Kiely, Edmond K., *Surveying Instruments. Their History and Classroom Use*, New York, Columbia University, 1947.
Kimble, George H. T., *Geography in the Middle Ages*, London, Methuen and Co., Ltd., 1938.
Markham, Sir Clements R., *The Lands of Silence. A History of Arctic and Antarctic Exploration*, Cambridge, University Press, 1921.
Shackleton, Edward, *Arctic Journeys*, Farrar and Rinehart, New York, 1936.
Finch, J. K., Our Indebtedness to the Old Surveyors, *The Military Engineer*, Vol. XVII, No. 94, July–August, 1925, pp. 320–325.
Report of the Second Norwegian Arctic Expedition in the "Fram" 1898–1902, Kristiania, Videnskabs-Selskabet, 1907.
Mirsky, Jeannette, *To the Arctic*, New York, Alfred A. Knopf, 1948.
Baker, J. N. L., *A History of Geographical Discovery and Exploration*, London, George G. Harrap and Co., Ltd., 1931.

Arctic Air Photography

Part 1

Operational Problems in Arctic Survey Photography

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SYNOPSIS

Selection of areas:
Supply of gasoline and oil
Climate, the operational time-table

The weather:
Effect of open water
Need for good forecasts
Work of arctic weather team

Communications:
Part of weather forecasting system
Navigation aids
Aircraft following service
Contact with supply bases

Navigational problems:
Low directional pull of magnetic pole
Effect of local attractions
Map reading
Use of solar navigator and astro compasses

Servicing the operation:
Remarkable results in spite of handicaps
Detailed planning of spares
Safety training

Improvements since pioneering days

In my talk I will discuss the operational aspects of Arctic aerial photography under the general headings of: selection of areas, operating supplies, climatic conditions, navigation problems, communications, and logistic support. W/C Ross, who will follow me, will provide the technical details of our Arctic aerial photographic problems.

Unlike planning of aerial mapping in more developed areas, the selection of areas in the Arctic involves an important operational problem, because of the scarcity of aerodromes suitable for four-engined aircraft. We have suitable landing strips at Norman Wells, Yellowknife, Churchill, Whitehorse, and one in the Arctic islands. We do not build aerodromes in the Arctic specifically for our photo operations; our requirements therefore affect the maintenance at aerodromes already established. The fact that aerodromes are unserviceable for varying periods during the spring break-up must also be taken into consideration. It is apparent then, that any selection of areas must take into account their accessibility from one of the existing aerodromes, and whether the aerodrome has sufficient supplies of petrol and lubricants in stock to permit flying before the next year's deliveries are made.

Provision of gasoline and oil is a major problem at such places as Yellowknife and in the Arctic islands, since the quantities required can be put in economically by surface transport only. As transportation is by water, and as the season is very short, varying from approximately 4 months at Yellowknife to 6 weeks in the islands, it is necessary to plan the supply approximately 18 months ahead of an operation. If a substantial portion of the available stock is used for some emergency, it may necessitate changing flying plans for the entire season. Such a case occurred at Yellowknife in 1951; an extensive search for a lost commercial pilot consumed some 75,000 gallons of gasoline which were earmarked for photographic operations.

Climatic conditions in the Arctic govern the operational timetable to a very great extent. The best period of photo weather

is usually in the early spring, which on the mainland comes in late May or early June, and on the islands about the middle of June. We attempt to take advantage of this period of weather, provided the snow has disappeared sufficiently for topographical features to be identified. Generally there is a period of two weeks between the snow going and open water when excellent photographic weather prevails. Once open water has arrived, work is hampered by clouds of various types. Over the mainland section, cumulus clouds prevail, while over the islands a heavy layer of stratus forms over large areas at a time. Conditions can usually be forecast fairly accurately by the weather station located at Edmonton specially to provide forecasts for the Arctic regions. With the large areas involved, and the great distances from base to the operational areas, aircraft would waste a lot of time unless fairly accurate forecasts were given.

It is well to clarify one common misconception about Arctic aerial photography, namely that it is carried out under ideal weather conditions only. When it is realized that these aircraft may range 700 miles from their base to find clear weather, it will be evident that they must at times take off and land under instrument weather conditions.

Another common misconception in regard to Arctic weather concerns temperatures. While it is not uncommon to experience temperatures below 32°F. in midsummer in the islands, temperatures of 75 to 80° also occur. It is surprising how much growth can take place during the long northern days. At Norman Wells a small plot of land has yielded as much as 5 tons of vegetables in a season of three months.

Without an effective communication system, efficient photographic operations would be impossible. Existing facilities are therefore supplemented by a special system which broadcasts meteorological data, provides navigational aids at the bases where necessary, and maintains constant touch with planes while they are on operational flights. Weight restrictions make it necessary to use high-frequency equipment, and blackouts therefore cause considerable difficulty at times, but by changing frequencies it is usually possible to maintain contact.

