(14)

Evaluation of SLAR image quality and geometry in PRORADAM

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ABSTRACT

In this article the evaluation of the SLAR imagery of PRORADAM will be described, starting with an outline of its organization, then analyzing the contract and extracting the information relevant to the evaluation. Next, the results of the control of image quality and geometry are discussed, together with the standards applied whenever there was freedom in the contract to set these standards. In the ultimate section the conclusions are summarized and recommendations formulated for the further flow of activities relevant to cartographic aspects of PRORADAM.

RÉSUMÉ

Cet article évalue la valeur des documents obtenus par le radar latéral aéroporté utilisé dans le projèt PRORADAM. L'auteur commence par décrire rapidement l'organisation de ce projet, puis analyse le contenu du contrat et en extrait l'information qui lui permet de l'évaluer. Ensuite il traîte des résultats du contrôle de la qualité de l'image et de sa géométrie. En même temps il explique les normes qu'il utilise toutes les fois que le contrat le laisse libre de les fixer. Dans la dernière partie il résume les conclusions auxquelles il est arrivé, et formule des recommandations quant aux développements ultérieurs relatifs aux aspects cartographiques du projèt PRORADAM.

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0. INTRODUCTION

The aim of radargrammetric and image quality evaluation within the Colombian Project for Radargrammetric Mapping of the Amazon (PRORADAM) is to check the fulfilment of the specifications, according to the contract undertaken between the Instituto Geográfico 'Agustín Codazzi' and Messrs. Aero Service Corporation, U.S.A. These specifications concern the quality of the geometry as well as the type and amount of information present in the Side Looking Airborne Radar (SLAR) imagery of the area to be mapped.

For the planning and supervision of the evaluation of SLAR imagery, assistance was obtained from the International Institute for Aerial Survey and Earth Sciences (ITC), The Netherlands, which made the author available to PRORADAM for a period of 6 weeks.

Within this period, the contract for the acquisition of SLAR imagery had to be analyzed, a team of counterparts formed, the team trained, and the actual evaluation of image quality and geometry carried out.

1. PRORADAM

Mapping the Amazon basin with the help of Side Looking Airborne Radar (SLAR) imagery began in Brazil with Project RADAM in October 1970, and followed thereafter in Venezuela, Colombia, and Peru. All these projects have made use of a synthetic aperture SLAR system of the Goodyear Aerospace Corp., operated by the Aeroservice Corp., Philadelphia, U.S.A.

The Colombian PRORADAM (Proyecto Radargramétrico del Amazonas) aims at the mapping of about 360,000 km^2 of an area as shown in figure 0. The same aerial system was used for data acquisition as in the Brazilian RADAM, which is well documented in the literature (see [1], [2]). There are however two major differences between RADAM of Brazil and PRORADAM of Colombia:

- there is no continuous SHORAN tracking of the aircraft in PRORADAM;
- image sidelap is always more than 52% in PRORADAM, as opposed to the 25% sidelap of RADAM.

Naturally these differences resulted in data processing methods different from those used for RADAM. The present report elaborates only the first data processing activity after acquisition of the imagery, namely the checking of the fulfilment of the contractual requirements concerning image quality and geometry.

For PRORADAM, the Colombian Instituto Geográfico 'Agustín Codazzi' (IGAC) routinely co-operates with the Centro Interamericano de Fotointerpretacion (CIAF), and the Colombian Armed Forces (FFMM). Further support is obtained from a number of Colombian institutes in the field of the Earth Sciences, and from the Interamerican Geodetic Survey (IAGS), who measured 13 Transit Satellite Stations after image acquisition. These points will in future be the geodetic base for cartographic data processing.

Figure 0.
Proyecto Radargrammetrico del Amazonas (PRORADAM):
Locality Map

2. ORGANIZATION OF THE WORK

2.1 Planning

According to the contract between the Instituto Geográfico Agustín Codazzi and Aero Service Corporation, evaluation of the SLAR imagery had to be completed within 30 days of delivery. A delay in this delivery further reduced the available time to 24 days. This was a prime constraint in planning the work and determined the methods and manpower applicable to it. Table 1 lists the activities necessary to the evaluation of SLAR-imagery. Figure 1 shows a network plan for the evaluation. This plan could be adhered to fairly strictly.

