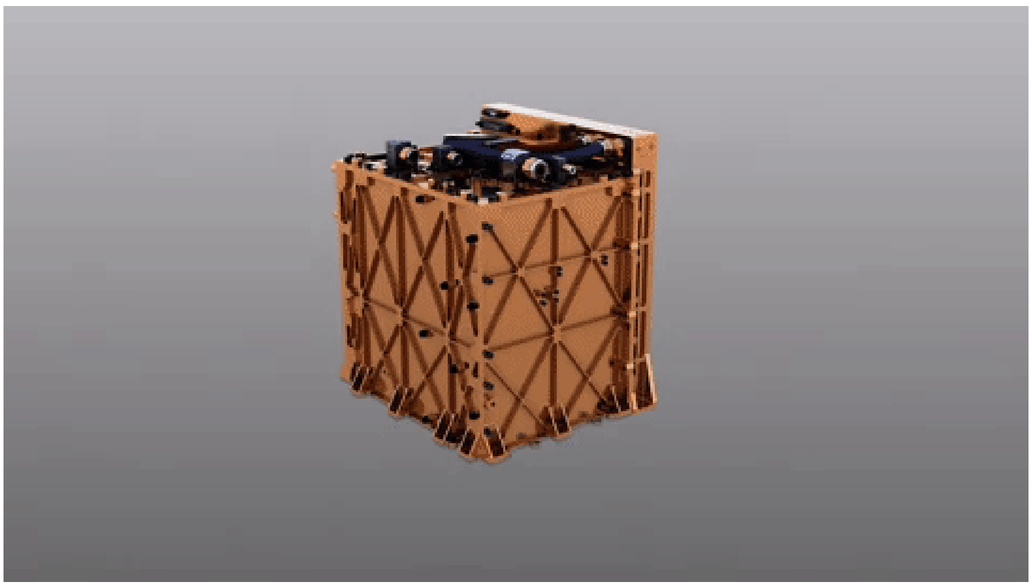
With Perseverance and a little MOXIE, MIT is going to Mars

July 29 2020, by Sara Cody



MOXIE will collect carbon dioxide (CO2) from the Martian atmosphere and electrochemically split the it into oxygen and carbon monoxide molecules. Credit: NASA/JPL

On July 30, a two-week window of opportunity opens for Perseverance—the newest Mars rover, forged in the spirit of human curiosity—to begin its journey toward the Red Planet with a launch from the Cape Canaveral Space Launch Center on the eastern Florida coast. With MIT's help, this latest NASA mission will build upon the legacy of its roving laboratory predecessors and dig deeper than ever before into questions about life on Mars.

In its current state, Mars is inhospitable; the surface is dusty, and the only available water is frozen near the poles, deep underground, or so tightly bound to the soil that it would have to be cooked in an oven to extract it. The air is unbreathable, and the thin atmosphere allows worrisome levels of radiation while maintaining an average temperature of -81 degrees Fahrenheit. At one time in the past, however, it may have looked a lot more like Earth, and may have been more sustainable for life.

The goals of Perseverance—a signature component of the larger Mars 2020 mission—are to explore questions of this former habitability, to characterize the environment, and to help pave the way for future human exploration. One of seven experiments traveling on the rover will specifically address future human missions to Mars: MOXIE, short for the Mars OXygen In situ resource utilization Experiment, will help us prepare for those first missions by demonstrating that we can make our own oxygen on Mars to use for rocket propellant and for the crew to breathe when astronaut explorers arrive there. MOXIE was proposed and developed through a collaboration between researchers at MIT's Haystack Observatory and the MIT Department of Aeronautics and Astronautics (AeroAstro), along with engineers at NASA Jet Propulsion Laboratory (JPL).

