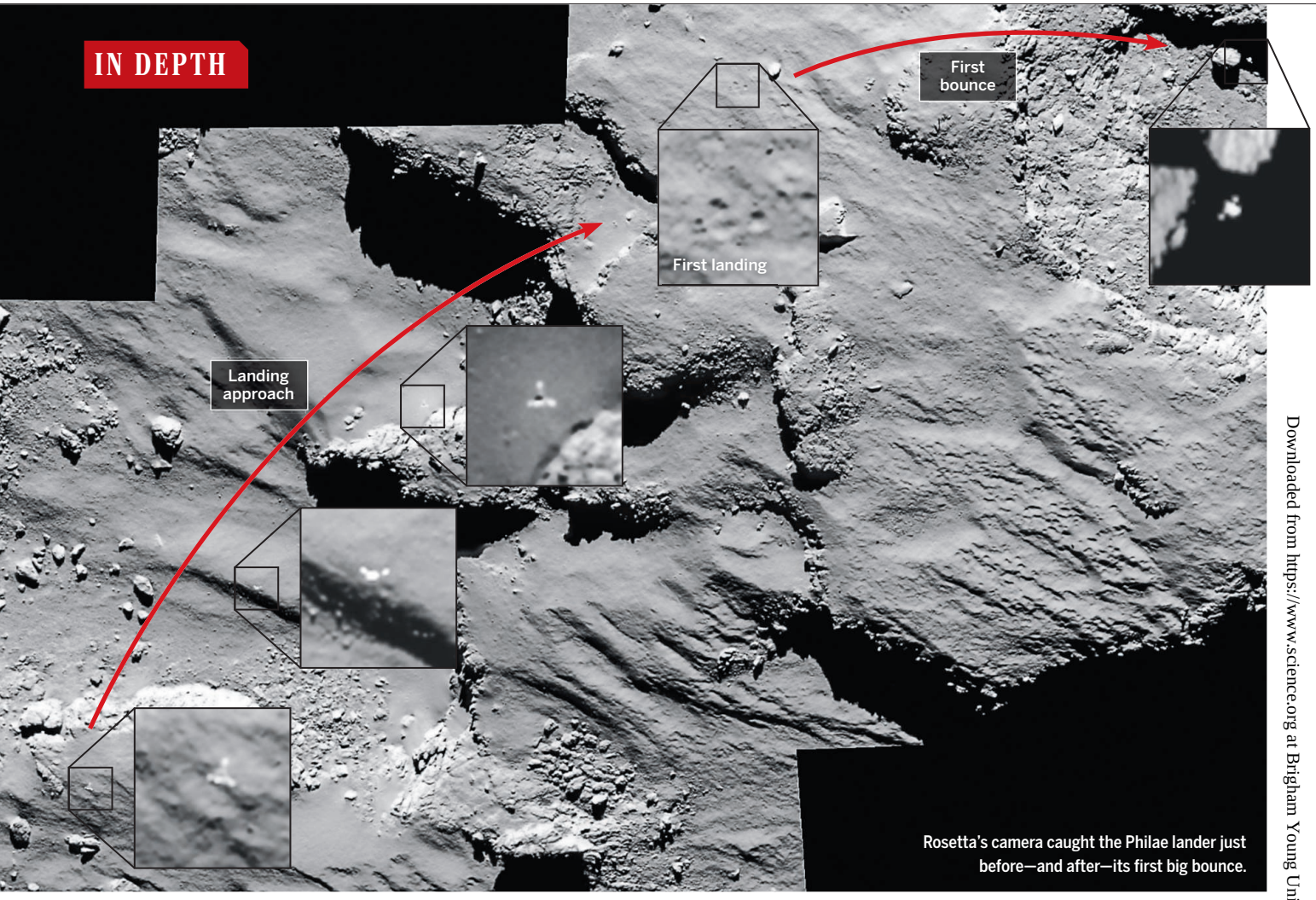


Rosetta's camera caught the Philae lander just before—and after—its first big bounce.

PLANETARY SCIENCE

Philae probe makes bumpy touchdown on a comet

Elation and disappointment as lander goes into early hibernation, curtailing experiments

By **Eric Hand**, *in Darmstadt, Germany*

After the Philae probe bounced its way to a tenuous, unanchored perch on a comet—a bittersweet victory for the European Space Agency (ESA) and its Rosetta mission—Fred Jansen cried in the control room. Hours later, Jansen, the Rosetta project manager at ESA's European Space Research and Technology Centre in Noordwijk, the Netherlands, took himself to his hotel bar, bleary and hoarse. Colleagues asked to join him, but he brushed them off and drank two glasses of white wine alone. "I didn't know you could feel this bad and be so happy at the same time," he says. "Emotions are still running through my system in a way that is unbelievable."

