A **Model Robotic Vehicle** was driven over 25-cm obstacles on simulated terrain at a tilt of 20°.

Models of rocks, trenches, and other obstacles can be placed on the simulated terrain.

For example, for one of the Mars-Rover tests, a high-friction mat was attached to the platform, then a 6-in.-(≈15 cm) deep layer of dry, loose beach sand was deposited on the mat. The choice of these two driving surface materials was meant to bound the range of variability of terrain that the rover was expected to encounter on the Martian surface. At each of the different angles at which tests were performed, for some of the tests, rocklike concrete obstacles ranging in height from 10 to 25 cm were placed in the path of the rover (see figure).

The development of the VTTP was accompanied by development of a methodology of testing to characterize the performance and modes of failure of a vehicle under test. In addition to variations in slope, ground material, and obstacles, testing typically includes driving up-slope, down-slope, cross-slope, and at intermediate angles relative to slope. Testing includes recording of drive-motor currents, wheel speeds, articulation of suspension mechanisms, and the actual path of the vehicle over the simulated terrain. The collected data can be used to compute curves that summarize torque, speed, power-demand, and slip characteristics of wheels during the traverse.

This work was done by Randel Lindemann of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

NPO-42522

Interferometer for Low-Uncertainty Vector Metrology

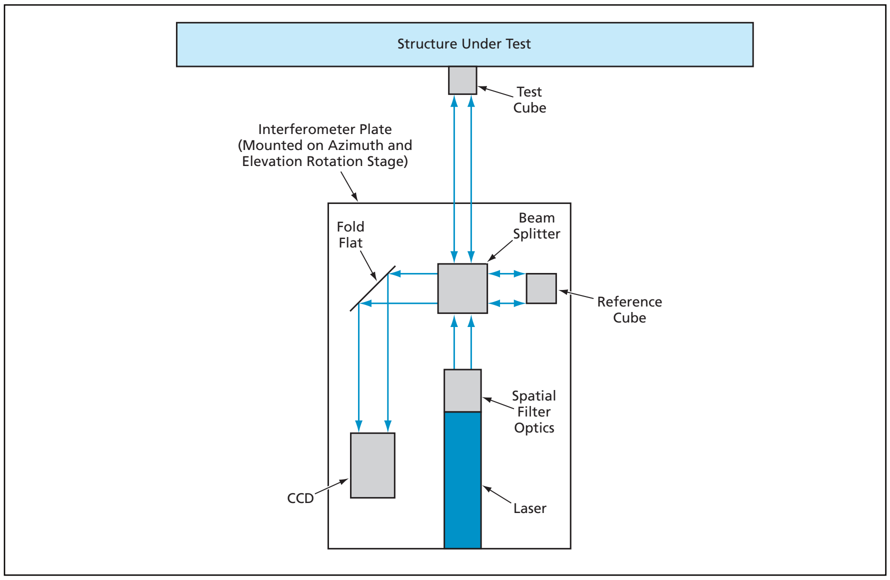
Accuracy is increased; time and cost are reduced.

Goddard Space Flight Center, Greenbelt, Maryland

The figure is a simplified schematic diagram of a tilt-sensing unequal-path interferometer set up to measure the orientation of the normal vector of one surface of a cube mounted on a structure under test. This interferometer has been named a "theoferometer" to express both its interferometric nature and the intention to use it instead of an autocollimating theodolite.

The theoferometer optics are mounted on a plate, which is in turn mounted on orthogonal air bearings for near-360° rotation in azimuth and elevation. Rough alignment of the theoferometer to the test cube is done by hand, with fine position adjustment provided by a tangent arm drive using linear inchwormlike motors.

In the operation of the theoferometer, the interference pattern formed by the collimated laser beams reflected from the two cubes is focused onto a



In this **Interferometer**, the interference pattern formed by the laser beams from the cubes is imaged onto the CCD. This pattern would depend on the angular misalignment between the cubes and would be analyzed to determine the misalignment.

charge-coupled device (CCD) detector. The resulting digitized interference fringe pattern is then analyzed by dedicated software to determine the angular misalignment between the two laser beams (and, hence, the misalignment between the cubes) at the sub-arcsecond level. If a null fringe pattern were achieved, it could be concluded that the laser beam points anti-parallel to the surface normal of the test cube. Knowledge of the distance from null (via the angular misalignment seen in the interference pattern) coupled with readings from azimuth and elevation encoders calibrated to the laser-pointing direction then gives the orientation of the cube surface normal vector in two (angular) dimensions. This is the same information as would be given by a theodolite aligned to the test cube, albeit with greater accuracy.

This system offers several advantages. The parts used in the prototype unit were off-the-shelf and relatively inexpensive. Whereas the uncertainty of a typical theodolite measurement is 1 to 2 arcseconds, the current theoferometer prototype has a demonstrated uncertainty of about 0.3 arcsecond. Moreover, the theoferometer makes it possible to completely automate the data-taking process, reducing the time required to take measurements. The net result is better metrology at lower cost, relative to metrology by use of an autocollimating theodolite.

