

Photo: R.C.A.F.

Photographic Lancaster on an arctic flight.

PHOTOGRAPHIC OPERATIONS OF THE ROYAL CANADIAN AIR FORCE

*By Wing Commander R. I. Thomas, R.C.A.F.**

A SERIOUS program of mapping Canada was begun in 1902 but it soon became apparent that the accepted ground methods were too slow to keep pace with the development of the country. After the First World War the Department of the Interior, faced with the apparently hopeless task of mapping Canada within the lifetime of that generation, requested that the Air Board should cooperate in carrying out aerial mapping.

The first attempts were made in 1921 and although the results were limited they were sufficiently successful to reveal the possibilities of aerial photography. The role of the operator of the aircraft was handed to the Royal Canadian Air Force when it was formed in 1924, and the development of equipment for the work was the responsibility of the National Research Council. Through the years the closest possible cooperation has evolved between three widely separated branches of government: Department of Mines and Technical Surveys, the National Research

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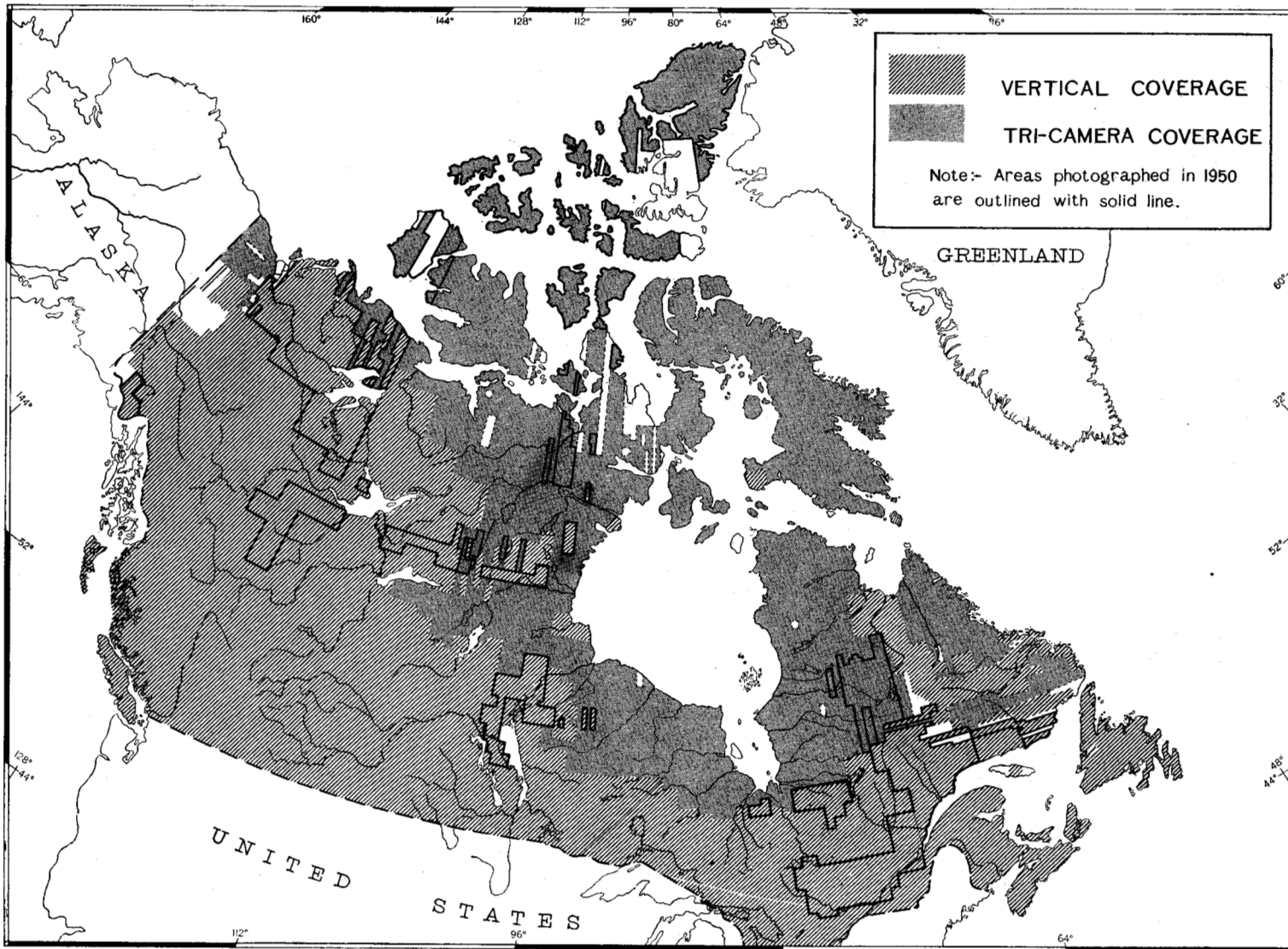
Council, and the Royal Canadian Air Force, representing the photogrammetrist, the research worker, and the air operator. This close liaison has been an important factor in the growth and efficiency of Canada's photographic survey program. During the past twenty-nine years Canada's program of aerial photography has increased from a yearly coverage of 280 square miles in 1921 to the all-time record of 911,500 square miles in 1948. An additional 1,741,500 square miles of coverage were added in 1949 and 1950 to bring the total number of negatives held in the storage vaults at Ottawa to 3,750,000.

