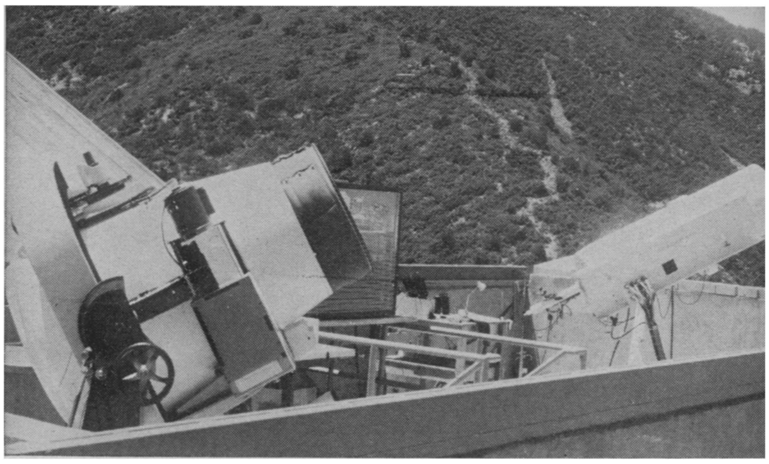
GEOPHYSICS

Measuring the earth

Scientists may soon be using lasers to measure the movements of the earth's crust

by Louise Purrett


SAO

SAO laser-camera pair at Mt. Hopkins Observatory.

Since the first one was built in 1960, lasers have repeatedly proved their versatility, finding uses in such widely varied fields as eye surgery, communications, welding, crystallography and even tailoring.

One of the laser's newer uses is in geodetics. If two ground stations simultaneously bounce laser beams off an orbiting satellite and record the time the light beam takes to make the round trip, the distance between the station and satellite can then be calculated, since the speed of light is known. This gives the length of two sides of a triangle; the distance between the stations—the baseline of the triangle—is then easy to calculate.

In 1967, the National Aeronautics and Space Administration and the French space agency Centre National des Etudes Spatiale (CNES) began using this technique to measure distances between locations on earth. Later, the Smithsonian Astrophysical Observatory was able to refine its Standard Earth—a precise model of the earth's size, shape and geopotential—using new laser data.

Other possibilities have opened up. Scientists from eight nations are now setting up a network of laser stations that they hope will tell them the rate at which the earth's continents are drifting. The nations involved are the United States, Germany, Bulgaria, France, Soviet Union, Poland, Japan and England. In the International Satellite Geodesy Experiment (ISAGEX), expected to continue through July, four baselines spanning several continents will be established. The longest baseline, from Wettzell in southern Germany to Natal on Brazil's eastern coast, extends 6,200 miles. The others are from Dyonisos near Athens, to Olifantsfontein near Pretoria, South Africa; from Olifantsfontein to Woomera, South Australia; and from Naini-Tal in northern India to Guam. Thirty stations, each consisting of a laser, a camera and a receiver, will be located along these baselines.

Laser beams will be bounced off seven already orbiting satellites, ranging in age from the United States' Explorer 22, launched in 1964, to France's Peole, launched last December. The reflected beams will be recorded by the ground stations, which will note the angle and distance of the satellite. Sightings can be made within an accuracy of about two feet, says Dr. Ivan I. Mueller of Ohio State University.

The purpose of the observations is to determine the exact length and directions of the four baselines. Analysis of data from the observation stations over a 5- to 10-year period will enable scientists to detect slight changes in the baselines and the rate at which such changes occur.

But using satellites that were designed for other purposes, says Dr. Edward Gaposchkin of the Smithsonian Astrophysical Observatory, will limit the accuracy of the ISAGEX data. Scientists at the SAO, which is also deeply involved in ISAGEX, would like to launch a satellite that would be better suited to fine laser measurements. Two SAO scientists, Drs. G. C. Weiffenbach and T. E. Hoffman, proposed last November that such a satellite might be a solid uranium sphere, 30 inches in diameter and weighing 4 tons, equipped with special laser reflectors (SN: 12/26/70, p. 479). With improvements in the accuracy of theoretical models and with improved lasers, the scientists say, this satellite would permit position accuracies of better than 10 centimeters. This and better accuracy is essential to measurement of the two- to five-centimeter-per-year rates of continental drift.

This specialized satellite, called the Cannonball, would also, the SAO scientists propose, contribute to other objectives of the United States' earth physics program, permitting measurement of the rotation of the earth, polar motions, earth body tides and tidal loading, and establishment of a 10-centimeter coordinate system.

The Cannonball satellite, says Dr. Gaposchkin, is not the only possibility. An alternative which SAO scientists have considered is two satellites, one solid and one hollow. Two satellites with different mass-to-area ratios would give a measure of the effects of radiation pressure on their orbits.

Since some of these motions are on a larger scale than movements of the earth's crustal plates, or tectonic motions, says Dr. Gaposchkin, they can be measured with the ISAGEX data. Solid earth tides—vertical motions of the earth's surface—may be as great as 50 centimeters. Polar motions—slight changes in the earth's spin axis or movements of the earth with respect to its spin axis—are even larger: up to 10 meters.

The laser-satellite technique, the scientists feel, is particularly suited to measuring tectonic motions, provided the necessary accuracy can be attained. Tectonic motions, they point out, are very complex, involving vertical and horizontal motions that vary widely from place to place. To understand them, the geophysicists need data on a global scale.

Another problem in interpreting observations of tectonic motions is in differentiating between absolute and relative motions and in finding a fixed reference point by which to measure absolute motions. A satellite could provide such a reference point.

Ground stations, the scientists propose, must be placed in particular geographic locations in order to give a comprehensive picture of tectonic motions. They would like to establish a three-station net in the Canadian shield, a tectonically stable area, to serve as an anchor. Other stations would be placed in more active areas, such as the eastern Mediterranean, Ethiopia and Japan.

But in spite of its advantages in studying tectonic movements, Dr. Gaposchkin cautions that the laser-satellite technique does have limitations on its accuracy. The ultimate uncertainty of the technique, Dr. Gaposchkin believes, is about three to five centimeters. Nevertheless, he says, SAO scientists are pressing for the launching of the Cannonball or a similar satellite. "We're very, very interested in it." ☐