form of the F-13 appeared on the scene. Crews received more training and the results improved proportionately. There still was a long way to go however. With the arrival of Shoran, many felt that tremendous progress had been made in the right direction.

It is evident that we are moving toward the goal outlined by Col. Sewell when he said "Precision automatic flying would be highly desirable, since automatic equipment is generally more sensitive and reliable than human reaction."

The straight line computer with the airborne Shoran sets keep the planes on a straight line in this difficult navigational area.

Shoran provides the most economical, accurate and rapid means of providing aerial photographs for mapping purposes today. To conduct a successful operation requires tons of equipment of all kinds, cargo aircraft, helicopters, photo-mapping planes and outstanding electronic specialists. This is why we do not see many of these units in existence today. But in the long run it is cheaper in cost since the number of re-flights are reduced, and the insurance on the chances of carrying out the missions correctly the first time are increased 100 per cent.

The specifications for our mapping require staying within a 53 to 65 per cent forward overlap, the desired being 60 per cent and an average of not greater than 56 per cent; a sidelap of between 15 and 30 per cent; a tilt of not greater than 3 degrees in any case and an average of not exceeding one degree; and a crab of not over 5 degrees. With such specifications and considering the limited mapping experience of the crews, it is a wonder that any of the photography was considered acceptable.

Automatic equipment is one answer; another is intensive training of the crews. The photo school at Lowry Field is considering expanding its present course to satisfy this requirement.

With regard to those involved in a mapping program I mentioned that they must understand the need for the maps. They must also have an individual interest in the program.

A specialized mapping Squadron is once more being formed. The recent concept that a Reconnaissance Unit could do this work as part of its training is changing. A survey of personnel recently taken in one of our major commands indicated a considerable interest in joining the unit. The objective is to select the personnel with the most experience for this unit. We are headed in the right direction in this respect, for personnel with little or no interest in this work will result in considerable unnecessary cost in both time and money.

There are also new types of automatic equipment to be provided these units eventually. This will permit staying within our specifications easily and require only the surveillance of the crews for it to function properly. We should soon see the time when aircraft, operating automatically and unmanned, will be dispatched on a mapping mission and return to a predesignated base.

Perhaps we shall see the day when nuclear powered aircraft capable of staying aloft for days and limited only by the endurance of its crew, will search out areas of good weather and thereby achieve the now very ambitious goal "complete accurate mapping of the earth's surface."

Control for Arctic Mapping

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SYNOPSIS

Possible methods are classified under two headings—astronomic and electronic.

Astronomic Methods:

(a) Precise astronomical telescope
(b) Astrolabe
(c) Zenith camera
Inherent errors of the methods

Electronic Methods:

(a) Shoran
(b) Decca
(c) Raydist
Use of methods and inherent errors

Vertical Control

Barometric and trigonometric levelling supplemented by radar altimetry

Organization and Transportation:

Main and satellite depots
Transportation: helicopter, dog team, aeroplanes, and freight canoes
Portable radio transceivers a prime necessity for integration of work.

For the establishment of mapping control in the Arctic, a number of possible methods suggest themselves. In general, they may be considered under three classifications—astronomic, electronic and direct measurement.

PRECISE ASTRONOMICAL METHOD

The precise astronomical method, using a broken-axis type astronomical telescope oriented in the meridian plane, will give relatively high accuracy in sub-polar areas. The instrumental equipment weighing about 600 pounds may be set up ready for work in less than two hours time. A position determination accurate to 30 or 40 feet, astronomically, may be secured by a three hours' observation. One hour will usually suffice to determine the position with an accuracy of 75 to 100 feet. In high latitudes where the atmosphere is free from smoke and dust, star observational work may be carried on during mid-morning or mid-afternoon periods of bright sunlight. With instruments having objective lenses of 50 or 60 mm., first, second and third magnitude stars may be used for daylight observation.

THE ASTROLABE METHOD

The astrolabe method applied to precision theodolites has been used extensively in the Canadian northland. Four or five stars are observed in each quadrant at a fixed altitude (usually 45 degrees or 60 degrees). The instrumental equipment, which weighs about 200 pounds, may be set up ready for work in less than one hour. To determine a position accurate to 150 or 200 feet, astronomically, four or five hours observing is required. To ensure an accuracy of 100 feet, observations should be made over two nights.

