mounted over the bands under light spring tension to prevent damage in case of band failure.

Reversible electric-motor drives are provided to directly vary magnification, lens tilt and easel tilt. Switches in a walk-around hand-held control box actuate these three motors through relays. Negative carriage tilt is automatically maintained at the Scheimpflug[3] condition by the Carpentier inversor. Limit switches safeguard all power driven motions against exceeding mechanical limits.

These instruments were originally delivered to the Ground Photogrammetry Section at Wright-Patterson Air Force Base, Ohio, and successfully passed acceptance tests at that installation. They have since been moved to the U.S.A.F. Aeronautical Chart and Information Center at St. Louis in order that additional tests may be performed with respect to operational suitability for mosaic compilation from high-oblique aerial photographs.

References

1. Chapter IX, MANUAL OF PHOTOGRAMMETRY, 2nd edition, The American Society of Photogrammetry.
2. The Pythagorean and Carpentier inversors are fully described in *Photogrammetry*, by O. Von Gruber, American Publishing Co., and more recently in Reference 1.
3. The Scheimpflug condition specifies that for sharp imagery, the object, lens, and easel planes, extended, must all intersect at a common line in space.

*Mapping for the Mid Canada Line**

COLONEL C. H. SMITH,
Director of Military Surveys,
Army Headquarters, Ottawa, Can.

ABSTRACT: *The Mid-Canada Line is part of the North American Radar Early Warning System and it is being constructed and paid for by Canada as her major contribution to this system. Siting of the radar station required a strip of 1:50,000 mapping fifteen to twenty-five miles wide extending across the continent at roughly the 55th parallel of latitude.*

This mapping was carried out by the Army Survey Establishment with the extensive assistance of other Canadian Government mapping agencies. Much use was made of radar altimetry and shoran controlled photography. The great value of these two new tools, where the terrain is difficult and time is an important factor, was clearly demonstrated.

THE North American Radar Early Warning System consists of three lines of detection stations. In the south, generally in the vicinity of the United States-Canadian border, there is the "Pine Tree" line. Roughly along the 55th parallel of latitude is located the "Mid Canada" line. In the far north, the "DEW" line is being established. While the construction of these systems is part of the co-ordinated United States-Canada defence programme and a high degree of international co-operation is involved in all three, the "DEW" line is basically a United States undertaking, whereas the "Mid Canada" line is being built, and paid for, by Canada. The latter is therefore the project which we in Canada have been most intimately associated from the mapping point of view, and it is the purpose of this paper to outline the general methods we employed in that mapping.

The requirement was for a strip of maps at a scale of 1:50,000 with a 25 foot contour interval having a minimum width of fifteen miles extending from coast to coast. Since there was insufficient time for additional ground surveys, it was agreed that

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while each section of the strip was to be of normal relative accuracy, some deviation would be permitted in absolute accuracy to cover the case where long extensions between control were necessary. Although accuracy was important, time was the paramount consideration; the construction programme demanded that we produce at a rate of 100 lineal miles of mapping per week, starting early in April 1954.

In a project of this type it was obvious that there would be a great variation in the quality of the material available. The air photography for example, ranged from sparse trimetrogon to recent medium and high altitude vertical. But the larger part of the area was covered by nothing better than either the trimetrogon or by poor and almost random vertical photography. In no case did flight lines bear any relation to ground control, and lateral overlaps varied from almost 100 per cent to actual gaps. Existing photography over about a quarter of the route was, however, generally usable but it was necessary to arrange for new photography to cover the remaining three quarters.

The existing control too ranged in density from almost adequate to zero. In general, horizontal control was available for the portion west of Hudson Bay where the skeleton land-survey system intersected the route at intervals that varied from 30 to 150 miles, but non-existent east of that feature. The vertical control was everywhere inadequate, although in the west most of the land-survey lines had been spirit levelled and, sparse though these lines were, they did provide a datum for radar altimetry. The most difficult area from the control standpoint was Quebec—Labrador. The horizontal control consists of these four trilateration stations plus a small area of third-order triangulation. Barometric altitudes had been determined at the primary stations and, in addition, elevations were available in the small mapped area.

In March 1954, in view of the winter conditions still prevailing in northern Canada, it was not possible to take immediate action to provide additional photography or horizontal control. It was however feasible to begin radar altimetry. This was laid out in flight lines at about four-mile intervals laterally and straddling the proposed route. Figure 1 indicates the plan for elevation control in the Quebec sector. To ensure against major local discrepancies, we specified a number of cross-flights and started our adjustment by closing the return circuit from the Atlantic Ocean to Lake "A." We then used a return cross-flight from Lake "C," whose elevation was known, plus a closed circuit from

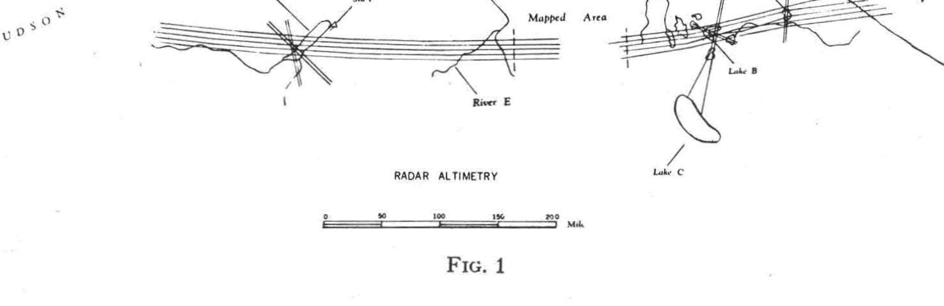

Fig. 1

Lake "A" and plus a similar closed circuit from the mapped area to establish a mean elevation for Lake "B." While we did have more basic vertical control in other areas, this was the general method of adjustment followed throughout.