LIST OF ACTIVITIES
Study of the contract
Design of evaluation procedures
Preparation of new (and modification of existing) computer programmes
Preparation of forms for image quality evaluation
Preparation of forms for radargrammetric evaluation
Recruitment of team of co-operators
Preparation of accommodation and instruments
Adjustment of measuring equipment
Preparation of training material
Training of team in radargrammetry
Training of team in radargrammetric and quality evaluation
Preparation of control points
Image quality evaluation
Identification, numbering and transfer of image points
Measurement of image co-ordinates of identified and transferred points
Punching of measured co-ordinates
Computation of block triangulation with SLAR imagery
Image geometry control
Preparation of report with results of evaluation

Table 1.

List of activities in radargrammetric and quality control of SLAR imagery

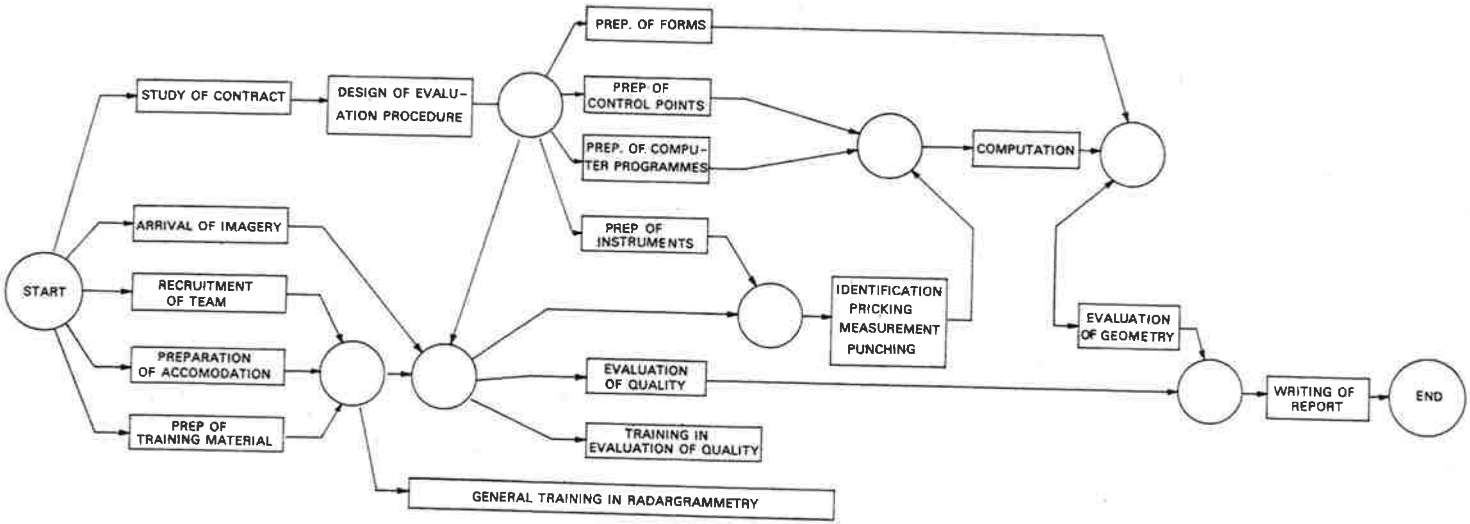

Figure 1.
Network plan for the evaluation

2.2 Team

The co-ordinator of PRORADAM, Dr. RODOLFO LLINÁS, had originally nominated three co-operators for the evaluation; these were:

- Dr. JULIO MURILLO, of the Centro Interamericano de Foto-interpretación
- Tte. Cor. ALVARO HERRERA, of the Colombian Armed Forces
- Dr. GERMÁN RODRIGUEZ, of the Instituto Geográfico 'Agustín Codazzi'.

These persons were selected on a basis of their capabilities as well as to represent the three organizations co-operating in PRORADAM.

This group of specialists was assisted by the author during the whole of the evaluation. In addition 4 photogrammetric operators were available for the identification and measurement of image points, as well as for other auxiliary activities.

2.3 Analysis of the Contract

It was originally intended to use the specifications of the contract between the Instituto Geográfico and Aero Service Corporation and to apply them strictly to the evaluation of the SLAR imagery.

A number of problems and loose formulation were, however, encountered, which made it necessary to specify in either more detail, or even to change, some of the specifications. This was done with the agreement of the co-ordinator of PRORADAM and a representative of Aero Service and is described in a separate chapter, 3.

