ARMY MAP SERVICE MAPPING ACTIVITIES IN THE SPACE AGE

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IHB NOTE

Col. DIERCKS has been Commanding Officer of the Army Map Service since September 1957, following recent assignments with the Office of the Chief of the Engineers in Washington and with the U. S. Army in Europe. A graduate of the U. S. Military Academy in 1937, Col. Diercks has also earned a Master of Science degree in Civil Engineering from the Massachusetts Institute of Technology, and a Master of Science degree in Photogrammetry from Syracuse University. He has spent most of his Army career in topographic-mapping and engineering-evaluation assignments. His tours of duty have included the Philippines and Japan as well as Europe and the United States.

Introduction

Methods of acquisition of information for geodesy and mapping are being revolutionized by the employment of artificial earth satellites. Already, valuable geodetic data on the shape of the earth have been obtained, and programs underway at present are expected to yield more precise values on various inter-island distances. Future plans extend not only to the geodetic area, but also to the procurement of photography for the actual compilation of maps themselves.

It is the purpose of this paper to discuss some of the programs of the Army Map Service underway and those being studied which utilize artificial earth satellites for geodesy and mapping, and then to mention the implications, extensions, and future possibilities of these programs.

Project Betty

At the request of the Hydrographer, United States Navy, the Army Map Service has been engaged since 1954 in a program of determining the geodetic relationships among various Pacific islands and the Asiatic and American continents. Since the distances involved were too great for measurement conventionally, or even by electronic means such as Hiran, an astronomic technique based on the occultations of stars by the moon was developed. This method has yielded good results; however, observations are limited severely by weather conditions and the relatively infrequent number of observations available in a reasonable period of time. The Army Map Service, therefore, decided in 1956 to transfer its chief emphasis in this program to a technique utilizing the electronic signals from Project Vanguard artificial earth satellites.

Project Vanguard was a program originally assigned to the U.S. Navy for launching a series of artificial earth satellites in conjunction with the International Geophysical Year. A network of ground stations was set up in a north-south chain along the American continents to electronically track these satellites. The tracking method employed measures the direction of the satellite by a radio-interferometer technique. The ground station equipment, called *Prime Minitrack,* measures continuously the direction angles with respect to an east-west baseline and a north-south baseline. There are three independent sets of angle-measuring equipment, graduated in successively coarser units for ambiguity resolution. A simplified system, called Mark II Minitrack, is similar to Prime Minitrack, except for the absence of the ambiguity resolution, and for the measurement of angles at specific times only, instead of continuously.

In 1956 the Army Map Service procured three sets of Mark II Minitrack equipment, two of which were placed in operation in the Pacific to supplement and gradually replace the occultation program. These sets, up to now, have observed mainly satellite 1958 β, and have obtained data on six Pacific islands. The results are presently in the process of reduction. This program of observation by Mark II Minitrack has been named Project Betty.

Figure 1 illustrates the method of operation of Mark II Minitrack. The observed time of measurement of the direction of the satellite from the station is compared with the theoretical time predicted by carrying forward the orbit from the Prime Minitrack net. The discrepancy between measured

