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"LASER RANGING GROUND STATION DEVELOPMENT"

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Though this Final Report* concludes the work carried out at Wesleyan University, Middletown, Connecticut 06457, the project has and is continuing at the Joint Institute for Laboratory Astrophysics in Boulder, Colorado 80302 under NASA Order Number W13,349 to the National Bureau of Standards, Laboratory Astrophysics Division.

* Herbert S. Snyder and J. B. Phillips, Jr. of NASA Headquarters served as Grand Officers for this grant. Col. A. T. Strickland of NASA Headquarters was (and is) NASA's Technical contact via the LURE (Lunar Ranging Experiment) Team.

Full utilization of lunar retroreflector arrays requires an observing program which lasts decades and which employs a number of ground stations around the world in order to accurately measure wobble and rotation variations of the Earth and to look for differential tectonic drifts. At the present time, with three U.S. and two French-Russian arrays on the moon there is a very real scientific need for additional ground stations as well as ground station capability. If the lunar range is to be corrected for both the effects of polar motion and fluctuations in the Earth rotation rate, data is required from a minimum of two and preferably three or more well-located observing stations. In addition, observations from a large number of ground stations, well distributed over the Earth, are needed in order to permit mapping the motions of the lithospheric plates which form the Earth's surface. A considerable enhancement of the geophysical results would result from a greatly increased international participation in the experiment so as to provide worldwide coverage. Indeed, the Apollo 15 array was built larger to specifically encourage this.

Experience to date has pointed out the desirability of full-time availability of several telescopes for laser ranging as well as some of the difficulties and operating costs attendant in "piggy-backing" the primary ranging stations on large telescopes designed and used primarily for astronomical work.

The identifiable goals desirable in any new type of ranging station are: (1) full-time availability of the station for laser ranging, (2) optimization for signal strength, (3) automated operation to the extent possible, (4) the capability for "blind" pointing, (5) reasonable initial and modest operational costs, and (6) transportability which would considerably enhance its value for geophysical purposes.

The approach we have taken is to functionally separate the laser telescope's transmitting and receiving role. This separation provides a basis for both a practical and realizable laser ranging station meeting the above identified goals.

In so far as the receiving function is concerned, the important point that needs to be recognized is that telescopes used for laser ranging (and indeed for looking at a large class of astronomically interesting objects) are being used in effect to look at point sources in the sky. And as such, the requirement for field (in addition to aperture) can be removed. This observation can be exploited experimentally to build a relatively compact "telescope" of modest cost in the form of a multi-lensed "fly's eye" large aperture receiver.

The front plate of the LURE (Lunar Ranging Experiment) Scope (see Figs. 1 and 2) consists of 80 archromatic f/10 lenses each 7½" in diameter. They are rigidly mounted into a hexagonal array of overall dimension 92" × 90". An almost identical back plate holds 80 small (.004" diameter) aperture stops corresponding to a 11 sec of arc field all of which are co-registered with each other. The light which passes through each of these pinhole stops is brought together by articulated optical links through a variable (field determining) pinhole onto a common photomultiplier.

The operation of the telescope depends on the different apertures staying aligned when the telescope points to different parts of the sky. To assure this the front and back plate are solidly connected together and rigidly constructed. A considerable experimental advantage is gained by using transmission rather than reflection optics since the transmitted image positions are quite insensitive to slight angular rotations of the individual lenses.

The faceted receiver developed under this grant and presently nearing completion at JILA has a size of approximately 8' × 8' × 8' and a total wieght (exclusive of the bearing) of approximately 4500 lbs. Of this total the 80 lenses contribute 700 lbs. The lenses will perform essentially at the diffraction limit for the range from about 4000 Å to 1 μ. Using achromates, while minimizing the mechanical and the optical problems associated with covering the laser wavelengths of present interest [5300 Å, 6943 Å, and 1.06 μ], permits a desirable several seconds of arc resolution: for a singlet of this size and f-number, spherical aberration would limit the resolution and hence the minimum operating stop size to about 14 seconds of arc rather than the 3 or 4 seconds of arc stop size which the instrument will be capable of employing.

The telescope has an Elevation-Azimuth type mounting and utilizes a hydrostatic (oil) bearing for the azimuth axis and conventional ball-type bearings for the smaller elevation axis. Guidance is accomplished by on-line computer control. The availability of an angle emphemeris for the moon with an accuracy of about 1 sec of arc together with highly accurate shaft encoders which permit this same level of absolute angular pointing accuracy makes possible fully automated telescope guiding and pointing -- and hence routine ranging operations whenever the moon is in the sky, be it lunar night or lunar day. The costs of automation are expected to be well repaid in operational as well as functional savings of time and money.