MIT is well-represented in other aspects of the mission as well. Perseverance will carry a sophisticated system for selecting, coring, caching, and preserving rock and soil samples to someday bring back to Earth. Associate professor of geobiology Tanja Bosak and professor of planetary sciences Ben Weiss, both from the MIT Department of Earth, Atmospheric, and Planetary Sciences (EAPS), are participating scientists who will work with this system to help choose which samples from the Martian surface to collect and analyze. And Ariel Ekblaw, a graduate student in media arts and sciences and the founder and lead of the MIT Media Lab Space Exploration Initiative, contributed to a rover experiment during a summer at JPL that will search for evidence of past microbes.

The little mechanical tree

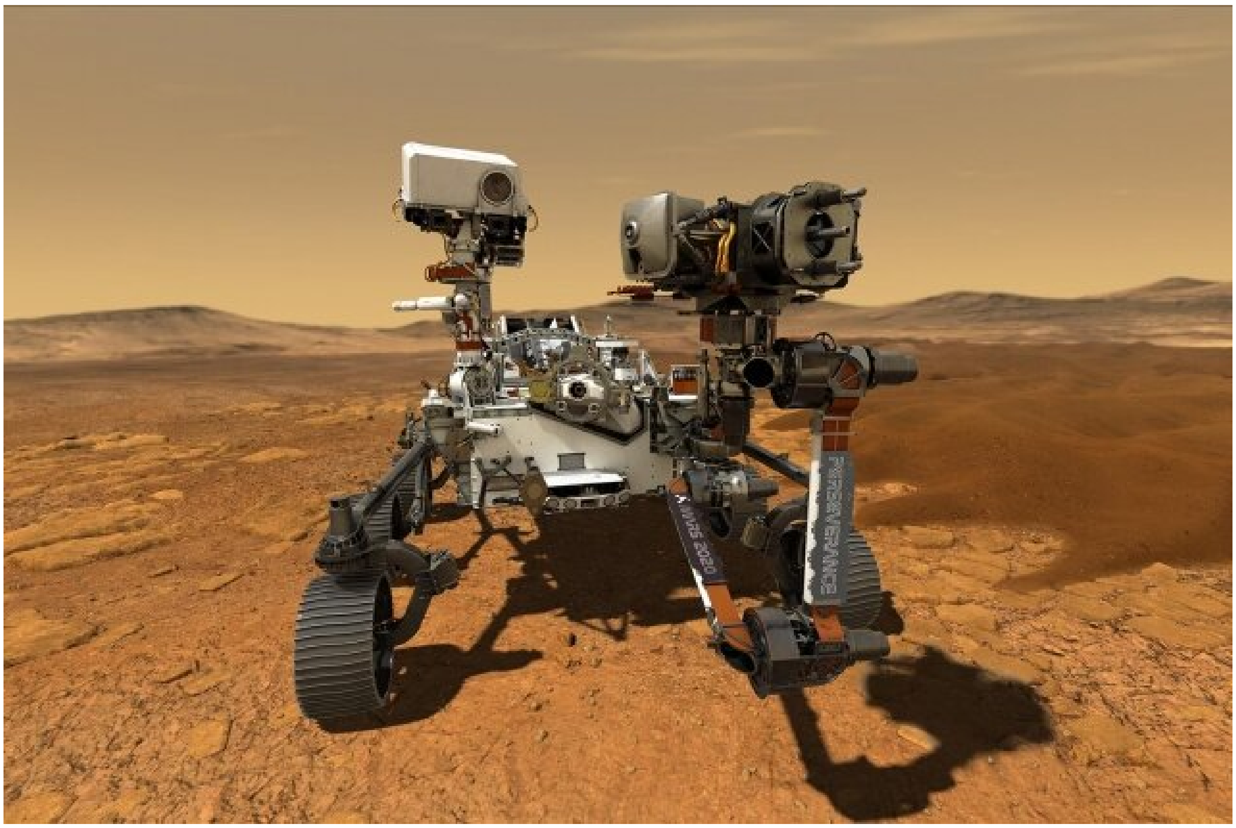
In the 2015 film The Martian, when astronaut Mark Watney (played by Matt Damon) was left stranded on Mars, he managed to survive long enough to coordinate a rendezvous rescue mission with his crew by living off the land of the Red Planet. This is the basic principle behind in situ resource utilization, or ISRU, and MOXIE represents an important first step in realizing ISRU for future Mars explorers.