Although aerial survey formed quite a large part of the overall R.C.A.F. commitment during the period 1924-39, progress was slow. The type of aircraft available and the angle of the lens in use in aerial cameras kept the coverage at a relatively low figure. The largest coverage in any one year was approximately 109,900 square miles, and the total by 1939 was only 868,600 square miles.

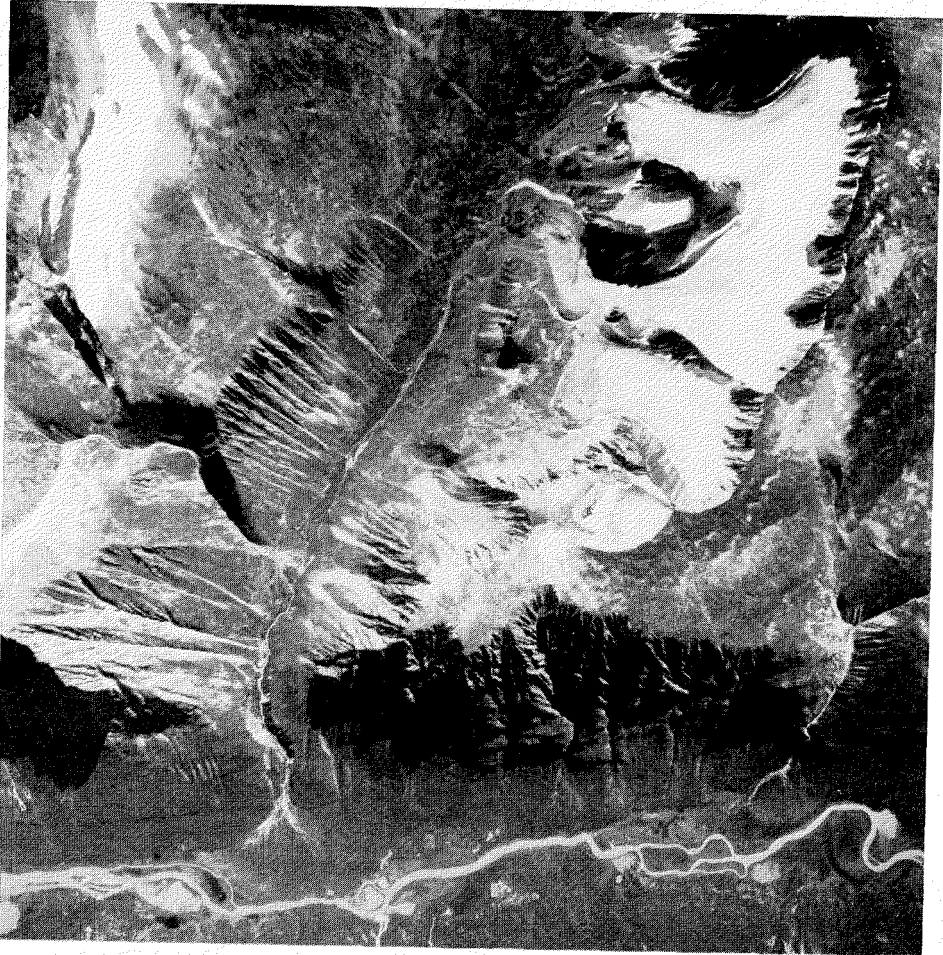
With the outbreak of the Second World War in 1939, the squadrons employed in photo survey operations were converted to bomber reconnaissance work and survey operations came to a standstill. However, in 1944 photo operations were again requested of the R.C.A.F. and as a result No. 13 Survey Squadron (later renamed 413 Survey Transportation Squadron in 1947) was formed at Rockcliffe (Ottawa) to undertake limited commitments. By 1945 the urgency for maps along the proposed Alcan Highway and in the Mackenzie Basin was so great that two squadrons were committed to photo survey and since then the effort of the R.C.A.F. has been increased to three squadrons and has mainly been concentrated in the Canadian north. In 1949 and 1950 it involved some 550 personnel and 33 aircraft in the field with several hundred personnel at Rockcliffe.

The organization set up to handle the tremendous commitments of photo survey in 1949 and 1950 consisted of 22 Photo Wing Headquarters, which coordinates all the work; three squadrons, 408 and 414 Photo Squadrons and 413 Survey Transportation Squadron; and No. 1 Photo Establishment, which is responsible for processing the films. Under the latter unit, but operating as a separate entity, is No. 1 School of Photography where photo training of the R.C.A.F. is undertaken. 22 Photo Wing Headquarters at Rockcliffe effects control in the field through a network of nine signals units linking all advanced bases direct with Rockcliffe. This efficient signals link has proved a vital factor in the achievement of large coverage during the past three years.