2.4 Training of the Team

The aim of training the team of 3 counterparts was twofold: first a general introduction to side-looking radar and radargrammetry should be given; secondly, the training should also be specifically for the evaluation of image quality and geometry.

Originally it was intended to base the training on individual study and discussion with the author. As this turned out to be ineffective, the training subsequently took the form of daily lectures of 2 hours, which went on until the end of the evaluation period. Training in the principles and methods of evaluation was given at appropriate times in special classes. Due to the time constraint set by the 30 days deadline, general training in radargrammetry could only be in the form of the lectures, without practical excercises. Consequently it had to remain incomplete.

Training for the evaluation work proper was hampered by the lack of appropriate imagery. The quality of available imagery was generally either too good, or the type of imagery different from what was expected in PRORADAM.

2.5 Quality of Image Content

The quality of the imagery was evaluated on paper prints at scale 1:400,000. This was the first part of the work to be carried out and did not need any further preparation apart from training, which was given directly with the evaluation of the first few images.

A check list was prepared to assist in detection of any defects in image quality. The results of the analysis were entered in forms, as discussed in section 4.1.

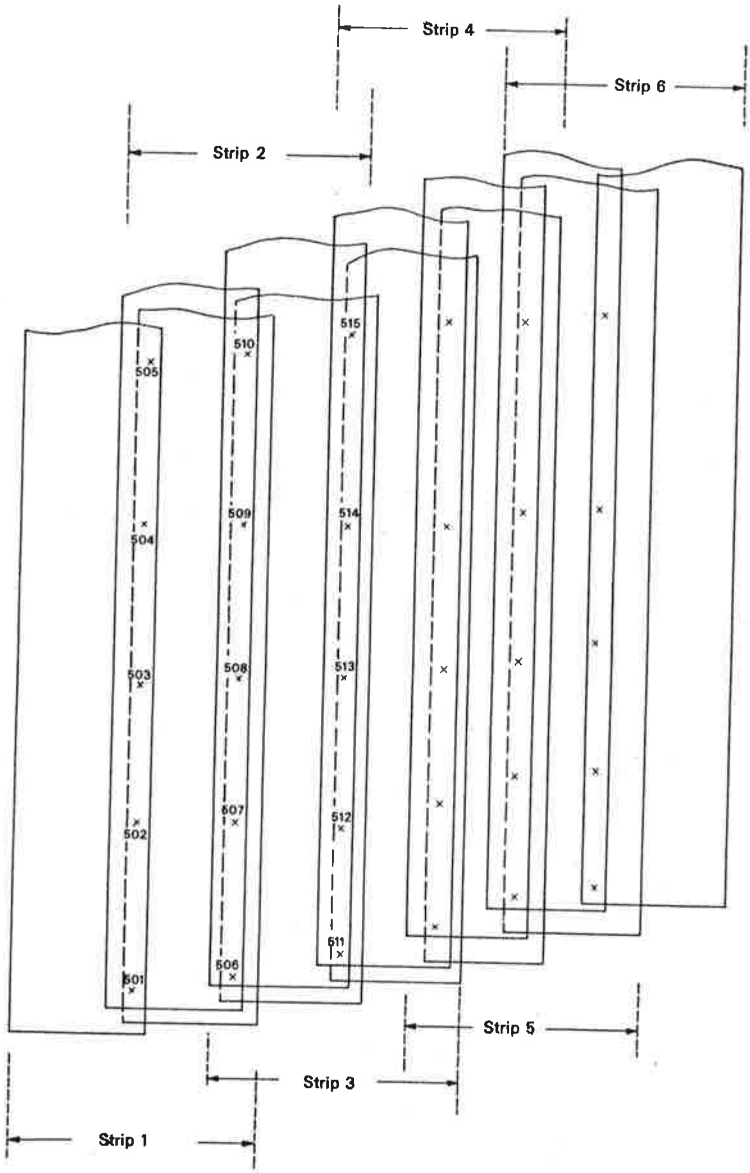

Figure 2.
Selection of tie points in a block of SLAR images with near and far range views having common overlap, and an overlap of more than 50% between adjacent strips

The evaluation of image quality was carried out by the three co-operators named in section 2.2. Each strip of imagery was then verified by the author. The whole block of imagery was finished in about 7 days. This means an average performance of 1700 km of flight line per day per man.

2.6 Identification and Transfer of Points

In the design of a procedure for the radargrammetric evaluation it was decided to base this evaluation on triangulation with the SLAR imagery, similar to photogrammetric block triangulation. This numerical procedure is based on the measurement of a large number of 'tie points' between overlapping strips of imagery. The computations are described in section 2.8.