"Not only do you need oxygen for people to breathe, but you need it for the rocket to breathe too. If you are burning fuel, you need oxygen to consume it," says Michael Hecht, MOXIE principal investigator and director of research at MIT Haystack Observatory in Westford, Massachusetts. "There is a reason why oxygen tanks are the heaviest items on a spaceflight manifest."

Launches consume a lot of fuel: Propelling a spacecraft to exit the Earth's gravitational pull requires a great deal of energy, and returning back to Earth requires doing it all over again. What's more, the heavy tanks required to transport the oxygen needed for a given mission take up precious real estate in a carefully calibrated spacecraft. This is where the ISRU approach comes in.

"Instead of taking it with us, why not just make it when we get there as we need it?" Hecht says. "Oxygen exists on Mars, just not in a form we can use it. So that is the problem we were trying to solve with MOXIE."

One potential source of oxygen is ice that exists under the Martian surface. But mining this ice would require complex machinery, and the physical act of digging and drilling would put significant wear and tear on equipment, which is a problem when a repair person is a planet away. Thankfully, there was another potential resource the team can tap to generate oxygen: the atmosphere.



This artist’s rendering shows the NASA’s Perseverance rover in action exploring the Jezero Crater on Mars. With MIT’s help, Perseverance will dig deeper into questions about life on the red planet than ever before. Credit: NASA/JPL-Caltech

"With the mining approach, you have to mine the ice, refine and process it to release the oxygen, and bring it back, which is just not something we can do robotically, especially within our space constraints," says Hecht. "I wanted to find a much simpler approach. The Martian atmosphere is about 96 percent carbon dioxide, so we built a little mechanical tree, because that is much easier than building a miniature, self-contained mining company."

MOXIE's objective: collect the carbon dioxide abundant in Martian air, convert it to oxygen, and measure the oxygen's purity. After pulling in Martian air, the system filters out dust, compresses it, and then feeds it into the Solid OXide Electrolyzer (SOXE), the key element that takes pressurized carbon dioxide and uses a combination of electricity and chemistry to split the molecule into oxygen and carbon monoxide. The purity of the oxygen is analyzed, and then the oxygen is released back into the Martian atmosphere.

Currently, the plan is to perform at least 10 oxygen-producing runs throughout the mission under as many different seasonal and environmental conditions as possible. Due to the intense amount of energy required to run the MOXIE experiment, the team will coordinate with the other researchers, who will have to power down for the duration of MOXIE's several-hour run time, and then wait for most of a Martian day (called a sol) for Perseverance's batteries to recharge. The data will be sent back to a lab on MIT's campus, where MOXIE's performance will be analyzed.

Assembling the team

In 2013, NASA put out a call for proposals for oxygen-generating experiments for the 2020 rover within specific parameters. Despite working on the Phoenix Mars Lander mission during his 30-year tenure at JPL, when Hecht moved to his current position at MIT Haystack Observatory in 2012, he didn't expect to be a "Mars guy" anymore—he thought he was done with Mars for good. But his former JPL colleagues disagreed and asked him to lead the experiment as principal investigator. According to Hecht, even after he signed on, he believed the project proposal was a long shot, but in July 2014, he and his colleagues got word that they landed the project.

