

# MOXIE experiment reliably produces oxygen on Mars

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On the red and dusty surface of Mars, nearly 100 million miles from Earth, an instrument the size of a lunchbox is proving it can reliably do the work of a small tree.

The MIT-led Mars Oxygen In-Situ Resource Utilization Experiment, or MOXIE, has been successfully making [oxygen](#) from the Red Planet's

carbon-dioxide-rich atmosphere since February 2021, when it touched down on the Martian surface as part of NASA's Perseverance rover mission.

In a study published in the journal *Science Advances*, researchers report that, by the end of 2021, MOXIE was able to produce oxygen on seven experimental runs, in a variety of atmospheric conditions, including during the day and night, and through different Martian seasons. In each run, the instrument reached its target of producing six grams of oxygen per hour—about the rate of a modest tree on Earth.

Researchers envision that a scaled-up version of MOXIE could be sent to Mars ahead of a human mission, to continuously produce oxygen at the rate of several hundred trees. At that capacity, the system should generate enough oxygen to both sustain humans once they arrive, and fuel a rocket for returning astronauts back to Earth.

So far, MOXIE's steady output is a promising first step toward that goal.

"We have learned a tremendous amount that will inform future systems at a larger scale," says Michael Hecht, principal investigator of the MOXIE mission at MIT's Haystack Observatory.

MOXIE's oxygen production on Mars also represents the first demonstration of "in-situ resource utilization," which is the idea of harvesting and using a planet's materials (in this case, carbon dioxide on Mars) to make resources (such as oxygen) that would otherwise have to be transported from Earth.

"This is the first demonstration of actually using resources on the surface of another planetary body, and transforming them chemically into something that would be useful for a human mission," says MOXIE deputy principal investigator Jeffrey Hoffman, a professor of the

practice in MIT's Department of Aeronautics and Astronautics. "It's historic in that sense."

Hoffman and Hecht's MIT co-authors include MOXIE team members Jason SooHoo, Andrew Liu, Eric Hinterman, Maya Nasr, Shravan Hariharan, and Kyle Horn, along with collaborators from multiple institutions including NASA's Jet Propulsion Laboratory, which managed MOXIE's development, flight software, packaging, and testing prior to launch.

## Seasonal air

The current version of MOXIE is small by design, in order to fit aboard the Perseverance rover, and is built to run for short periods, starting up and shutting down with each run, depending on the rover's exploration schedule and mission responsibilities. In contrast, a full-scale oxygen factory would include larger units that would ideally run continuously.

Despite the necessary compromises in MOXIE's current design, the instrument has shown it can reliably and efficiently convert Mars' atmosphere into pure oxygen. It does so by first drawing the Martian air in through a filter that cleans it of contaminants. The air is then pressurized, and sent through the Solid OXide Electrolyzer (SOXE), an instrument developed and built by OxEon Energy, that electrochemically splits the carbon dioxide-rich air into oxygen ions and [carbon monoxide](#).

The oxygen ions are then isolated and recombined to form breathable, molecular oxygen, or O<sub>2</sub>, which MOXIE then measures for quantity and purity before releasing it harmlessly back into the air, along with carbon monoxide and other atmospheric gases.

Since the rover's landing in February 2021, MOXIE engineers have started up the instrument seven times throughout the Martian year, each

time taking a few hours to warm up, then another hour to make oxygen before powering back down. Each run was scheduled for a different time of day or night, and in different seasons, to see whether MOXIE could accommodate shifts in the planet's atmospheric conditions.

"The atmosphere of Mars is far more variable than Earth," Hoffman notes. "The density of the air can vary by a factor of two through the year, and the temperature can vary by 100 degrees. One objective is to show we can run in all seasons."

So far, MOXIE has shown that it can make oxygen at almost any time of the Martian day and year.

"The only thing we have not demonstrated is running at dawn or dusk, when the temperature is changing substantially," Hecht says. "We do have an ace up our sleeve that will let us do that, and once we test that in the lab, we can reach that last milestone to show we can really run any time."

## **Ahead of the game**

As MOXIE continues to churn out oxygen on Mars, engineers plan to push its capacity, and increase its production, particularly in the Martian spring, when atmospheric density and [carbon dioxide](#) levels are high.

"The next run coming up will be during the highest density of the year, and we just want to make as much oxygen as we can," Hecht says. "So we'll set everything as high as we dare, and let it run as long as we can."

They will also monitor the system for signs of wear and tear. As MOXIE is just one experiment among several aboard the Perseverance rover, it cannot run continuously as a full-scale system would. Instead, the instrument must start up and shut down with each run—a thermal stress

that can degrade the system over time.

If MOXIE can operate successfully despite repeatedly turning on and off, this would suggest that a full-scale system, designed to run continuously, could do so for thousands of hours.

"To support a human mission to Mars, we have to bring a lot of stuff from Earth, like computers, spacesuits, and habitats," Hoffman says. "But dumb old oxygen? If you can make it there, go for it—you're way ahead of the game."

**More information:** Mars Oxygen ISRU Experiment (MOXIE)—Preparing for human Mars exploration, *Science Advances* (2022). [www.science.org/doi/10.1126/sciadv.abp8636](https://www.science.org/doi/10.1126/sciadv.abp8636)

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