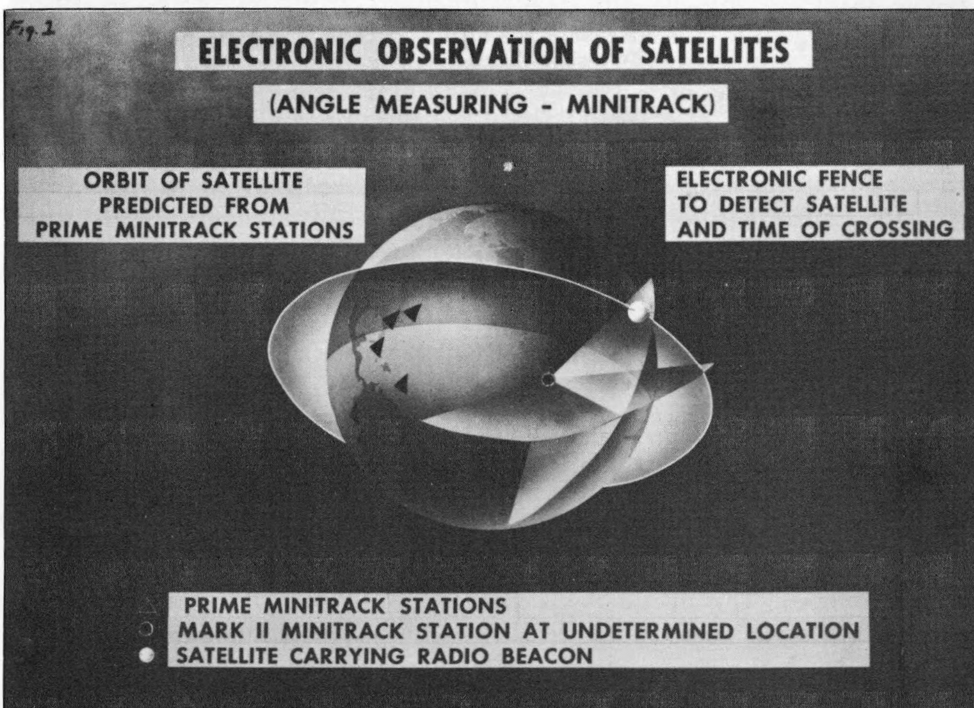

Fig. 1.

and predicted times yields the basis for the adjustment of the geodetic position of the station.

Electronic Range Measuring

In April 1960, the first of a series of artificial earth satellites for navigational purposes was launched as part of the U. S. Navy program called Project Transit. The Army Map Service plans to participate in future Project Transit shots by placing a transponder in the satellite, which, in conjunction with suitably placed ground stations, will yield distance measurements for a trilateration network.

Thus far, the only electronic distance-measuring equipment used on satellites has been of the radar type. Radar equipment has been of the permanent-installation type, requiring a great deal of power, and hence has not been considered for general use in geodesy. There are, however, several distance-measuring systems which, while untried on satellite-carried beacons, are sufficiently based on practice that they can be expected to work with satellites. The one planned for use by the Army Map Service is called Secor. This system is a variant of the same phase-measuring technique that is used in the Tellurometer and Microdist. A very-high-frequency carrier is frequency modulated by four low-frequency measuring signals

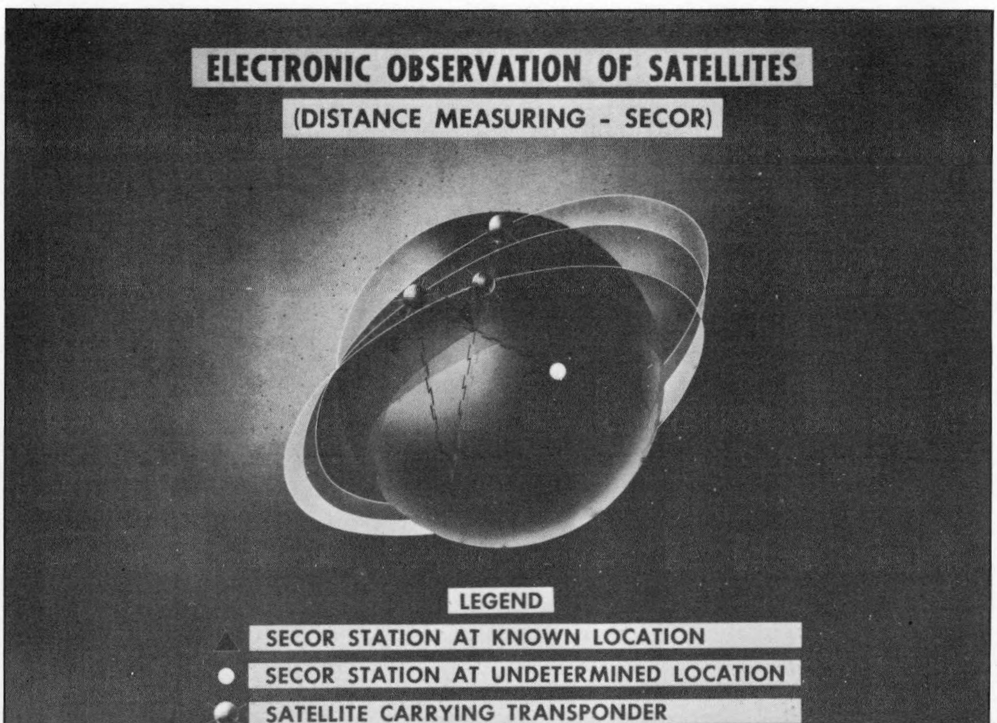

Fig. 2.

with wavelengths between 300 metres and 800 kilometres, and the phase difference between the emitted and the returned modulation measured in a phasemeter gives the distance travelled by the signal. Figure 2 indicates how Secor will be applied for geodetic connections. Three stations are set up at known locations, and a fourth at the station to be tied in. Simultaneous ranging on the satellite beacon will enable a trilateration net to be formed from which the unknown distances can be found.

