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Out there somewhere could be A PLANET LIKE OURS

The breakthroughs we'll need to find Earth 2.0 Page 30

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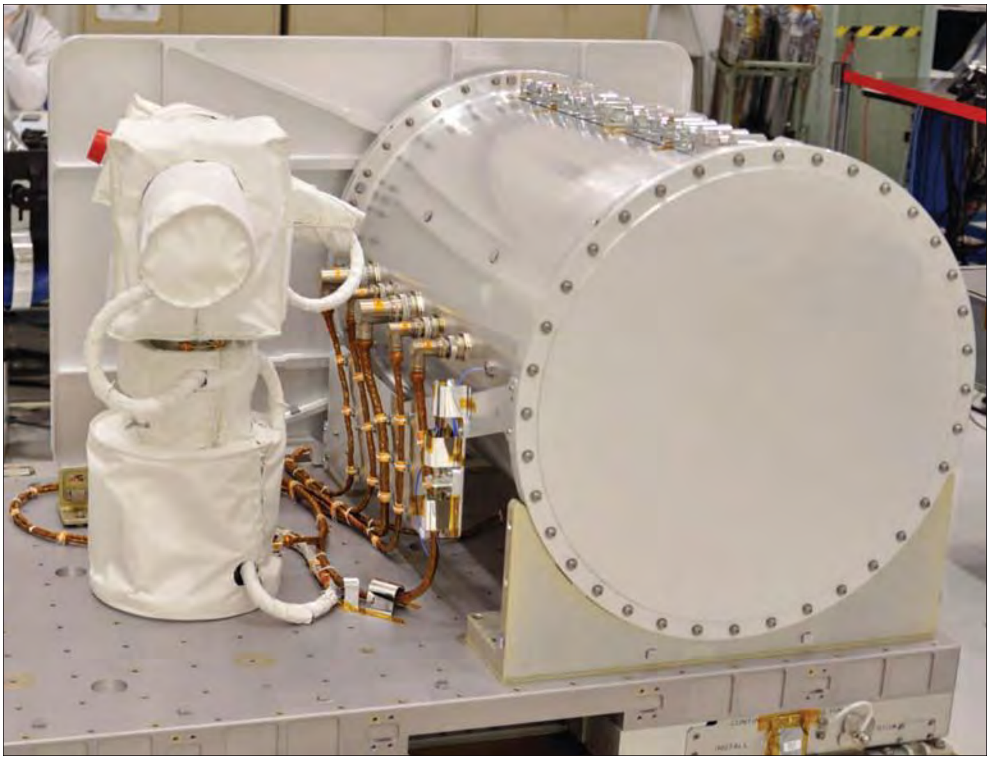
Demonstrating laser comms

A small communications package attached to the exterior of the International Space Station could have an outsized impact on the future of communications from space to Earth. Marc Selinger explains the technology underlying OPALS, the Optical Payload for Lasercomm Science.

On a June night, Jet Propulsion Lab engineers Matt Abrahamson and Bogdan Oaida ran outside their mission control room for the joy of watching the space station cross overhead. They knew by telemetry that the station had just transmitted a 36-second, high definition video montage showing a Pony Express rider; a hand tapping a telegraph machine; a floppy disk being inserted into a computer; and a computer display rich with graphics. This "Hello World!" video was an homage to the progression of communications technology, and it was sent via what could be the next step in that progression: Laser light beamed through space to the ground.