Since 1929, the Geodetic Survey of Canada and to a lesser extent the Topographical Survey, have established some 1,500 astronomic control stations in northern Canada. About 380 of these points are located in the Arctic or sub-Arctic areas north of the tree line.

ZENITH CAMERA METHOD

During the 8-months period of each year when stars are visible to the naked eye, the zenith-camera photographic method might be useful. By this method, several photographs are taken of the stars close to the zenith at the point of observation. The Greenwich time of each exposure is also recorded by photographing the face of the chronometer at the instant of plate exposure. After processing, the rectangular coordinates of the stars' images are scaled off the photographic plates.

From these data, the geographical position of the camera station may be deduced. It is claimed by the proponents of the zenith-camera method that an accuracy comparable to that of the astrolabe may be secured in a short period of time. During the long summer period in the Arctic when stars are not visible to the naked eye, the zenith-camera could not be used. In addition, the processing of the plates in the field would involve considerable difficulty attended by possible breakage. Up to the present time, the portable field Zenith camera has not been used in Canada.

As is generally known, all astronomical methods of position determination are subject to inherent errors due to unknown deviations of the vertical, which, in Canada, are found to have an average value of 300 feet. For this reason, astronomical fixations are suitable only for small-scale mapping where the anomalies due to the deviations of the vertical are obscured by the smallness of the map scale.

CONTROL BY TRIANGULATION AND ROUTE TRAVERSES

Considerable control comprising tertiary triangulation and route traverses has been established in northwestern areas by the Topographical Survey and the Army Survey Establishment of the Department of National Defence. Some of the route traverses have involved winter tractor operations in the barren-land area west of Hudson Bay.

Among other projects in this category are the following:

(a) Winter traverse from Fort Nelson to Fort Simpson.

(b) Tertiary triangulation from the 141st meridian eastward to the Mackenzie River basin.

(c) Winter traverse along the 60th

parallel of latitude westward from the Mackenzie Highway to the northwest corner of the Province of Alberta and thence southerly to Hay Lake.

SHORAN ELECTRONIC METHOD

Shoran trilateration provides control of excellent ultimate value—comparable almost to second-order triangulation, and free from the effects of deviation of the vertical. With the co-operation of the Royal Canadian Air Force, the National Research Council, and the Meteorological Service of the Department of Transport, the Central Canada Shoran net has been extended since 1948 from the vicinity of the 49th parallel of latitude northerly and northwesterly as far as the Arctic coast. A few hundred miles to the south of the northern extremity, this net has been extended in 1952 eastward towards Hudson Strait. At the close of the 1952 season, line measurement operations have been finished as far as the westerly limits of Baffin Island. Altogether 230 lines have been measured in the network in which the average and maximum lengths of line are 210 and 362 miles respectively. The reconnaissance and station preparation work has been completed for several hundred miles both northward and southward from Hudson Strait. During the 1953 season it is hoped that the southerly arm will be extended to a junction with the Gulf of St. Lawrence primary triangulation net.

However, in an area such as the Arctic where transportation involves major difficulties, the inherent disadvantages of Shoran should be carefully considered. These unfavorable features include the necessity of repeated visits to each station site, the transportation of heavy and bulky equipment, the employment of numerous personnel, and the comparatively long time necessary to complete a station. Yesterday, Major Thompson presented a paper dealing with the application of Shoran-controlled photography to Canadian mapping.

DECCA-ELECTRONIC METHOD

Decca is a radio system of position-fixing in which three transmitting stations, at known points on the earth's surface, lay down two intersecting patterns of hyperbolic-shaped position lines. These patterns are printed on topographical maps or charts, or on a basic grid for use in unmapped areas. The position-fixing instrument is a portable radio receiver tuned to the transmitters and driving a pair of "Decometer" indicators which display continuously the numerical values of the two position lines on which the receiver is located. The desired geographical position is given by the point of intersection of the pair of correspondingly-numbered position lines on the chart. The process of position fixing is therefore simply the matter of reading two dials and plotting the intersection of the two position lines.

The degree of accuracy obtainable from Decca fixations at the present stage of development is not too well known. Comparative tests over ranges covered by geodetic triangulation should prove of great interest.

FIXATION METHODS RECOMMENDED

In the northern part of the Arctic archipelago, there remain vast areas with little or no control.

