(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-

* Paper read at Nineteenth Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., January 14 to 16, 1953.

tic reply: "It is always better to be asked why we *didn't* publish a paper than to be asked why we *did!*" Such a motto is one which many publishers—not only in the field of photogrammetry—might do well to adopt. Remembering this answer a certain feeling of restraint influenced the preparation of this paper.

As a result of the increasing interest in photogrammetry and the application of photogrammetric methods, Canada recently decided to establish a special center to further research in photogrammetry. Although surveying, and therefore photogrammetry, is an applied science which can be regarded as a facet of engineering, the research center was set up in the Physics Division of the National Research Council. There were several reasons for this choice.

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First and foremost, photogrammetry is very closely allied with the fields of optics and of photography and the Physics Division of the National Research Council seemed to offer the greatest opportunities for a study of these fundamental physical problems encountered in photogrammetry. This is particularly true in view of the fact that for some time the Division has been doing considerable research, under the direction of Dr. Howlett, on the various physical aspects of aerial photography. Also a number of well-known papers have been published.

Moreover, the increasing application to photogrammetry of new physical methods, such as the use of radar profiles, also indicates that the National Research Council is the organization best suited to the future development of photogrammetric methods. If the need should arise, it would be a simple matter to consult other specialists working in the same organization. A well-equipped precision workshop, an optics shop and optical designers are also available which makes the work of the photogrammetrist considerably easier. Even in the light of short experience, these conditions have been found to be a decided advantage.

Then, too, from the very beginning, it was intended that photogrammetric research would not be limited to its application to topography but would be of a more general nature. This too suggested the choice of the National Research Council as the organization to which the prosecution of photogrammetric research should be entrusted.

On the other hand, conditions in Canada in general and in the field of surveying in particular leave no doubt that the close contact between the country's mapping organizations and the National Research Council will ensure the new laboratory being closely concerned with the practical problems confronting Canadian photogrammetry; there is no danger of the research becoming purely academic in character. The full co-operation of the Royal Canadian Air Force, and the relatively modest means at the Council's disposal, have made possible establishing a research laboratory capable of investigating any photogrammetric problem.

The first step after the Photogrammetric Section, as it is called, was set up, was to procure equipment and to establish a test area adapted to Canadian conditions. Great care was taken in equipping the Section properly and as a start only the most indispensable pieces of apparatus were acquired. These were chosen so as to offer the greatest possible advantage in all the experimental work. It includes a field and aerial camera. In addition to the standard Fairchild and Williamson cameras, there is available, through the courtesy of the Royal Canadian Air Force, a Swiss automatic plate camera R.C.7. Last Fall, there was also obtained a fully automatic Wild R.C.5 camera, equipped with the normal Aviotar lens and the new Aviogon wide-angle lens. This makes it possible to take advantage of the most recent achievements in the field of lens design.

So far, the main plotting equipment consists of these typical instruments:

Bausch and Lomb Multiplex equipment
a Zeiss Stereoplanigraph C8 and
a Wild A7 Autograph

The next most pressing problem was the establishment of a test area suited to Canadian requirements. This problem cannot be avoided for without a suitable test area it is very difficult to carry out photogrammetric research. Since there is a great advantage, from the practical point of view, in having the test area near the research laboratory, the field chosen was the area between Ottawa and Montreal. The field work which was begun last year encompasses a sector 100 miles long and about 20 miles wide. The section of this test area around Ottawa has a particularly dense network of control points and will be useful in the experiments on individual stereograms; on the other hand, the strip as a whole is intended chiefly as the basis for an investigation of the methods of aerotriangulation. Distinctive ground points are used as control so that it is unnecessary to mark the control points—at least at the present time. This field work is being carried on with the co-operation of the Army Survey Establishment, the Topographical Survey and the Geodetic Survey.

In addition to this general outline, learning something of the actual research program will undoubtedly be of interest.

As mentioned earlier, the concern is not restricted to the use of photogrammetry in topographical work; it is possible to deal both with the topographical and non-topographical applications of photogrammetry, and in this connection concrete proposals have already been made. Purely for organizational reasons, however, this program is not being pushed at the present time because the most important problems are those relating to cartography—a field in which the problems are many.

In this connection the Multiplex technique raises a great number of problems. The Multiplex is the most widely used plotting instrument in Canada; an exact knowledge of its possibilities and shortcomings is of great importance both for practical purposes and from a purely scientific point of view. In this work, which combines the problems of optics with those of Multiplex technique, the most interesting question is that of the use of the Multiplex in aerotriangulation, particularly when applied in conjunction with the radar profile. This question is now being investigated.

Another no less important problem is the relationship of flying altitude and plotting scale, taking the camera factor into account. It is known that there is a definite correlation between these quantities. The maximum flying altitude which can be considered for a certain scale is conditioned upon the accuracy of the plotting, which decreases with the increase in altitude, and by the limited resolving power of the photographs and the plotting apparatus. The first experiments with the new lenses, particularly those with the Aviogon, led to a suspicion that one must count on noticeable changes in this regard. In addition to laboratory experiments, there has been initiated and partially completed a special photographic program which should make possible a thorough study of this problem.

