Optimising Oxygen Production on Mars

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The first human mission to Mars may not be far away, but many preparations still need to be made to ensure the safety of crews once they arrive. One of the key requirements of these missions will be producing a steady supply of oxygen. This will allow crews to survive inside their habitats on the Martian surface, while also providing propellant for a Mars Ascent Vehicle, allowing them to return home.

To better understand the requirements of such a system, NASA has commissioned the Mars Oxygen ISRU experiment, or MOXIE, to be housed aboard NASA's Perseverance rover. In April 2021, MOXIE began to extract small amounts of carbon dioxide from the Martian atmosphere, and convert them into oxygen.

MOXIE operates using a multi-stage process. Firstly, it acquires and compresses carbon dioxide – which makes up 95% of the Martian atmosphere, and heats it to temperatures of 800 degrees Celsius. The heated gas then undergoes an electrolysis reaction, which splits its molecules into carbon monoxide and oxygen. Finally, this oxygen is measured and released. In a future version of MOXIE, the oxygen would be converted into a liquid, which could be stored until needed.

In its current form, MOXIE can produce around 0.5% of the oxygen required to support a human mission. A scaled-up version of this instrument will be sent to Mars 26 months before the first people arrive, and produce oxygen at a rate of around 3 kilograms per hour. This will provide crews with breathable air, while allowing them to leave at a moment's notice if major problems arise.

In a recent study, Eric Hinterman and his colleagues at MIT investigated MOXIE's performance so far. They combined the lessons they learned with the constraints that will likely be faced by crewed missions to Mars. They then used these results to design a system for producing oxygen on a larger scale.

Using advanced optimisation algorithms, the researchers showed how such a system could operate as efficiently as possible – with minimal mass and power requirements. Their examination had many interlinking aspects to consider: including the power, electronics, and heat exchange systems needed to convert atmospheric carbon dioxide into liquid oxygen.

Using these algorithms, Hinterman's team developed a virtual model to simulate the operation of an upscaled MOXIE instrument in the changing environment of Mars. Based on their analysis, they calculated that an optimised MOXIE architecture would produce 30 metric tons of oxygen over 14 months; while weighing just over 9 tons, and consuming fewer than 27 kilowatts of power.

The researchers hope their results will provide valuable guidance for space agencies that are planning to send humans to Mars, opening up a whole new chapter in the story of human space exploration. With the optimised MOXIE system they propose, Hinterman's team hopes that these missions will avoid spiralling budgets, while minimising risks for the daring humans who undertake them.

This video is based on the paper **'Multi-objective system optimization of a Mars atmospheric ISRU plant for oxygen production'** published in the 2021 IEEE Aerospace Conference (50100). doi.org/10.1109/AERO50100.2021.9438331