Tie points are points in the common overlap of three SLAR strips, which is available if more than 50% of overlap exists between adjacent images. Figure 2 demonstrates the typical location of tie points in the common overlap of 3 different strips, and also the common overlap of the near, and far, range views of a single strip. Consequently each tie point is identified in 4 different views.

The triangulation procedure can also make use of ground control points. At the time of the evaluation, however, no such points were available.

To speed up measurement of the image points, which were by necessity made monocularly on a co-ordinatograph, all points were pricked with a fine needle in the emulsion on the film base. The process of identification and pricking was carried out simultaneously, using mirror stereoscopes.

In order to measure with adequate intensity, and still to finish the work by due date, it was decided to select points at approximately 20 cm. intervals along the flightlines. The total number of points to be identified was therefore 598, but each point was pricked on average four or five times, so that in total 3000 points were pricked. This work was finished by 2 operators in 11 days, so that about 140 points were pricked per man/day.

2.7 Measurements

The dimensions of SLAR strips, which are of up to 2.50 m long in PRORADAM, as well as the limited resolution, justify the use of a co-ordinatograph rather than comparators for the measurement of image co-ordinates. The instrument used in the evaluation was the Haag-Streit A.G. co-ordinatograph, with a range of 120 x 120 cms^2. Before using it for actual measurements, it was verified that the X and Y axes were perpendicular. Measurements were done by 2 operators, one reading, one recording. A sample of the recordings is presented in figure 4.

The accuracy of measurements could not be established independently from errors of identification and point transfer. Experimental evaluation of the total accuracy of point transfer and measurement resulted in a root mean square error of $\pm$ 0.2 m. For the long strips of more than 1.20 m, measurements had to be made in parts, each part with an overlap with previous ones but in a different co-ordinate system.

The time taken for measuring the 3000 image points was approximately equal to that necessary for identification and measurement, though with only one co-ordinatograph.

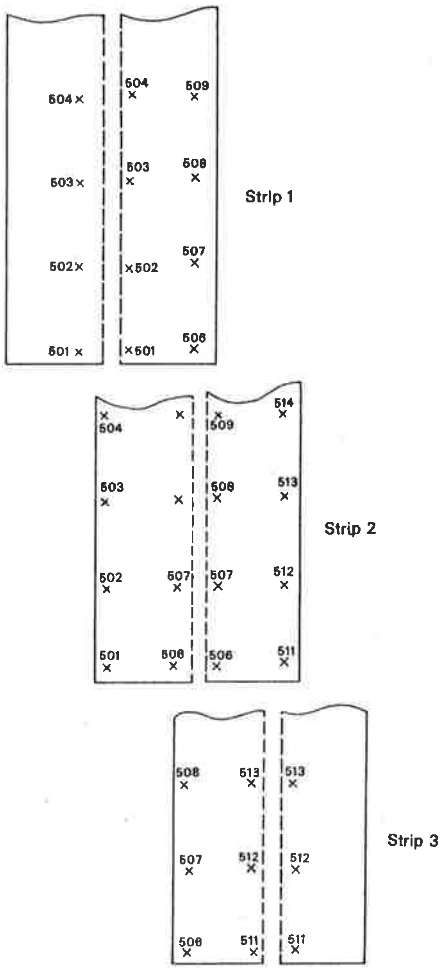

Figure 3.
Numbering of points in the near and far range views

FAJA	64/FR	Y	64/NR
	- 642.	.00	.00
	665.	258.50	160.25
	666.	247.40	141.22
	674.	235.89	132.45
	668.	421.35	142.11
	675.	452.46	136.69
	667.	445.82	178.25
	669.	570.19	143.20
	676.	623.70	137.49
	670.	614.00	170.60
	672.	725.22	155.72
	671.	740.40	140.60
	- 999.	.00	.00
	- 641.	.00	.00
	674.	236.03	106.85
	678.	234.43	70.25
	679.	408.42	70.65
	675.	452.60	111.00
	676.	623.95	111.90
	680.	589.60	71.65
	681.	750.35	70.00
	671.	740.65	115.00
	- 999.	.00	.00

Figure 4
Sample of recordings of measurements in the co-ordinatograph, of strip 64/near range (641) and 64/far range (642)

2.8 Computation

In total 5 computer programmes were prepared to assist in the evaluation of the image geometry. Due to the experimental nature of the problem, and the novelty of carrying out of a kind of block triangulation with SLAR images for the evaluation of image geometry, it was necessary to study alternative approaches to the problem. But the stringent time constraint did not allow for a complex approach.

