E. A. FLEMING
Department of Energy, Mines and Resources
Ottawa, Ontario K1A 0E9, Canada

Positioning Off-Shore Features with the Aid of LANDSAT Imagery

Shoals in Ungava Bay, Quebec were located with an RMS error of 20 metres when positioned to photogrammetrically derived control.

ABSTRACT: *LANDSAT imagery has been used to position off-shore shoals in Ungava Bay, Quebec, for the completion of a 1:50,000 map. Map-identified control points and photographically identified photogrammetric points were used in independent adjustments of four Landsat images. The most satisfactory results were obtained with photogrammetric control, where the RMS error of the average position for the image points was 20 metres at control. The positions determined for shoal points were used to position aerial photography for plotting the map detail.*

INTRODUCTION

THE PHOTOGRAMMETRIST likes to believe that he can solve most mapping problems, but one of the nagging problems that often eludes his grasp is that of positioning off-shore features that are separated from mainland control by water gaps in the photogrammetric models. For a country such as Canada, with 243 382 km (151,489 mi.) of coastline and more than 52,500 islands, this problem places an added burden on the resources allotted to field surveys, be they topographic or hydrographic, for if the feature cannot be positioned photogrammetrically, its location will not be established until it has been occupied by a ground (or sea) survey crew. The problem is not confined to coastal features. Many lakes in Canada also present water gaps in the 1:60,000 photography used for topographic compilation.

One of the potentials of satellite imagery that makes it attractive to the photogrammetrist is the large area coverage of a single image. Water gaps of 100 km could conceivably be bridged with imagery such as that obtained from LANDSAT if the geometry of the image were known and if ground points could be identified precisely. The ground positioning capability of space imagery has been investigated a number of times[1, 4-6] but it takes the exigency of a mapping project to force its practical use.

UNGAVA BAY SHOALS

In the Ungava Bay region of northern Quebec there are areas where rocky shoals exist off-shore. The tidal range in the Bay is about 13.5 m (45 ft), which at low tide exposes rock ridges about 4 km long, 20 km from the mainland. These larger shoals are, of course, surrounded by many smaller ones. They were plotted during the 1:250,000 mapping of the area by spacing out aerial photography, assuming constant forward overlap and azimuth on those flights that extended out from the coast. In 1975, 1:50,000 mapping progressed into this area and the sheet boundaries for one of the maps indicated that, on the basis of the 1:250,000 maps, shoal areas would occur in one corner

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of the sheet. The area is illustrated in Figure 1. No new position information was available for these shoals from ground surveys. The only new source of data was LANDSAT imagery. A search of the available imagery turned up four coverages on two adjacent orbital paths that showed the area under almost cloud-free, ice-free conditions. Three of the coverages were at high tide and one was at low tide. The low tide image showing the extent of the shoals is shown in Figure 2.

DESCRIPTION OF THE IMAGERY

The imagery used for this project was produced by the Canada Centre for Remote Sensing from satellite transmissions received at the Prince Albert Satellite Station.

Although produced by slightly different techniques,[3, 7] the geometry of the image should be comparable with that of NASA bulk imagery. The working negative is a 1:1,000,000-scale enlargement of the original 1:3,370,000-scale 70 mm positive generated by the electron beam image recorder.

The four images available for the study are listed in Table 1.

The choice of band was based on a visual inspection for the best definition of possible control points. Since these were either water features such as lakes, or sea features such as small islands, the infrared bands gave the best discrimination, and in two instances provided useful images even in the presence of thin cloud. Image 15-19-62 had been created on two different occasions in the EBIR and both negatives were used in the measurements. Since the area involved was only a portion of a LANDSAT image, it was possible to produce, by enlargement, 9 by 9 inch diapositives of the area at a scale of 1:350,000 from each of the images.

IDENTIFICATION OF POINTS TO BE MEASURED

In photogrammetry the position of a point cannot be established any better than its identification, and precise identification of natural points in a LANDSAT image is difficult. Although interesting work has been