Navigation is the most difficult operational problem in Arctic photo survey work. Much of the area, both on the mainland and in the islands, is centered around the Magnetic Pole, situated on Prince of Wales Island. In this region the magnetic directional compass is of very little use, and other methods of maintaining direction must be used. On all long-range Arctic flights, R.C.A.F. aircraft employ grid navigation, using an astro compass to correct an electric or vacuum-driven gyro instrument. The large magnetic variation which reaches 180 degrees in the islands, is thus eliminated. Grid navigation depends, for its accuracy, on a very accurate calibration of the precession rate of the gyro instruments, and frequent checks by the sun to assure that the aircraft is being kept on course. For flying actual photo lines, another instrument, called the solar navigator, is used. This instrument makes it possible to maintain the direction of the aircraft with extreme accuracy. It is linked to a gyro-stabilized drift sight, and by frequently correcting for drift the navigator can maintain course.

Once the aircraft reaches the operational area, the problem of locating its position by map reading faces the crew. The innumerable lakes and rivers on the mainland in the Arctic and the many discrepancies in the maps of the islands make this extremely difficult, and much experience is required to correlate the maps and the actual landscape.

Because of this problem, as well as to speed up the production of small-scale maps, two types of photography—tri-camera and vertical—are used. The former takes three photographs simultaneously, one vertical, one right oblique, and one left oblique; the machine flies at 20,000 feet, and the cameras cover an extent of country that makes it possible to fly lines sixteen miles apart. Experience has shown that in tri-camera work, flights may be made by dead reckoning with sufficient accuracy to avoid gaps; it has also been found that accurate maps on a scale of 8 miles to the inch can be produced from the photographs. These maps can then be used as a guide for the vertical photography, which uses one camera with a 93° angle lens. Verticals are taken at 20,000 feet, with the lines of flight from $2\frac{3}{4}$ to 3 miles apart.

The need for such a procedure can be appreciated by considering one example of the type of errors found on previous maps. Kent Peninsula, which lies on the Arctic coast of Canada about 650 miles east of the mouth of the Mackenzie River, was shown some 30 minutes of longitude too far west on certain maps. Since it was a prominent landmark which could be easily identified, and was therefore used as a check point, serious mistakes in navigation would result from such an error.

Even with the improved maps secured by use of tri-camera photography, navigators need a great deal of training before they can produce acceptable results. The mass of lakes on the Arctic mainland and the configuration of the Arctic islands may easily confuse the inexperienced navigator.

Royal Canadian Air Force policy specifies that the aircrew should be trained in all types of operations, and a limit of three years has been set for training in any one type of squadron. Training is a major problem: we lose one-third of our personnel each year, and as the squadrons are on operations during the summer, training must be carried out in winter, when the snow-covered terrain presents a totally different appearance, and many features are obscured. Navigators, therefore, must learn map-reading largely on actual operational flights.

In addition to the need for technical training, a certain mental attitude has to be developed in pilots and crews for Arctic work. Because of much misconception and lack of knowledge, green crews are apt to turn back at the slightest sign of anything abnormal about either their aircraft or the weather when flying in the Arctic. We try to offset this tendency by giving survival training which involves spending two weeks in the open in mid-winter. After a little experience the crews carry on as if operating anywhere else in Canada.

Servicing planes in the Arctic in summer is very much the same as in detached operations in other parts of Canada. The equipment used must be portable, and such items as hangar cranes and similar equipment must be dispensed with. What makes the problem more acute in photographic operations is the fact that the crews are away from a main base for so long at a time. With the concentrated flying that is necessary to take advantage of the short season and the long days, maintenance is carried out on a 24-hour basis during good weather. In spite of the handicaps of working outside without shelter in dust and wind at temperatures often near freezing point, some outstanding results are achieved. On one occasion an aircraft stranded in the islands had an engine changed between 10:30 P.M. and 6:30 A.M. and then flew some 2,000 miles of photo lines the same day. The continuous daylight helped of course, but a 15 m.p.h. wind at 34°F. made work in the open extremely uncomfortable.

One of the major difficulties in Arctic servicing is the supply of spares. Although large quantities of spares, based on past experience, are taken up, it is simply impossible to provide against all contingencies, and a season seldom goes by without some shortage developing. In such cases it is considered well worth while to fly the necessary parts in from outside, in order to take all possible advantage of the very short season of good flying weather which, in at least one case, amounted to three days only.

While all the problems in Arctic photo operations are not yet solved completely, we have progressed a long way from the pioneering aspects in which Canada has played so great a part. From the days of multi-oblique photography from the open-nose cockpit of a Vickers Vedette Flying Boat doing 70 m.p.h. at 5,000 ft. to tri-camera and vertical photography at 250 m.p.h. and 20,000 ft. is a long step. That such a step has resulted in the present level of efficiency is due in very large measure to the effective and devoted work of the earlier pioneers.

The major problems in Arctic flying are due to climate, lack of navigational aids, and difficulties in supply and servicing arising out of the remoteness of the area. In future operations, such problems should be greatly simplified by improved maps, the installation of radio aids, and the development of improved directional instruments. It is possible that even the climatic problems may ultimately be overcome to a large extent by the improvement of radar photography, which has already produced some striking results.