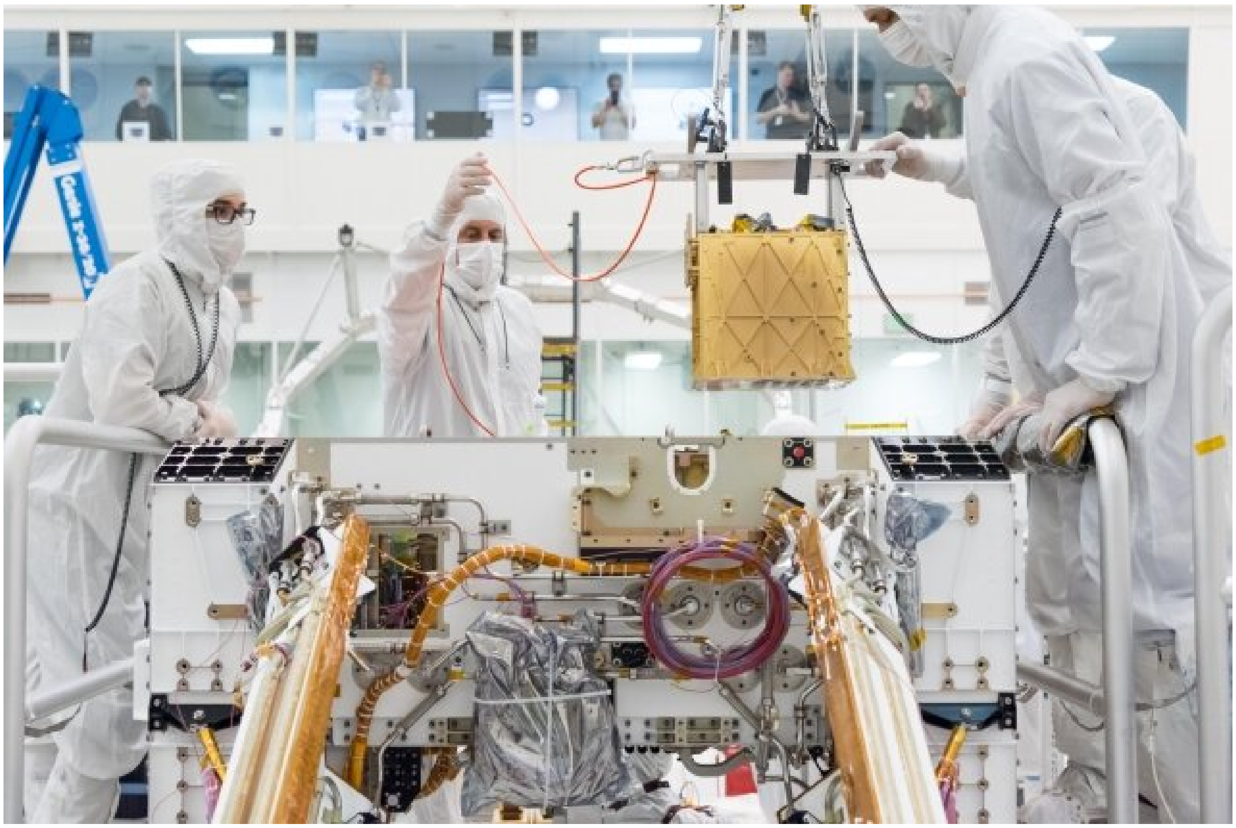
"Researchers at other NASA labs had a huge head start and a lot of technology heritage. MOXIE's selection was a huge surprise to me," says Hecht. "Since this mission has a human-centered focus, I knew we had to establish real credibility with the human exploration community, that we weren't just looking for an excuse to do some interesting science. So, how do we convince them that we are for real and we want to help with human exploration? It took me about five minutes to think of Jeff Hoffman."

Hoffman, a professor of the practice in MIT AeroAstro, certainly knows a thing or two about human space exploration. He logged four spacewalks on his five space flights during his career as a NASA astronaut—including the initial rescue/recovery mission to repair the Hubble Space Telescope in 1993.

