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*Aerial Photographic Coverage of Canada**

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ABSTRACT: *The Canadian air survey program covers a period of forty years and has its roots in the phototopographical work undertaken in the Western Cordillera. The oblique method for covering large areas of Central Canada in the early days of air photography was a logical development. The first stage of the program was completed by the RCAF in 1947 using the trimetrogon method. The second stage is now virtually completed with vertical air photographs available for the whole of Canada, and copies of some three million prints are contained in the National Air Photographic Library. Air photography is entering still another stage and in future programs the emphasis will be on smaller areas for a number of special purposes.*

THE early history of Canadian air photography not only parallels but is closely interwoven with that of the United States. However, in view of the great difference that existed in the state of mapping of our two countries, differences in the major effort and type of photography used are understandable. Our most pressing needs were for small-scale mapping of the areas immediately north of the fringes of the northern limit of settlement, whereas the U. S. needs were for better mapping of areas already mapped to good reconnaissance standards.

The foundation for mapping using air photographs was laid before the Wright brothers took to the air. In Canada photogrammetrical mapping had been used for mapping our mountainous regions since the 1880's and in fact mountain photography or photo-topography was extensively used well into the 1930's. Many square miles of Canada's more rugged topography were mapped to scales of 1/253,440 and 1/63,360 by this method, and more recently ground photography has been used to provide supplementary control for vertical air photographs in mountainous areas.

The earliest Canadian air photograph on

* Presented at Semi-Annual Meeting, American Society of Photogrammetry, Alexandria Bay, N. Y., September 12–14, 1963.

record is that of the Citadel of Halifax taken in 1883 from a balloon by Captain Henry Elsdale of the Royal Engineers. However, practical use of air photography in Canada was not begun until shortly after the First Great War when happily we had the four very necessary ingredients—the camera, the aeroplane, the men to do the job and the organization to provide the support. Cameras to take reasonably good photographs were already available—certainly not to the precision of today's cameras—but nevertheless adequate for the job. The aeroplane had progressed greatly during the war and a number of the planes were turned over to the Canadian Government at the conclusion of the hostilities.

Furthermore, we were fortunate in having a large number of experienced flying officers of World War I from which to form the nucleus of a flying service and amongst the members of the Air Board formed in June 1919 were a number of enthusiastic and research minded surveyors and persons interested in mapping such as Dr. E. Deville, the Surveyor General, and Dr. W. F. King, the Dominion Astronomer; the secretary was Mr. J. Armitage Wilson, father of J. Tuzo Wilson of Toronto University, former President of the I.U.G.G.

Also there were a number of enthusiastic young surveyors, many of whom were veterans, who were only too willing to risk their lives and limbs in the challenge of blazing trails in the unknown and advancing the knowledge about our less accessible areas. Typical of this latter group was the late Mr. R. D. Davidson who won the Kodak Award commemorating the fiftieth anniversary of powered flight in Canada. This was presented at the Annual Meeting of our Canadian Institute of Surveying in 1959 in recognition of his outstanding contribution to Canadian mapping.

In reading over the records of the Air Board of the early 1920's, it is apparent that the interest was of the same high order as the enthusiasm for photogrammetry that permeated throughout this Society and radiated from its early post-war meetings at which arguments and discussions on photogrammetrical problems continued long after the exhibits and the conference rooms had been put to bed.

This enthusiasm for air photography is not too difficult to understand when one recalls that topography before that time was in the realm of the plane-tabler. Consider the task of traversing or resecting sufficient points on some of our northern lake areas to map them to any reasonable standard. Consider also the problem of getting to and from such areas, which were then considered remote, without the benefit of air transport. Two to three weeks of hard paddling and portaging would be an average trip from the nearest railroad or highway to what we might now call the near north. Indeed to those charged with the responsibility of mapping Canada the aircraft was, or must have appeared to be, an angel in disguise—a fixed-wing angel.

There seem to be several stages of development or change in emphasis in the pattern of Canadian air photography. Needless to say, these are closely associated with and, in fact, to a very considerable extent were brought on by the improvements in the camera, the aircraft, photogrammetrical equipment and the science of photogrammetry. Some of these stages overlap considerably, but this is natural in view of the differences in terrain to be mapped and the difference in scale of mapping required at any given time. Although a paper could be written on each stage, I am attempting to summarize them into a few pages and will mention them in chronological order.

