# Johns Hopkins engineers helping NASA restore links to long-lost 'zombie' satellite

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When aerospace engineers launch a satellite, they don't expect it to last forever. So when the NASA orbiter known as IMAGE disappeared from view after five years in orbit, few were alarmed.

What did stun the field came last January, when an amateur satellite watcher spotted IMAGE in the skies again after a dozen years—and realized it was still trying to talk to earth.

"I've been in this field since the late 1980s, and it almost never happens that a lost spacecraft is found again, especially after so long," said Jeffrey J.E. Hayes, program executive for missions at NASA headquarters in Washington. "IMAGE is this zombie that came back to life."

Now space scientists across the United States are working on the long-lost spacecraft again, trying to help NASA keep steady contact and assert control. Among them is a team at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md.

It was Bill Dove, an engineer who manages the Hopkins lab's Satellite Communications Facility, and his colleague Tony Garcia, lead engineer in APL's Space Exploration Sector, who led the way in locking down communication with the $150 million craft, first launched in 2000. They've spent months downloading its signals and feeding them to NASA.

After they re-established communication between the spacecraft and earth, the signal was strong for three weeks in February before dropping out again. It returned more weakly in March, then came back strong early this month.

The APL team has been monitoring the proceedings throughout, and Dove, a 38-year veteran of the field, said he has never had a project quite like it.

"We've been presented with a rare and unique technical challenge," he said. "We continue to get (radio communication) from IMAGE, and we're helping NASA out as much as we can."

The story of IMAGE began toward the end of the last millennium, when scientists at the Southwest Research Institute in San Antonio, Texas, and elsewhere set out to explore the relationship between solar wind—the stream of charged particles that flow into space from the sun's upper atmosphere—and the magnetosphere, the vast, dynamic sphere of magnetic gas that surrounds the earth and protects its inhabitants from the sun.

They wanted to learn more about how changes in the speed, density and temperature of solar wind affect atmospheric conditions on earth—specifically how they create and shape aurora borealis and aurora australis, the northern and southern lights.

To that end, NASA designed and built Imager for Magnetopause-to-Aurora Global Exploration, the first spacecraft ever dedicated to producing visible images of the magnetosphere.

The agency launched IMAGE—a solar battery-powered, 1,087-pound hexagonal satellite with six specialized imagers, or cameras, on board—on March 25, 2000.

It orbited the earth around the north and south poles at an altitude of 650 kilometers, producing the first comprehensive images of the plasma in the earth's inner magnetosphere, or plasmasphere.

Though astrophysicists know that the magnetospehere responds to solar winds when those winds reach speeds of several hundred kilometers per hour, they're still trying to "understand the actual mechanism in fine detail," Hayes said.

IMAGE was doing unexpectedly well at providing answers. It transmitted images leading to 39 new discoveries, including some that confirmed theoretical predictions and others that identified new, unpredicted features.

NASA headquarters had just deemed it the second most valuable space-physics mission flying when it suddenly went dark and stopped responding to commands on Dec. 18, 2005.

Several theories emerged as to why—the most widely cited was a shorted-out power converter—but no clear answer emerged.

After months of trying to reestablish contact, NASA cancelled the mission and its funding.

"At some point, you have to cut your losses," said Hayes, whose current projects include overseeing the Voyager program and the Hubble Space Telescope.

Then this past winter, Scott Tilley, a hobbyist astronomer in Roberts Creek, British Columbia, near Vancouver, was searching for another satellite on Jan. 20 when he spotted an object roughly where IMAGE would have been if it were functional—one that was emitting a radio signal similar to the last one IMAGE had sent.

He notified NASA, where astonished officials, including Hayes, asked several of the agency's affiliated sky-watching stations to run more detailed tests.

The sites included Goddard Space Flight Center in Greenbelt, Wallops Flight Facility on Virginia's Eastern Shore and White Sands Test Facility in Las Cruces, N.M.

Goddard located the new signal on Friday, Jan. 26, but it was Hopkins APL that took the next crucial steps.

Dove and Garcia dialed the facility's 60-foot satellite dish toward the spacecraft's expected location. That weekend, Dove reconfigured the 56-year-old antenna so that it receive signals from IMAGE's equipment, much of which had become obsolete in the intervening years.

On Monday, Garcia went to work.

He adjusted the antenna's frame of vision in half-degree increments, then zeroed in on the moving object's radio frequency, which turned out to be exactly 44.44 kilobits per second.

"Tony worked what I call his 'magic,'" Dove said. "He basically used his 30-plus years of expertise to change the values, bit by bit, until he cracked the code."

They had achieved "telemetric lock." Data from the satellite began flowing in.

Hopkins APL doesn't have the facilities to interpret such data files, but the engineers sent them to NASA, which quickly used it to decode the object's spacecraft ID—166.

Richard J. Burley, the original mission director for IMAGE, notified Tilley by email, and the space buff tweeted the news to the world.

"NASA confirms IMAGE is indeed alive!" he wrote.

Early information from the spacecraft has been "housekeeping" data that indicates its condition—which Hayes said is "surprisingly healthy."

At least three major scientific instruments have been disabled, Hayes said, and the inconstancy of its signals—IMAGE "disappeared" again once, and its signals have fluctuated wildly—suggest that it's now "tumbling" through space, which means its spin control is out of whack.

Engineers have so far failed to establish the two-way communication they would need to correct problems on the craft, let alone revive its original mission.

That kind of happy ending, Hayes said, would require engineers to exhibit such clear control of the craft that NASA's review board would reapprove its funding stream at a time when competition for funds among missions is more intense than ever.

In the meantime, Dove, Garcia and their counterparts at Goddard, White Sands and elsewhere are working on their own time—and using whatever hours they can secure on NASA's busy worldwide antenna network—to monitor IMAGE.

"We're all still waiting for that epiphany when we hit the right path at the right time, and not only lock on but establish control," Hayes said. "Is it a long shot? Yes, but I learned something important a long time ago: Spacecraft do very strange things."