The distance-ranging method has two advantages over the Minitrack angle-measuring method : first, it has a higher potential accuracy, and second, it does not depend on knowledge of the satellite orbit, since measurements from the various ground stations are made simultaneously. However, the method is limited to those satellites in which a special transponder can be placed. Hence, this method will not completely replace Project Betty. The latter will still be of use in observing those satellites which contain only a transmitting beacon.

Optical Tracking

The U. S. National Aeronautics and Space Administration has announced plans for a satellite which will carry a flashing light. Optical observations have been made on a number of satellites up to now, but since their source of illumination is reflected sunlight, they could be observed only at dawn or dusk. The proposed flashing-light satellite can be observed

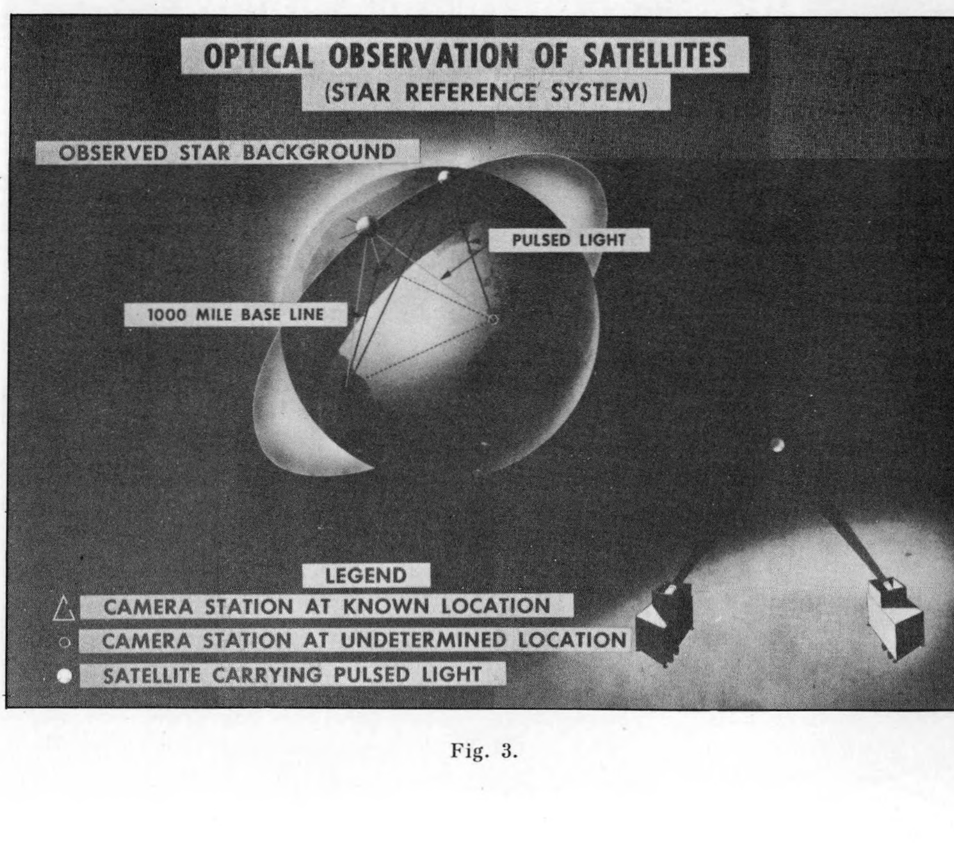

Fig. 3.

during all hours of darkness while above the horizon (and if weather conditions do not interfere).

Figure 3 illustrates the operation of an optical tracking system. The satellite beacon is observed by a camera against a star background. The position of the beacon's light against the stars determines the direction of the beacon with respect to the observing station. Three stations are used, two of which are known, and the measured directions determine a triangulation net which can be solved for the unknown distance.

The optical method is limited, in contrast to electronic methods, by its restriction to nighttime hours and to areas of good weather. However, it has the advantage over Secor of needing only three sets of stations for a fix, rather than four, and the equipment is much simpler and more easily maintained. In order to take advantage of the desirable features of each system, the Army Map Service expects to make provision in its geodetic program for all three types of acquisition methods discussed above, i.e., electronic angle measuring, electronic distance measuring, and optical angle measuring.

Geodetic Products

The above methods of data acquisition are expected to provide data which, if other means were used, could not be obtained at all, or else much more slowly or expensively. These data will provide :

1. Connections over long distances.
2. Improved figure of the earth.
3. Description of the earth's gravitational field.
4. Geodetic control in sparsely controlled areas.

