SHORAN CONTROLLED PHOTOGRAPHY IN CANADA*

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ABSTRACT

Canadian mapping agencies feel that the introduction of Shoran-controlled photography is an advance in mapping comparable to the introduction of the aerial photograph. The very nature of Canada's northland made it imperative to find some method of reducing the expense and time required to install ground control for aerial photography. For this reason all Shoran mapping operations, both experimental and operational, have been watched with great interest.

By 1951 the Canadian Geodetic Shoran net had reached the valley of the Mackenzie River and it was decided that the technique of Shoran mapping was sufficiently developed to attempt a fairly large Shoran photographic operation. The area selected for the project, 100,000 square miles in the vicinity of Yellowknife, had previously been covered with vertical photography. It was planned to superimpose a grid of Shoran controlled photo flights for horizontal control and to run barometer lines by helicopter for vertical control. Almost all of the camps and ground stations were located on remote lakes and therefore all equipment and supplies had to be air portable.

All in all the project was satisfactory. As with most new techniques the operation could not be called an unqualified success but many lessons were learned and an area roughly the size of Wisconsin was controlled. It has been calculated that if the traditional methods of survey had been used it would have taken ten years to complete the job and the cost would have increased threefold.

MANY major changes in mapping techniques have been seen in the past fifty years. The turn of the century saw terrestrial photographs brought into use. In 1923 the first oblique photographs were flown for mapping in Canada and the thirties brought in verticals. These changes along with the development of photogrammetric instruments to complement them have revolutionized the approach to mapping problems. In the past few years a new aid has been made available; this promises to provide another approach to the problem of obtaining basic field control. The development of electronic methods of distance measurement to a high standard of accuracy now offers a new means of establishing both horizontal and vertical control.

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Thirty years ago it is doubtful whether any person could have foreseen the manner in which aerial photographs would be used and could have predicted the strengths and the weaknesses of maps compiled from them. It was only after years of use by men of many nations that full advantage could be taken of their properties. Today the position is similar with respect to electronic methods in spite of an amazing record of development and achievement.

The first Canadian association with radar controlled photography came in 1945 when the Multiplex section of the Canadian Air Survey Co. carried out

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tests in England under the direction of the British War Office. These tests were twofold in purpose, the first to assess the accuracy of the work and the second to work out a procedure for practical use of the control provided. The interest arising from this work and from early tests in the United States led to the inception of a Canadian project which brought together the resources of the Royal Canadian Air Force, the National Research Council, the Geodetic Survey and the Army Survey Establishment.

The purpose of this project was to extend the investigations of the Shoran system previously carried out in the United States and to develop procedures for its practical application to geodetic and mapping problems in Canada. Responsibility for the maintenance and operation of the Shoran equipment in addition to the aircraft requirements was assumed by the Royal Canadian Air Force, the development of new electronic equipment by the National Research Council, the mathematical analysis of distance measurements and their application by the Geodetic Survey and analysis of Shoran controlled photography by the Army Survey Establishment. It was anticipated that this division of activity would lend itself most easily to the transition from development to operational work.

The results attained in 1948 in geodetic tests were very promising and plans were laid for a trilateration net extending from first-order triangulation stations to the south of Winnipeg, Manitoba to other first-order stations in central Alberta and Saskatchewan. The axis of this loop would be almost 1,100 miles in length, requiring the measurement of 74 lines varying in length from 80 to 310 miles. In the fall of 1948 near Ottawa a test area of approximately 350 square miles was covered by Shoran controlled photography, the first to be flown in Canada. The analysis of this work indicated that Shoran control was acceptable for standard mapping at a scale of 1:250,000 and for reconnaissance mapping at 1:50,000.

The first requirement in the north was primary control. In 1949 and 1950, the main effort, therefore, was concentrated on the trial trilateration net. Operating and navigational procedures were tested and improved and invaluable field experience was obtained. Finally in the spring of 1951 when the final computations had been made, the error in closure between the two sets of first-order terminals was found to be 1:59,000. Shoran trilateration could now be said to have passed from the development to the operational stage.

