The Lab in the Sky Says *Goodbye*

A NASA DC-8 aircraft used to train many Caltech student-scientists has taken its final flight.

By Andrew Moseman

When the vintage DC-8 airliner made one of its harrowing low passes over California's Central Valley, things got a little bumpy for the undergraduates packed inside.

It was often hot and stuffy inside the flying atmospheric chemistry laboratory, which NASA had rebuilt in the 1980s and which gave students the chance to perform research, says Emily Schaller (PhD '08), who ran the NASA internship program from 2011 to 2021. On any given research flight, the jet full of budding chemists and climate scientists, some of whom came from Caltech, might plow through the turbulent air at low altitudes to measure methane emissions from a large cattle ranch or study the health of kelp in the Santa Barbara Channel.

"A fair number of the students would end up losing their lunch," Schaller says. "But that bonded them in a new way. We used the hashtag #IPukedforScience on social media and, one summer, they made a T-shirt to that effect. But they were all very proud of the data they collected."

The trusty aircraft gave countless undergraduates a turbulent baptism as airborne scientists. Because it was based at the NASA Armstrong Flight Research Center in the nearby California desert, the DC-8 also helped a generation of Caltech scientists conduct research on Earth's atmosphere. Now its day is done: The DC-8 made its final science flight in April 2024.

Paul Wennberg, the R. Stanton Avery Professor of Atmospheric Chemistry and Environmental Science and Engineering, tweeted a photo of the DC-8 after it landed at Armstrong, which is near Palmdale, following its swan song. "This was the last science flight of the aircraft," he wrote. "It is headed to a well-deserved retirement."

Kat Ball, a graduate student in Wennberg's lab, was aboard that flight and many others, as the DC-8's airborne lab powered her graduate research in atmospheric chemistry. Ball uses mass spectrometry to study and quantify pollutants that come not only from vehicle emissions but also from volcanoes, wildfires, agriculture, and manufacturing. While satellites can analyze the atmosphere below them, Ball says they measure the whole column of air and cannot determine the composition of gases at discrete elevations. For that, you still need a plane.

"We could look at different altitudes in a pretty quick time span as the plane went up and down," Ball says. "The composition can change as you go up and down. That is important for understanding chemistry and how things are transported in the atmosphere."

Graduate student Kat Ball fills a cryogenic pump with liquid nitrogen. The pump keeps her instruments clean during the downtime between flights.

History in the Air

The Douglas DC-8 line was among the planes that powered the jet age. It debuted in the 1950s as one of the first narrow-body airliners, allowing for six seats in each row. Douglas (later McDonnell Douglas) made hundreds of DC-8s for clients such as Pan American World Airways up until the early 1970s, when bigger and better jets came on the market. Kirsten Boogaard, deputy project manager for NASA's DC-8 program, says the specific plane bought by the agency in the 1980s had flown for Alitalia in its previous life. Refitted as a platform for aerial science, the DC-8 would fly for nearly four more decades.

NASA's plane retained some of the first-class seats from its passenger days, and the retro blue carpeting remained too. Apart from that, the DC-8's redesigned interior bore little resemblance to an airliner. The fuselage was packed full of metal racks where researchers could mount the computers and tools they would monitor during the flight. These machines were connected to instruments mounted on the outside of the plane that sampled the air and were changed to meet the needs of each mission. "We stripped the entire inside to be able to do specific configurations of the scientists and their instruments for each flight," Boogaard says.

Cushy seats aside, the DC-8 trips were not an exercise in aerial luxury. Flight days, Ball explains, included three hours of prep to work out preflight procedures and instrument calibrations. Then came eight hours in the air, followed by one more after landing to shut down the tools and retrieve data. Some researchers worked these 12-hour shifts for days on end.

John Crounse (PhD '11), lead staff scientist at Caltech's Ronald and Maxine Linde Center for Global Environmental Science, flew on the DC-8 for nearly 20 years to map the composition of the atmosphere throughout each year. The proximity of the plane's home base to Caltech gave Institute researchers a terrific opportunity to study the atmosphere firsthand, he says. "We could take our instrument in a rental truck up to Palmdale in half a day, unload it, put it on the plane, and go back home."

He also remembers the heat. Much of the plane's air-conditioning equipment was stripped to make room for laboratory gear. Ducts to blow cool air remained in the front and back of the plane. "By the time you got to the middle, there's not a lot of airflow that comes out," he says. "The heat concentrates there, and that's where we sat for 20 years."

Around the World

The rewards were worth the discomfort, Ball says, and not just because of the unique atmospheric chemistry dataset and scientific opportunities. Flying in the DC-8 allowed her to see the world. Ball's missions included the Atmospheric Emissions and Reactions Observed from Megacities to Marine Areas campaign in summer 2023, which sampled air above big cities; this meant Ball rode in the plane as it made low passes by the Statue of Liberty. A similar campaign called ASIA-AQ early in 2024 took Ball across the Pacific Ocean to study the atmosphere above East Asian nations such as South Korea, Thailand, and the Philippines. "I've been able to see cities all over the world that I would not have gotten to see otherwise," she says. "And I got to see them from pretty low altitudes."