In 1920 a series of experiments were undertaken at Ottawa. These are faithfully recorded in Bulletin No. 2 of the Air Board dated March 1921. The opening paragraphs of the Engineer's Report summarized the objectives of the experiments as follows:

> "A study of the remarkable developments in aerial photography during the war has aroused the conviction in the minds of many engineers and surveyors that its application to all forms of topographical survey is possible. The development of successful methods would be revolutionary in its effect and of great moment to a country such as Canada where vast tracts of unexplored and unsurveyed lands exist."

Needless to say a great deal of useful information on such matters as navigation for photography, the mounting of cameras and the necessary amount of overlap, was obtained during the course of these experiments. Cotton markers were placed on the ground at key positions and surveyed in the hope that they could be seen and accurately measured on the photographs. Generally the mapping experiments consisted of preparing mosaics from the verticals and some difficulty was encountered until the rectifying camera was used. One of the mosaics was made up from three negatives taken at 10,000 feet and was rectified by three control points and enlarged

to 400 feet to the inch. From these it was found that the city mapping was so greatly in error that the tilts indicated were in no relation to the actual tilts in the camera. One of the conclusions reached as a result of these experiments would seem to be still valid:

> "Although it is not essential that the personnel carrying out the work in the air should be engineers, a general appreciation of the difficulties involved from the engineer's point of view and the problems which he is endeavouring to solve will always prove a valuable asset to both the pilot and the photographer in carrying out their part of the program. The engineer directing the work as a whole should likewise be familiar with the conditions and difficulties to be met with in the air, and if possible an opportunity should be afforded him to carry out some of the photographic work himself. This would lead to a close liaison between the work on the ground and that in the air, without which successful results cannot be obtained."

Further experiments were continued and these are included in the annual reports of the Air Board. One of these was the result of a proposal in 1920 by Professor H. L. Cook of Princeton University for mapping by using low-oblique views of the same area taken from two different air stations, not too unlike the method adopted by Mr. Russell Bean in his twinplex plotter. Although Professor Cook's method was sound in theory, suitable photogrammetrical equipment was not then available, and one is led to believe that the photographs proved difficult to process. Further, the vertical and near-vertical methods of air photography offered little towards the reconnaissance mapping of our northern areas. Only flying boats could be used under such conditions, and they had limited ceilings of operation varying between 6,000 and 8,000 feet; the cameras of the day were, by today's standards, narrow of angle.

Considering, therefore, the experience Canadian surveyors had had in using ground cameras in mountainous areas, it is not surprising that experiments were soon tried using oblique photographs. This method showed great promise and was soon developed into a practical method for mapping areas of modest relief such as are to be found in the northern parts of Ontario and the three Prairie Provinces. Oblique photographs taken in northern Manitoba for the purpose of filling in detail along with traverse routes in northern waters proved their advantage in this class of work.

Following the success of the experiments using oblique photographs for mapping, the program for this work was gradually extended and continued for about fifteen years over a great many square miles of hitherto little known country. Although the maps lacked hypsometric information and their absolute positioning is something less than perfect, they were extremely useful and considered good maps; a number are still in use. Where the photographic pattern was up to standard, the detail was well portrayed and little improvement can be made in the topography from vertical photographs.

Initially the surveyor doubled as navigator and at times was even the photographer as well. However, as time went on, the RCAF provided the photographer and later the navigator. The surveyor was also responsible for taking sufficient astro positions at identifiable points on the ground to control the positioning of the map; so in the early days he worked both day and night. To get the maximum out of each photo flight, views were taken forward and to port and to starboard. Subsequently a triple camera was used in the aircraft, thus obviating the necessity for the camera operator having to point the camera in three different directions in quick succession.

To facilitate the plotting of the oblique photographs a series of glass grids was produced for various combinations of focal lengths, depression angles and flying heights. This system of mapping subsequently became known as the Canadian oblique method. Our records indicate that 226,000 oblique photographs were taken and 77 maps at 1/253,440 covering over 400,000 square miles were plotted in this manner.

Up until 1935 the major effort for the government photographic program was based on obtaining oblique air photos. A few figures showing the square miles covered per annum by the two methods indicate the trend which continued to the mid-thirties—

1921	280 square miles of vertical air photos	none by obliques
1922	1,300 square miles of vertical air photos	470 by obliques
1923	360 square miles of vertical air photos	1,605 by obliques
1924	355 square miles of vertical air photos	37,020 by obliques
1925	10,815 square miles of vertical air photos	38,355 by obliques

However, quite apart from the Federal Government air photo work, a number of the provincial governments and larger public and private utilities and forestry companies were making extensive use of air photographs. Even as early as 1923 there were two private air photo companies in existence in Canada which were catering to the needs of private companies and, on occasion, were engaged on government work. Their operations were primarily vertical photography so that even if the major effort of the Federal Government were on oblique photography for reconnaissance mapping, vertical photography was being used for a number of purposes.