In 1951 the Shoran net was extended northerly down the Mackenzie River to the Arctic coast, and in this past season easterly to Hudson Bay and across to the western end of Hudson strait. For the first time in its history Canada's North West Territories, an area of over 1,300,000 square miles, had a widespread net of positions established with high relative accuracy. These positions however were too widely spaced for effective mapping control so there remained the problem of "breaking down" this network to meet topographical requirements.

Accordingly in the fall of 1951 work was again resumed on Shoran controlled photography. In the first operational task in Canada, the Royal Canadian Air Force flew approximately 1,100 lineal miles to form a control grid over existing vertical photography covering an area of 15,000 square miles. The conditions under which it was flown were far from ideal, but subsequent analysis has shown that this control is adequate for 1:250,000 mapping.

The need for geodetic control to precede topographical mapping is self evident and has accounted for the emphasis placed on the geodetic operations. A further complication is that the more northerly lakes are free of ice for only a few weeks in the year; this consequently limits the period of operation. These factors combined with increased demands on Royal Canadian Air Force resources made it evident that Shoran controlled photography over large areas could not be attempted by the RCAF until the geodetic operations had been completed. With this in mind it was decided to have the work in an area of over 100,000 square miles in the Mackenzie Valley done by a private company; in April 1952 a contract was awarded to carry out this task.

This area had previously been covered with vertical photography, and it was intended that the Shoran would be used for horizontal control. Vertical control was to be provided as a separate operation by helicopter barometric levelling. The specifications for Shoran photography called for flights at a minimum altitude of 20,000 feet with the spacing along the parallels of latitude at 20 minute intervals and along the meridians at one degree intervals; this provided lines of positions spaced roughly 25 by 30 miles. The limits set on the angles subtended at the aircraft by the two ground stations were 60 and 120 degrees. All work was to be based on the stations and values established by the Geodetic Survey in their preliminary adjustment the previous year. It was the contractor's responsibility to set up any additional stations needed to maintain the requirements for angles of cut; these auxiliary stations were to be established to the same accuracy as the geodetic stations. Shoran and auxiliary equipment, aircraft, and living accommodation were to be supplied by the contractor.

Operations were based at Yellowknife, a modern mining town in the North West Territories, approximately 1,000 miles north of the 49th parallel. In spite of its isolated position the town provided good accommodation (including such luxuries as indoor plumbing) and good airport facilities. Canadian Pacific Airlines provide a daily link with Edmonton and the Royal Canadian Corps of Signals maintained 24 hours communication service. From here float planes in two hours or less could reach all the ground station sites used.

A Vega Ventura was the aircraft selected to carry the camera and the airborne Shoran. A second Ventura was used as a stand-by to reduce the risk of losing photographic weather due to temporary unserviceabilities. Four ground station sites were available and were in continuous use throughout the operation. Supplies and relief operators were flown into the ground station sites by float aircraft such as the DeHavilland Beaver.

All but two of the ground station sites occupied were on remote lakes which could be reached only by float planes. When occupying stations of the Shoran trilateration net, the aircraft would take the two operators with their load of Shoran and camping equipment and food to the lake near the site of the station, and place the load on the beach nearest to the trail which had been cut out when the site had been prepared originally. The equipment was then packed to the clearing and set up over the geodetic marker. Usually two trips were required to set up the camp completely. Operators were changed every two weeks but occasionally weekly visits were required to bring in food and gasoline.

The aircraft and equipment reached Yellowknife about June 10, but due to the apparently inevitable difficulties encountered in the initial stages of a new job and to unfavorable weather, the first productive photographic flight did not take place until July 9. Work continued as the weather permitted with the final operational flight flown on September 10. Photographic flights were attempted on 18 days in the 12 week period during which operations were conducted. In these 18 days, it was possible to fly the entire period of photographic light on 7 days only. During the remainder of the time, clouds and weather cut the effective time to as small an amount as 3 hours.

