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*Photogrammetry, Navigation, and Space Problems**

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IN THE past, photogrammetry was mostly used to produce topographic maps. It is, however, a well-known fact that photogrammetry—due to the versatility of this method—can be applied not only for producing such maps but with equal advantage as a measuring method in many other fields of science and technology. Photogrammetry applied for non-topographical purposes is normally designated as Non-Topographical Photogrammetry.

Photogrammetric methods are closely related to geodetic methods because both sciences in their practical application are greatly concerned with performing measurements of various kinds. As far as concerns the accuracy, which can be attained by both measuring techniques, one was of the opinion—at least in the past—that geodetic measuring methods would yield a higher accuracy than photogrammetric measuring methods. It seems, however, that in the future this conception must be modified to a certain extent because of the remarkable progress which has been made in recent years in improving photogrammetric measuring techniques. The use of high-performance cameras, high-quality photographic material and high-precision measuring or plotting instruments already permits one for certain measuring tasks to obtain an accuracy which is considered as standard geodetic accuracy. An example is the photogrammetric determination of numerical coordinates for boundary points in land surveying, in which photogrammetric methods are today capable of replacing certain geodetic methods.

The universal acceptance of photogrammetry as a measuring method and its increasingly high degree of accuracy have permitted applying photogrammetric methods in the most recent time to such diverse fields as flight testing and navigation, satellite and missile tracking, and lunar investigations. It is the purpose of this paper to discuss these three applications.

A. Stellar Photogrammetry

The application of this method is at present being studied to produce information on the pitch, roll and heading of an aircraft in flight for instrument testing. For this purpose star photographs are made with a special photogrammetric camera, namely, a stellar camera or star camera. From these star photographs pitch, roll and heading can be computed at the exposure stations by means of formulas which have been derived at the Institute of Geodesy, Photogrammetry and Cartography of The Ohio State University.

One of the main problems in stellar photogrammetry is that regular aerial cameras are unable to produce useful star pictures. There are three reasons for this: first, the relative aperture is too small to produce star images, especially of stars of smaller magnitude; second, the exposure time has to be kept very short because of the aircraft motion and oscillation; and third, the resolution of the combination of camera objective and photographic emulsion is not always sufficient to produce pictures of a sufficiently large amount of stars. [Figure 1]

To overcome these difficulties a system is being worked out at this Institute consisting of high-performance camera and a stabilized camera mount. In order to obtain correct information on pitch, roll and heading, the rela-

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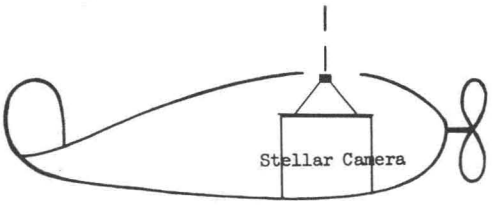

FIG. 1. Scheme of a stellar-photogrammetric system.

tive motions of the camera mount, with respect to the aircraft frame, have to be recorded. This system permits choosing much longer exposure times, and it is expected that by this method a sufficiently large number of stars will be portrayed on the individual exposures.

To obtain information on pitch, roll and heading the picture coordinates of at least three stars on each exposure are measured. Although such measurements require considerable time, it is expected that by such a system valuable information for flight testing can be gathered. An ultimate goal of this preliminary system might be seen in an automatic continuous recording of pitch, roll and heading. This would require a replacement of the rather lengthy star coordinate measuring procedure by a much faster and automatic system containing among other elements a scanning device for automatic recording of star picture coordinates. If such a system could be realized a valuable means would be available for navigation purposes.

B. Satellite and Missile Tracking

Tracking missiles and the determination of their trajectories is today a fairly well-established photogrammetric procedure. This branch of photogrammetry is named Ballistic Photogrammetry and has been considerably developed in the last years, especially in this country. Pioneer work was done by specialists such as Dr. Hellmut Schmid of Aberdeen Proving Ground, Maryland. The instrumentation consists mostly of Wild Ballistic Cameras, Askania Theodolites, Wild Autographs A7 and Wild Stereocomparators.

In the field of satellite tracking by means of photogrammetric, geodetic or electronic methods, a great amount of development work still must be done before workable procedures are available. In connection with these problems the question immediately arises, What is the practical use of satellite tracking? The present answer to this question from the geodetic standpoint is that satellite tracking may be a means to obtain more precise information about the shape and size of the earth than is available up to now on the basis of classical geodetic triangulations. Especially one hopes to obtain from satellite tracking more precise measures for the geodetic connections between the various continents on the earth. The accuracy of presently established geodetic ties between the various continents is of the order of several hundred feet, as can be seen from Table 1.