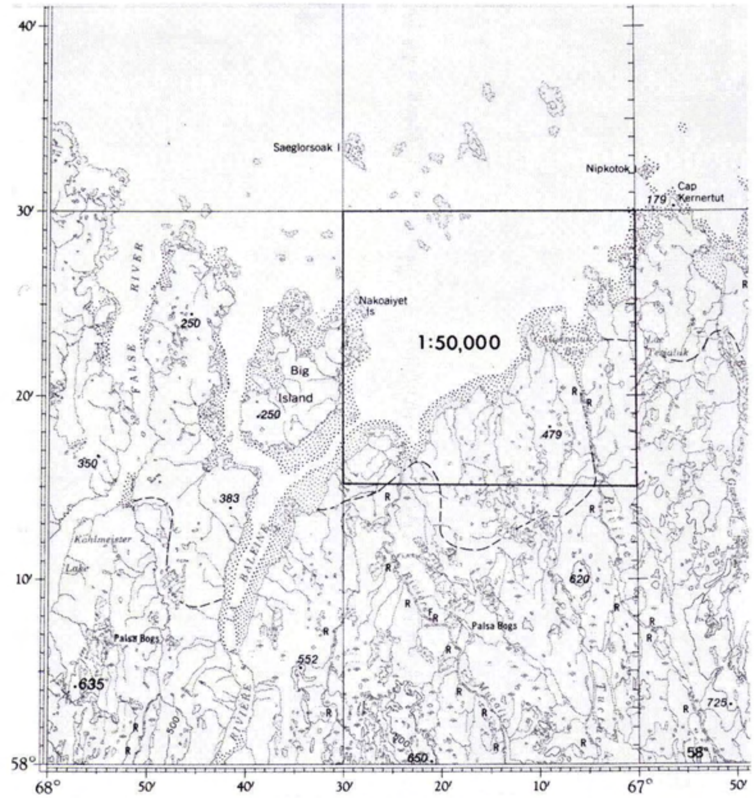


FIG. 1. 1:500,000 map of the project area showing the off-shore shoals and the particular 1:50,000 map area for which shoal positions were required.

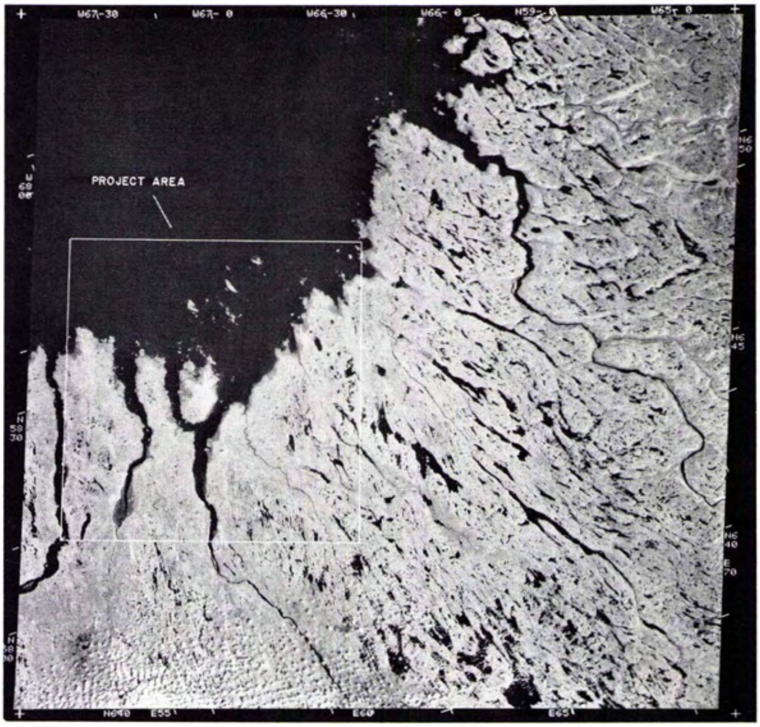


FIG. 2. LANDSAT image 15-19-22 (low tide) showing the shoal area in Ungava Bay. The outline indicates the area in which control points were selected and the adjustments made.

done in targeting points on satellite imagery[2], it is unlikely that such an approach would ever have application for the purpose described here, since targeting requires that the position be occupied by a ground party—precisely what one wishes to avoid in this case.

