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# NASA's ICON mission ends with several ionospheric breakthroughs

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The lowest reaches of space glow with bright bands of color called airglow. Credit: NASA

After contributing to many important findings on the boundary between Earth's atmosphere and space, the Ionospheric Connection Explorer

(ICON) mission has come to an end. ICON launched in October 2019 and after completing its two-year mission objectives in December 2021, it operated as an extended mission for another year.

"The ICON mission has truly lived up to its name," said Joseph Westlake, heliophysics division director at NASA Headquarters in Washington. "ICON not only successfully completed and exceeded its primary mission objectives, it also provided critical insights into the ionosphere and the interplay between space and terrestrial weather."

The ICON spacecraft studied a part of our planet's outermost layer of the atmosphere, called the ionosphere. From there, ICON investigated what events impact the ionosphere, including Earth's weather from below and space weather from above.

The ionosphere is the lowest boundary of space, located between 55 miles to 360 miles above Earth's surface. It is made up of a sea of particles that have been ionized, a mix of positively charged ions and negatively charged electrons called plasma. This frontier of space is a dynamic and busy region, home to many satellites—including the International Space Station—and is a conduit for radio communications and GPS signals.

Both satellites and signals can be disrupted by the complex interactions of terrestrial and space weather. Studying and understanding the ionosphere is crucial to understanding space weather and its effects on our technology.

The ICON mission captured unprecedented data about the ionosphere with direct measurements of the charged gas in its immediate surroundings alongside images of one of the ionosphere's most stunning features—airglow.

ICON tracked the colorful bands as they moved through the ionosphere. Airglow is created by a process similar to what creates the aurora. However, airglow occurs around the world, not just the northern and southern latitudes where auroras are typically found. Although airglow is normally dim, ICON's instruments were specially designed to capture even the faintest glow to build a picture of the ionosphere's density, composition, and structure.

Through the principle of Doppler shift, ICON's sensitive imagers also detected the motion of the atmosphere as it glowed. "It's like measuring a train's speed by detecting the change in the pitch of its horn—but with light," said Thomas J. Immel, ICON mission lead at the University of California, Berkeley. The mission was specifically designed to perform this technically difficult measurement.

## A new ionospheric perspective

The ICON mission's comprehensive view of the upper atmosphere provided valuable data for scientists to unravel for years to come. For instance, its measurements showed how the 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption disrupted electrical currents in the ionosphere.

"ICON was able to capture the speed of the volcanic eruption, allowing us to directly see how it affected the motion of charged particles in the ionosphere," Immel said. "This was a clear example of the connection between tropical weather and ionospheric structure. ICON showed us how things that happen in terrestrial weather have a direct correlation with events in space."

Another scientific breakthrough was ICON's measurements of the motion of ions in the atmosphere and their relationship with Earth's magnetic field lines. "It was truly unique," Immel remarked. "ICON's measurements of the motion of ions in the atmosphere was scientifically transformational in our understanding of behavior in the ionosphere."

With ICON's help, scientists better understand how these interactions drive a process called the ionospheric dynamo. The dynamo, which lies at the bottom of the ionosphere, remained a mystery for decades because it is difficult to observe.

ICON provided the first concrete observation of winds fueling the dynamo and how this influences space weather. Unpredictable terrestrial winds move plasma around the ionosphere, sending the charged particles shooting out into space or plummeting toward Earth. This electrically charged tug-of-war between the ionosphere and Earth's electromagnetic fields acts as a generator, creating complex electric and magnetic fields that can affect both technology and the ionosphere itself.

"No one had ever seen this before," Immel said. "ICON finally and conclusively provided experimental confirmation of the wind dynamo theory."

## An iconic legacy

On Nov. 25, 2022, the ICON team lost contact with the spacecraft. Communication with the spacecraft could not be established, even after performing a power cycle reset using a built-in command loss timer. Though the spacecraft remains intact, other troubleshooting techniques were unable to re-establish contact between the ICON spacecraft and mission operators.

"ICON's legacy will live on through the breakthrough knowledge it provided while it was active and the vast dataset from its observations that will continue to yield new science," Westlake said. "ICON serves as a foundation for new missions to come."

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