Photonics dawning as the communications light for evolving NASA missions

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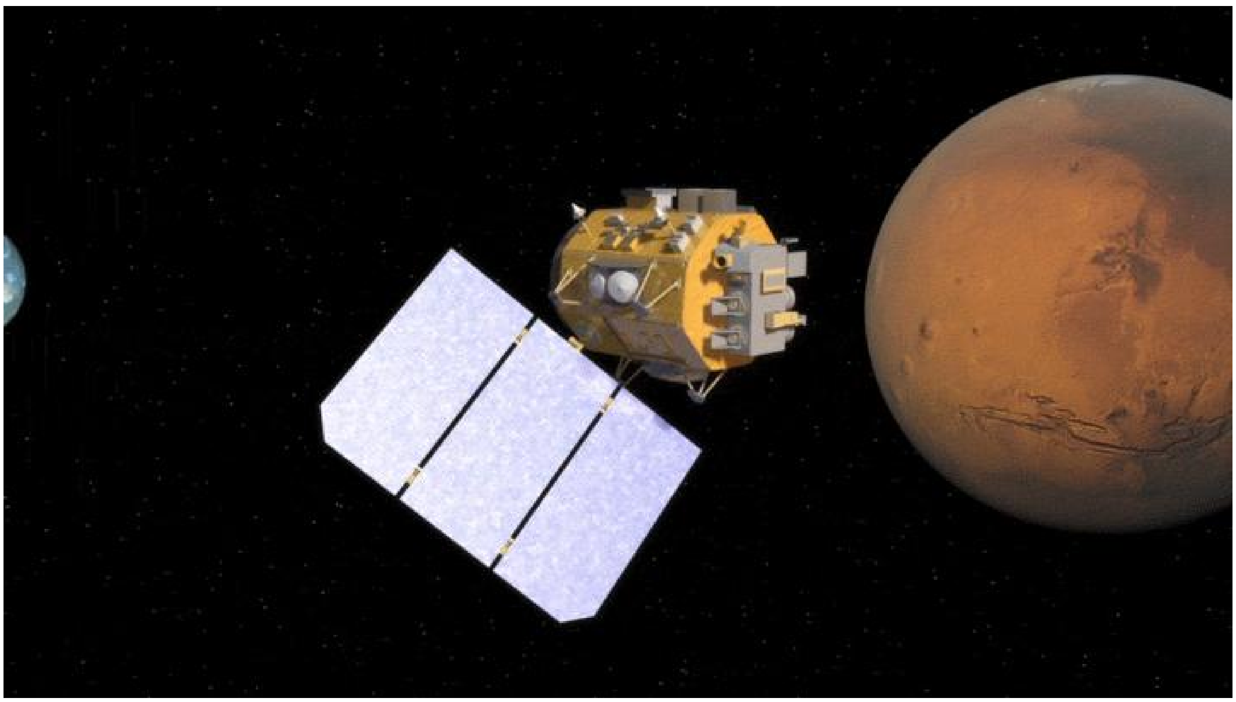

Artist concept of satellite relaying data from Mars to Earth via laser. Credit: NASA's Goddard Space Flight Center

A largely unrecognized field called photonics may provide solutions to some of NASA's most pressing challenges in future spaceflight.

Photonics explores the many applications of generating, detecting and manipulating photons, or particles of light that, among other things, make up laser beams. On this day in 1983, the General Conference of Weights and Measures adopted the accepted value for the speed of light, an important photonics milestone. Oct. 21, 2016, is Day of Photonics, a biennial event to raise awareness of photonics to the general public. The study has multiple applications across NASA missions, from space communications to reducing the size of mission payloads to performing altitude measurements from orbit.

One major NASA priority is to use lasers to make space communications for both near-Earth and deep-space missions more efficient. NASA's communications systems have matured over the decades, but they still use the same radio-frequency (RF) system developed in the earliest days of the agency. After more than 50 years of using solely RF, NASA is investing in new ways to increase data rates while also finding more efficient communications systems.

Photonics may provide the solution. Several centers across NASA are experimenting with laser communications, which has the potential to provide data rates at least 10 to 100 times better than RF. These higher speeds would support increasingly sophisticated instruments and the transmission of live video from anywhere in the solar system. They would also increase the bandwidth for communications from human exploration missions in deep space, such as those associated with Journey to Mars.