THE UNKNOWNS

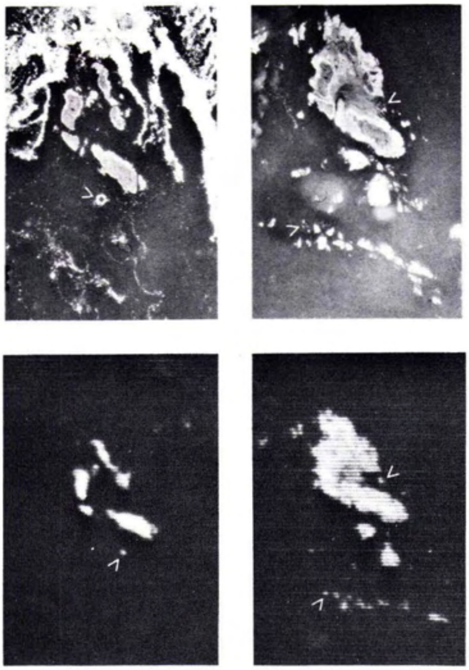
Points in the shoal area whose positions were to be determined were selected by comparing the aerial coverage with the satellite imagery and choosing shoal points which were just visible on the satellite imagery. Since there were both low tide and high tide aerial photos, these could be matched with corresponding images for two sets of unknown points. In general it was found that a detectable island on the satellite imagery was approximately 100 m across when measured on the aerial photographs. The center of the feature was chosen as the point. Examples of this type of point are shown in Figure 3.

TABLE 1. IMAGES USED IN THE STUDY

Image	Band	Tide Level	Date
15-19-19	7	high	June 19, 1973
16-19-22	7	high	Aug. 13, 1973
16-19-41	7	high	July 21, 1974
15-19-62	6	low	Aug. 2, 1975

THE UTM CONTROL POINTS

The control points fell into two categories, which were treated separately: (1) Map points, and (2) Photogrammetric control points. The map points were identifiable places on lakes whose positions were determined by reading the UTM map coordinates of the points from the newly compiled 1:50,000 map manuscript. These points suffered from the immediate limitation of how well one can define and measure the location of a natural feature on a map. It seems reasonable to put an uncertainty factor of about 20 m on this determination. The difficulty of defining this same "point" on a very fuzzy image compounds the uncertainty. It was decided to make the map-to-image identification once, and then transfer the point from this first image to each of the others in a PUG transfer device. A sample of this type of point is shown in Figure 4.



High Tide Low Tide

FIG. 3. The selection of target points in the shoal area by comparison with aerial photos taken at similar tide levels.

The photogrammetric control points were pugged minor control points whose UTM positions were known as a result of the block adjustment of control for the map compilation. The transfer of the position of a 60 μm pug hole on a 1:60,000 diapositive to a 1:350,000 diapositive was accomplished in two steps, one photographic and one optical. The PUG hole was marked with a 0.7 mm "Letraset" concentric circle and the diapositive photographed with a 35 mm camera. This produced a 1:380,000 control identification photograph which could then be used in a PUG-4 for stereoscopic transfer to the 1:350,000 LANDSAT diapositive. This smaller scale for the aerial image was chosen so that the zoom enlargement of the PUG might be done with this image rather than the LANDSAT image, which was already past useful enlargement (1:350,000 plus 6× PUG-4 enlargement).

The transfers were made to each image from the air photo identification. The indexing dot of the transfer device just fitted inside the circular marker and when the best fusion was obtained between images, the point was drilled. The LANDSAT image was oriented with the scan lines parallel to the x-axis. In some images this created a false stereo "washboard" effect due to x-displacements in the scan direction. The drilled hole was 60 μm or approximately 21 m at the scale of the LANDSAT diapositive. The photo transfer of points had the advantage that imagery surrounding the point was fused before the point was picked, whereas with map identification only the point itself was studied. As a result, points could be drilled with some confidence even when the imagery was quite poor at the point itself. An example of this type of point is shown in Figure 5.

ADJUSTMENT TO CONTROL

The diapositives were measured monocularly in a Wild STK-1 stereocomparator with the scan line direction oriented parallel to the x-axis of measurement. This permitted separate scaling in the scan direction and in the cross-scan direction prior to transformations in similarly and projectivity and the least squares adjustment to control.

MAP-POINT CONTROL

Of the 21 points initially identified and transferred, four points were eliminated because of blunders in identification (wrong lake or wrong point on lake) and two other points were discarded because poor imagery made the identification of the points very doubtful. The remaining 15 points were used for the final adjustment which yielded RMS errors in position between 39 and 52 metres (Table 2) for each of the images. Since each point was measured on at least three images an RMS error for the average position could be determined. This value of 44 metres RMS does not show any marked improvement in position as a result of averaging because the positions were not randomly scattered about the control. They tended to be grouped together, indicating a better cross-identification between images than between the map point and the first image on which the identification was made (Figure 6).

