NEWS TELECOMMUNICATIONS

NASA's Laser Link Boasts Record-Breaking 200 Gbps Speed › Researchers doubled the downlink record they set just last year

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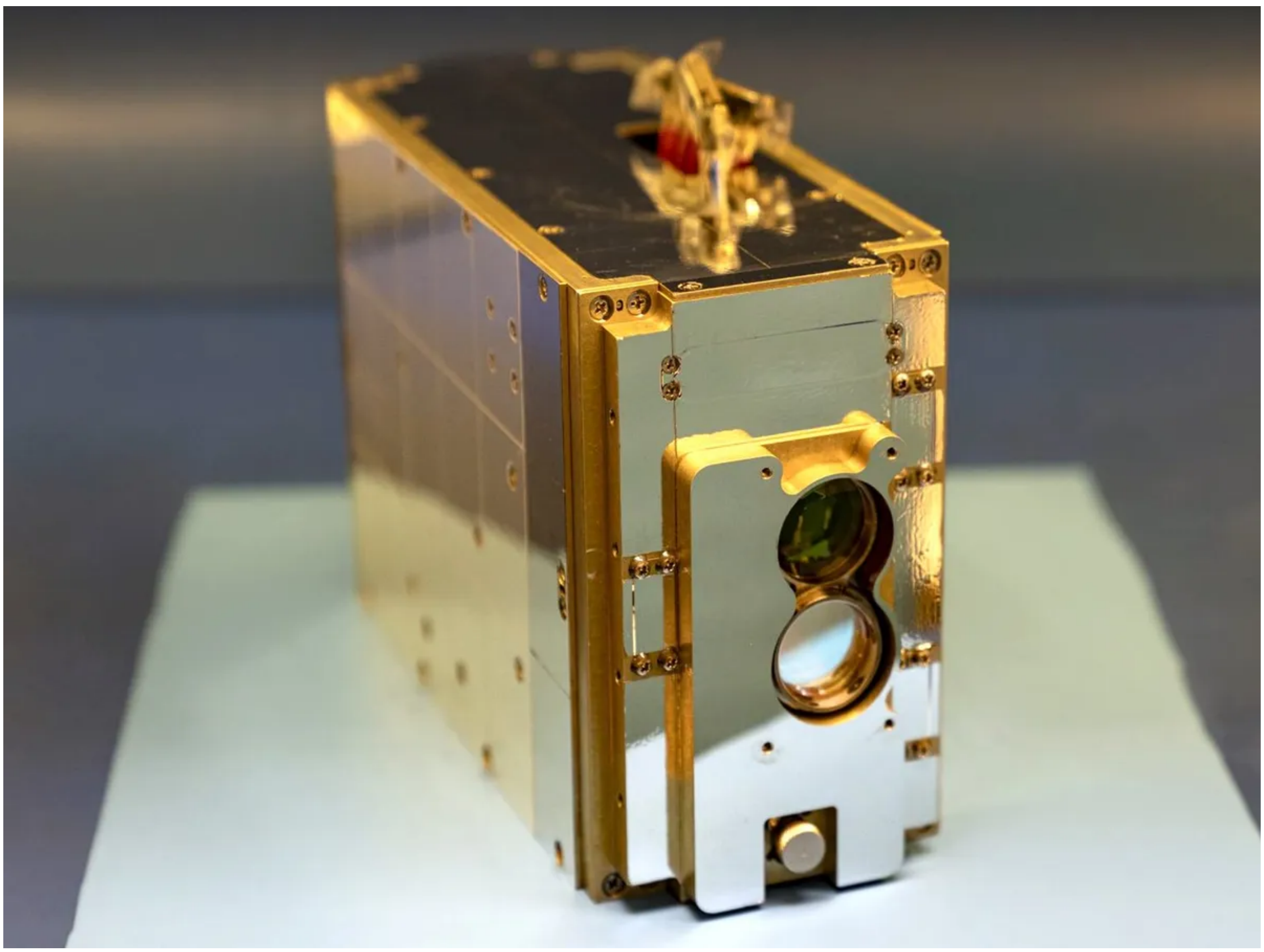

The TBIRD platform, currently orbiting Earth on NASA's Pathfinder Technology

The TBIRD platform, currently orbiting Earth on NASA's Pathfinder Technology Demonstrator 3 satellite, is illuminating a potential route toward very high data rate optical communications from low Earth orbit and beyond. MIT LINCOLN LABORATORY

A **GROUP OF RESEARCHERS FROM NASA, MIT,** and other institutions have achieved the fastest space-to-ground laser communication link yet, doubling the record they set last year. With data rates of 200 gigabits per second, a satellite could transmit more than 2 terabytes of data—roughly as much as 1,000 high-definition movies—in a single five-minute pass over a ground station.

"The implications are far-reaching because, put simply, more data means more discoveries," saysJason Mitchell, an aerospace engineer at NASA's Space Communications and Navigation program.

