NASA facts

Space Technology
Game Changing Development
Deep Space Optical Communications

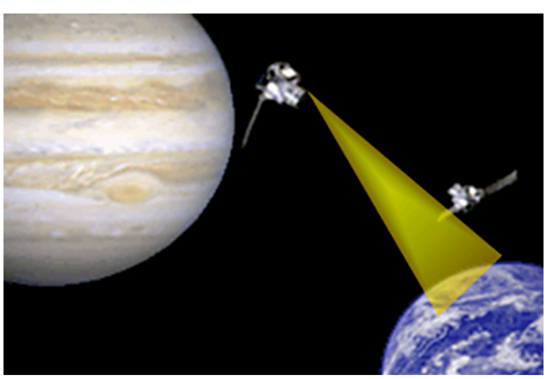
New high-rate telecommunications systems are needed for NASA's future deep space missions. These systems would result in increased science data return and high definition video, which would give NASA a virtual presence across the solar system and beyond.

Increased data return translates directly into an increased return-on-investment for costly deep space missions.

Space optical transceivers are currently in use for near-Earth operations, and in October 2013 NASA demonstrated optical communications from the Moon with the Lunar Laser Communications Demonstration on the Lunar Atomosphere and Dust Environment Explorer (LADEE) mission. But these systems are not sufficient for deep space operations. Challenges include signal loss and round-trip communication times of minutes to hours, versus less than a second for near-Earth missions.

Signal loss between a transmitter and receiver is proportional to the square of the distance between them. Even when Mars is at its closet point to Earth, the signal loss of communication is greater than 2 million times the signal loss from a spacecraft in a geosynchronous orbit around Earth. The communication loss in going from Mars to Earth, at its farthest point, is more than 100 million times greater.

Compared with conventional RF systems, optical communication is a significant improvement. It transmits power along a very narrow beam. A narrower beam means that more information can be transmitted



Deep Space Optical Communications will increase the data return from NASA deep space missions up to 100 times more than radio-frequency (RF) systems.

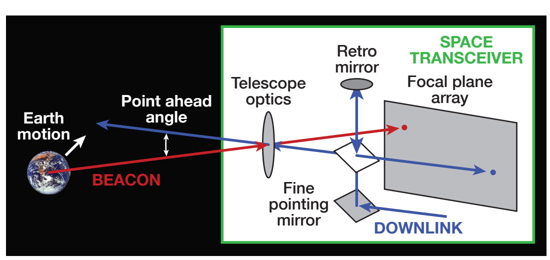
Range (R), in astronomical units (au), 1 au = 150 M km		Additional 1/R2 loss factor at Mars far range, 2.7 au	Round-trip light time
Earth geo. orbit	.00024	126,600,000	0.25 s
Moon	.0028	930,000	2.79 s
Earth-Sun L1 or L2	.01	72,900	10.00 s
Mars near range	0.4	46	6.70 min

Vastly increased range creates the problems that must be overcome for deep space optical commutnications.

using the same amount of power. The optical beam can easily be 500 times narrower than an RF beam, resulting in a signal that is 250,000 times stronger at Earth. This tighter, brighter beam is the optical advantage for faster data rates. For missions operating beyond the Moon, deep space optical communications will boost a spacecraft's data return capability by 10 to 100 times.

To assist the spacecraft transmitter in aiming its narrow beam, a laser "beacon" can be transmitted from Earth. For example, consider a spacecraft orbiting Mars. The beacon is aimed at a point ahead of Mars that ensures the signal arrives at a point where Mars will be after the one-way light transit time. Using this beacon as a guide, the spacecraft accurately aims its transmit beam to the point where Earth will be many minutes later when the signal finally arrives.

Looking back at Earth from Mars, the laser beacon appears as a dim spot on the Earth's disc. Even with a laser transmitter on Earth 1000 times more powerful than the lasers used for near-Earth communications, this pointing reference beacon is approximately 1000 times dimmer at the Mars spacecraft than near-Earth.



Photon counting array tracks beacon laser, Earth image, and transmit point-ahead with only one optical channel versus two or three for other deep-space optical terminal concepts.

The Deep Space Optical Communications project is developing three key technologies essential for operational deep space optical communications.

For the spacecraft optical transceiver:

Spacecraft disturbance isolation platform. Using the 1000 times dimmer laser beacon, the isolation platform provides a 100-times improvement in beam pointing accuracy. A hybrid active/passive isolation strut with ten times reduction in passive isolation 'break' frequency than previous solutions has demonstrated a 'first-of-a-kind' 53.8 dB (factor of 200,000) rejection of emulated spacecraft motion.

