

TRACKING OF THE BEACON-EXPLORER SATELLITES WITH LASER BEAMS

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Experiments are being conducted in the United States, directed toward developing techniques for accurate tracking of orbiting optical reflectors with lasers. The development is now sufficiently advanced to permit us to predict that laser tracking will undoubtedly prove a valuable tool for determining precise orbital positions, and thus can be added to the other useful radio and optical methods of satellite geodesy. From these experiments, we are also deriving information concerning the propagation of laser beams through the atmosphere, and a wealth of practical experience that must be assimilated before optical techniques can be extended to more sophisticated types of tracking and to long range, high information rate communication.

The Beacon-Explorers B and C (Explorers 22 and 27) were provided for this purpose, with arrays of cube-corner retro-reflectors designed to present as large an effective reflecting area as possible to tracking stations in the Northern Hemisphere (Ref. 1,2). Explorer 22 was launched October 9, 1964 into an orbit with inclination 79.7° , apogee 1,100 km, and perigee 939 km. Explorer 27 was launched April 29, 1965 into an orbit with inclination 41.186° , apogee 1,318.2 km, and perigee 939.3 km. In order to stimulate wide participation in this experiment, the satellites and plans were described by NASA at the Third International Conference on Quantum Electronics in Paris, on February 13, 1963. As a result before Explorer 22 was launched, laser tracking stations were established by the British D.S.I.R., Radio Research Station and by the French Service D'Aeronomie, CNRS, as well as by several organizations in the United States.

All of the experiments have, thus far, employed pulsed ruby lasers as their source of transmitted radiation. The first observations of laser

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reflections from Explorer 22 (Ref. 3, 4), were obtained shortly after its launch, by the General Electric Company at Phoenix, Arizona and by the Goddard Space Flight Center near Greenbelt, Maryland. They consisted of photoelectric signals photographed on an oscilloscope. More recently, the time from transmission of the pulse to reception of the echo has been measured to determine range at a large number of points during some passes of the Beacon-Explorers over Greenbelt. Figure 1 illustrates the history of range variation versus time for a typical pass of Explorer 27, in which each dot represents reception of a flash and a range determination, when the laser was fired at the rate of once per second.

Reflected ruby laser radiation from the Beacon Explorers has also been used to produce photographic images of the satellite against a star background. This was accomplished first by the Air Force Cambridge Research Laboratories (Reference 5), at Bedford, Massachusetts. More recently, the Smithsonian Astrophysical Observatory (Reference 6), collaborating with the General Electric Company, photographed laser reflections from Explorer 27 using the Baker-Nunn camera at Las Cruces, New Mexico.

These techniques thus promise to yield precise measurements of satellite position, when they are developed to an operational stage. The traditional optical tracking methods require photography of the satellite by reflected sunlight, at a time when the sky is dark enough to allow simultaneous photography of the stars. By imposing accurate time markings onto the trails of the satellite and/or the stars, and carefully measuring the satellite's coordinates with respect to the fixed stars, its angular position with respect to the observing

station at a particular time can usually be determined to within an estimated error of about two seconds of arc. This method was extended, in the U.S. satellite ANNA IB by installing satellite-borne beacon lights which could be commanded to produce powerful flashes at known times over an observing camera station. It was then possible to obtain accurate angular positions during portions of the satellite orbit that were in the shadow of the earth. The wider distribution of such measurements could be translated into improved determination of orbit parameters or into additional geodetic data.

Photography of reflected laser radiation offers the same improvement in wider distribution of angular data, with the added advantage that the satellite equipment is completely passive. To this we must also add the ability to measure range precisely, which is a very powerful geodetic tool. The photoelectric range measurement can also be performed in daylight, if we employ a narrow-band wavelength filter to reject scattered sky background light. Using very short bursts from a "giant-pulse" laser, and timing the two-way trip with a 100 mc/s counter, we expect resolution of three meters in each range measurement. Simultaneous range and angle measurements will enable establishing orbit parameters after a single pass over a laser tracking station.

The development of this tracking method will continue, particularly to permit laser range determination during daylight passes and when the satellite is in the shadow of the earth.

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