiling, each aimed at one well-defined scientific question, each chosen by open competition. The first was NEAR, sent to orbit the asteroid Eros; the second, Mars Pathfinder, put the first rover on the Red Planet. Stardust, proposed by University of Washington astronomer Donald Brownlee and selected in late 1995, became the program's fourth mission, and its assignment was the one scientists had wanted since the Apollo years: bring back a piece of a comet.

Brownlee was a natural choice. He had spent his career studying extraterrestrial dust, from the meteoritic particles that sift through the upper atmosphere to the interplanetary grains collected by aircraft flying above twenty kilometers, and his name was already on the entry in the field's vocabulary: the smallest meteoroids that slow gently enough in the atmosphere to survive, called Brownlee particles, are named for him. For a mission whose point was to capture comet dust intact and return it, the selection of a scientist whose life's work was the study of such dust was less a gamble than a statement of purpose.

The choice of target was made with the same deliberateness. Comet 81P/Wild 2 was, in mission terms, a fresh comet. Until 1974, Wild 2 orbited far out in the cold, on a long path that kept it beyond Jupiter; then a close pass by that giant planet bent its orbit inward, and only after that gravitational capture did sunlight begin to warm its surface for the first time. A comet that has made only a handful of passes close to the Sun has hardly begun to lose its volatile surface layers, which makes its dust a closer approximation to pristine building-block material than anything an older, sun-baked comet could offer. Wild 2's new orbit was also conveniently placed: perihelion just inside the asteroid belt, an aphelion short of Jupiter's orbit, and an encounter geometry that let an Earth-launched spacecraft reach it without a fuel budget that would break the Discovery Program's cost cap.

Building the spacecraft fell to Lockheed Martin Astronautics in Denver, with the Jet Propulsion Laboratory managing the mission for NASA. The design that emerged was a small, squat, boxy craft, roughly the size of a desk and about three hundred eighty kilograms with fuel, dominated by a single purpose:

protecting and delivering the collector. Nearly everything else was subordinate to that goal. Solar arrays fed the systems because a comet mission flying far from the Sun could not rely on scarce solar power for the encounter itself; a wrap of shield panels called a Whipple shield, a sandwich of bumpers and fabric layers, stood between the comet's dust and the spacecraft's vitals; and the sample return capsule, with its heat shield and parachutes, sat on top like a crown, ready to be left behind at Earth for the final descent.

The name was chosen, with a wink that the mission earned honestly, from the popular song: the spacecraft was sent to collect stardust, the dust of stars long dead, drifting through the solar system as interstellar grains, alongside the comet dust that was its main errand. The name was more than a public-relations touch. It captured the mission's most romantic fact, which is literal: some of the grains Stardust carried home were made inside other stars, before the Sun existed, and had been sailing through the galaxy ever since.

By the standards of the Voyager-era behemoths, the plan was almost austere. One spacecraft, one comet, one asteroid flyby taken along the way as a rehearsal, seven years in flight, and a payload that fit in a capsule the size of a car tire. But the science it promised, a laboratory full of comet, had never been done, and the Discovery Program had been created precisely to send missions like this one: cheap enough to risk, focused enough to finish.

The selection process that produced Stardust was itself part of the Discovery Program's experiment. NASA issued a broad announcement, the planetary science community proposed, and the proposals fought it out in open review, a competition that rewarded focused science over institutional size. The Stardust proposal won in 1995 against a strong field partly on the strength of its restraint: it asked for one comet, one collector, and a return, nothing more, and the reviewers could see exactly where every dollar went. That legibility became a Discovery Program virtue, and Stardust, delivered on schedule and at its cost cap, became the program's proof that the model worked.

The mission's structure followed the principal-investigator model that the Discovery Program popularized: Brownlee's science team set the objectives and interpreted the results, the Jet Propulsion Laboratory managed the flight project, and Lockheed Martin built and operated the spacecraft, with smaller instruments contributed by European partners whose mass spectrometer flew as international science. The pattern, science leadership, engineering partnership, international contribution, was new enough in the 1990s to be considered an experiment; it is now the standard shape of NASA's small missions, and Stardust was one of the first to prove that it could deliver.

The schedule the mission was then handed deserves a paragraph, because it

set the tempo of everything that followed. Selected in late 1995, Stardust was on the pad by February 1999, a shade over three years from a proposal's acceptance to a launch, a cadence the flagship era never approached, and the tight clock was the Discovery idea working as intended: a small spacecraft with one purpose can be built in the time a large one spends in design review. The budget's arithmetic was equally deliberate, a cost cap the proposal had promised and the project then honored, so that when the samples landed the mission stood in the record as the program's first unambiguous proof that a planetary mission could be delivered on time, on cost, and with its cargo's science intact, the precedent its siblings have been measured against since.

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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.