Today two main types of photographic survey are undertaken: vertical and tri-camera. The former employs a single camera and is used for detailed mapping. In this photography lines are flown at intervals of three miles or less in most areas, to give 60 per cent forward and

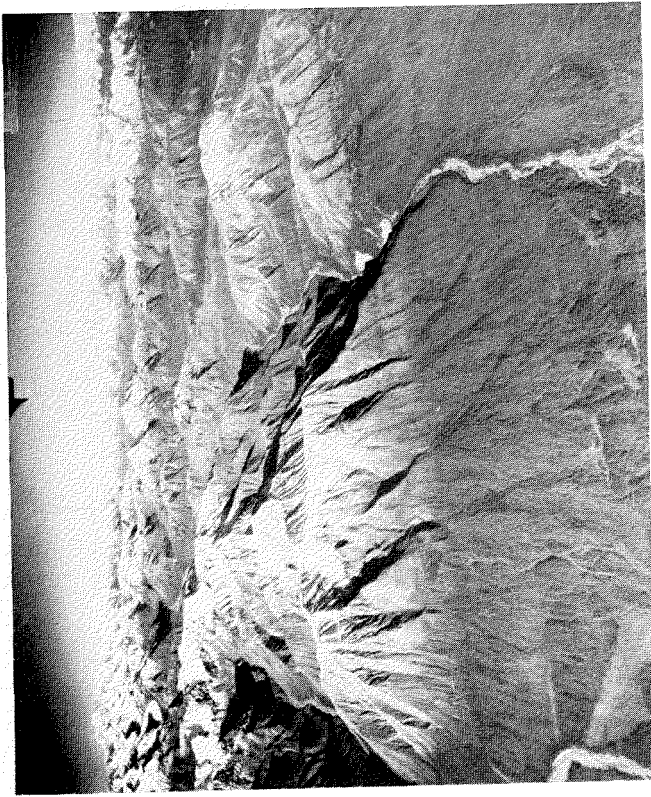


Air photographic coverage, December 1950

*Photo: R.C.A.F.*

Vertical photograph, Watson Lake area.

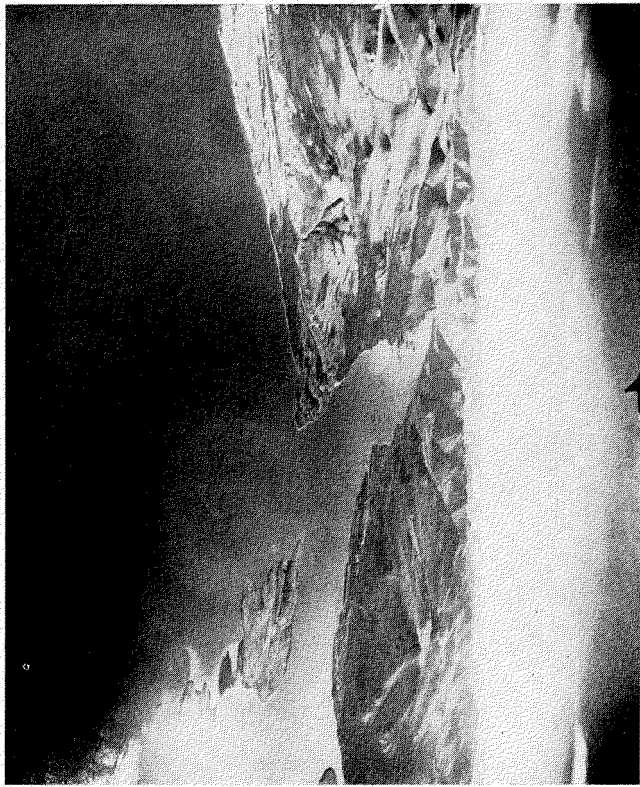
30 per cent lateral overlap. The resulting photographs can be used to produce contour maps of great accuracy and are normally used for maps of 4 miles to 1 inch or larger scale. Tri-camera photography, in which three cameras in a single mount work simultaneously from the aircraft, produces a fan of three photographs. This method sacrifices accuracy for coverage but is approximately six times as rapid as vertical photography. With the precise calibration now used it is possible to produce accurate 8 mile to 1 inch maps from tri-camera photographs and, where there is very little relief in the terrain, 4 mile to 1 inch maps of reasonable accuracy. Because of the large areas that can be covered in a comparatively short time this method has proved to be of great value in the initial mapping of the north where the season is short and detailed maps are lacking for the more precise navigation required to produce good vertical coverage. All the National Topographic Series maps of northern Canada are being produced from tri-camera photographs.



Tri-camera fan covering approximately 8000 square miles, Kluane Lake area. The Alaska Highway

When the aerial survey program was initiated, only vertical photography was used. However, the slow speed and low ceiling of the available aircraft and the relatively narrow angle of the camera lens soon led to the adoption of the speedier oblique photography. This type of photography was produced by one camera taking a fan of three exposures as close together as possible covering a field of 180° in front of the aircraft. The camera operator was in the nose of the aircraft, a Vedette flying boat. The camera was mounted on a scarf ring which could be adjusted to compensate for drift and the operator was responsible for getting the right angle of depression on each exposure. The plotting of such photography was difficult and the results not too accurate, but many maps still in use were produced from such work.