Photon counting receiver. Using new technology that provides a 10-times improvement in sensitivity, semiconductor optical detectors can time-tag and process the arrival of individual photons from the laser beacon. The DSOC project has developed a 'first-of-a-kind' radiation-tolerant small-absorber-volume indium gallium arsenide phosphide (InGaAsP) detector array with best-in-class performance of greater than 40% detection efficiency and under 500 Hz false count rate.

For the Earth-based optical receiver, the signal is so dim that a telescope 5 to 12 m in diameter is needed to collect the signal:

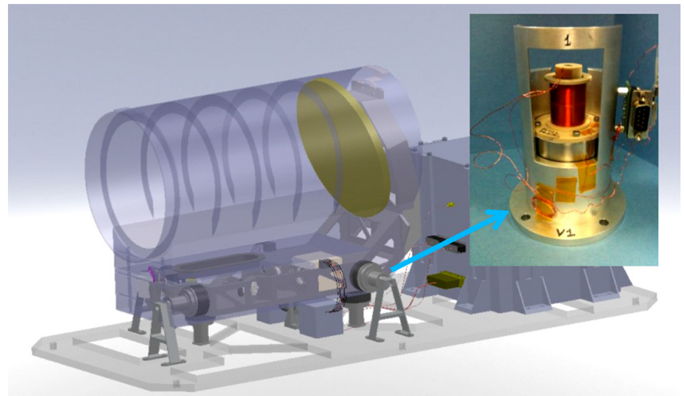
Superconducting photon counting detectors. The goal is to achieve near perfect efficiency with near zero noise. For telescopes 5 m and larger, this technology enables a 10-times increase in data rate for the same received power over the next best solution. In collaboration with National Institute of Standards and Technology (NIST), the DSOC project has developed amorphous tungsten-silicide (WSi) superconducting nanowire detectors with record-setting 93% efficiency and a 64-pixel array with record-setting 25,600 µm2 area.

Hybrid coil spring and voice coil struts are the key components for a platform to isolate the deep space optical transceiver from all spacecraft disturbances over a few hundred mHz.

32x32 InGaAsP Geiger-mode detector array with small absorber volume meets deep space sensitivity requirements and demonstrates minimal degradation in the deep space radiation environment. In addition to laser beacon acquisition and tracking, it also supports Mb/s uplinks to the spacecraft, a factor of greater than 100-times improvement over present RF deep space uplinks.

64-pixel dense packed WSi superconducting nanowire array developed and fabricated at NASA's Jet Propulsion Laboratory is optimized for free space coupling behind multimeter diameter telescopes and has more than 150 times the area of the niobium nitride (NbN) superconducting nanowire detectors used for the 2013 Lunar Laser Communications Demonstration.

The Game Changing Development (GCD) Program investigates ideas and approaches that could solve significant technological problems and revolutionize future space endeavors. GCD projects develop technologies through component and subsystem testing on Earth to prepare them for future use in space. GCD is part of NASA's Space Technology Mission Directorate.



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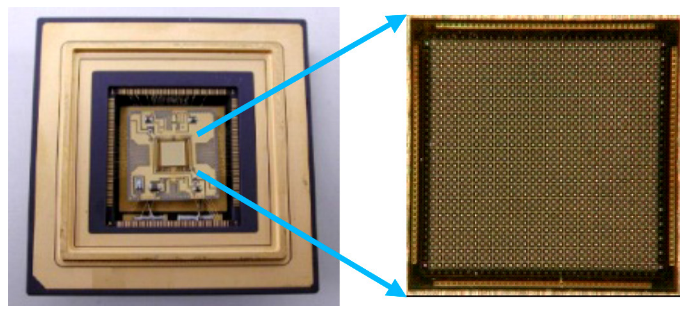

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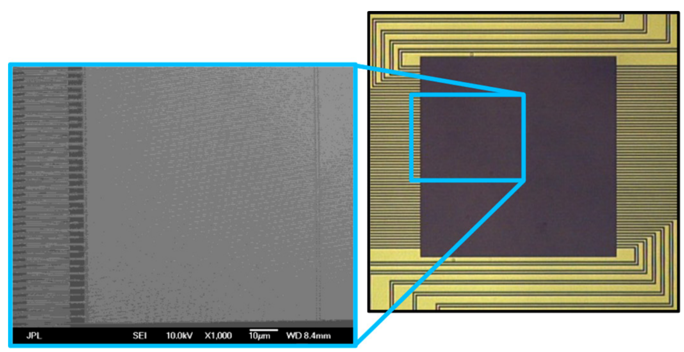

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For more information about GCD, please visit
http://gameon.nasa.gov/

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