trostrictive actuators that will be embedded in the SiC structures. The mode of operation of these actuators will be such that once power was applied, they will change in length and once power was removed, they will maintain dimensional stability to nanometer precision. This mode of operation will enable the use of low-power, minimally complex electronic control circuitry.

The wave-front-sensing and control system will be designed and built according to a two-stage architecture. The first stage will be implemented by a Shack-Hartmann (SH) sensor subsystem, which will provide a large capture range. The second, higher-performance stage will be implemented by an image-based wave-front-sensing subsystem that will include a phase-retrieval camera (PRC), and will utilize phase retrieval and other techniques to measure wavefront error directly. Phase retrieval is a process in which multiple images of an unresolved object are iterated to estimate the phase of the optical system that acquired the images. The combination of SH and phase-retrieval sensors will afford the virtues of both a dynamic range of 10^5 and an accuracy of <10 nm.

Optical Design of an Optical Communications Terminal

This airborne system would keep itself aimed at a ground station.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optical communications terminal (OCT) is being developed to enable transmission of data at a rate as high as 2.5 Gb/s, from an aircraft or spacecraft to a ground station. In addition to transmitting high data rates, OCT will also be capable of bidirectional communications. The OCT is meant to incorporate all of the design features of a prior apparatus denoted the Optical Communications Demonstrator (OCD), plus some improvements.

Like the OCD, the OCT would utilize a single telescope aperture for both transmitting and receiving. Also as in the OCD, a fine-steering mirror (FSM) would be included in the transmitting optical train.

The OCT design utilizes a 1,550-nm fiber-optic amplifier transmitter like that used in the telecommunications industry. Such an amplifier includes a single-mode oscillator, to which one can apply modulation such that the laser light emanating from the fiber can convey data at a rate in the gigabit-per-second range. The laser beam from each such amplifier would be coupled, via a collimating interface module, to a transceiver optical assembly, major optical components of which are shown in the figure.
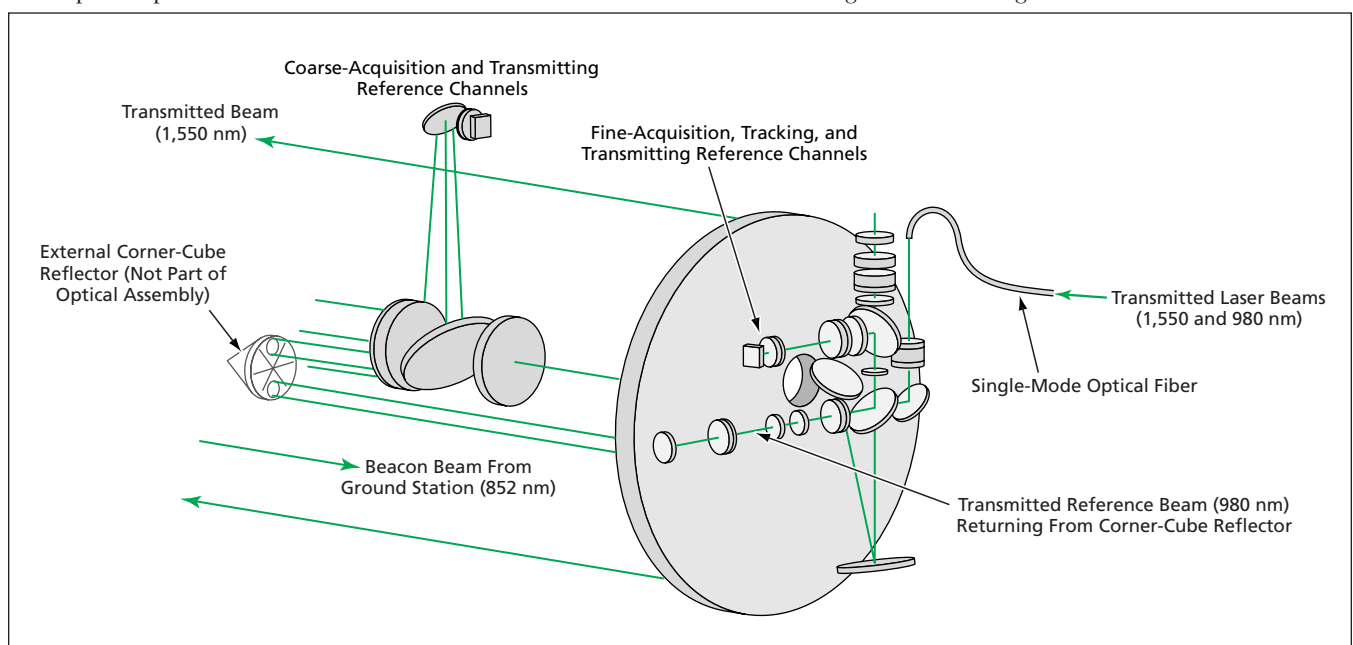
The OCT shall include large-field-of-view focal planes for receiving optical communications and for sensing remote beacon lasers for controlled acquisition, tracking, and pointing (in other words, beacons toward which the OCT would be aimed for transmitting or receiving). The OCT could be connected to a gimbal assembly that could be used for coarse aiming.