PHOTOGRAMMETRIC CONTROL

All 15 points that were identified photographically were transferred to all four images. Adjustment to photogrammetric control was achieved on the first computation. There were no blunders or anomalous points to eliminate. The RMS error at control ranged from 25 m to 37 m (Table 3) for the four images, and when the average position of each point was used, the R.M.S. error in

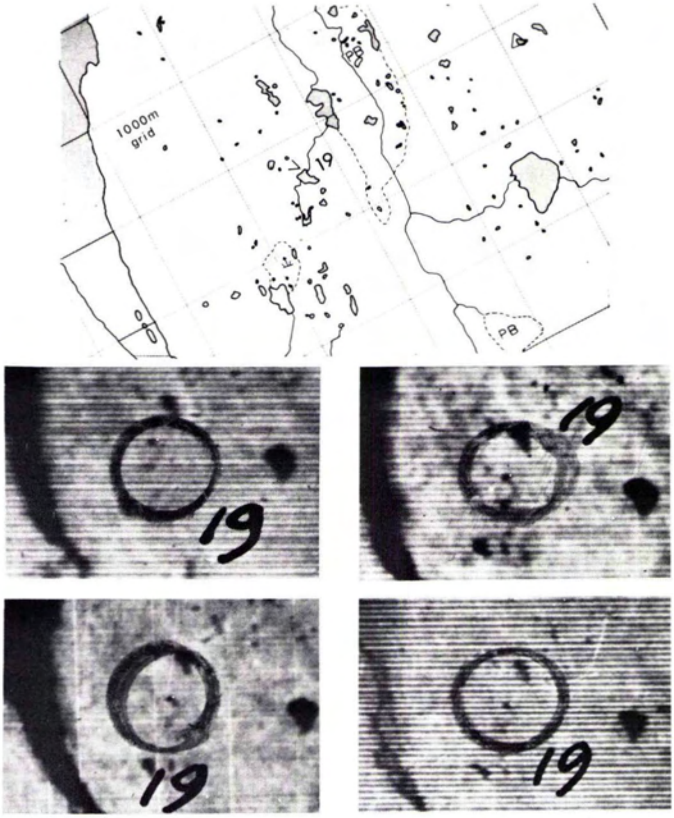


FIG. 4. A sample of a map feature used as a control point. The point is described as "the northeast point of the lake." Its identification on four satellite images is shown.

position dropped to a remarkable 20 metres (Figure 6).

POSITION OF OFF-SHORE FEATURES

The location of the off-shore shoals was such that the positions of the unknown points represented an extrapolation outside the control block. However, the deviation from an average position for these points, after adjustment to photogrammetric control, was 50 metres. This compares favorably with the 32-metre deviation on map-identified points in the same adjustment, particularly when one considers that the "points" themselves were even more difficult to define than the map-identified points.

The average positions of the shoal points determined in this manner were used to position the aerial photography over the area and complete the compilation of the 1:50,000 map. There was a position shift of about 800 metres between the position shown on the 1:250,000 map and that determined from the LANDSAT imagery.

CONCLUSIONS

This project represented an application of LANDSAT imagery in a production situa-

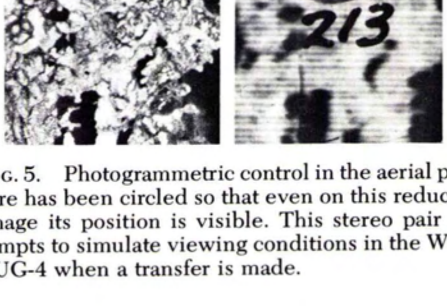


FIG. 5. Photogrammetric control in the aerial picture has been circled so that even on this reduced image its position is visible. This stereo pair attempts to simulate viewing conditions in the Wild PUG-4 when a transfer is made.

TABLE 2. ADJUSTMENT TO MAP POINTS

Image	Planimetric Coordinate Error (metres)	RMS Error in Position (metres)
15-19-19	29.5	41.6
16-19-22	35.8	50.7
16-19-41	36.6	51.8
15-19-62 (1)	27.6	39.0
15-19-62 (2)	37.6	51.1
Average Position of 4 images	30.9	43.7

TABLE 3. ADJUSTMENT TO PHOTOGRAMMETRIC CONTROL

Image	Planimetric Coordinate Error (metres)	RMS Error in Position (metres)
15-19-19	25.5	31.6
16-19-22	20.8	29.5
16-19-41	25.9	36.6
15-19-62 (1)	24.9	35.3
15-19-62 (2)	17.3	24.6
Average Position of 4 images	13.9	19.7

tion, using production materials and equipment. The RMS error of 20 metres at photogrammetric control was unexpectedly good and serves as an encouragement to apply the technique in other similar situations.