Jansen had reason to feel joyful. Until last week, robots had landed on just six bodies: the moon, Venus, Mars, Saturn's moon Titan, and the asteroids Eros and Itokawa. Philae had added another locale to the list: a comet. "It's a great day," said ESA Director General Jean-Jacques Dordain in a postlanding briefing. "Not only for ESA but, I think, for the world." But it was not the perfect landing that Jansen and others had hoped for, against admittedly long odds. A series of glitches had doomed Philae to a short life and left its scientific harvest uncertain.

On 12 November, the Rosetta comet orbiter dropped Philae from an altitude of 22.5 kilometers. It took about 7 hours for the washing machine–sized probe to drift to the surface of 67P/Churyumov-Gerasimenko, a duck-shaped comet about 4 kilometers long. First came a big bounce, a sign that the comet's black crust of dust, organic molecules, and ice is harder than thought. Philae rebounded at the speed of a slow walk. In the weak gravity, it reached a height of a kilometer and may have flown laterally another kilometer. After a second, smaller bounce, it finally came to awkward stop—tipped up on its side and sitting in the shadows of some sort of cliff wall, with scant sunlight to recharge its batteries.

Scientists made the most of their new home. They tried to gather data from its 10 instruments for 57 hours, before the lander's batteries were exhausted and it fell into hibernation. It could be many weeks before scientists understand what the lander data tell them about the formation and composition of 67P, which, like all comets, is a relatively pristine object that dates to the early days of the solar system.

Just getting to 67P had been an immense challenge. Rosetta spent a decade after its 2004 launch wheeling through the solar system, traveling 6.5 billion kilometers before finally meeting up with its target in August. The long, intricate voyage has shown that ESA can manage a €1.4 billion mission with many moving parts and competing national interests. For example, Philae was built primarily by France and Germany, and its instruments were managed from control rooms in Toulouse, France, and Cologne, Germany—which in turn relayed instrument commands to Rosetta via ESA's main control room in Darmstadt, Germany.

The Rosetta orbiter will continue to orbit 67P for the next 13 months, monitoring the comet as it draws closer to the sun and ever more of its subsurface ice sublimes, or outgasses, driving jets of gas and dust. But, the landing was always going to be the mission's climax. It almost didn't come to pass. Two days before the attempt, controllers had trouble turning on the lander. The next day, engineers discovered that reverse thrusters, meant to keep Philae pinned to the surface after touchdown, were unlikely to work. Mission managers came within a hair's breadth of postponing the landing. "You can imagine the four-letter words," Jansen says.

Deciding that a delay would solve nothing, managers went ahead with the attempt. The problems multiplied at touchdown: Not only did the reverse thrusters not thrust, but two harpoons meant to fasten the probe also failed to fire, leaving Philae to bounce across the comet into rugged terrain.

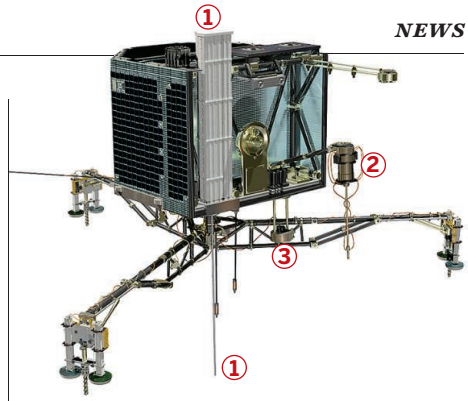
With just 1.5 hours of daylight a day falling on Philae in its shadowed position, hopes for recharging its batteries were dim. The elation of landing quickly turned into a frantic effort to wring science from the limited time. Not all turned out well. A rod meant to measure heat flow broke while the lander was attempting to hammer it into the comet's surprisingly tough surface. The shutters to another instrument—one that measures composition by bombarding materials with x-rays—did not open, so the instrument measured mostly the titanium and copper of the shutters. And the most sought-after result—an attempt to measure the composition of a subsurface sample obtained by a drill—did not come to pass. Fred Goesmann, principal investigator for one of two sample analysis instruments at the Max Planck Institute for Solar System in Göttingen, Germany, says the drill appeared to move down and up correctly. It also seemed to have delivered something to one of Goesmann's ovens. His ovens duly heated up. But the data show nothing. "It's indistinguishable from not having received a sample," Goesmann says. He doesn't know whether the problem was with the drilling or with his instrument.