The OCT would utilize six optical channels — three for transmitting, three for receiving. The transmitting channels would be the following:

- A channel for a 1,550-nm-wavelength laser beam, which would be the main data-modulated beam to be transmitted via the telescope;
- A channel for part of a split 980-nm laser beam used as a reference beam for fine-pointing servo control; and
- A channel for the other part of the split 980-nm beam used for calibration of a coarse-acquisition charge-coupled device (CCD).

The receiving channels would be the following:

The **Optical Assembly of the OCT** would be compact, yet would accommodate six optical channels, each playing a different role in transmission or reception.

- A channel for a portion of an 852-nm-wavelength beacon-and-data-communication signal from a ground station for use in the coarse-acquisition control system;
- A channel for another portion of the 852-nm signal for use in the fine-acquisition-and-tracking system; and
- A channel for yet another portion of the 852-nm signal, used for reception of data from the ground station.

The telescope in the OCT would have an aperture 100 mm wide and would be afocal: all beams would be collimated at the points where they would be split. The design would minimize vignetting and would include field stops, Lyot stops, and baffles to block stray light. To make the optical system compact, the primary mirror would have a focal-length/diameter ratio ("f" number) of 1.2.

In the first-mentioned transmitting channel, the 1,550-nm laser light coming from a single-mode optical fiber would be collimated and directed to a spot on the FSM coincident with a pupil image plane, then reflected from the FSM to a dichroic beam splitter (DBS), then reflected by four more mirrors, the last two of which would be the secondary and primary telescope mirrors. The divergence of the outgoing 1,550-nm laser beam could be tailored by altering the design of the collimating interface module: one would choose the amount of divergence according to

range of the free-space optical link and the degree of mechanical stability of the aircraft to carry the OCT. The FSM could steer the 1,550-nm laser beam over an angular range about 10 milliradians wide.

In the second-mentioned transmitting channel (the one used for reference for fine pointing), the 980-nm laser beam would be made to propagate with the 1,550-nm beam through the single-mode optical fiber and the rest of the optical train until the two beams reach the DBS. At the DBS, a significant fraction of the 980-nm beam would be transmitted through relay optics to a retroreflector. The retroreflected 980-nm beam would be guided back to a second beam splitter, where the reflected fraction would be brought to focus at a focal plane (the fine-acquisition focal plane), the field of view of which would be 10 milliradians wide. Thus, steering by the FSM would change the location of the 980-nm-wavelength beam spot on this focal plane.

The fraction of the 980-nm beam transmitted through the DBS would propagate through the rest of the optical train and out of the telescope along with the 1,550-nm beam. If the telescope were to be deliberately mechanically aimed at an external corner-cube reflector, the reflected portion of the 980-nm would travel back into the telescope, through the DBS, and onto the fine-ac-

quisition focal plane to a spot different from the reference spot mentioned in the previous paragraph.

Another portion of the returning 980-nm beam, constituting the beam in the third-mentioned transmitting channel, would impinge on the coarse-acquisition focal plane (that is, on the coarse-acquisition CCD). This arrangement would facilitate the calibration of co-boresightedness between the coarse-acquisition and fine-steering fields of view.

In the first-mentioned receiving channel, a portion of the 852-nm signal from the ground station would impinge on the coarse-acquisition focal plane, which would have a field of view 3° wide — wide enough to facilitate acquisition under most circumstances. In the second-mentioned receiving channel, a portion of the 852-nm signal would be guided to a focus on the fine-acquisition focal plane. The design would ensure that location of this focus would differ from that of the 980-nm beam. In the third-mentioned receiving channel, the beam splitter would divert a fraction of the received 852-nm beam to a detector that would extract any data signal conveyed as modulation of this beam.