While the first two points of the program are of considerable practical and general importance, they are not nearly as complex as the problem of aerotriangulation. Spatial aerotriangulation is, without a doubt, the most fundamental and most complicated problem which confronts photogrammetrists. It embraces both the purely theoretical problems inherent in the theory of errors and adjustment, problems of method and instrumentation and last, but certainly not least in Canada, operational problems. It is certainly not surprising that the leading mapping organizations in Canada are particularly active in this field and that several interesting concepts and methods have been proposed.

An extensive program for the study of spatial aerotriangulation has been planned. In addition to developing certain new ideas, last Fall several strips of photographs were taken over the test area; their use in making some comparative studies is hoped for. In taking these photographs, both film and plates were used. In view of the country's needs, the primary interest is in aerotriangulation for maps at a scale of 1 inch to a mile. The flying altitude therefore varies from 21,000 to 35,000 feet, and the focal distances of the cameras used are 115 mm., 153 mm., and 170. The test strips are 100 miles long.

A very important part of the program is the further development of the radar profile method. This work was initiated by Mr. B. W. Waugh, Surveyor-General of the Legal Surveys and Aeronautical Charts Division of the Department of Mines and Technical Surveys and is being carried out in co-operation with that Division. At the last International Congress of Photogrammetry in Washington, I described the main features of this method as well as the results achieved thus far in a series of experiments which have been made in Canada. Since then new radar profiles have been flown over the test area and these are now being analyzed. The main purpose of this special program is to reduce to a minimum the errors in the radar profile by using this method in conjunction with aerotriangulation. It is believed that the radar profile method can be very useful in photogrammetry; already it offers a quick and convenient—and in some cases the only—solution to many mapping problems.

In addition to spatial aerotriangulation, some time is being devoted to a study of other methods of bridging and preparations for undertaking some experiments with the slotted templet method are underway.

In carrying out the program, the importance of field methods of determining control points is not overlooked. To increase the overall economy of photogrammetric mapping, the way in which these points are determined must be adapted to the photogrammetric method. Last Fall an interesting experiment was made with a view to speeding up levelling on flat terrain. By means of a simple suspension device we attached the levelling instrument to a jeep, and in this way were easily able to proceed with the levelling along country roads and highways at the rate of 2–2½ miles per hour, and with the average closing error of a few inches in the distance of 5 to 10 miles.

At the present time an attempt is being made in collaboration with the Topographical Survey, to develop a method of determining barometric altitude by using helicopters, without recourse to landing and hovering of the helicopters.

Lastly, attention is being given to various instrumental problems encountered in the course of the work. Recently there was success in realizing one idea but since the patent position has not yet been clarified, more details should not now be given.

The Photogrammetric Research Establishment and its program have been described briefly. The work is still in the initial stages. The broad program can only be realized with the co-operation and interest which the efforts have evoked on many sides, a fact which is fully appreciated. Particularly pleasing is the evidence of the same interest on the part of American colleagues, some of whom have not hesitated to come to Ottawa to discuss technical problems of mutual interest.

AEROTRIANGULATION WITH THE KELSH PLOTTER*

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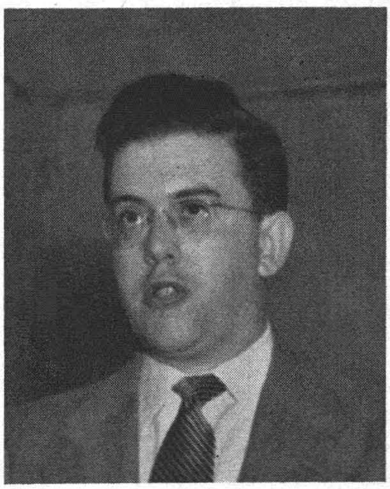
ABSTRACT

A method for aerotriangulation with the Kelsh Plotter is presented, test results are given and discussed, and it is concluded on the basis of tests made at ERDL that the Kelsh Plotter can be used successfully to bridge control stereophotogrammetrically.

INTRODUCTION

IN THE last several years we have witnessed the emergence and development of a relatively simple photogrammetric plotting instrument, the Kelsh Plotter, the capabilities and characteristics of which have attracted the attention of both government and commercial mapping organizations. The Corps of Engineers is among the organizations which have regarded the Kelsh Plotter as an instrument with a potential for solving certain aspects of its mapping problems. Through its Engineer Research and Development Laboratories at Fort Belvoir, the Corps of Engineers maintains a persistent program of evaluation of new instruments and techniques whereby the efficiency of military mapping may be improved. It is, therefore, not surprising that the Laboratories are interested in an instrument having characteristics of ruggedness, simplicity, light weight and relatively low cost closely approximating those required of a military instrument.


S. J. FRIEDMAN

A commercial model of the Kelsh Plotter was procured by ERDL in December 1948 and was made the subject of an investigation and evaluation. It was found that the basic design of the plotter lends itself readily to adaptation as a military topographic plotting instrument. Apparently the Kelsh Plotter offered a solution to the needs of the Corps of Engineers for a high precision, topographic, stereophotogrammetric instrument, simple to maintain and operate, cheap, portable, and rugged. However, one deterrent existed in that it was designed for stereo compilation and not for aerotriangulation.

Military mapping under wartime field conditions—a responsibility of the

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