Slingshotting around the sun would make a spacecraft the fastest ever

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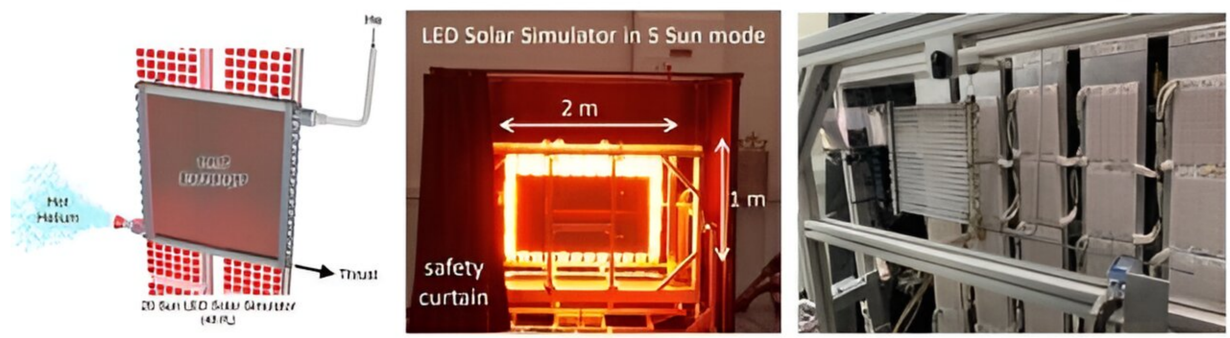

Image of the test set-up for the thermal shield. Credit: (2023). DOI: 10.2172/1960159

NASA is very interested in developing a propulsion method to allow spacecraft to go faster. We've reported several times on different ideas to support that goal, and most of the more successful have utilized the sun's gravity well, typically by slingshotting around it, as is commonly done with Jupiter currently.

But, there are still significant hurdles when doing so, not the least of which is the energy radiating from the sun simply vaporizing anything that gets close enough to utilize a gravity assist. That's the problem a project supported by NASA's Institute for Advanced Concepts (NIAC) and run by Jason Benkoski, now of Lawrence Livermore National

Laboratory, is trying to solve.

The project was awarded a NIAC Phase I grant in 2022, focused on combining two separate systems—a heat shield and a thermal propellant system. According to the project's final report, combining those two technologies could allow a spacecraft to perform what is known as an Oberth maneuver around the sun.

In this orbital mechanics trick, a spacecraft uses the sun's gravity well to slingshot itself at high speeds in the direction it aims. It's similar to the sundiver technology discussed in other articles.

So, what makes this project unique? One thing is the heat shield—Dr. Benkoski and his team developed a material that is capable of withstanding up to 2700 K. While that is still not anywhere near the temperature of the sun's surface, which can reach up to 5800 K, its enough to get pretty close, and thereby unlock a spacecraft's ability to use an Oberth maneuver in the first place.

Samples of the material with these thermal properties have already been produced. However, further research is needed to understand whether they're cut out for space flight. And a heat shield alone isn't enough to perform the maneuver—a spacecraft also must have a propulsion system that can withstand those temperatures.

A solar thermal propulsion system could potentially do so. These systems use the sun's energy to pressurize their own propellant and then expel those propellants out to gain thrust, which is a necessary component of an Oberth maneuver. There are several different types of fuels that could work for such a system, and a large chunk of the research in the Phase I project looked at the different costs/benefits of each.

Hydrogen is one of the more common fuels considered for a solar thermal propulsion system. Though it is lightweight, it requires a bulky cryogenic system to store the hydrogen because it is heated to the point of being used as thrust. In the end, its trade-offs made it the least effective of the propellants considered during the project.

Lithium hydride was the surprise winner for the fuel that allows for the fastest escape velocity. Calculations show it could result in a velocity of over 12 AU / yr. However, there are constraints with the fuel's storage and handling.

Dr. Benkoski settled on a more mundane fuel as the overall winner of the modeling he did—methane. While it generally results in a slower final velocity than lithium hydride, its final speed is still respectable at over 10 AU / yr. It also eliminates many storage hassles of other propellants, such as the cryogenics required to store hydrogen.

There are some drawbacks, though—the calculated maximum speed is only about 1.7 times faster than what could already be done with a gravitational assist from Jupiter, which wouldn't require all the fancy thermal shielding.

There are other downsides to that, though, such as the direction the spacecraft can travel in being limited by where Jupiter is in relation to other objects of interest. Orbiting the sun, on the other hand, it is possible to reach pretty much anywhere in the solar system and beyond with the right controlled burn.

As Dr. Benkoski notes in the final report, he made plenty of assumptions when doing his modeling calculations, including that the system would only be able to use already-developed technologies rather than speculative ones that could dramatically impact the results.

For now, it doesn't seem NASA has selected this project to move on to

Phase II, and it's unclear what future work is planned for further development. If nothing else, it is a step toward understanding what would be necessary to truly send spacecraft past the sun and into deep space at a speed much faster than anything else has gone before. Given NASA's continual attention to this topic, undoubtedly, someday, one of the missions will succeed in doing so.

More information: Jason Benkoski et al, Combined Heat Shield and Solar Thermal Propulsion System for an Oberth Maneuver (2023). DOI: 10.2172/1960159

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