The programmes were prepared for the unification of far and near range views, one using the tickmarks in the imagery, and the other using identical points in the common overlap of 5% between the near, and far, range view. Three more programmes were then made for the actual triangulation. An ANBLOCK programme had been brought from the ITC and was modified to account for the special in– and output requirements of the radargrammetric evaluation. This programme can make use of ground control points for block–adjustment. The other two programmes cannot make direct use of ground control points, but serves the purpose of block formation by transforming all individual images into a common reference, thus obtaining for each measured object point a single pair of co–ordinates in a block co–ordinate system.

These block co–ordinates can then be transformed into the system of geodetic co–ordinates using ground control points. This approach is the one applied in photo–grammetric strip adjustment or 'external' block adjustment (Schut) (e.g. polynomial). The two available programmes for block formation differ however in the type of transformation applied to individual SLAR strips. One version uses linear conformal, and the other an affine transformation.

It has not yet been pointed out that the basic unit in the computation was not a stereoscopic model, but single SLAR strips. This is fully justified by the fact that the area to be mapped is almost completely flat.

The unification of near and far range views could not be based on tickmarks for practical reasons: the marks were hardly identifiable in the available diapositives and also would have entailed a significant amount of extra measuring effort. Consequently this approach was not pursued. Due to lack of ground control, the ANBLOCK programme had to be used by selecting points in an arbitrary strip as ground control'. Unfortunately this made the system not very stable, and had the effect of causing large errors to occur throughout the block. In addition, the programme allowed for only 30 strips to be treated simultaneously.

It was found experimentally that the most effective programme for detecting gross errors ('blunders'), and for analysing image deformations, was a block formation with a linear conformal transformation. This was also found more convenient than using an affine transformation.

2.9 Quality of Image Geometry

The evaluation of image geometry was based on co–ordinate differences between 'adjusted' block co–ordinates and the transformed co–ordinates of a point in the various strips in which it appears. These co–ordinate differences ('errors') are thus the output for each independent strip. The 'errors' v_x, v_y of one strip were used to check each geometric specification independently. For this purpose, special forms were prepared. From the v_x, v_y errors of distances, scale and angular changes were then studied.

Unfortunately this evaluation could not be done completely mechanically. At times an image defect was found (by the mechanical approach) to be for example a change of scale in a cross-track direction. Checking showed, however, that actually the flight line was bent. In addition, the utmost care had to be taken throughout the whole activity, not to confuse errors of point identification and measurement with defects of image geometry.

The evaluation of quality based on the computed co-ordinate errors v_x, v_y took a total of 15 man/days, so that about 2900 km of flightline were evaluated per man/day.

3. CONTRACT

The contract can certainly be categorized as strict and complete in so far as a comparison between the specifications and actual technical and economic possibilities are concerned. Technical specifications in detail concerning the photographic processing were however completely omitted.

Some loose formulations, or slight contradictions, had to be resolved by mutual consent between a representative of Aero Service Corporation, the co-ordinator of PRORADAM, and the author. These modifications will be described in section 3.3.

3.1 Specifications of Image Quality

Table 2 summarizes the technical specifications concerning image quality as they can be extracted from the contract. These specifications contain the following controversial aspects:

- Specifications (a) and (b) refer to a sample of imagery, defining a reference for the quality of the image strips of PRORADAM. Unfortunately the portion of sample imagery concerned is part of a mosaic, and not original imagery. Also the sample imagery is on double weight paper, not on film. Consequently the range of densities cannot be measured in the Instituto Geográfico 'Agustín Codazzi'.
- Specification (c) concerning a dynamic range of 20 dB is loosely formulated, and does not specify where this range should be available (on the negative, the diapositive, or the paperprint). Photographically it is not possible to present a range of 20 dB, and certainly not on a paperprint. Nor is it possible to check, on production imagery, whether a range of 20 dB of received radiation, or less. is used for exposure of the datafilm.
- Specification (d) on image degradation due to rain does not mention clearly how the limit of 2% is to be assessed.

a.	Image quality must be equal to at least one of a sample included in the contract (5.3.1.13).
b.	The density range of the imagery must be equal to, or better than, the one of the sample included in the contract (5.3.1.11 and 4.1.9).
c.	The images must present a 'dynamic range' of 20 dB (4.1.8).
d.	Image degradation due to clouds or heavy rain must not affect more than 2% (4.1.7).
e.	The imagery must not show longitudinal or transverse banding, or the effects of electronic or mechanical malfunction of the equipment (5.3.1.4).
f.	Resolution in flight direction, or across it, must always be better than 23 m on the ground (5.3.1.4).
g.	Images must not be unsharp (5.3.1.9).