The next step was to use three cameras in a single mount facing to the rear of the aircraft. The cameras were calibrated with fair precision to the mounts and the results were considerably more accurate than those obtained with the oblique method. Further development led to the present day tri-camera set-up. This installation is a development, much refined, of the American tri-metrogon principle, which in turn goes back to the old oblique mounts. The side cameras are set at 90° to the centre line of the aircraft and depressed 30° while the centre camera is set vertical.



Photos: R.C.A.F.

shown in the centre photograph: note the overlap has been trimmed from the two side photographs.

This produces a fan covering from horizon to horizon through the vertical which is plotted in strips 16 miles wide, with the accuracy of vertical photography in the middle and a falling off of accuracy for eight miles to each side. Fairchild F224 cameras with 6-inch f.6.3 Bausch and Lomb Metrogon lenses are used for tri-camera photography. They have a 250-exposure magazine for a 9 inch by 9 inch negative. The suction back is used to hold the film and the fiducial marks are affixed to the body of the camera. These cameras give excellent definition even from 20,000 feet, the normal operating height, and they have been relatively trouble-free since brought up to R.C.A.F. specifications.

Vertical photography is carried out with Williamson Ordnance Survey cameras using 6-inch f.5.5 Ross Wide-angle Survey lenses. These cameras have a 500-exposure magazine, also for a 9 inch by 9 inch negative. The pressure plate method of holding the film is used and the fiducial marks are etched on the focal plane glass. The definition is excellent and the performance very good since R.C.A.F. modifications have been installed. Vertical coverage is also from 20,000 feet.

Since 1945 the major part of the photographic survey program has been carried out in the north. In 1948, when 911,500 square miles of northern Canada were photographed, photographic survey operations

were carried to the Arctic Islands for the first time. In that year all of Baffin Island was photographed in addition to large areas of the Labrador, Ungava, the Northwest Territories, and the Yukon. In 1949 operations were continued in the Arctic Islands. Photographs were taken of Victoria Island, King William Island, and parts of Somerset Island, Banks Island, Boothia Peninsula, further areas of the Yukon and Northwest Territories, the Labrador, Ungava, and northern British Columbia. In 1950 operations were pushed even farther north. Further coverage was obtained on Victoria and Banks islands and most of the islands north of Lancaster Sound were photographed.

Tri-camera photography is undertaken exclusively by 408 Squadron. This squadron consists of eight long-range Lancaster X aircraft, equipped with three Fairchild F224 cameras precision-mounted in a single mount. The cameras are tied-in to each other to within 10 seconds of arc and each camera is jig-drilled to be interchangeable without disturbing the calibration. In addition, these aircraft carry Williamson Ordnance Survey cameras for vertical coverage.

Three of 408 Squadron's aircraft are equipped with special instruments and wiring developed by the National Research Council for Shoran-controlled photography. Shoran is a recent development in the survey field and has been proved in operation in 1950. It involves using airborne radar equipment in conjunction with ground radar beacons spaced several hundred miles apart, and allows aerial photographs of the area concerned to be positioned accurately.

In addition to controlling photography accurately by Shoran, it is hoped that this method of control can be used to establish accurate fixes in the north. To do this the photo procedure is reversed. In photo, two ground stations at known positions are used to locate the position of the aircraft, whereas in applying Shoran to survey the aircraft flies at a known height above sea level and measures the slant distance between it and two ground stations. From the results the distance between the two ground stations is calculated. This method has been used in the United States successfully but not to the degree being attempted in Canada. In 1949 measurement was begun of a large network of Shoran stations stretching from the Winnipeg area to Fort Vermilion in Alberta, a distance of approximately 1200 miles. This program was completed in 1950 and the soundness of the procedure developed was definitely proved. Accuracy in the order of 1/58,000 has been achieved. Shoran measurement is believed by R.C.A.F. and Department of Mines and Technical Surveys authorities to be more accurate than the present system of setting up astronomical fixes.

Vertical photography is primarily allotted to 414 Squadron which is entirely committed to this work, although aircraft of 408 Squadron may



Photo: R.C.A.F.
Camera operator at the controls of a tri-camera mount in a Lancaster aircraft.