The multi-lensed telescope is designed to permit tracking at the rates appropriate for at least fairly high altitude satellites. Having range measurements of 3 cm accuracy (as can be obtained using the new short pulse lasers) to both the moon and artificial satellites from the same station will serve to tie together the geodetic and earth physics results from both types of measurements.

This receiver concept in addition to its usefulness for ranging and as a receiving antenna for long range optical space communications is also applicable to problems of stellar spectroscopy and photometry. Indeed, for applications requiring light-gathering-power but not field of view; this type of instrument appears to be very attractive on economic grounds, and its success for stellar observations could have a major im pact on the design of future very large astronomical instruments intended mainly for point source spectroscopy and similar applications.

Bibliography

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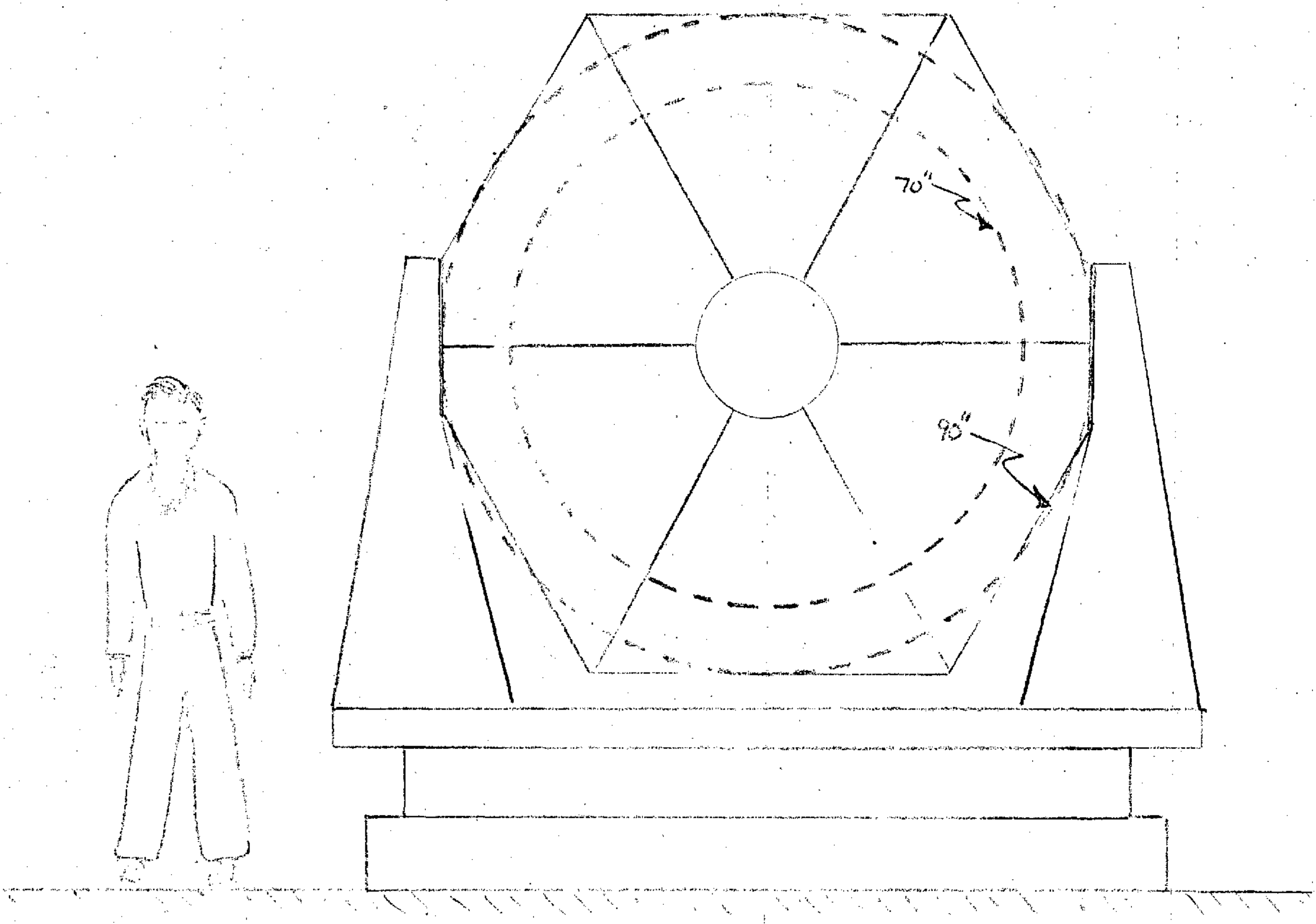

