LOOKING BACK:
Amateur Astronomy Comes of Age
PAGE 14

THE PRESENT:
Build or Buy a Telescope?
PAGE 66

LOOKING AHEAD:
What Will We Discover Next?
PAGE 38

SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

NOVEMBER 2021

THE FUTURE OF ASTRONOMY

Page 28

SKY & TELESCOPE 80 YEARS THE ESSENTIAL GUIDE TO ASTRONOMY

PLUS:
S&T Celebrates Its 80th Birthday

skyandtelescope.org

$6.99US $7.99CAN

11

0 74470 02207 7

LASERS IN SPACE NASA's Laser Communications Relay Demonstration will transmit data from the International Space Station to Earth using infrared lasers.

DAVE RYAN / NASA

Beam the Data Down, Scotty

Lasers will replace radio antennas as the interplanetary communications system.

Cassini. New Horizons. The Hubble Space Telescope. These spacecraft and so many others have given us mesmerizing views of the cosmos, expanding our knowledge and piquing our curiosity.

But it's no use sending instruments to space if we can't get the data back. Without a communications link, there is no exploration.

Throughout the Space Age, we've used radio wavelengths to transmit data to and from our space emissaries. Radio has major perks: It cuts through clouds above ground stations, and its wavelengths are so long that you don't have to aim too carefully in order to hit your antenna back on Earth.

But radio is also slow. Those same long wavelengths limit how much information a signal can carry. Take, for instance, the New Horizons spacecraft, which due to distance, bandwidth, and network sharing needed more than a year to send its 6.25 GB of Pluto flyby data back to antsy team scientists. That's similar to the file size of a single HD movie.

NASA and other spacefarers are thus developing an alternative: infrared laser communications.

Radio and laser communications operate on the same principle: Encode information by modulating a wavelength's properties, then transmit the signal to a receiver that can decode the modified stream. It's the same idea behind your Wi-Fi router, which uses microwaves to send information from the internet to devices around your home.

But infrared wavelengths are roughly 10,000 times shorter than the radio ones used to communicate with spacecraft, so lasers pack information into tighter waves. They can thus deliver more data in the same period of time than a radio signal can. Switching to infrared lasers — which go by the misnomer *optical communications* — would increase data transmission rates by a factor of 10 or more. That would boost the downlink rate from Mars — which is about 2 megabits per second (Mbps) when the planet is at its closest — to some 25 Mbps, the minimum uplink requirement for U.S. broadband.

There are downsides, however. First, infrared lasers can't pass through clouds, so ground stations need to be in clear-sky locations, such as Hawai'i and parts of California. Second, the signal beam is narrow. Electromagnetic waves spread out as they travel from their source; a radio beam transmitted from Mars is larger than Earth's diameter by the time it reaches our planet, making catching it easy. But a laser beam shot from that same distance would only be the size of California when it reached Earth, says Abhijit Biswas (Jet Propulsion Laboratory). Successfully hitting the ground station is like holding a meter-long soda straw so steady that the far end doesn't dip by a micron. "If we miss," he says, "there will be no one to catch the bits."

NASA successfully demonstrated laser communications from lunar orbit in 2013, achieving a downlink speed of 622 Mbps. Other experiments have followed. The European Space Agency now uses optical links to connect some of its low-orbit satellites with two geostationary relays (which then send the data down to Earth via radio), and the Starlink project has begun using inter-satellite lasers, too.

NASA's Laser Communications Relay Demonstration (LCRD) aims to be the first relay system based entirely on optical. From geosynchronous orbit, it will transmit data sent from the International Space Station at a rate of 1.2 Gbps, about double that of the 2013 lunar experiment. LCRD's June 2021 launch was delayed due to rocket concerns, however, and no revised launch date had been announced when this article went to press.

But explorers want to push beyond near-Earth space. Slated to launch in 2022, the Deep Space Optical Communications (DSOC) experiment will piggyback on NASA's Psyche asteroid mission to test how well laser links work beyond Mars. Using a setup similar to an off-axis telescope, DSOC will point a micron-wavelength laser at a 22-cm mirror and shoot it back to Earth, transmitting canned data that team members will check for accuracy. (They'll lock onto Earth thanks to a beacon beamed at a slightly different wavelength.)