In all, 4,440 lineal miles of Shoran controlled photography were flown. The area controlled for 1:250,000 mapping amounted to approximately 55,000 square miles, about the same area as the state of Wisconsin. It is estimated that it would take a traverse party about ten years, working in both summer and winter seasons, to cover the same area with equivalent control.

The ability to measure distances by the line-crossing method in any type of stable weather is of extreme importance. Repeated measurements between known positions, such as those in the Shoran net, are required to give a more precise determination of the value of the delay of ground station sites. The refinement that this procedure gives brings the values of individual photo fixes in closer sympathy with the control on which they are based and adds to the precision with which auxiliary stations may be fixed. The experience this past year showed that visual methods of navigation are not adequate for precise line-crossing work. Instrument or blind navigation methods would make possible utilizing about 80 per cent of the time available and mean that this information could be supplied shortly after operations are commenced, a factor of great importance in computation. It also would mean that no photographic weather need be utilized for line-crossing work.

The reduction of an observed Shoran distance to the geodetic counterpart is made from corrections based on three factors—the velocity correction or the estimated effect of the atmospheric conditions on the time of travel of the Shoran impulse—the flying height of the aircraft computed from soundings and meteorological data (radar altimeter and basic elevations are not available)—and the "delay" or the length of time it takes the Shoran impulse to pass through the ground station. Each of these is important but probably the one which can cause the greatest trouble is the "delay." Canadian experience has been that ground calibration over three miles of range gives an excellent relative value and accounts for about 95 per cent of the delay; the remainder being determined in the adjustment of the Shoran net between fixed geodetic bases. A short range definitely weakens the value of the ground calibration and it is the feeling that under no circumstances should it be less than two miles.

A very important feature while the Shoran aircraft is in flight is communication between the aircraft and the ground stations. Often it is necessary to switch from one combination of stations to another without interrupting the flight. With good communication this can be carried out with a minimum of effort; without it the line is generally broken and considerable time is lost. Occasionally a cloud condition may exist over the ground stations themselves while parts of the area controlled by these stations are clear. In such cases good communications ensure that the ground station operators are always on the job. These points may appear trivial but when photo weather is at a premium and represents revenue to the contractor of as much as $4,000 per hour, they assume different proportions.

The problem of establishing auxiliary stations is two-fold in nature. Their actual location is generally restricted to a comparatively small area if it is to fulfill its purpose—to ensure adequate coverage of areas beyond the range of primary stations. Fortunately in this part of Canada there is an abundance of lakes and no major relief features, making it possible to use such points as islands or small isolated hills. Usually the auxiliary stations need a clear line of sight over a limited angular field which reduces the difficulty of selecting their sites. The second part of the problem is the actual determination of the position. The Shoran distances used to establish this may have errors of 20 or 30 feet in their length, a possibility which requires a strong figure to ensure precise value. The four ground stations available for the project were not sufficient to allow the positions of auxiliary stations to be strongly determined without moving a set from one of the main stations. This involved the possibility of loss of coverage in case photographic weather extended over several days, a risk which was too great to take. A minimum of equipment for six stations would increase the flexibility of the operation considerably.

In normal photographic operations, temporary unserviceabilities of the aircraft and camera are not uncommon. With Shoran three additional pieces of equipment which are even more subject to similar weaknesses are introduced, the airborne set and the two ground stations. Each of the crew must have the ability and training to carry out his task thoroughly, as well as an understanding of the duties of the other members and a desire to cooperate fully. If there was ever a task in which it could be said that there is no substitute for ability and experience, Shoran controlled photography is it.