In regions where only small-scale mapping is required, precise or second-order astronomy is recommended as the most practical method of establishing horizontal control. For areas such as harbor approaches, anchorages and airports where large-scale mapping is planned, Decca should be investigated. Should it appear to be unsatisfactory, the alternative would be the adoption of route traverses or tertiary triangulation.

VERTICAL CONTROL

Vertical control has been carried by trigonometric levelling through a secondary triangulation net extending from the Gulf of St. Lawrence to Ungava Bay. In the winter of 1950–51 precise levels were extended along the winter tractor road from Fort Nelson, B. C., to the 60th parallel of latitude

In the more remote Arctic areas, vertical control could be best established by barometric and trigonometric levelling and radar altimetry. At the completion of the horizontal control work, aeroplanes equipped with radar altimeters would be flown between control stations or along route traverses, so that profiles of the lines might be accurately determined. As Mr. Waugh discusses the use of the radar altimeter in his paper, the subject will not be elaborated here.

ORGANIZATION AND TRANSPORTATION

The general plan for the establishment of control would involve the placing and retention of survey units at main or satellite depots throughout the entire year. In this way, the work could be carried on during the favorable periods of both the winter and summer seasons. In the extreme north, the weather station at Resolute on Cornwallis Island could be used as the main depot. Farther south, Cambridge Bay, Frobisher or Coral Harbor could be used for the same purpose.

In the areas where astronomical methods are to be used, it is proposed that each depot should be manned by two or three survey units, each consisting of an observer, a recorder and two labor assistants, all under the supervision of the depot chief.

The survey units would proceed out radially from each depot to establish the necessary control stations. During the months of March, April, May, October, November and December, helicopter or dog team transportation supplemented by aeroplane drops of food and fuel should prove highly satisfactory. A 10-dog sled team will haul a load of 1,600 to 1,800 pounds under normal winter conditions. During the winter months, aerial co-operation would be more or less limited to the bright periods of the moon. Due to the excessive cold no work would be planned for January or February.

During July, August and September considerable progress could be made using helicopter, aeroplane, or canoe-plane-drop transportation.

In coastal areas, the use of 22 foot freight canoes equipped with outboard motors is recommended. These craft will carry $\frac{3}{4}$ ton with ample free board; they weather surprisingly high seas and have the added advantage of lightness and mobility. In case of theatening danger from ice or storm, both the cargoes and canoes may be removed from the water to the relative safety of an ice pan or on the shore. Geodetic survey parties have travelled hundreds of miles along the Hudson Bay coasts with this type of craft which has proved to be preferable to a schooner or whale boat.

RADIO COMMUNICATION

Good radio communication between the depot and its field survey units is a prime necessity. The modern type of small radio transceivers (G.S.11 or P.F.1) used for some years by the Geodetic Survey of Canada, are quite satisfactory. They are powered by dry batteries and operate on either continuous wave or phone with plate voltages varying from 90 to 200 volts.

In general, the problems of transportation are much more complex than those connected with the technical end of the project. However, if the new high-ceiling, freight-carrying type of helicopters were made available for the work, no serious difficulty would be expected to attend the establishment of mapping control.

Horizontal and Vertical Control for Arctic Mapping

Comdr. Hubert A. Paton, Chief, Baltimore Photogrammetric Office, U. S. Coast & Geodetic Survey

SYNOPSIS

A detailed survey of the Arctic Coast of Alaska by the U. S. Coast and Geodetic Survey has been in progress since 1945. New methods of transportation of supplies and personnel were employed. An arc of second order triangulation was extended along the shore for a distance of 680 miles and astronomic stations were established and base lines were measured. Elevations referred to sea level datum were placed on triangulation stations. Extreme weather conditions required the development of new techniques in surveying methods. New types of clothing were tested and new living procedures devised.

For eighty years the U. S. Coast and Geodetic Survey has been sending field parties to Alaska, but only in recent years has it been feasible to send them into the Arctic regions. The Bureau did cooperate in the early part of this century with the Alaskan Boundary Commission in establishing an arc of triangulation along the 141st meridian; this was completed in 1912. In 1945 a party was ordered to proceed to Point Barrow to begin a detailed survey of the Arctic coast in order that hydrographic charts could be published. These charts require accurate topographic and hydrographic surveys, and to control them it was necessary to extend an arc of