TABLE 1

Continental Connection	*Accuracy*
North America—Europe	400 ft.
North America—Japan	500 ft.

The photogrammetric-geodetic approach in determining continental ties considers the use of satellite-tracking cameras, mostly Baker-Nunn Cameras [see Figure 2]. Such cameras are placed at various positions on the earth and simultaneous photographs of the satellite are made [see Figure 3].

In this way the directions from the various camera stations can be recorded. This is normally done by means of the so-called star background method, i.e., the picture points of the satellite orbit points are measured with respect to the nearest star images. It is hoped that by using such satellite-tracking cameras a directional accuracy from camera stations to orbit points of $\pm 2''$ can be reached, and that in this case more accurate information for relative positions between the various camera stations can be obtained than would be possible on the basis of existing geodetic triangulations.

The photogrammetric part of this method consists of a sufficiently accurate calibration of the satellite-tracking cameras. This problem is complicated by the fact that, for the sake of maximum picture sharpness and resolution, the pictures in the Baker-Nunn Camera are produced on a spherical backup plate. The solution of this problem, with which the Institute of Geodesy, Photogrammetry and Cartography of The Ohio State University is concerned, offers some of the most fascinating aspects of modern photogrammetry.

C. Photogrammetric Mapping of the Moon's Surface

The launching of rockets to the moon makes desirable having available more accurate topographic maps of the moon's

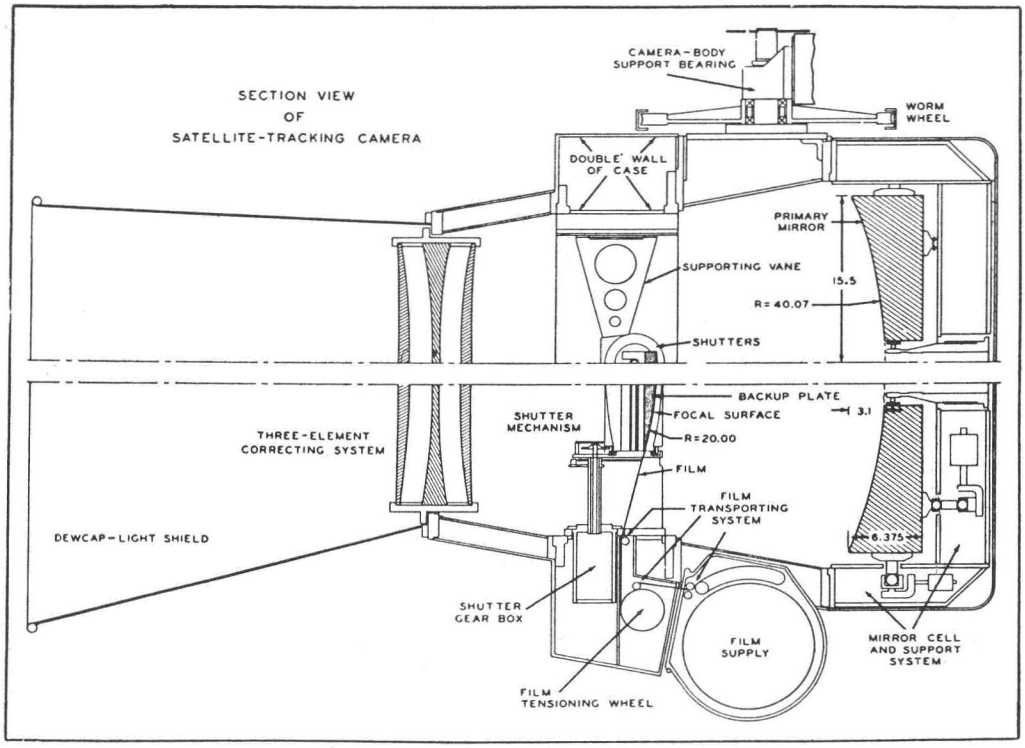

FIG. 2. Baker-Nunn Tracking Camera. Two cross sections of the Baker-Nunn satellite-tracking camera, showing the film-transport and shutter mechanism. The two halves are at right angles to each other, and all dimensions are in inches. The double-walled camera case is in four sections (right to left), one holding the mirror, the next the support trunnions, the next the focal surface and film-transport system and the last the three-element Schmidt correcting plate.

surface. It is considered that this could be done by appropriate stereophotogrammetric methods which would be more efficient than the well-known moon-mountain-shadow method, which is a very time consuming procedure and does not always yield reliable results.