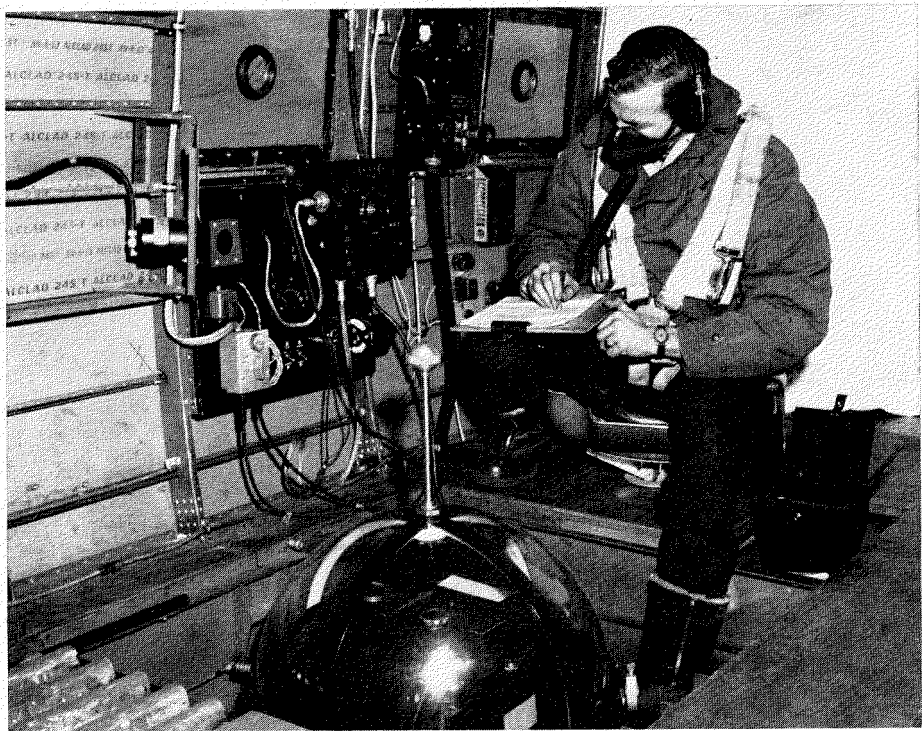


Photo: R.C.A.F.
Camera operator and control panel for Williamson Ordnance Survey camera as installed in a photographic Dakota aircraft; camera in foreground.

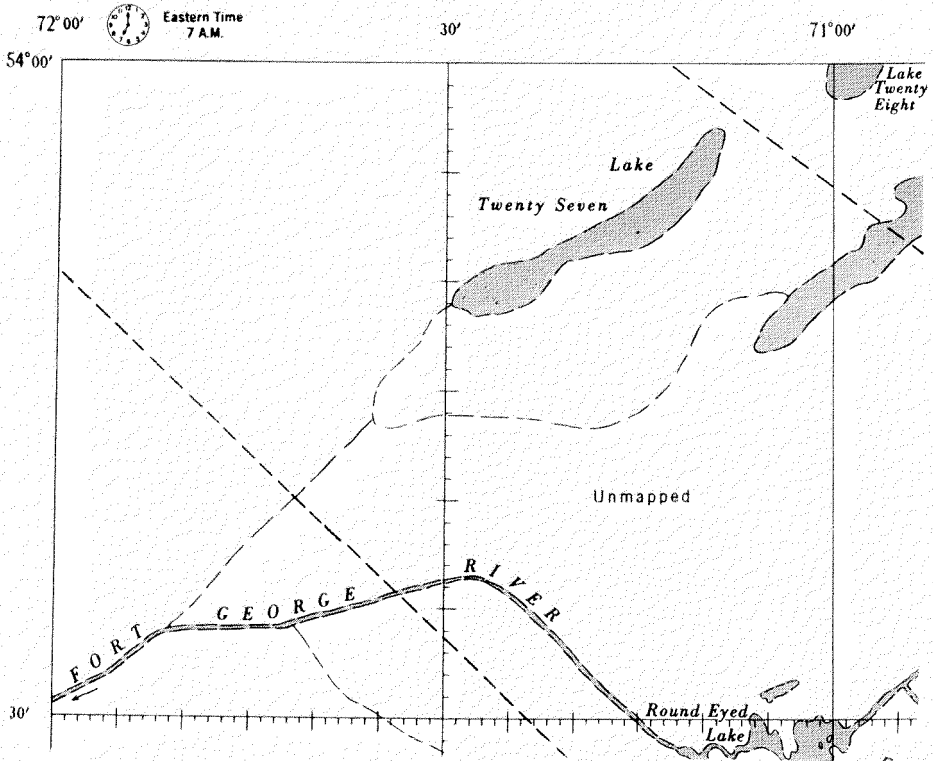
take vertical photographs when tri-camera areas are not available. 414 Squadron was formed in 1945 to meet the requirements of the defence mapping program in the Yukon and Northwest Territories. It is equipped with 14 Dakota Mark IV aircraft specially modified with long-range cabin tanks and a cabin well to accommodate a Williamson Ordnance Survey camera. The cameras are electrically heated and thermostatically controlled to within $\pm 4^{\circ}\text{C}$.

The supply problem for the two photo squadrons had grown to such large proportions by 1949 that a survey transportation squadron was organized. The original postwar photo squadron, 413 Squadron, was chosen for this work. It is equipped with 4 Dakota, 6 Canso, and 5 Norseman aircraft. In addition it undertakes flying boat transportation for other government departments.