NASA's Goddard Space Flight Center in Greenbelt, Maryland, launched the first laser communications pathfinder mission in 2013. The Lunar Laser Communications Demonstration (LLCD) proved that a space-based laser communications system was viable and that the system could survive both launch and the space environment. But the mission was short-lived by design, as the host payload crashed into the lunar surface in a planned maneuver a few months after launch.

The Goddard team is now planning a follow-on mission called the Laser Communications Relay Demonstration (LCRD) to prove the proposed system's longevity. It will also provide engineers more opportunity to learn the best way to operate it for near-Earth missions.

"We have been using RF since the beginning, 50 to 60 years, so we've learned a lot about how it works in different weather conditions and all the little things to allow us to make the most out of the technology, but we don't have that experience with laser comm," said Dave Israel, Exploration and Space Communications architect at Goddard and principal investigator on LCRD. "LCRD will allow us to test the performance over all different weather conditions and times of day and learn how to make the most of laser comm."

Scheduled to launch in 2019, LCRD will simulate real communications support, practicing for two years with a test payload on the International Space Station and two dedicated ground stations in California and Hawaii. The mission could be the last hurdle to implementing a constellation of laser communications relay satellites similar to the Space Network's Tracking and Data Relay Satellites.

NASA's Jet Propulsion Laboratory in Pasadena, California, and Glenn Research Center in Cleveland are also following up on LLCD's success. But both will focus on how laser communications could be implemented in deep-space missions.

Missions to deep space impose special communication challenges because of their distance from Earth. The data return on these missions slowly trickle back to the ground a little at a time using radio frequency. Laser communications could significantly improve data rates in all space regions, from low-Earth orbit to interplanetary.

JPL's concept, called Deep Space Optical Communications (DSOC), focuses on laser communications' benefits to data rates and to space and power constraints on missions. The data-rate benefits of laser communications for deep-space missions are clear, but less recognized is that laser communications can also save mass, space and/or power requirements on missions. That could be monumental on missions like the James Webb Space Telescope, which is so large that, even folded, it will barely fit in the largest rocket currently available. Although Webb is an extreme example, many missions today face size constraints as they become more complex. The Lunar Reconnaissance Orbiter mission carried both types of communications systems, and the laser system was half the mass, required 25 percent less power and transferred data at six times the rate of the RF system. Laser communications could also benefit a class of missions called CubeSats, which are about the size of a shoebox. These missions are becoming more popular and require miniaturized parts, including communications and power systems.

Power requirements can become a major challenge on missions to the outer solar system. As spacecraft move away from the sun, solar power becomes less viable, so the less power a payload requires, the smaller the spacecraft battery, saving space, and the easier spacecraft components can be recharged.

Laser communications could help to solve all of these challenges.

The team at Glenn is developing an idea called Integrated Radio and Optical Communications (iROC) to put a laser communications relay satellite in orbit around Mars that could receive data from distant spacecraft and relay their signal back to Earth. The system would use both RF and laser communications, promoting interoperability amongst all of NASA's assets in space. By integrating both communications systems, iROC could provide services both for new spacecraft using laser communications systems and older spacecraft like Voyager 1 that use RF.

But laser communications is not NASA's only foray into photonics, nor is it the first. In fact, NASA began using lasers shortly after they were invented. Goddard successfully demonstrated satellite laser ranging, a technique to measure distances, in 1964.

Satellite Laser Ranging is still managed at Goddard. The system uses laser stations worldwide to bounce short pulses of light off of special reflectors installed on satellites. There are also reflectors on the moon that were placed there during the Apollo and Soviet rover programs. By timing the bounce of the pulses, engineers can compute distances and orbits. Measurements are accurate up to a few millimeters. This application is used on numerous NASA missions, such as ICESat-2, which will measure the altitude of the ice surface in the Antarctic and Greenland regions. It will provide important information regarding climate and the health of Earth's polar regions.

NASA's Satellite Laser Ranging system consists of eight stations covering North America, the west coast of South America, the Pacific, South Africa and western Australia. NASA and its partners and associated universities operate the stations. SLR is part of the larger International Laser Ranging Service, and NASA's contribution comprises more than a third of the organization's total data volume.

From communications to altimetry and navigation, photonics' importance to NASA missions cannot be understated. As technology continues to evolve, many photonics applications may come to fruition over the next several decades. Others may also be discovered, especially as humanity pushes further out into the universe than ever before.

Provided by NASA's Goddard Space Flight Center