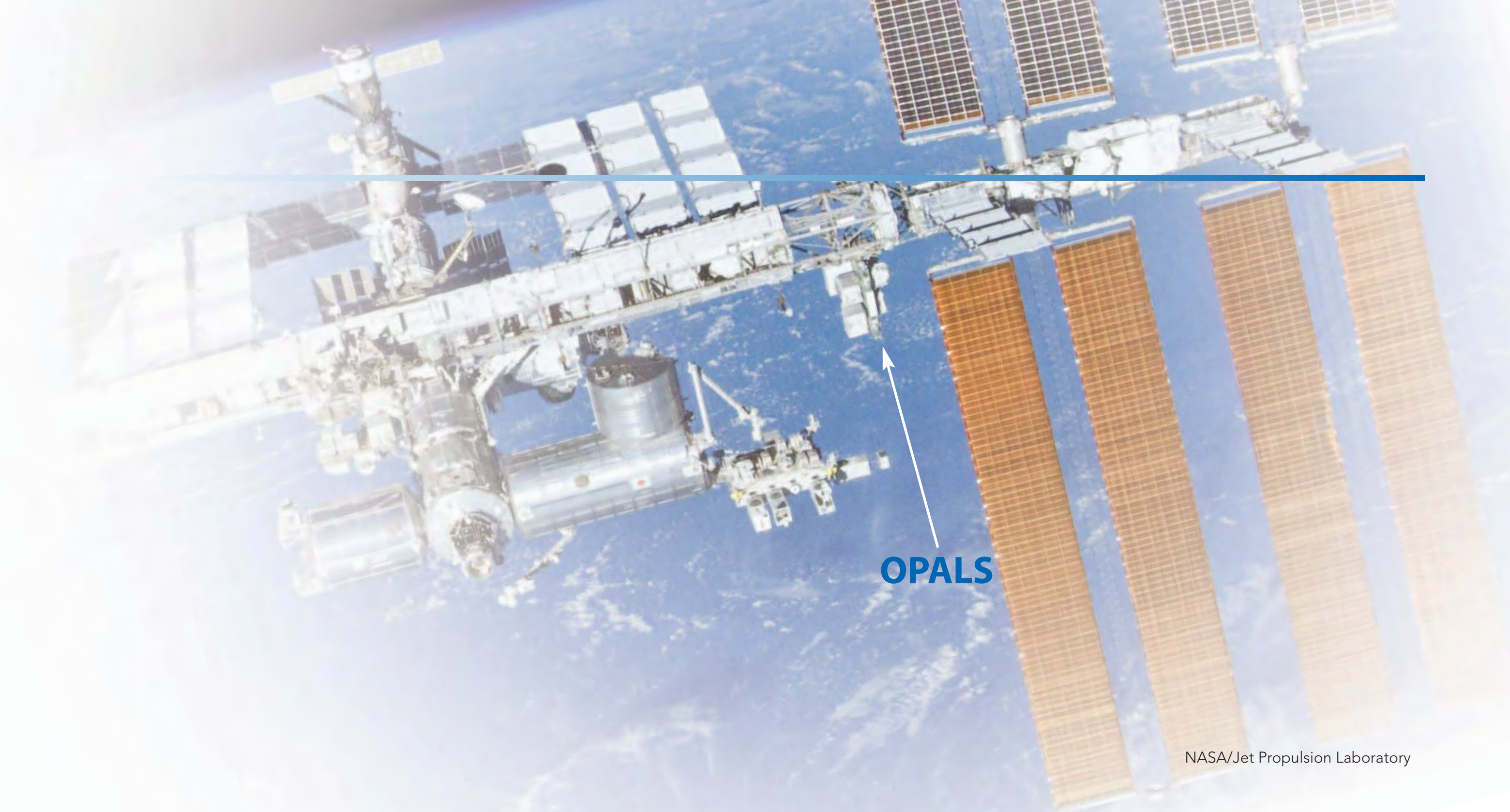
Abrahamson is mission manager for the Optical Payload for Lasercomm Science, or OPALS, and Oaida is the project's systems engineer. The 159-kilogram package of electronics was launched to the international space station in April inside a SpaceX Dragon module and attached to the exterior of the station by the station's Dextre mechanical arm as directed by a robotics team in Houston. OPALS consists of a box with laser electronics and a computer, plus an optics box attached to a mechanical gimbal. The "Hello World!" video was beamed to a ground station at Table Mountain Observatory high in the San Gabriel Mountains above Los Angeles.

The OPALS team had to solve numerous technical challenges to get to the point where it has now repeated the downlink feat a dozen times. On each pass, OPALS must keep its laser locked onto a receiving telescope at Table Mountain, a task Oaida likens to keeping an office laser pointer on "an area that's the diameter of about a human hair, from about 20 or 30 feet away, while I'm moving at about half a foot per second." Coming soon, engineers plan to show how OPALS can be redirected to another ground station to avoid cloud cover. There were also challenges related to



NASA/JPL-Caltech

The electronics and laser for OPALS, the Optical Payload for Lasercomm Science, are protected by a cylindrical housing. The gimbal that steers OPALS is to the left.



getting OPALS to space, including integrating it with the new SpaceX Dragon module. But perhaps most significantly, space station safety overseers needed to be satisfied that the laser would not accidentally touch the exterior of the space station. The laser starts out at 2.5 watts with some energy dissipating through cables and optics, leaving a 2-watt beam – about the equivalent of 400 laser pointers. That's probably not enough to burn a hole, but it might be enough to render some of the cells on the station's solar arrays nonfunctional, Oaida says. Astronauts are never at risk, because the laser is not operated if an astronaut is outside the station.

The team's ability to work through those problems suggests it might be possible to make a miniaturized version of the technology for deep space applications, including NASA's planned Mars 2020 Rover mission.

Game-changing speed

The advantage of laser beams is that they have shorter wavelengths than radio waves, which means more bits and bytes can be packed onto them. Light waves also spread out less over long distances, so more of the signal reaches the intended receiver. The "Hello World!" high definition video took 3.5 seconds to download via laser; radio waves would have needed 10 minutes, a contrast that has NASA excited about laser communications at Mars. Today, "it takes minutes to almost hours to get just single images down from Mars," Abrahamson says. With lasers, "you might be able to get streaming video from the surface of Mars, and I think that's a game-changer," he says.