Stereophotogrammetric mapping of the visible moon's surface is principally possible due to the so-called libration of the moon. This libration is comparable to a relative oscillation of the moon of about $\pm 8°$ when rotating around the earth [see Figure 4].

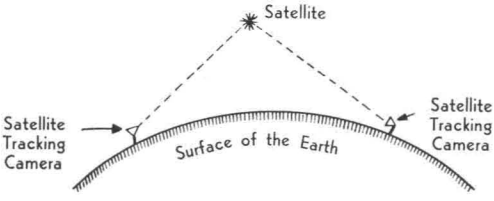

FIG. 3. Scheme showing the tracking of satellites by means of satellite-tracking cameras.

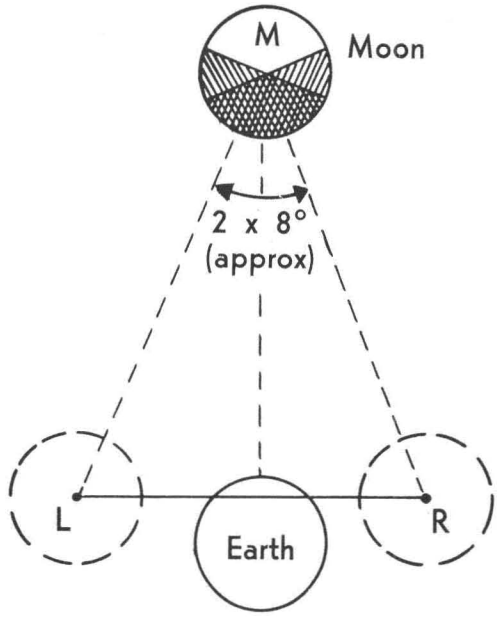

FIG. 4. Effect of the moon's libration on photographs from the earth.

If now the visible moon's surface is photographed from our earth in two extreme libration positions, two stereophotographs are obtained as if the photographic stations were located at L and R, which determine a fairly favorable stereoscopic base [b]. It is obvious that the accuracy of the directions LM and RM must be extremely high due to the considerable distance between the moon and earth, which amounts to about 240,000 miles. Such a high directional accuracy can be obtained only by making the photographs through a high performance telescope with a very long focal-length. Using the 80-foot focal-length telescope of Mt. Wilson Observatory in California seems to be a feasible way. If such photographs are available, it seems possible that a planimetric and elevation accuracy of about 200 ft. can be reached by using high-precision measuring devices. The use of such devices and automatic plotting procedures which would produce contour lines on the moon's surface are at present under investigation at The Ohio State University, Princeton University and some other universities.

*American Commercial Practices in Large-Scale Topographic Mapping**

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ABSTRACT: *This paper is an attempt to place in print information which although of common knowledge to a number of photogrammetrists has not been well publicized and may be novel and of interest to many others. The paper discusses generally the private commercial company aspect of photogrammetric mapping. Representative company equipment, personnel, client relation, and technical operations are covered.*

A GREAT expansion of the science of photogrammetry in the United States in the last fifteen years has encouraged a release of a large amount of information which has been made available internationally through such publications as the "PHOTOGRAMMETRIC ENGINEERING," "*Photogrammetria*," and numerous other publications on various phases of photogrammetry and its associated sciences. This information has dealt principally with the activities of governmental bodies, universities, and other quasi-official organizations. It has concerned descriptions of new techniques of mapping, new applications of instrumentation and details of actual projects which various public agencies have undertaken. All of this information has been most important and interesting and absolutely essential to the growth of the science of photogrammetry. However, one aspect of photogrammetry has been described very lightly in the literature.

A review of recent publications indicates a scarcity of information concerning the practice of commercial photogrammetry in the United States. This is most unfortunate for a tremendous amount of effort and money is now invested in the pursuance of photogrammetric engineering by private companies. It can be assumed that these companies, working competitively, would be responsible for developing new approaches, techniques, and equipment to more efficiently compete with their contemporaries. Of course it should be recognized that not much information is available for exactly that reason. A company which has developed an efficient technique for producing maps is not enthusiastic about revealing such information to its competitors unless it can be protected by legal methods such as patent or copyright.

The author has been in the interesting position of having had during the past fifteen

* This paper is condensed from the original paper prepared for presentation to the IX International Congress of Photogrammetry.