Table 2

Image quality specifications for PRORADAM (the numbers in brackets refer to the numbering in the contract)

3.2 Specifications on Image Geometry

The geometric specifications to be evaluated concern image geometry and the flight plan. Table 3 summarizes the specifications as they occur in the contract. The following controversial aspects were noted.

It is obvious, that specifications (b) and (c) contradict each other: A flightline spacing of 13.7 kms does produce an overlap of 63%, and not 56%.

Specification (c) is very reasonable as long as no reflights are necessary. To limit the validity of this specification to the first flight (but not to reflights) seems logical.

Specification (l) is technically impossible of fulfilment when applied to all image strips. An error of 0.5 km on the ground corresponds to 1.25 mm at a scale of 1:400,000. Strips are up to 250 cms long. An error of 1.25 mm in a distance of 250 cms corresponds to 0.5% or 1 in 2000.

Specification (m) requires a check of angular distortion every 12 cms along all image strips. This causes an amount of work barely practicable within the 30 days available for evaluation. Specification (m) should preferably refer to a distance of 12 cms 'or more'.

a. The mapping area as indicated in the contract must be covered in such a way that complete stereoscopy is obtained (1.2, 3.3.5).

b. The distance between parallel North – South flight lines will be 7.5 geographical minutes (3.3.2), or 13.7 kms (3.1).

c. The transversal overlap between adjacent flightlines will be 56% with not more than 4% variation (3.3.5).

d. The look – direction of the antenna will always be to the west (3.3.2).

e. Flightlines will be continuous and not shorter than 3 geographical degrees, unless national boundaries or the boundaries of the mapping area interrupt (3.3.2).

f. The flying height will be 12500 m above mean sea level (3.3.2).

g. The width of an image strip is 37 kms on the ground (3.3.2).

h. Angles of depression must be between 13^{o} and 35^{o} (3.3.6).

i. Near range and far range views of one image strip must have the same longitudinal scale, with not more than 1% difference (5.3.1.2).

j. Longitudinal scale must be uniform along an image strip, with not more than 1% variation (5.3.1.2).

k. Transversal scale must be uniform along an image strip, with not more than 1% variation (5.3.1.2).

l. The distance between 2 points must be the same if they appear in the overlap of different images, with differences of not more than 1%, or 0.5 km on the ground, whichever is smaller (5.3.1.2).

m. The angular distortion within one strip of image must not be more than 10 mrad, when measured every 12 cms at a scale of 1:400,000 (5.3.1.3).

Table 3.
Technical specifications for image geometry in 'PRORADAM'

3.3 Modifications of the Contract

In accordance with the ultimate statement of the contract, changes were proposed, discussed and accepted at a meeting between the co-ordinator of PRORADAM, the representative of Aero Service Corporation and the author.

The following change referred to image quality.

(d): The specification on the degradation of image quality due to rain must refer not to percentages nor to the area of an image strip. Instead, a strip will be rejected due to rain, if an area of 20 cms^2 at the scale 1:400,000 is lost to stereovision. This way an area of rain is cause for rejection independent of whether it occurs in a short or long strip. This formulation also offers the advantage of considering the fact of overlapping imagery. This consideration would not be possible in evaluating rain effects in each section of imagery without reference to adjacent strips.

The following changes referred to image geometry:

(b) and (c): Overlap between adjacent flightlines must be not less than 52%. Specification of a maximum overlap is omitted.

(c): The specification on the length of flightlines loses validity where reflights are concerned.

(1) Distance between pairs of homologue points in the overlap of image strips must be equal, with discrepancies of not more than 1%. The maximum error of 1.25 mm at a scale of 1:400,000 (0.5 km on the ground) will refer to mosaics only, where identical points on adjacent flightlines must be at distances of not more than 2.5 mm (scale 1:200,000).

(2) The distances at which angular distortion must be less than 10 mrad will not be shorter than 12 cms and will be chosen by the persons involved in the evaluation.