The new communications link was made possible with the TeraByte InfraRed Delivery (TBIRD) system orbiting about 530 kilometers above Earth's surface. Launched into space last May, TBIRD achieved downlink rates of up to 100 gigabits per second with a ground-based receiver in California by last June. This was 100 times faster than the quickest Internet speeds in most cities, and more than 1,000 times faster than the radio links traditionally used for communications with satellites.

The fastest data networks on Earth typically rely on laser communications over fiber optics. However, a high-speed laser-based Internet does not exist yet for satellites. Instead, space agencies and commercial satellite operators most commonly use radio to communicate with objects in space. The infrared light that laser communications can employ has a much higher frequency than radio waves, enabling much higher data rates.

"There are satellites currently in orbit limited by the amount of data they are able to downlink, and this trend will only increase as more capable satellites are launched," says Kat Riesing, an aerospace engineer and a staff member at MIT's Lincoln Laboratory on the TBIRD team. "Even a hyperspectral imager—HISUI on the International Space Station—has to send data back to Earth via storage drives on cargo ships due to limitations on downlink rates. TBIRD is a big enabler for missions that collect important data on Earth's climate and resources, as well as astrophysics applications such as black hole imaging."

MIT's Lincoln Laboratory conceived TBIRD in 2014 as a low-cost, high-speed way to access data on spacecraft. A key way it reduced expenses was by using commercial, off-the-shelf components originally developed for terrestrial use. These include high-rate optical modems developed for fiber telecommunications and high-speed large volume storage to hold data, Riesing says.

Located onboard NASA's Pathfinder Technology Demonstrator 3 (PTD-3) satellite, TBIRD was carried into orbit on SpaceX's Transporter-5 rideshare mission from Cape Canaveral Space Force Station in Florida on 25 May, 2022. The PTD-3 satellite is a roughly 12-kilogram CubeSat about the size of two stacked cereal boxes, and its TBIRD payload is no larger than the average tissue box. "Industry's drive to small, low-power, high-data rate optical transceivers enabled us to achieve a compact form factor suitable even for small satellites," Mitchell says.

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The development of TBIRD faced a number of challenges. To start with, terrestrial components are not designed to survive the rigors of launching to and operating in space. For example, during a thermal test simulating the extreme temperatures the devices might face in space, the fibers in the optical signal amplifier melted.

The problem was that, when used as originally intended, the atmosphere could help cool the amplifier through convection. When tested in a vacuum, simulating space, the heat that the amplifier generated was trapped. To solve the issue, the researchers worked with the amplifier's vendor to modify it so that it released heat through conduction instead.

In addition, laser beams from space to Earth can experience distortion from atmospheric effects and weather conditions. This can cause power loss, and in turn data loss, for the beams.

To compensate, the scientists developed their own version of automatic repeat request (ARQ), a protocol for controlling errors in data transmission over a communications link. In this arrangement, the ground terminal uses a low-rate uplink signal to let the satellite know that it has to retransmit any block of data, or frame, that has been lost or damaged. The new protocol lets the ground station tell the satellite which frames it received correctly, so the satellite knows which ones to retransmit and not waste time sending data it doesn't have to.

Another challenge the scientists faced stemmed from how lasers form in much narrower beams than radio transmissions. For successful data transmission, these beams must be aimed precisely at their receivers. This is often accomplished by mounting the laser on a gimbal. Due to TBIRD's small size, however, it instead maneuvers the CubeSat carrying it to point it at the ground, using any error signals it receives to correct the satellite's orientation. This gimbal-less strategy also helped further shrink TBIRD, making it cheaper to launch.

TBIRD's architecture can support multiple channels through wavelength separation to enable higher data rates, Riesing says. This is how TBIRD accomplished a 200 gigabit per second downlink on 28 April—by using two 100 gigabit per second channels, she explains. "This can scale further on a future mission if the link is designed to support it," Riesing notes.

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The research team's next step is to explore where to apply this technology in upcoming missions. "This technology is particularly useful for science missions where collecting a lot of data can provide significant benefits," Riesing says. "One mission concept that is enabled by this is the Event Horizon Explorer mission, which will extend the exciting work of the Event Horizon Telescope in imaging black holes with even higher resolution."

The scientists also want to explore how to extend this technology to different scenarios, such as geostationary orbit, Riesing says. Moreover, Mitchell says, they are looking at ways to push TBIRD's capabilities as far away as the moon, in order to support future missions there. The rates under consideration are in the 1 to 5 gigabit per second range, which "may not seem like much of an improvement, but remember the moon is roughly 400,000 km away from Earth, which is quite a long distance to cover," Mitchell says.

The new technology may also find use in high-speed atmospheric data links on the ground. "For example, from building to building, or across inhospitable terrain, such as from mountaintop to mountaintop, where the cost of laying fiber systems could be exorbitant," Riesing says.