On receipt of the radar altimetry for the western portion where photography existed, it was accordingly treated in this way. With the existing horizontal control, it provided us with sufficient data so that we could proceed with the plotting in Manitoba. This work progressed slowly due to the poor quality of the photography and the difficulties in adjusting and identifying the control. However, by the end of April the job was well in hand and the first one hundred miles had been completed. Thereupon occurred one of those things which happen so frequently in time of war, but which we do not expect quite so often in peace-time. *The plan was changed! Not by much; just by enough to move the Mid Canada line clear of the area we had mapped.* Consequently, by the first of May, we had accumulated quite a lot of useful experience but very little mapping. Meanwhile specifications were being written for the shoran-controlled photography in the Quebec-Labrador area.

The flight lines for the vertical photography were laid out parallel to the proposed route, but since this was by no means firm at this stage, we asked for a much wider band of photography than we expected to use. Because of the urgency, we decided not to attempt shoran control of all the photography as it was taken. So the normal photography from 20,000 feet above sea level proceeded while the shoran stations were being installed and "fixed" by trilateration. The grid of shoran control flights was then flown over the basic photography with its axis approximately parallel to the line between sites. Cross-flights were flown at intervals of forty miles, and on either side of the primary line as many parallel flights were flown at twenty-mile intervals as could conveniently be controlled from the trilateration stations (Figure 2). This again provided insurance against a change in route and ensured this work being of the greatest possible use in the future general mapping of the area. The provision of this photography and vertical and horizontal control involved our Air Force in a major operation, and tied up about fifteen aircraft for most of the summer.

In the actual map compilation, we employed standard instruments and conventional methods. We used multiplex for plotting from photography taken from altitudes up to 20,000 feet, and Kelsh and Wild autograph equipment for altitudes up to 35,000 feet. We found it did not pay to conduct bridging and topographical plotting as one operation. It was better to make a preliminary rectification set-up and then to produce a minor controlled

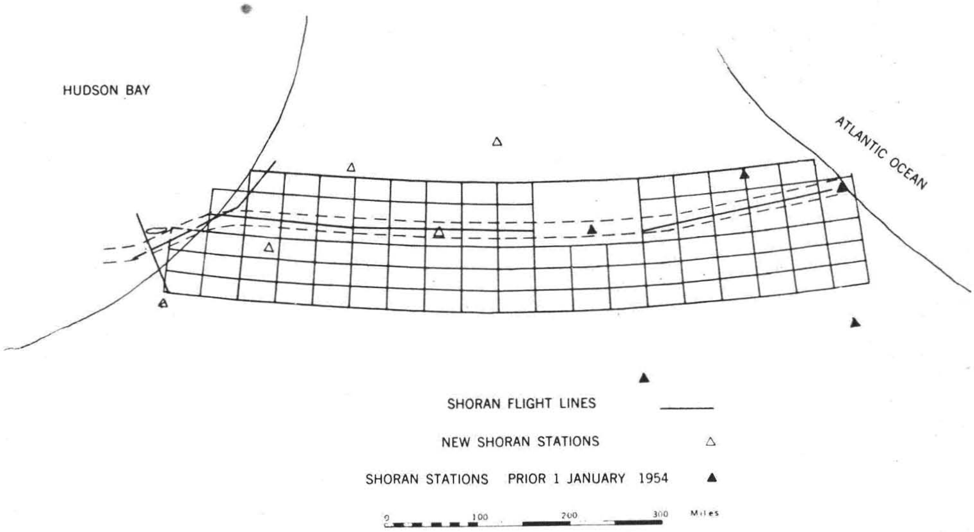

FIG. 2

block adjustment using stereo templets even though this meant setting up many models twice. In fact, where plumb-point determination of shoran co-ordinates was necessary, some models were set up first for this purpose, making a possible total of three set-ups. To determine the plumb-point positions from the shoran co-ordinates, sets of three overlaps were set up in the multiplex and levelled on bodies of water or radar profile values. The set-up was scaled to the plotted positions of the shoran plumb points of the two outside models, and the discrepancy between the plotted positions and shoran co-ordinates to the center plumb point was scaled. Where this discrepancy was less than twenty meters, the mean position was accepted. If not, an additional model was set up at each end of the group, and an attempt was made to eliminate the error by rescaling the two end models and checking the intermediate positions. If, in spite of this, there was still a disagreement, the entire set was discarded as unreliable. This however occurred in only about three percent of the cases. Our method of relating the shoran co-ordinates to the ground could undoubtedly be refined and improved but, as with every other phase of the project, it was conditioned by the time limits imposed.