In 1939, when war broke out, there was an urgent need for air navigational charts of the whole of Canada. As comparatively little was known of the more northern areas, all types of information such as explorers' and even trappers' notes and sketches were examined and assembled in order to provide some form of map coverage. As aircraft flew over such areas and took photographs, efforts were made to improve the information and thanks to the trimetrogon operations of the U. S. Air Force, it was not long before much more was known about our less frequented regions.

Towards the close of the war a co-ordinated Canadian trimetrogon program was developed and the R.C.A.F. was engaged in flying coverage from then until about 1947. The late Mr. Robert B. McKay was instrumental in developing a new and more precise method of plotting by having a special mount designed that ensured a constant angle between the oblique and vertical cameras. For his work he was honoured by both your Society and the Canadian Institute of Surveying.

The 1/506,880 scale maps produced from trimetrogon photographs for air navigation have provided good interim coverage for a great number of purposes not the least of which was to help those engaged on subsequent vertical photographic operations with their navigational problems and thus ensure better vertical photographs for future mapping operations. The completion of this program ensured that all of Canada could be put on a map and marks the completion of the reconnaissance program initiated in 1923. At the conclusion of the 1947 photographic season 1,893,000 square miles of Canada had been covered by photography. This was made up as follows:

Oblique coverage	589,915 square miles from 1922–1938
Vertical coverage	825,485 square miles from 1921–1947
Trimetrogon coverage	477,600 square miles from 1944–1947

From 1938 on the vertical air photography program was on the ascendency but, unfortunately, the civilian mapping program was interrupted for several years before this program really got into its stride. However, at the conclusion of the war, the RCAF had a number of aircraft available for photographic purposes and several of them were assigned to vertical photo missions and the vertical program started in earnest.

Initially the scale of photography used in the more settled areas was 1/15,840, and with the new graphical methods of plotting that had been developed as well as the elementary photogrammetrical equipment that had become available, a field party could accomplish several times the quantity of mapping over that of pre-war days. It was about this time that the wide-angle six-inch lens camera became available, and air photo scales of 1/31,680, and 1/40,000 became the order of the day. These were well suited for mapping at 1/63,360 using the multiplex. Because of the great reduction in the number of prints to cover a given area the compilation of 1/253,440 scale mapping from vertical air photographs became a more practical operation.

The RCAF continued its vertical coverage program, particularly in the northwestern areas, until the late 1940's and a great number of the maps of British Columbia, the Yukon, and Northwest Territories, were compiled from this photography. However, as the interest had turned to high-altitude photography and the RCAF became more concerned with its military assignments, it gradually withdrew from the field.

The Interdepartmental Committee on Air Surveys, the agency that arranged for the procurement of Federal Government air photography, therefore became almost fully dependent upon commercial air survey companies for its air photographs.

On the 1st of April 1949 Newfoundland joined Canada and one of the terms of union was that up-to-date mapping of the island

should be given early attention. There were two areas of the northern peninsula for which photo coverage was lacking and in 1950 photography from 25,000 feet A.S.L. was specified. This requirement caused some concern amongst the air photo contractors and forced them to re-assess the type of aircraft that would be required for future government air photo programs. One company purchased a P38 aircraft and, having successfully supplied the Newfoundland photography in 1951, was awarded a contract for 35,000 feet A.S.L. photography for a part of western Ontario. The company was able to produce the photographs at a very reasonable price by May of that year and from that time on the emphasis was on high-altitude photographs for mapping. As experience was gained it became apparent there were some problems in flying at this height over extended periods. A ceiling of 30,000 feet was agreed upon.

In 1957 the government decided that vertical air photography with radar-altimeter, or air profile records, should be obtained for the islands of the Arctic Archipelago. The Interdepartmental Committee on Air Surveys negotiated contracts with three air survey companies each being assigned a specific area and supplies were placed in the field during the Arctic navigational season. To ensure that the greatest advantage was taken of favourable weather, some of the companies established their own weather observation posts to supplement those already in existence. This greatly speeded up their work and the first year's operations proved to be much more successful than anyone would care to have predicted. Approximately 50% of the area was covered in the one season whereas six years had been allowed for the completion of the work. Reasonable progress was also made during the following year and the full operation was completed within a five year period.