The exact position of these shoals is yet to be determined by a ground party, but the position determined by LANDSAT imagery is better than existing information. As a result of the adjustment to control in the project area, the more distant shoals, which have not yet been mapped at 1:50,000, are shown to be as much as 2000 m out of position on the 1:250,000 map. Their orientation could be improved and there are other shoals present that were missed on the aerial survey flights.

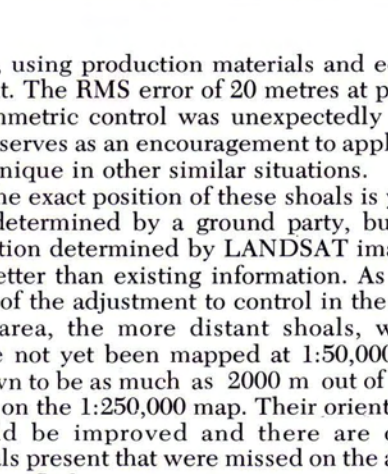


FIG. 6. Plots of the position of points after adjustment to (a) map control and (b) photogrammetric control shows, characteristically, that the map-identified control points were not so randomly distributed about the U.T.M. value as the photographically identified control points.

The results obtained from the two methods of control identification confirmed what is already well known in photogrammetric procedures, that photo-identified control is superior to a descriptive identification. Stereo-transfer eliminates blunders, it can be made even onto poor imagery, and the overall adjustment to control is considerably improved.

ACKNOWLEDGMENT

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BOOK REVIEWS

European Organization for Experimental Photogrammetric Research (OEEPE) Publication No. 10. Printed and Published by the Institut für Angewandte Geodäsie, Frankfurt a.M., W. Germany. 17.5 cm × 24.2 cm.; 158 pp. Numerous line-drawn illustrations (several in color), paper back; publication date: November 1975. Price DM 26,50 plus mailing costs.

Official reports of this type often tend to run the familiar gamut from how-we-did it to it-is-possible-to-do-it. This volume's value, which should not be underestimated, lies in the opportunity to hear an international (largely north western European) orchestra play not only familiar tunes but some new compositions as well. The report gives interesting information.

It comprises four separate elaborated reports given in French, followed by a short version in English. The English versions are more or less extended abstracts (although they contain most of the relevant information).

The first report by H. Härry, "Measurements of Non-Signalized Points in the test field Oberriet", broadly concludes "that the accuracy of the photogrammetric measurement lies within the uncertainty of identification." [Note: A r.m.s. planimetric error of ±24 cm with unsignalized points against ±8 cm. with signalized points during the same working process.] The author aptly points out that "the same uncertainty applies also to the field surveyor when he is looking for spots to mark his boundary points."

The second report is by A. Stickler and P. Waldhäusl: "Graphical Plotting of Non-Signalized Points and Lines, and Comparison with Terrestrial Surveys in the test field Oberriet." The study indicates that for graphical plotting in scale of 1:2000, photogrammetry gives a point-by-point accuracy equivalent to the field survey techniques (polar method of survey based on triangulated points with optimum accuracy for the test field survey). Furthermore, it was noticed that "interpretation can be done more easily and more exactly from the air and a greater certainty is demonstrated in the aerial survey method. . . The survey of objects and lines is more complete and more true to nature."

The third paper is by R. Förstner: "Further Results from Co-ordinate Transformations of the Test Oberriet of Commission C of the OEEPE". It is observed that the affine transformation of the model coordinates showed a gain in the accuracy with film photographs (r.m.s. errors decreased by 30 percent as compared with the results of the conformal transformation). It was noticed that the direction of the axis of affinity coincides with the direction of flight, this indicates that the affinity is caused by film shrinkage. Furthermore, the larger base-height ratio with wide-angle photography is only of partial effect on the height error. Alas, with increasing height and with decreasing photo-scale, respectively, one obtains generally smaller planimetric and height errors in "μm in the image."

The fourth (and last) paper by K. Schürer concerns the comparison of photogrammetrically measured distances in the "Oberriet" test field. Some interesting conclusions are drawn:

"The results demonstrate:

(a) a minor dependence of the distance-error on the projection enlargement in the restitution instrument.
(b) a dependence of the distance-errors on the photo-scale.
(c) the independence of the distance-errors of the distance (length), if both terminals are situated in different models.
(d) a dependence of the distance-errors on the distance (length) if both terminals are in the same model."

The collection is an interesting study. Although published with some delay (about 10 years), the results are of benefit today.

—S. K. Ghosh