NASA's Deep Space Communications demo exceeds project expectations

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In this infrared photograph, the Optical Communications Telescope Laboratory at JPL's Table Mountain Facility near Wrightwood, California, beams its eight-laser beacon to the Deep Space Optical Communications flight laser transceiver aboard NASA's Psyche spacecraft. Credit: NASA/JPL-Caltech

NASA's Deep Space Optical Communications technology has successfully shown that data encoded in lasers can be reliably transmitted, received, and decoded after traveling millions of miles from Earth at distances comparable to Mars. Nearly two years after launching aboard the agency's Psyche mission in 2023, the technology demonstration recently completed its 65th and final pass, sending a laser signal to Psyche and receiving the return signal from 218 million miles away.

"NASA is setting America on the path to Mars, and advancing laser communications technologies brings us one step closer to streaming high-definition video and delivering valuable data from the Martian surface faster than ever before," said acting NASA Administrator Sean Duffy. "Technology unlocks discovery, and we are committed to testing and proving the capabilities needed to enable the Golden Age of exploration."

Record-breaking technology

Just a month after launch, the Deep Space Optical Communications demonstration proved it could send a signal back to Earth. It established a link with the optical terminal aboard the Psyche spacecraft.

"NASA Technology tests hardware in the harsh environment of space to understand its limits and prove its capabilities," said Clayton Turner, associate administrator, Space Technology Mission Directorate at NASA Headquarters in Washington. "Over two years, this technology surpassed our expectations, demonstrating data rates comparable to those of household broadband internet and sending engineering and test data to Earth from record-breaking distances."

On Dec. 11, 2023, the demonstration achieved a historic first by streaming an ultra-high-definition video to Earth from over 19 million miles away (about 80 times the distance between Earth and the moon), at the system's maximum bitrate of 267 megabits per second. The project also surpassed optical communications distance records on Dec. 3, 2024, when it downlinked Psyche data from 307 million miles away (farther than the average distance between Earth and Mars). In total, the experiment's ground terminals received 13.6 terabits of data from Psyche.

Managed by NASA's Jet Propulsion Laboratory (JPL) in Southern California, the experiment consists of a flight laser transceiver mounted on the Psyche spacecraft, along with two ground stations to receive and send data from Earth. A powerful 3-kilowatt uplink laser at JPL's Table Mountain Facility transmitted a laser beacon to Psyche, helping the transceiver determine where to aim the optical communications laser back to Earth.

Both Psyche and Earth are moving through space at tremendous speeds, and they are so distant from each other that the laser signal—which travels at the speed of light—can take several minutes to reach its destination. By using the precise pointing required from the ground and flight laser transmitters to close the communication link, teams at NASA proved that optical communications can be done to support future missions throughout the solar system.

Another element of the experiment included detecting and decoding a faint signal after the laser traveled millions of miles. The project enlisted a 200-inch telescope at Caltech's Palomar Observatory in San Diego County as its primary downlink station, which provided enough light-collecting area to collect the faintest photons. Those photons were then directed to a high-efficiency detector array at the observatory, where the information encoded in the photons could be processed.

"We faced many challenges, from weather events that shuttered our ground stations to wildfires in Southern California that impacted our team members," said Abi Biswas, Deep Space Optical Communications project technologist and supervisor at JPL. "But we persevered, and I am proud that our team embraced the weekly routine of optically transmitting and receiving data from Psyche. We constantly improved performance and added capabilities to get used to this novel kind of deep space communication, stretching the technology to its limits."

Brilliant new era

In another test, data was downlinked to an experimental radio frequency-optical "hybrid" antenna at the Deep Space Network's Goldstone complex near Barstow, California. The antenna was retrofitted with an array of seven mirrors, totaling 3 feet in diameter, enabling the antenna to receive radio frequency and optical signals from Psyche simultaneously.

The project also used Caltech's Palomar Observatory and a smaller 1-meter telescope at Table Mountain to receive the same signal from Psyche. Known as "arraying," this is commonly done with radio antennas to better receive weak signals and build redundancy into the system.

"As space exploration continues to evolve, so do our data transfer needs," said Kevin Coggins, deputy associate administrator, NASA's SCaN (Space Communications and Navigation) program at the agency's headquarters. "Future space missions will require astronauts to send high-resolution images and instrument data from the moon and Mars back to Earth. Bolstering our capabilities of traditional radio frequency communications with the power and benefits of optical communications will allow NASA to meet these new requirements."

More information: To learn more about the laser communications demo, visit this link.

Provided by NASA