This work was done by Ronald W. Toland and Douglas B. Leviton of **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1). GSC-14753-1*

Rayleigh Scattering for Measuring Flow in a Nozzle Testing Facility

The facility can test nozzles up to 8.75-in. (22.2-cm) in diameter.

John H. Glenn Research Center, Cleveland, Ohio

A molecular Rayleigh-scattering-based air-density measurement system was built in a large nozzle-and-engine-component test facility for surveying supersonic plumes from jet-engine exhaust. The facility (see Figure 1) can test nozzles up to 8.75 in. (22.2-cm) in diameter. It is enclosed in a 7.5-ft (2.3-m) diameter tank where ambient pressure is adjusted to simulate engine operation up to an altitude of 48,000 ft (14,630 m). The measurement technique depends on the light scattering by gas molecules present in the air; no artificial seeding is required. Commercially available particle-based techniques, such as laser Doppler velocimetry and particle image velocimetry, were avoided for such reasons as requirement of extremely large volume of seed particles; undesirable coating of every flow passages, model, and test windows with seed particles; and measurement errors from seed particles not following the flow. The molecular Rayleigh-scattering-based technique avoids all of these problems; however, a different set of obstacles associated with cleaning of dust particles, avoidance of stray light, and protection of the optical components from the facility vibration need to be addressed.

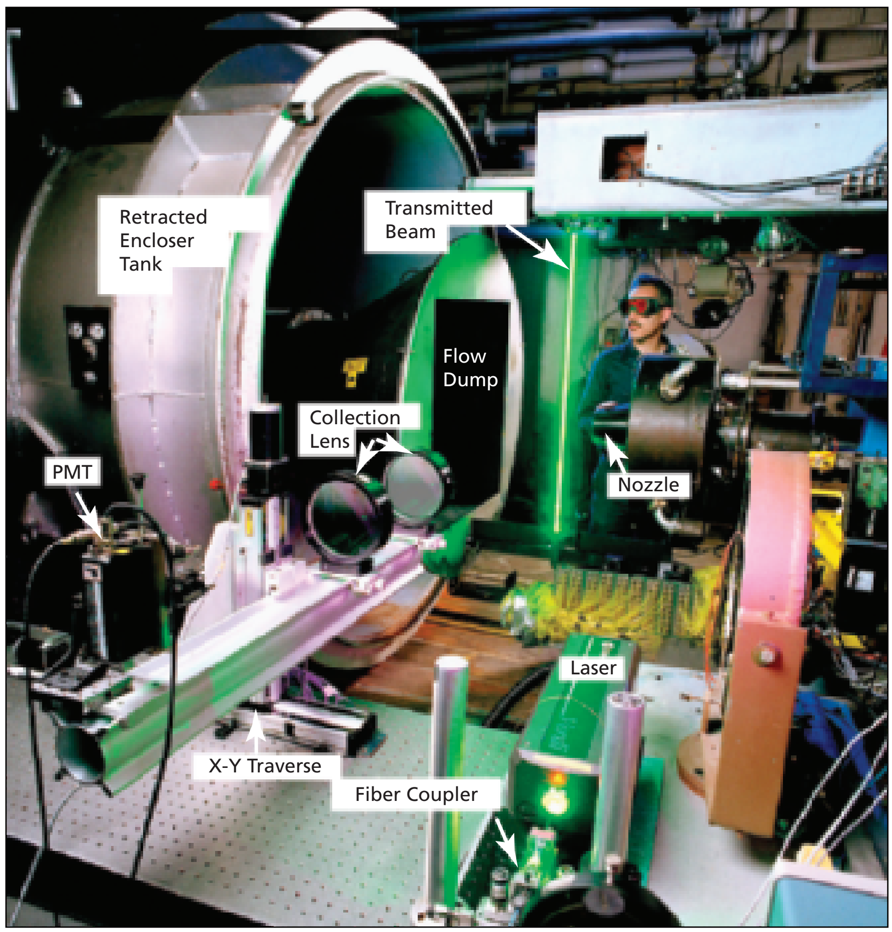


Fig. 1. The **Optical Arrangement** is shown with the enclosing tank retracted downstream.

To avoid a problem with facility vibration, light from a single-mode continuous-wave laser was transmitted into the vacuum tank by the use of an optical fiber. It was then collimated and passed through the plume. Rayleigh-scattered light from various points along the collimated beam was collected by a set of collection lenses placed outside the vacuum tank and measured by a photomultiplier tube (PMT). Large glass windows on the tank provided optical access. The collimator for the transmitted beam and the light-collection optics were placed on two synchronized traversing units to enable a survey over a cross-section of the nozzle plume. Although the technique is suitable to measure velocity, temperature, and density, in this