tubes. The tubes and manifolds are configured in two independent flow loops for operational flexibility and protective redundancy.

This work was done by Cynthia Cross and Hai D. Nguyen of **Johnson Space Center,** *and Warren Ruemmele, Kambiz K. Andish, and Sean McCalley of Lockheed Martin Corp. For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809.*
MSC-23331

Actuated Hybrid Mirror Telescope

A new type of lightweight, wide-aperture, precise telescope is under development.

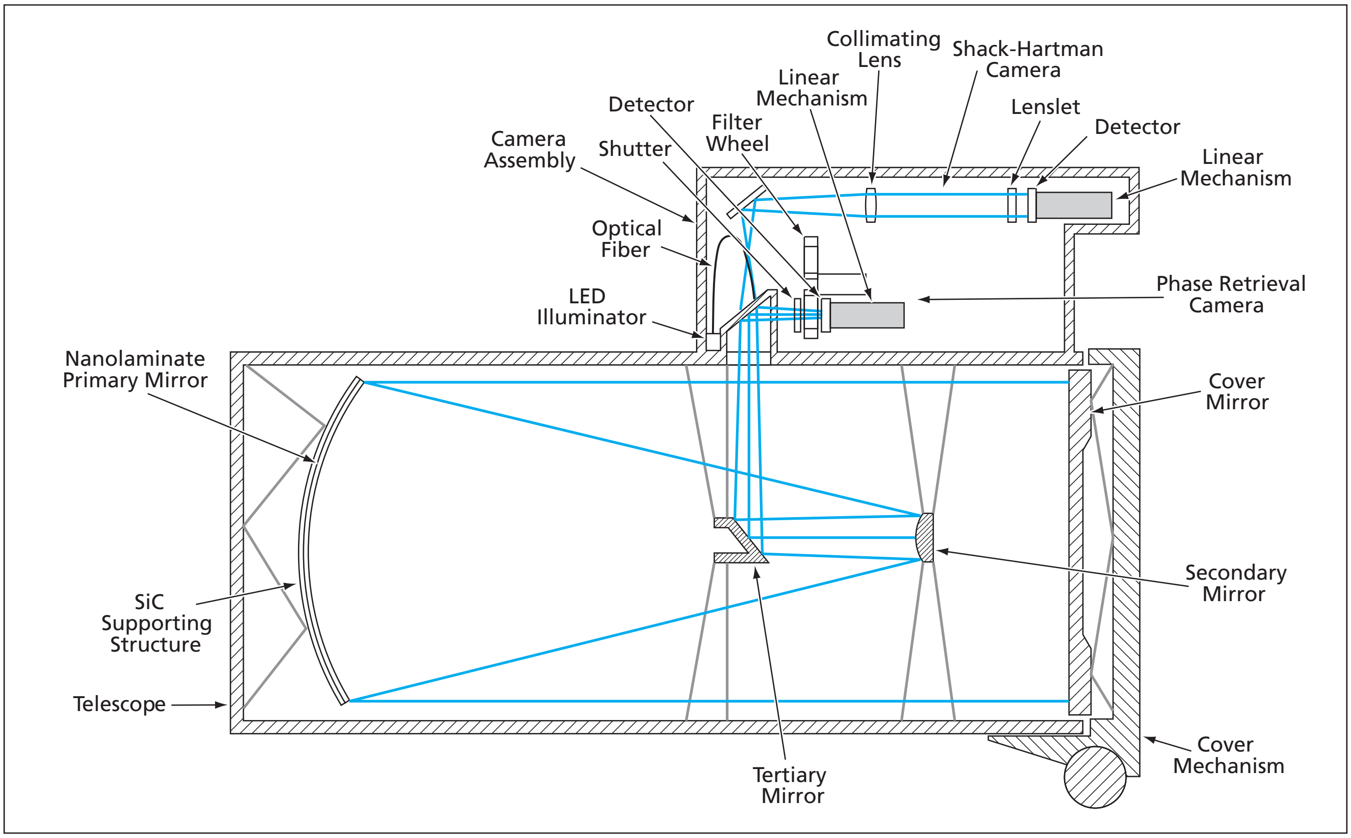
NASA's Jet Propulsion Laboratory, Pasadena, California

The figure depicts the planned Actuated Hybrid Mirror Telescope (AHMT), which is intended to demonstrate a new approach to the design and construction of wide-aperture spaceborne telescopes for astronomy and Earth science. This technology is also appropriate for Earth-based telescopes.