Considering the shortness of the season, the remoteness of the area, and the associated logistic problems, the Arctic Islands photographic project turned out to be far less complicated than predicted. It would seem that the companies involved had profited from their experience in flying the northern portions of the mainland and had generally prepared themselves well for this more challenging operation. Altogether over 500,000 square miles of photography was flown in these areas and about 100,000 line miles of air profile records obtained.

Thus, for the small-scale mapping all that is required is a modest amount of horizontal control and this has been obtained during the past few summers by tellurometer traverses tied to the geodetic shoran control.

Since 1951, including the Arctic program, something in the vicinity of 2 million square miles of Canada were photographed at altitudes of 30,000 feet or higher. This greatly accelerated our mapping particularly at the reconnaissance scale of 1/250,000. Although there still remains some of this type of photography to be done, the quantity required per year has now decreased to the point where it scarcely warrants the upkeep of high altitude aircraft by the air survey companies.

No account of Canadian Government photographic operations would be complete without mention of the Royal Canadian Air Force and the National Air Photographic Library. Up to about 1950 the major part of the civilian government photography was supplied by the RCAF and all the early oblique work and experiments were supported directly by the Air Force. We are indeed indebted to the hearty co-operation it extended to our mapping agencies particularly during the first quarter century of the work and we believe they in turn took advantage of the opportunity to train and develop their staff under something resembling operational conditions. Furthermore, No. 1 Photo Establishment of the RCAF stores all the negatives of Federal Government photography and supplies the photo prints and diapositives at a nominal charge to those requiring them. The agency through which this information is ordered is the National Air Photographic Library which is an integral part of the Surveys and Mapping Branch.

The N.A.P.L. was established in 1925 when it became apparent that the air photographs would serve a number of purposes and that various agencies and the public would wish to refer to them over the years. Fortunately this need was foreseen sufficiently early so that virtually all government photography is properly indexed and prints filed in the library and the indexing and filing system has stood up well to the test of time.

Anyone who wishes to do so may visit the library and examine photographs at his leisure. For some areas there are several lots of photo coverage. Occasionally, the original photographs are almost forty years old. Using these accurate records one can readily detect the changes that have taken place due to both

natural causes and the works of man. There is certainly a tremendous amount of information available in such a library. In a number of fields, more and more use is being made of photographs for research purposes. The library now has just under three million prints in its files. The steady increase in the number of orders and quantity of prints procured for customers is further evidence of its growing usefulness.

The Interdepartmental Committee on Air Surveys has since 1925 been the procurement agency for Federal Government photography. The principal users of air photographs are represented on this committee as well as the Air Transport Board. It is charged with the responsibility of setting specifications, reviewing orders, assessing the quality of photographs supplied; it generally attempts to satisfy the needs of the Federal Government agencies for air photo services. This committee is concerned about the future trends in air photography. All but a very small area southeast of Ungava Bay is covered by vertical photographs and this is presently under contract. So the second stage of our air photo program—the vertical photo program—is virtually completed.

There will be a continuing need for new air photography in areas where there have been cultural changes or for the revision of forest inventories. But the days of awarding contracts for tens of thousands of square miles in one general area and at the same scale have passed. Up to now probably over 90% of the outlay for air photography has been for mapping and forestry purposes. Admittedly, the photographs will serve many other purposes but the scales have been determined to best serve the two big users. In the future it would seem that the proportion of photography required by other users, and specifically flown to meet their needs, will rapidly increase. Some are more interested in the interpretative quality of air photographs than in using them for precise measurements. This would seem to lead to new types of film. It does not necessarily follow that the precise mapping camera is the best to use with such films.

With the object of having a good hard look at the future air photo needs of various agencies the Interdepartmental Committee on Air Surveys serves, we are holding a symposium in Ottawa in October. The whole meeting will be devoted to the interpretative aspects of photogrammetry. We hope that some of your members will join with us and take part in the discussions.

In Canada, as you have in the United States, we have witnessed the gradual and progressive development of an air survey industry. In the Canadian Federal Government Service we have enjoyed the whole-hearted co-operation of industry. Through our associations with industry, both government and private photographic and photogrammetrical standards have been greatly improved.

In my opinion the future for air photography is bright. Already we have made many improvements, and can look for further improvements in the photographic equipment and platforms used to transport the camera to the area of interest. As these improvements occur, the air photograph is proving to be a valuable tool for more and more purposes. Much has been learned and we can hope not too much of value forgotten since the early days of air photography.

All that is needed to ensure the furtherance of air survey is the spirit and enthusiasm that was so prominently displayed in the early days of this art or science.