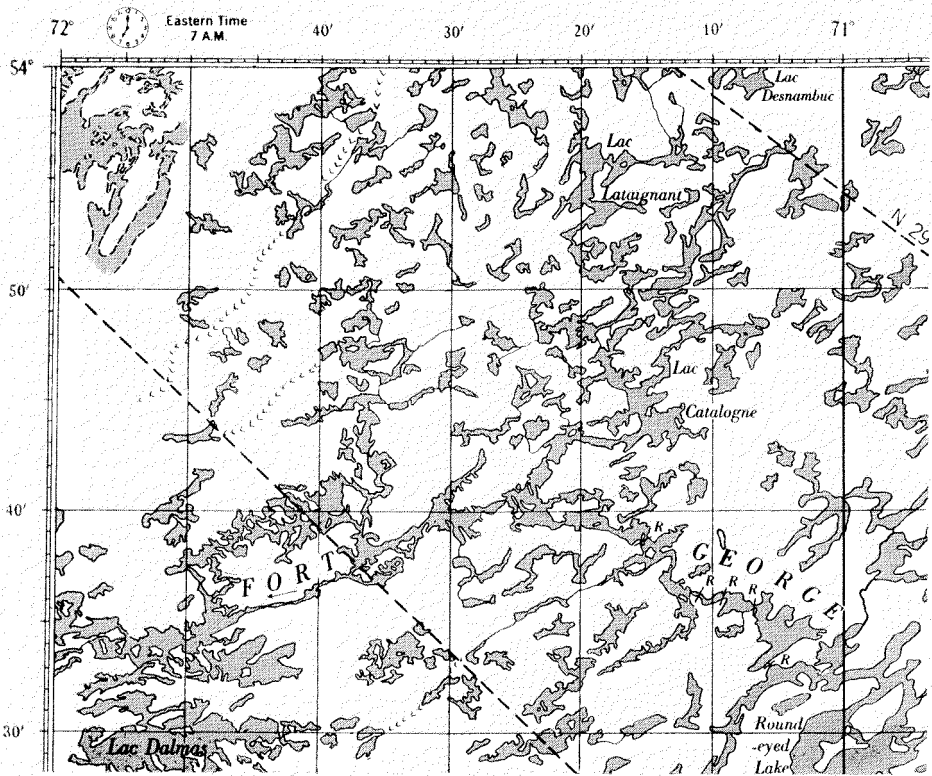
The commitments for each season of aerial photography are decided by the Interdepartmental Committee on Air Surveys. A sub-committee, with a permanent secretary from the Department of Mines and Technical Surveys and representatives from the government departments using the R.C.A.F. aerial photographs, considers requests for photography and decides on the specific areas to be covered by the R.C.A.F. and by civilian companies. Members of the Air Transport Command and of the photographic squadrons also attend the meetings of the sub-committee to advise on the possibility of carrying out the various requests. Thus it is known by both the R.C.A.F. and the requesting agency that the commitments are practicable.

Whenever possible tri-camera coverage is obtained before vertical photography is attempted. Although this involves an additional year's delay in producing 4 mile to 1 inch maps, it means that much improved maps become available earlier for use by commercial firms wishing to explore what may be almost virgin territory and the procedure has proved to be beneficial to all concerned. The areas allotted to commercial companies are normally adjacent to rail or sea transportation and are of a much smaller size than those assigned to the R.C.A.F.

As soon as the specific areas to be photographed have been determined, plans can be made. Coverage is assigned to the two squadrons, bases are decided upon, and the flight line maps are drawn up. The R.C.A.F. always requests a considerable area over and above the expected coverage, thus adding greatly to the flexibility of the program and to the coverage that may be possible in one season. For example, in 1949, when operations were being carried out in the Yukon, flight line maps were prepared for approximately 100,300 square miles more than the original vertical commitment. The weather turned out to be particularly good that season and in three weeks practically the entire commitment, including the additional area, was covered. Had the extra flight line maps not been



Part of the Nichicun (23 S.W.) 8 mile to 1 inch sheet before photography.



Part of the Nichicun (23 S.W.) 8 mile to 1 inch sheet after photography.

available, the aircraft would have been on the ground for approximately one week of good weather because of lack of areas to photograph.

The timing of the detachments into various areas is a major factor in planning. Because of the short season in the north it is now left to the R.C.A.F. to decide when operations in a particular area are carried on. In the past a great deal of good weather was lost by holding detachments in southern areas until a high priority commitment was completed. Now detachments work in the south only until photography is possible in the north. The detachments go into the field any time after the snow has gone from southern areas and ice on lakes has started to break away from the shores. This usually means that the first detachment leaves Rockcliffe between April 25 and May 1. A detachment generally makes four moves in a season: the first from Rockcliffe to a southern base, then to the northern base when the area opens, and back to a southern base before returning to Rockcliffe. The season is normally over by the middle of October but special commitments are sometimes received which drag the season on to December.

The preparation for any aircraft operation in the north must begin approximately 18 months ahead of time. It is necessary to lay in gas and oil one year ahead to have it available to start photography when the season opens, as snow is gone from the land and photography is possible before navigation starts. Once a cache has been assured at a base the detailed planning gets under way in the fall and winter. Rations, accommodation, and spares are laid on, crews trained, and aircraft serviced for the photo season.

The extensive manner in which photo operations are undertaken today calls for the greatest amount of flexibility within the organization of the squadrons. This is attained by sub-dividing the squadron into smaller formations or detachments. Each detachment is a completely self-sufficient unit and consists of ground crew and air crew. The ground crew includes aero engine, air frame, radio, electrical, instrument and safety equipment technicians, in addition to cooks and mess orderlies. The air crew includes pilots, navigators, and radio officers as well as the camera operators. Each detachment must take with it spares for the aircraft, ground handling and servicing equipment, rations, and personal clothing. This latter is quite an item alone since the weather at such places as Coral Harbour or Norman Wells can be very cold in early May or June and in late August. The weight of equipment for a Dakota detachment of three aircraft and forty-five personnel is approximately 75,000 lbs. which gives some idea of the effort involved.