Fig 1

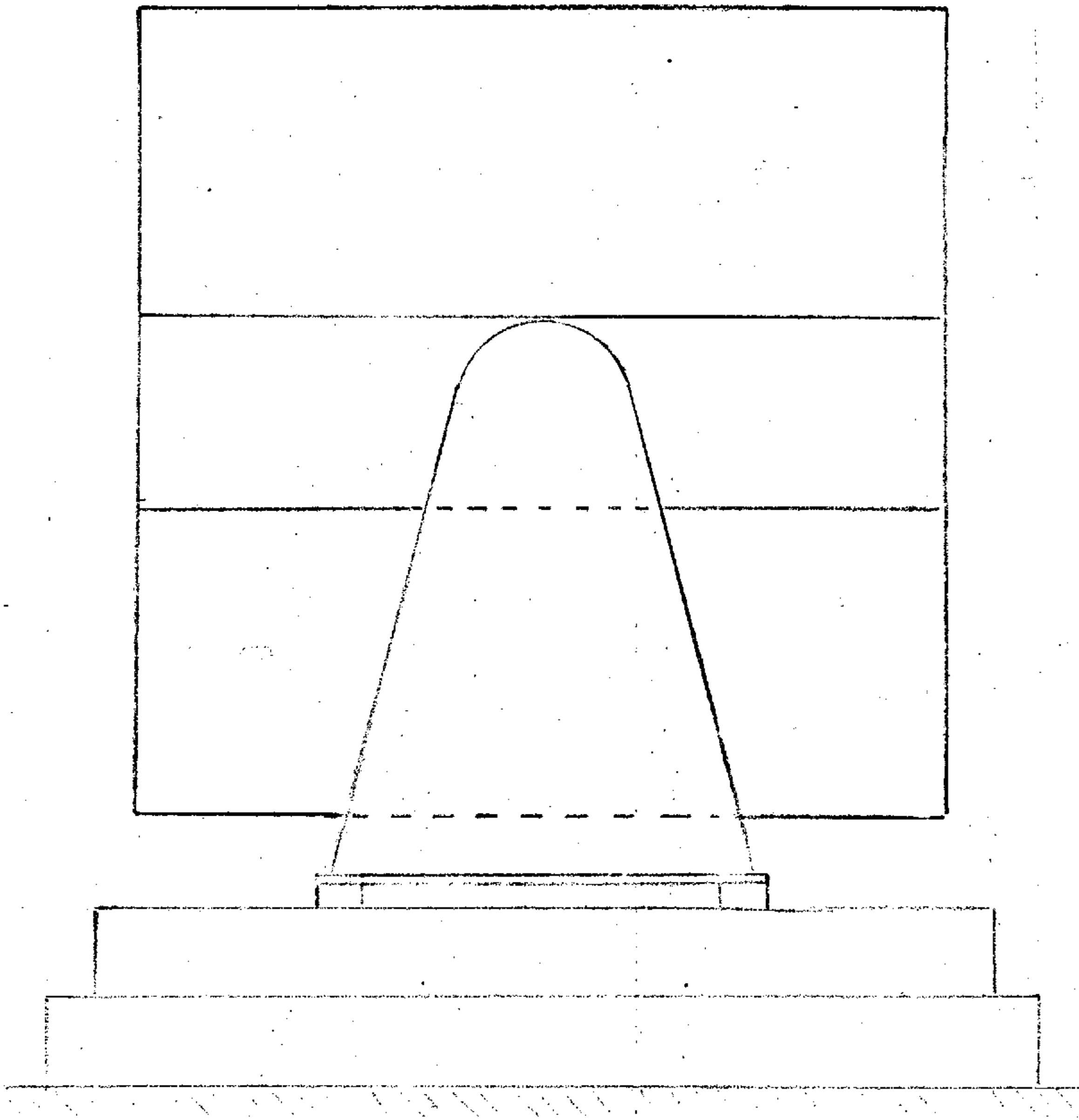

Fig 2