DSOC's ground station will be the 5.1-meter Hale Telescope at Palomar Observatory in California — "which is on the skinny side for what we'd like for these distances," admits Biswas, who serves as DSOC project technologist. Ideally, he says, laser communications will utilize 8- to 10-meter telescopes in the future.

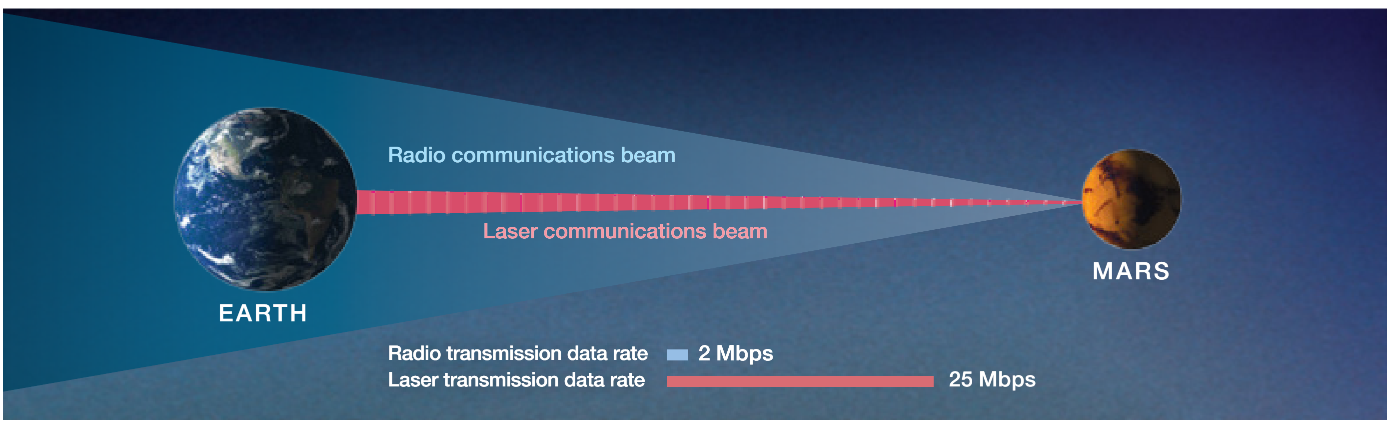
The DSOC team's goal is to downlink at 100 Mbps from a quarter of an astronomical unit away and about 2 Mbps from 2 a.u., which would be well into the asteroid belt. (For comparison, Psyche's main telecommunications system will probably achieve a rate one-tenth as fast.) Beyond 2 a.u., the spacecraft will be in the daytime sky and thus unobservable.

It may be 20 years before laser communications are routine on space missions, but routine they must become. The aging Hubble Space Telescope collects an average of 18 GB of science data each week. The Transiting Exoplanet Survey Satellite (TESS), launched in 2018, downloads 94 GB of compressed data on a 2-week cycle, and the new James Webb Space Telescope (see page 20) is expected to send about 30 GB over 4 hours, twice a day. But future flagship missions will likely collect *terabytes* of data each day, says astrophysics chief technologist Mario Perez (NASA). Radio networks cannot handle the data deluge.

▲ **TO DEEP SPACE** Team members test the Deep Space Optical Communications experiment in a JPL clean room. The 22-cm primary mirror (center, pointed at camera) will transmit and receive infrared lasers to and from ground stations on Earth. The aluminum base plate will bolt to the Psyche spacecraft.

Lasers can. In the future, laser communications may enable astronauts to send high-def videos from the Moon. We'll receive streaming imagery from Mars. A fleet of laser-enabled, TESS-like satellites could take exoplanet observations to a new level. And maybe we'll position our receivers in space, avoiding the cloud and daylight problems entirely.

■ Science Editor **CAMILLE M. CARLISLE** learned more about Wi-Fi and downlink speeds during the pandemic than she ever thought she'd need to know.



▲ **DOWNLINK** Laser beams arrive at Earth much narrower than radio beams do, making precise pointing crucial. But lasers also transmit data 10 times faster than radio does.

COMMUNICATIONS INFOGRAPHIC: LEAH TISCIONE / S&T, SOURCE: NASA; LAB: NASA / JPL-CALTECH