Many of the earlier problems encountered by the photo crews have now been eliminated or solved through the use of long-range aircraft and the availability of northern bases. The problem that still retains its formidable stature and determines the area that can be covered in a season

is the weather. The retreating winter season is followed closely northward, and the work is done on the heels of the melting snow and ice. In some areas convection cloud forms as the land warms, and it is not unusual to find only a few days during the entire season suitable for photo operations. To obtain coverage of these areas the R.C.A.F. must be on the spot, ready to fly 10 to 15 hours a day, while conditions remain good, a feat made possible by nearly continuous daylight during the summer months.

To reduce the flying required to check weather and to be able to concentrate available aircraft on an area where weather conditions are suitable for photography, a system of control has been worked out with the Meteorological Division. Certain centres are chosen to supply meteorological information to the survey squadrons and, where possible, the Department of Transport assigns an extra forecaster at these centres who passes special forecasts to the detachments. The aircraft may then be moved from one base to another to take maximum advantage of the weather. In some cases quite extensive communications channels have had to be set up. For instance in 1948, when operations were being carried out in Baffin Island and northern Quebec, meteorological data from the northwestern Arctic was picked up by R.C.A.F. field units from the Department of Transport at Coral Harbour and then passed to Goose Bay through the R.C.A.F. unit at Fort Chimo. Had normal Department of Transport channels been used the data would have had to be sent to Edmonton and Winnipeg for re-transmission to Goose Bay and the delay caused would have been too great for the data to be of use in the survey operations.

The normal day on a photo detachment starts at about 3 a.m. when the duty crew checks the final weather forecast and prepares to make a flight to check actual weather. The first aircraft are usually off by 5 a.m. and if clear conditions are found the other aircraft are called by radio and take to the air. Where areas are widely dispersed two aircraft will go out from the same base on weather checks if forecasts are at all favourable.

On the average flight the aircraft is climbed gradually to approximately 10,000 feet and the flight in search of clear areas continued at that altitude. In this way a great deal of oxygen is conserved since many flights prove fruitless. This is important since it requires three high pressure bottles of oxygen to replenish an aircraft's system after approximately 10 hours of use and each of these bottles weighs 155 lbs. Waste-fulness would soon cause a serious problem of resupply.

When a clear area is sighted the aircraft climbs to 20,000 feet and the crew makes final preparations for the photo line flying. Cameras are given a short test run, the solar navigator (an adaptation of an astro compass) is set up, and the aircraft is trimmed carefully for straight and

level flight. The trips to the operational area are done on Dead Reckoning navigation since maps are very inaccurate. A three course wind¹ is usually found before starting down the first line to give the navigator a course to fly and to help him in checking the end of a line.

Once the area is reached the navigator becomes virtually the captain of the aircraft and directs the pilot to the beginning of the first line to be attempted. Turn onto line is done about 15 to 20 miles back from the start of the line shown on the map. The drift is checked carefully and



Photo: R.C.A.F.

Photo survey Norseman refuelling from drums at Sawmill Bay.

the solar navigator started. Meanwhile the camera operator checks the interval and drift on his view finder and levels the camera. As the start of the line approaches the navigator gives the order to start the camera.

On the line the navigator is very busy checking drift every ten minutes at least and making new settings on the solar navigator. In between times he is trying to pick up pin points and also sketch in on his flight line map any details which might help him on his next line. This latter takes a lot of experience and the degree to which a navigator can learn to sketch generally measures his success at flight line flying in the north where maps are most inaccurate.

The second pilot assists the navigator in map reading while the first pilot is occupied in maintaining the required heights within ± 50 feet and

¹Previous to flying photo lines determinations of the drift are made on three headings and with knowledge of the true air speed the wind velocity can then be calculated on a navigational computer.

holding course to within less than 1 degree. This calls for intense concentration and not all pilots can measure up to this exacting requirement. When flights last as long as 10 hours the two pilots and the navigator are very weary indeed by the time they reach base again. Even those crew members who are not engaged in such exacting tasks are tired out after 10 hours at 20,000 feet on oxygen.

One of the major problems in the north is maintaining direction. The best magnetic compass becomes erratic in higher latitudes and the