In addition to Hoffman's extensive experience with human spaceflight, he shared another connection with Hecht: Hecht was Hoffman's first graduate student advisee as a new MIT researcher before he was called up to enter the astronaut program in 1978 and pursue a career with NASA. He returned to the MIT faculty in 2001, and in addition to being deputy principal investigator on MOXIE, he directs the Human Systems Lab at MIT and teaches courses about human spaceflight systems.

"It's a great experience to collaborate with a former graduate student as colleagues, especially on a project like MOXIE because it shows how important graduate students are to the research process in a story that comes full-circle," says Hoffman. "Not only do graduate students carry out the day-to-day work on a project, but we are also developing the next generation of people who will carry on the exploration of not just Mars, but the entire solar system."

AeroAstro Ph.D. students Eric Hinterman SM '18 and Maya Nasr '18 have been on the MOXIE team since 2016, when Hinterman was working on his master's degree and Nasr was performing a MOXIE-related research project as a junior in aeronautics and astronautics.



In March 2019, members of NASA's Mars 2020 project installed the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), which is no bigger than a car battery, into the chassis of the Perseverance rover. MOXIE will demonstrate a way that future explorers might produce oxygen from the Martian atmosphere for propellant and for breathing. Credit: NASA/JPL

For her master's thesis, Nasr focused on calibrating the sensors in the MOXIE unit by performing experiments under different pressures and temperatures and conditions that mimic the environment on Mars. The goal of her master's work was to understand how the sensors may behave differently in an environment like that of Mars, and to calibrate them accordingly so they would send back accurate data while on the mission. Her Ph.D. work will focus on processing and analyzing both the MOXIE experimental laboratory data and telemetry data that will be sent back from Mars, which will help determine how well the unit functions at its task of extracting oxygen.

"For me personally, it means a lot to work on this project and it's amazing that the launch is already happening. I grew up in Lebanon and remember watching the Curiosity Rover landing, and at the time the NASA JPL director was Dr. Charles Elachi, who is originally Lebanese," says Nasr. "Seeing him in mission control made me realize that it was possible to be part of a Mars mission, and it's one of the reasons why I applied to MIT."

The newest member of the MOXIE team is AeroAstro master's student Justine Schultz, who joined in the late spring of 2020. Schultz, who also works full time at General Electric, will focus her graduate work on constructing a detailed thermal model of MOXIE.

What's in a name?

Since "Mars OXygen In situ resource utilization Experiment" is a mouthful, Hecht wanted to get creative with the project name. The initial inspiration comes from Moxie soda, which was invented in Massachusetts in the 1800s as a nerve-calming tonic. When the company mixed it with soda water for added carbonation, it started flying off the shelves and became one of the first mass-produced sodas in the U.S.

In addition to the local connection and the important role of carbon dioxide in Moxie soda's success story, Hecht thought the meaning behind the word that has become part of our cultural lexicon was particularly fitting to the project. Merriam-Webster defines "moxie" as "energy, pep, courage, determination, and know-how." The deeper meaning became even more relevant as the world grappled with a dangerous global pandemic with the finish line in sight.

"The situation with the coronavirus certainly caused some delays from where we thought we would be, but thankfully it never endangered the mission. Despite some setbacks, we were able to pivot and adapt to keep the launch on track," said Hecht. "But COVID-19 be damned, we are launching this rover."

The launch window is an important factor because it marks the period of time where Earth's orbit around the sun is aligned with that of Mars in such a way to allow a rocket to follow a flight trajectory like changing lanes in a highway to rendezvous with its target landing point on Mars' Jezero Crater. The window closes on Aug. 15, and won't open again for another 26 months.

"While it will be sad not to have that moment of celebration in person together, the critical thing is that we are going to get on the surface Mars and produce oxygen, which we will be doing online from home," says Hoffman. "Looking at everything that has happened over the past few months and all the people who have worked hard to get Mars 2020 ready for launch despite the world around us closing down, I'm happy we went with the name Perseverance because hanging in there and persevering with the mission has become the name of the game."

Provided by Massachusetts Institute of Technology