The first challenge was to get OPALS to the space station. Work was progressing on the OPALS design in 2010 and 2011 at the same time SpaceX was finishing up its Dragon design. "Since we were designing our payload in parallel with the Dragon design, we encountered an issue with our power interface," says Abrahamson. The power connector pin planned for OPALS turned out to be incompatible with Dragon. "So SpaceX designed a custom power interface for OPALS," he says.

Also, electronics like those in OPALS must be designed to withstand specific launch vibrations. Calculations of the intensity of those vibrations were revised repeatedly during the design, because OPALS and Dragon were to be launched on an updated version of a Falcon 9 rocket. "In the end, it did not require any change to our design, but it did require extra effort to understand the new implications with each change," Abrahamson says.

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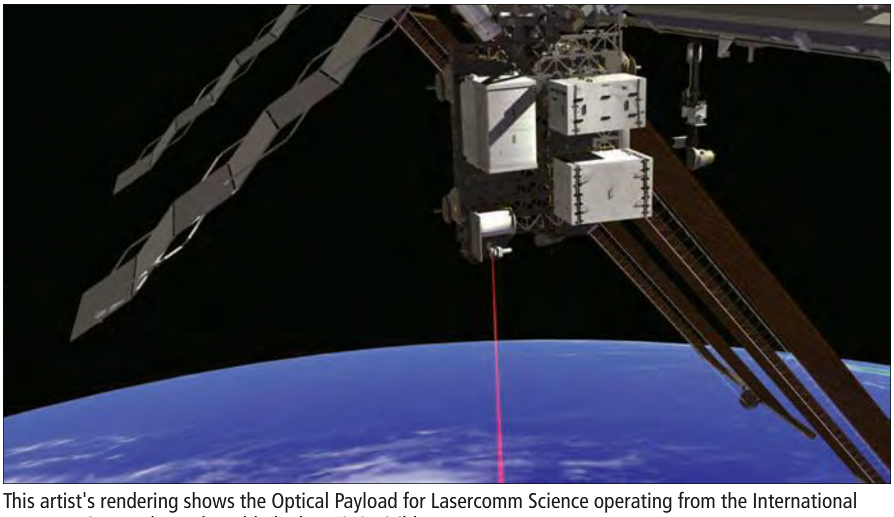

This artist's rendering shows the Optical Payload for Lasercomm Science operating from the International Space Station. In the real world, the laser is invisible.

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Canada's two-armed Dextre robot was photographed installing the Optical Payload for Lasercomm Science on the space station exterior.

Safety first

On the safety issue, space station officials told the OPALS team to make sure the laser would swivel only within a 110 degree area during each pass. If you were looking straight down from the station, this communications window would extend 75 degrees ahead and 35 degrees behind. The OPALS team needed to devise three ways to keep the laser within that window: "If any two would fail, there would be a third feature preventing the laser from pointing outside of this window," Oaida explains. Specifically, the team devised a system of electrical switches and mechanical hard stops. "The electrical limit switches are tied to the power distribution board and designed to cut power to the laser when actuated. The hard stops prevent any movement beyond the field of regard," says Abrahamson. The hard stops counted as two features, a certification that took a lot of paperwork, adds Oaida.

Safety considerations were paramount. "This required many design iterations with ISS safety engineers and a significant amount of documentation to capture the design and how it works in practice," Oaida says.

A big challenge was finding and staying locked onto the ground station. With the station flying at 17,500 miles per hour, the communications window would open for at most 165 seconds, and the connection had to be made quickly to provide plenty of time for downloading. On each pass, OPALS's onboard camera must detect a laser beacon sent from Table Mountain. OPALS locks onto it and begins firing its laser, rotating at about 1 degree per second to maintain this precision pointing. Devising a system to meet that challenge required early testing of the gimbal components and at least one redesign of the pointing software.

Possible partnering

OPALS is not the first time NASA has used lasers to communicate. The Lunar Atmosphere and Dust Environment Explorer spacecraft launched in 2013 did too. LADEE didn't have the challenge of rotating rapidly to stay locked on a ground station. In its lunar orbit, it was almost stationary relative to the ground station that received its transmissons in New Mexico.

The OPALS and LADEE demonstrations have engineers talking about how the two concepts might work together at Mars in a hybrid approach. The Mars laser would send video and images from the Martian surface to a spacecraft orbiting Mars, which is similar to what OPALS has done but in the opposite direction. The Mars laser would then beam the information to Earth, which is similar to what LADEE did from the moon.

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