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Similarly, flights for NASA's Operation IceBridge mission throughout the 2010s carried Schaller to the far ends of the planet, with close passes over glaciers in Antarctica and Greenland. "One of my fondest memories is flying over the North Pole at about 1,500 feet while the Icebridge team was making measurements of the thickness of the sea," she says. "I was leading a live chat with a classroom back in the United States, and they were asking if we saw Santa."

Crounse has flown on nearly a dozen DC-8 research campaigns over the past two decades. One of the most memorable projects, he says, was the Atmospheric Tomography Mission from 2016 to 2018, during which the DC-8 circumnavigated the globe during each of the four seasons of the year. The missions took him to sites including Alaska, Hawaii, the Azores, Chile, and New Zealand. He also traveled over the western United States in 2019 to quantify the atmospheric impacts of major wildfires. "The airplane would go from its maximum altitude, which is somewhere around 12 kilometers, down to about 500 meters above the ocean," he says. "And it would do that repeatedly throughout the whole flight. That dataset has proven invaluable for understanding the global atmosphere."

The DC-8's rugged nature—this was a tough, overbuilt machine, the scientists agree—helped it to withstand its many shaky trips through the atmospheric boundary layer, the lowest portion of the atmosphere affected by Earth's surface. But even a durable plane does not last forever, especially when decades have passed since the last one was built. "Every time something breaks it's just a big effort to find that part," Boogaard says. "You can compare it to an old car."

But, Wennberg notes, "this old car was an enormous asset for airborne investigations. With its ability to host a large payload and operate from only a few hundred feet above the ground to more than 40,000 feet, the DC-8 was a workhorse for Caltech earth scientists studying global change in atmospheric composition, the glaciers, the oceans, and the terrestrial biosphere."

NASA recently acquired a Boeing 777 to serve as its next-generation airborne lab, and Boogaard will be moving to the East Coast to oversee its various missions. The DC-8, meanwhile, is not going to the boneyard. NASA has donated the plane to Idaho State University. "They are using it to train the next generation of aircraft technicians," Boogaard says. "They're going to get hands-on real-time experience with a beautiful aircraft."

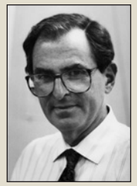
In Memoriam

To learn more about their lives and work, visit **magazine.caltech.edu/post/in-memoriam**.

Camilla Chandler Frost (1925–2024)

Frost, a life member of the Caltech community, passed away on February 7, 2024, at age 98. Frost was appointed to the Caltech Board of Trustees in 1977 and became a life member in 2007. She served as co-chair of Caltech's Biological Sciences Initiative. The Chandler family's philanthropy has supported endowed professorships as well as the Norman Chandler Scholarship Fund, the Norman Chandler Memorial Laboratory, and the Camilla Chandler Frost Laboratories.

David Goodstein (1939–2024)



Goodstein, the Frank J. Gilloon Distinguished Teaching and Service Professor, Emeritus, and professor of physics and applied physics, emeritus, passed away on April 10, 2024, at age 85. He served as a professor at Caltech for 40-plus years and as the Institute's vice provost from 1987 to 2007. In the 1980s, Goodstein was the director and host of *The Mechanical Universe,* an educational TV series. He authored several books, including *Feynman's Lost Lecture,* which was written with his wife, Judy Goodstein, Caltech university archivist, emeritus.

Fred C. Anson (BS '54, 1933–2024)

Anson (BS '54), the Elizabeth W. Gilloon Professor of Chemistry, Emeritus, passed away on May 22, 2024, at age 91. Anson spent his entire career at Caltech. He was appointed assistant professor in 1958, associate professor in 1962, full professor in 1968, and the Gilloon Professor in 1995. His research focused on the kinetics, mechanisms, and catalysis of electrode reactions. Anson was chair of Caltech's Division of Chemistry and Chemical Engineering from 1984–1994.

Virginia V. Weldon (1935–2024)

Weldon, a life member of the Caltech community, passed away on May 23, 2024, at age 88. Weldon was first named to the Caltech Board of Trustees in 1996 and became a life member in 2010. She served on the pediatrics faculty at the Washington University School of Medicine and as co-director of the division of pediatric endocrinology and metabolism. Later, she became deputy vice chancellor for medical affairs and vice president of Washington University Medical Center. She was Monsanto's senior vice president, public policy, from 1989–1998.

Edward C. Stone (1936–2024)

Stone, the David Morrisroe Professor of Physics, Emeritus, passed away on June 9, 2024, at age 88. Stone spent six decades at Caltech, leading numerous space missions, overseeing the construction of the W. M. Keck Observatory, establishing the Institute's Space Radiation Lab, and more. He served as project scientist for NASA's twin Voyager spacecraft for 50 years. He was chair of Caltech's Division of Physics, Mathematics and Astronomy from 1983–88, and director of JPL from 1991–2001.

Jeff Kimble (1949–2024)

Kimble, the William L. Valentine Professor of Physics, Emeritus, passed away on September 2, 2024, at age 75. Kimble became a professor at Caltech in 1989, the William L. Valentine Professor in 1997, and professor emeritus in 2021. He helped found and served as the inaugural director of the Institute for Quantum Information (now the Institute for Quantum Information and Matter). A giant in the field of quantum optics and quantum information science, Kimble's cavity quantum electrodynamics experiments formed the basis of many current quantum technologies. Kimble and colleagues conceived and demonstrated the methods for generating squeezed light that are now employed at LIGO (the Laser Interferometer Gravitational-wave Observatory).