The prediction of photographic weather in the North West Territories is extremely difficult. Few weather stations are in operation and generally unstable weather conditions prevail. The method followed was to have radio reports made on conditions by the ground station operators, at various times throughout the day starting at 5:00 A.M. This had two weaknesses—the first being that communication is often poor, and the second that the photo areas may be over 100 miles from the ground stations themselves. On more than one occasion photographic weather prevailed in one section while partial clouds covered one of the ground stations controlling the area. Two methods have been suggested to help remedy this deficiency. One is to have a "weather" plane make a check when there is any possibility of photo weather, and a second is to increase the density of weather reporting stations in the photographic area.

It is believed that the light tables presently in use could be revised to take into account the clarity of the atmosphere in northern latitudes. The period of photographic light is somewhat longer than indicated by comparison with other land areas in similar latitudes.

When the tenders were called for only one company had the necessary equipment so there was no alternative but to accept its terms. These called for a large initial payment for placing the equipment on the site of operations in a serviceable condition, the remainder to be paid for on the basis of the mileage flown, the rate decreasing as the mileage increased. It is obvious that the success of the project depended on the contractor's ability to bring the equipment into effective operation quickly, to adjust his methods to suit the conditions encountered and to keep pushing the job throughout the entire season. The area actually controlled was about 55,000 sq. miles and the cost per square mile was $6.25. It is believed that this cost is much too high and would be difficult to justify in any area where an alternative method was feasible. However no doubt exists that the cost figure would have been much more attractive had more adequate equipment and a more experienced crew been available at the outset to utilize fully the limited photographic weather encountered in the summer of 1952. There is confidence that in this area a fair season's work should be at least 10,000 line miles; this would bring the cost per square mile down to about $2.50 per square mile.

In conclusion, a few of the lessons learned and the measures which it is hoped will be put into effect for the 1953 operation are:

(a) The contractor's field supervisor must be thoroughly conversant with the survey requirements.

(b) The operation should be organized to make full use of all photo weather during the short operating season. To this end all testing, adjusting and calibration should be carried out before the season opens.
(c) The season might be lengthened by making use of all available landing fields before the ice goes out. Some of the best photo weather usually occurs just before the break up.
(d) A study should be made of light values with the idea of making better use of early morning and evening photo weather. Owing to lack of trees and the relative flatness of the country, heavy shadows from the low sun are not very prevalent.
(e) Flight procedure should be put in drill form to insure that all data required for accurate reduction of Shoran readings is recorded, and that the synchronization of the three cameras is absolute both as regards exposure and the numbering of negatives.
(f) Crews should be thoroughly trained in line crossing technique as used on major Canadian trilateration.
(g) The number of ground stations operated should be increased to six with preferably one additional standby station.
(h) The aircraft should be equipped for straight instrument navigation. This is essential if line crossing flights are to be up to the required standard and also not interfere with photo operations. Line crossings should be made and computed as soon as the station is installed.
(i) Daily weather charts cannot be considered as an accurate guide to local photographic weather in NWT because weather stations are too few and too widely spaced, and because of the time lag between recording of data and receipt of map at the operation station. Ground crews must therefore be well trained in weather interpretation.

The techniques and equipment of Shoran controlled photography are still very much in the development stage but it is believed that the results of the Yellowknife operation last year justify a continuation of this work and that both better accuracy and reduced costs in the future can be confidently expected.

PHOTOGRAMMETRIC RESEARCH IN CANADA*

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BEFORE enlarging on the theme of today's talk a few words of explanation regarding the title should be presented. Although Canada has at present only one official photogrammetric research center, this does not mean that all research and development in the field of photogrammetry is carried out at that center. In this vast country, several organizations are engaged not only in the production of maps but also in the development of new methods. These organizations are located in various cities and although excellent liaison is maintained between the majority of them, it would be difficult to summarize the development work which they have done. This is particularly true since, due to lack of time or perhaps to modesty, many really original ideas and methods have not yet been reported in the literature. A comment on this brought the characteris-

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