Connections over long distances are needed for navigation systems utilizing transmitting stations on different land masses as well as for military purposes. The application of artificial satellites is expected to reduce, in some instances, current positional discrepancies by as much as a factor of 20.

It is well known that satellite observations have already bettered by a factor of 10 knowledge of the earth's flattening. Future data and further reduction of present data will provide better information on the size of the earth as well. Analysis of the orbit of a geodetic satellite is the least expensive and fastest method of improving these figures.

Measurement of the orbit of an artificial satellite also provides the most precise method of obtaining information on the large-scale variations of the earth's gravitational field. This has already been demonstrated by the discovery of the so-called pear shape of the earth by scientists of the National Aeronautics and Space Administration based on analysis of the satellite 1958 β orbit.

Finally, there is a double requirement for both accuracy and for density of control points which is met by a widespread framework of precise measurement filled in by less accurate methods. These control points are needed for large-scale and medium-scale mapping, and for navigation.

Satellites provide the only practical method for meeting these requirements rapidly.

Mapping Satellites

The use of satellites for mapping is a far more complex problem than for geodesy. In the case of geodetic-data acquisition discussed above, all data are actually obtained by ground stations, using the satellite as a beacon. For mapping, however, the actual acquisition of data must be accomplished by the satellite itself in an active sense. What is referred to here is the actual acquisition of photographic imagery which can be used to compile or revise topographic maps. To satisfy the stringent requirements of scale and geometric fidelity, it appears that the sensing device should be an optical, long-focal-length camera, and that the data be physically recovered. Unlike conventional mapping projects flown with aircraft where the flight height is selected based on the project map scale, satellite photography cannot be selected as a function of the optimum altitude. This is because various factors come into play which cannot be simultaneously optimized. These include : 1) satellite life span, 2) instrument-package size and weight, 3) photographic scale, and 4) photographic resolution. Because of such restrictions, maps to be produced initially from artificial satellites will probably be confined to medium and small scales.

Since it would be desirable to obtain maximum uniform coverage in the shortest time, a polar circular orbit would be the optimum configuration. It would also be desirable to obtain auxiliary data to assist in the accurate determination of the orbit and the position of each exposure station. Simultaneous stellar photography and time records should provide means for establishing camera orientation and distances between exposure stations.

Date Reduction from Mapping Satellites

If an adequate distribution of control is available, one now has the tools to accurately recreate the path and motion of a satellite as it has travelled through space. The production of maps from satellite data, however, will pose radically different problems for the cartographer. First, the data will be much smaller in scale than conventional aerial photography; second, continuity will be interrupted by clouds, darkness, etc.; third, control points will be much more difficult to establish; fourth, there will be a great amount of extraneous material which will have to be carefully eliminated. These factors have led the Army Map Service to study the feasibility of introducing new data-reduction processes. Some of those that are being evaluated include electronic image correlation for automatic scanning and adjustment of overlapping photography, an integrated mapping system which compiles in a single step a contoured orthophotomap from a properly adjusted stereo pair of photographs, and digital methods employing high-speed electronic computers for more rapid data reduction.

Some Benefits of a Mapping Satellite

One of the most important benefits of a mapping satellite will be the more rapid acquisition of mapping information. For an instrument package and altitude compatible with present satellite boosters, photography could be obtained for the production of medium-scale maps over vast areas in a matter of days. This is a speed impossible to achieve by other means.

Conventional methods normally prepare medium- and small-scale maps from large-scale photography. Satellite data provide means to compile medium- and small-scale maps directly, thus yielding a large time and cost saving.

To accomplish map revision by conventional means, the data-acquisition operation is essentially the same as is required for preparation of the initial map. However, the information for map revision would be an immediate bonus from the world-wide coverage of a satellite-mapping system, thus yielding a significant cost saving.

Benefits such as these indicate that the artificial earth satellite will eventually revolutionize the art of producing medium- and small-scale maps, both in the data-acquisition and compilation phases, just as it is currently revolutionizing geodesy.

Final Remarks

This article has briefly described the impact of artificial earth satellites on present and future geodetic and mapping programs of the Army Map Service. It is evident that the potential of a tool like the artificial satellite has barely been tapped, and that many more uses, both in refinements of methods described above, and in totally new applications, can be visualized. An example of the latter is in the mapping of extraterrestrial bodies, such as the moon and the planets. The Army Map Service is presently engaged in preparing a 1/5 000 000-scale map of the moon based on terrestrial photography. To obtain better maps, larger scale photography will be needed. Artificial satellites provide a method of obtaining this, as well as vertical- and horizontal-control data of the moon. Studies in this area are currently in progress.