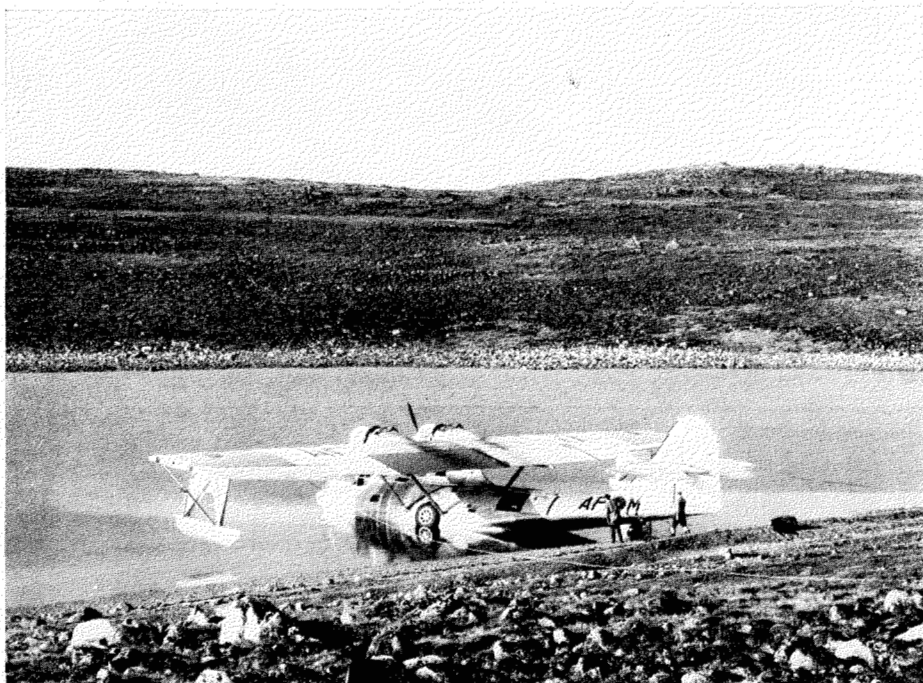


Photo: R.C.A.F.

Photo survey Canso being hauled up the beach at Ross Bay, Melville Peninsula, for replacement of damaged nose section and propellor.

vacuum driven gyros do not stand up very well. Even gyros corrected for the mean latitude of the operations may go unserviceable and precess excessively after a very short time. The solar navigator is used to direct the pilot for straight line flying, and the astro compass is used to supply settings for the gyro instruments.

Another major problem is servicing the aircraft in the more isolated bases. No hangars or other permanent facilities are available at such places as Norman Wells, Yellowknife, or Coral Harbour, and the work must be done in the open, in rain, snow, or sun as the case may be. Dust is another constant torment to the hard-worked ground crew. Refuelling has to be done from barrels and even with portable electric or gas operated pumps this is a long process. Often the caches are established some distance from the nearest taxi area and the barrels must be man-handled

to the vicinity of the aircraft. In spite of the limited facilities remarkable records of serviceability are achieved. One squadron maintained 100 per cent serviceability on twelve aircraft for approximately a month during which they flew 1700 hours and covered 120,000 square miles of vertical photography.

Film exposed in the field by the survey planes is shipped to No. 1 Photo Establishment at Rockcliffe for processing. Possessing one of the



Photo: R.C.A.F.

Laying down photographs to make a mosaic.

world's finest and most modern aerial photographic laboratories, this establishment plays a vital part in the overall photo survey program. The exposed rolls of film are sent in with a full report listing the area covered, weather conditions at the time of exposure, height and speed of aircraft, and other details. The film is put through continuous processing machines for development, and is turned out at the rate of 5 feet a minute. The negatives are then placed on annotating tables with glass tops lit from underneath. Here the film is given an initial check for accuracy and quality, and each negative is numbered to allow instant identification. Possible gaps in the area being covered, caused by camera failures or lack of forward overlap, are spotted at this stage. Highly skilled personnel are required, and the ability of the establishment personnel to analyse camera faults quickly from the negatives and pass the information to the

detachment in the field has been an important factor in reducing the amount of film wasted in recent years.

The negatives are then printed and laid out in a mosaic. The mosaic shows whether any lateral gaps exist as a result of errors in navigation. The lay down, as this mosaic is called, is photographed and, if there are gaps, the detachment which flew the lines is notified and prints of the lay down are sent out to be used in doing the re-fly. In the past only the latitude and longitude of each end of the gaps were sent to the detachment and with the inaccuracies of the existing maps it was not uncommon for two or three attempts to be made before complete coverage was obtained. The present method of checking and re-flying gaps has proved most effective and has reduced flying time to a minimum.

All negatives taken for the government are stored at No. 1 Photo Establishment and are indexed at the National Air Photographic Library of the Department of Mines and Technical Surveys. The centralizing of all processing and storage of negatives has permitted rigid control of quality and has contributed materially to the success of Canada's aerial survey program.

The R.C.A.F. is not responsible for map making. The finished prints are turned over to the Department of Mines and Technical Surveys or the Army Survey Establishment which are responsible for the compilation of maps.

Canada's aerial survey program has not only made it possible to map vast areas of the country that were previously almost unknown, it has also revealed startling inaccuracies in existing maps. In 1934, for instance, it was discovered that on current maps Akimiski Island in James Bay was lying north-south instead of east-west, and in 1948 photo survey aircraft rediscovered two uncharted islands in Foxe Basin, with a total area of more than 5500 square miles. Although the government's survey program is primarily designed for the compilation and correction of maps, the air photographs serve many other purposes. They have proved to be useful in mineral exploration, water power development, forest and agricultural surveys, and town-planning investigations and are made available to both government agencies and commercial organizations.

As of December 1950 2,391,300 square miles vertical and 2,176,300 square miles tri-camera photo has been obtained by the R.C.A.F. There remains approximately 10 per cent of Canada which has not been photographed. That these figures add up to more than the accepted land mass of Canada is explained by the fact that vertical coverage duplicates the tri-camera and some areas are re-flown at a different scale. Today tri-camera photography of the north is practically complete and future effort in this area will concentrate on vertical photography for detailed mapping and the completion of Shoran control.