Detailed organization and close supervision of the work were necessary to permit simultaneous operation by a large number of plotters in order to minimize the difficulties of matching work edges. The complete strip was divided into sheets, each covering 20 miles; where feasible, we worked alternate sheets so that the same diapositives would not be in demand by operators in adjacent sheets. Because the priority of the work was generally from east to west, each section of 100 miles more or less had to be delivered as quickly as possible in this order. It was therefore necessary to concentrate our operations, and to employ a maximum number of plotters in each area. The work was inked at the multiplex plotting scale and this inking constituted our final drafting. These drawings were photographically reduced, printed on a stable base material, and these latter prints were assembled to form the map compilation. To this compilation, contour numbers were adeed, also names, etc., and the compilation was then re-photographed for reproduction. The details of the end product are scale 1/50,000, 25 foot contour interval, sheet size 22″ ×29″; all detail in black except for a blue water fill on lakes and wide rivers. The total job consisted of 125 of these sheets. The appendix provides further statistics.

This project was a good example of co-operation of the many Canadian Government and private mapping organizations involved. The radar altimetry was carried out by 408 Squadron R.C.A.F., with technical assistance from the Aeronautical Charting Section of the Department of Mines and Technical Surveys. The shoran was a joint venture of the Geodetic Survey of Canada and 408 Squadron R.C.A.F. The necessity of covering a wider area to allow for changes in line position made the photography a major task which was completed by the R.C.A.F. and by private contract. About three-fifths of the plotting was completed by the Army Survey Establishment, another fifth by the Topographical Survey and the balance by contracts by the Photographic Survey Corporation and Canadian Aero Services Limited. Over-all organization of the project was an Army Survey Establishment responsibility, as was the final reproduction work. In listing the agencies participating, I express our appreciation for the services of two excellent multiplex operators from St. Louis, loaned to us by ACIC.

Had the project been straightforward with control and photography available as required, it would have been possible to complete it in much less time than it actually took. As it was, work had been under way for four months before snow conditions permitted any new photography, and it was another three months before all the photography was available and before the shoran control was finally computed. It was therefore not possible to use all the available plotting power until some seven months had elapsed. We started in March 1954, with eighteen tables of multiplex. This was stepped up to 30 by July and in November we were able to add the equivalent of another ten tables. However, by January, as the area left to map became smaller, we had reversed the trend because the law of diminishing returns placed definite limits on the number of plotters it was feasible to employ. At the conclusion of the project in March, 1955, only four plotters were in use.

Other unforeseen factors, that had an

adverse effect on the progress, were difficulties in making an effective use of existing control and photography, the exceedingly intricate pattern of the topography in Eastern Quebec and Labrador, and minor changes in the location of the line that increased the width of the area required in several places. Despite our not taking these things into account in our original estimate, we did not fall short of our delivery target. We take some pride in the successful execution of what was, to us at least, a very big task. Although we have not been able to make any rigid tests, all evidence supports our opinion that the accuracy attained is well within the tolerance specified. The maps have proved to be completely adequate for our particular purpose and I believe they will serve any other purpose for which 1:50,000 maps may be required within the foreseeable future. Perhaps one of the most significant features of the entire project was the effective co-operation of the Federal Civil and Military mapping agencies and of private firms to meet a national need.

Appendix

Supplementary Data

New vertical photography	104,500 sq. miles
Shoran controlled photo flights	8,100 miles
New shoran ground stations	5
Number of lines measured by shoran crossing	24
Air-borne profiles (radar altimetry)	14,184 miles
Total area mapped	38,625 sq. miles
Total number of map sheets produced	133
Approximate length of line mapped	2,050 miles
Number of photogrammetric models set up	3,887
Average elapsed time per map sheet	19 days
Average work per map sheet	
compilation	78 man days
reproduction	4 man days
Work progress on lineal basis	82 miles/week
Progress on area basis	1,470 sq. miles/week
Multiplex compilation scale	1/15,000
Publication scale	1/50,000
Contour interval	25 feet

Airborne Magnetometer Survey in Guatemala

Flying of a survey covering over 40,000 square kilometers of unmapped jungle in northern Guatemala was started on Feb. 11. Aero Service Corporation is performing the survey for 15 major oil companies.

A specially modified DC-3 based at Guatemala City, is being used. Aero Service installed the magnetometer in a tail or "stinger" position, rather than trailing on a cable 60 or 70 ft. below the aircraft. The Douglas carries the recording instruments. Shoran is used to guide the survey plane because few roads, towns or other landmarks break the dense jungle cover in the survey area. The mapping pilots are flying at a mean average clearance of 1200 feet above terrain, on a grid of north-south lines spaced at 2 kilometer intervals and east-west lines spaced at 15 kilometers.

The Shoran data will provide 200 control points as the network for ground surveys to establish oil companies' concession boundaries. This is believed to be the first such use of Shoran for land surveys. It has the approval of the Guatemalan government. Flying and field operations will be finished in four months. Shoran data and magnetic maps will be delivered next October. The survey will cost about $500,000.