There are still plenty of data to be thankful for. Both sample analysis instruments were able to "sniff" the gases present near the surface. Goesmann says one of his sniffs—just after the big bounce—seems richer than the others, perhaps a sign that dust was stirred up by the landing and sucked into his machine. The other sample analysis instrument, called Ptolemy, used its last moments to analyze a sniff chamber that had been trapping and concentrating ambient gases. Ptolemy's principal investigator, Ian Wright, of the Open University in Milton Keynes, U.K., hopes concentrations are high enough for researchers to measure rare isotopes of hydrogen, oxygen, and nitrogen. "We were pretty pleased at how things turned out," he says.

For Gerhard Schwehm, former project scientist for Rosetta, Philae was always going to be the cherry on top of a very big cake. The Rosetta orbiter remains entirely healthy and powerful, he says. Already, scientists are making significant findings. At a planetary science conference last week in Tucson, Arizona, members of the orbiter's camera team presented images that showed arcs of dust emanating from jets—a finding that could help them understand the mechanisms of outgassing. A radar instrument, working in concert with a receiver on Philae, got data about the interior of the comet that could help unravel a major question: Does 67P have its duck head and body because two separate cometesimals came together? Or was 67P stretched and nearly broken apart—perhaps by a gravitational perturbation from Jupiter?

And ROSINA, a Rosetta instrument that uses spectrometers to measure gas abundances, has obtained a highly sought after result: the so-called deuterium-to-hydrogen ratio of water in the comet's thin atmosphere, or coma. The measured value for 67P is much higher than the ratio in Earth's oceans and higher than in other comets, says ROSINA principal investigator Kathrin Altwegg, of the University of Bern. Three years ago, the comet Hartley-2 was found to have a D-to-H ratio near that of Earth's oceans—sparking interest in the notion that comet impacts delivered much of Earth's water. Altwegg says the result for 67P could make asteroids the primary suspect again.

In one of their last commands to Philae, controllers made the lander turn by 35° and lifted it up several centimeters, in hopes of putting Philae's solar panels in a more favorable position. Goesmann says he is still optimistic that they will get to do science again with Philae. As 67P approaches the sun and the comet's orientation changes, more light could reach its solar panels. He says the emotional roller coaster of last week is over for now, but not for good. "The battle's over, we're still alive," Goesmann says. "Did we win? I don't know." ■



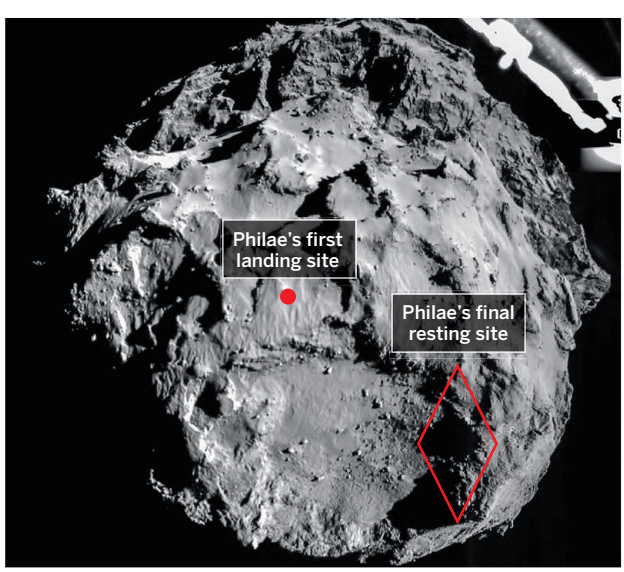
Out in the cold

Philae tried to use all 10 of its instruments during its 57 hours on the surface, but some encountered problems.

1. SD2: Philae's drill tried to deliver a subsurface sample to an oven, but data indicate nothing was in the sample.

2. MUPUS: This heat-measuring device broke during attempts to penetrate the comet.

3. APXS: The shutters to this x-ray experiment never opened.



A camera on the belly of Philae took this image 3 kilometers above the comet's surface. Scientists are still searching for the lander's final resting place.

IMAGES: ESA (2)