The new approach can be broadly summarized as using advanced lightweight mirrors that can be manufactured rapidly at relatively low cost. More specifically, it is planned to use precise replicated metallic nanolaminate mirrors to obtain the required high-quality optical finishes. Lightweight, dimensionally stable silicon carbide (SiC) structures will support the nanolaminate mirrors in the required surface figures. To enable diffraction-limited telescope performance, errors in surface figures will be corrected by use of mirror-shape-control actuators that will be energized, as needed, by a wave-front-sensing and control system.

The concepts of nanolaminate materials and mirrors made from nanolaminate materials were discussed in several previous *NASA Tech Briefs* articles. Nanolaminates constitute a relatively new class of materials that can approach theoretical limits of stiffness and strength. Nanolaminate mirrors are synthesized by magnetron sputter deposition of metallic alloys and/or compounds on optically precise master surfaces to obtain optical-quality reflector surfaces backed by thin shell structures. As an integral part of the deposition process, a layer of gold that will constitute the reflective surface layer is deposited first, eliminating the need for a subsequent and separate reflective-coating process. The crystallographic textures of the nanolaminate will be controlled to optimize the performance of the mirror. The entire deposition process for making a nanolaminate mirror takes less than 100 hours, regardless of the mirror diameter.

Each nanolaminate mirror will be bonded to its lightweight SiC supporting structure. The lightweight nanolaminate mirrors and SiC supporting structures will be fabricated from reusable master molds. The mirror-shape-control actuators will be low-power, high-capacitance lead magnesium niobate elec-



The **Design of the AHMT** will utilize advanced materials and advanced sensing and control techniques to obtain imaging. The primary mirror will have a diameter of 0.75 m and an areal density less than 10 kg/m^2.

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.

This work was done by Gregory Hickey, David Redding, Andrew Lowman, David Cohen, and Catherine Ohara of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40105

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.

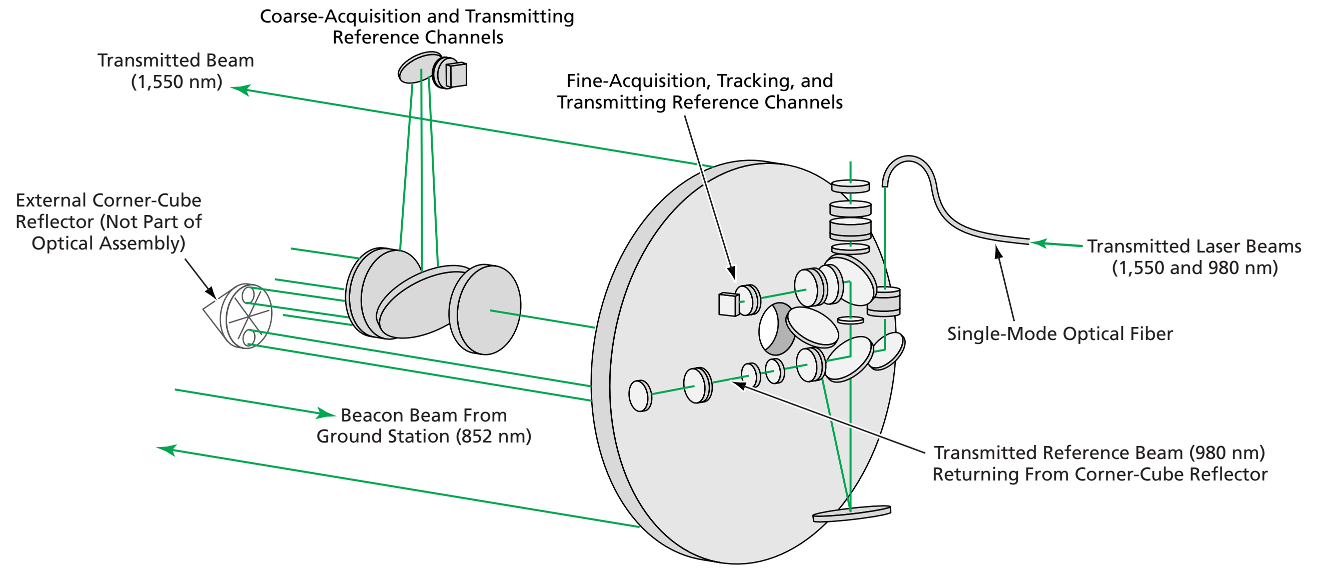
The OCT design utilizes a 1,550-nm fiber-optic amplifier transmitter like that used in the telecommunications industry. Such an amplifier includes a single-mode oscillator, to which one can apply modulation such that the laser light emanating from the fiber can convey data at a rate in the gigabit-per-second 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.