In addition to these changes of the contract, there were a number of standards discussed for the rejection of strips due to banding.

Since banding occurs in practically all strips, and thus none of these strips strictly fulfils the contract, it was decided that the standard for acceptance could not be an absolute absence of banding. Instead, a certain amount of banding would be accepted, but this standard would be set by the persons charged with the evaluation of the imagery.

4. IMAGE QUALITY

4.1 Method of Evaluation

The quality of imagery was evaluated using a check list and forms to enter the results of the evaluation. The check list is shown as table 4. Each strip was inspected using the overlaps with adjacent strips and stereoscopic viewing. After finishing a strip, tentative conclusions were formulated which were verified by another co-operator..

1.	Is there longitudinal tonal banding?
2.	Is there transversal tonal banding?
3.	Is there transversal distortional banding?
4.	Is there a change of tone?
5.	Is there speckle in the image?
6.	Is the range of densities satisfactory?
7.	Are the effects of rain or clouds obscuring an area in the strip such that 20 cms^2 or more are lost to stereo coverage?
8.	Is the image sharp, and does it compare in resolution with the sample from the contract?
9.	Are there other defects of the image not mentioned before?

Table 4.
Check list for image quality evaluation

4.2 Examples of Defects in Image Quality

Figure 5 gives examples of image quality defects according to the check list of table 4. These examples are taken from the area of PRORADAM and are self-explanatory. As stated in section 3.3 there was slight longitudinal banding in all strips correlated in the field correlator (an example is shown in figure 5 a). Correlations in the laboratory - correlator showed less longitudinal banding.

During the survey flights for PRORADAM, the near range channel of the SLAR system seems to have had serious problems. Some near range views were completely useless and had to be reflown directly. In a large number of other near ranges, which appear at first sight acceptable, there occurs 'speckle', evidently due to electronic malfunction of the automatic gain control. An example of this speckle is shown in figure 5 d. It causes serious problems for photo-interpretation since it obscures the actual reflections from the ground. Consequently this speckle was on several occasions considered reason enough to reject near range views.

It is suggested that the possibility of employing optical coherent filtering to remove speckle from the near ranges should be considered. If recorrelations and optical filtering cannot remove it, reflight must be considered to remedy this lack of image quality.

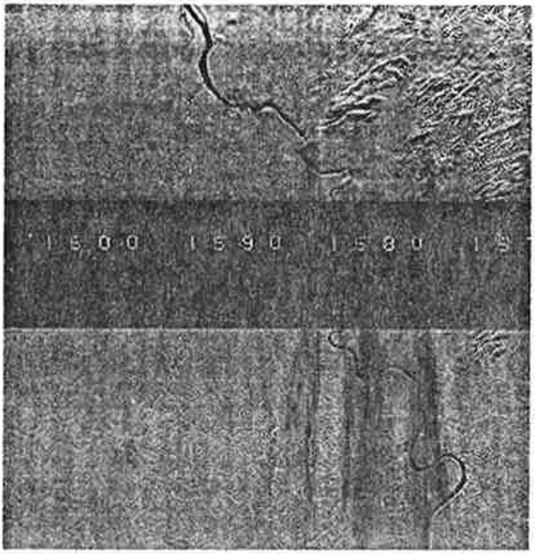

Figure 5 a.
Longitudinal banding on field correlation, and effects of rain

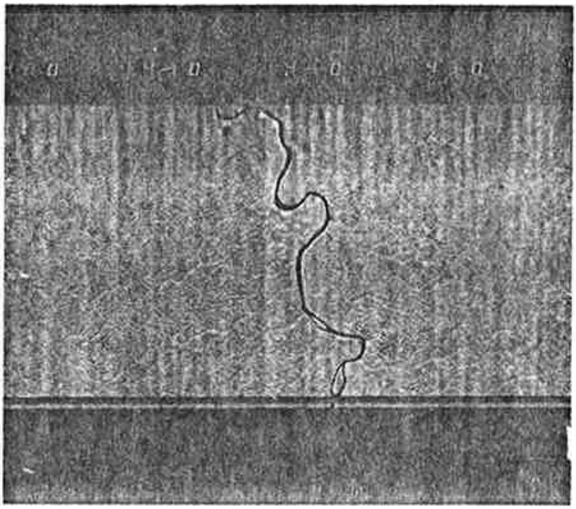

Figure 5 b.
Medium transversal banding and some 'speckle'

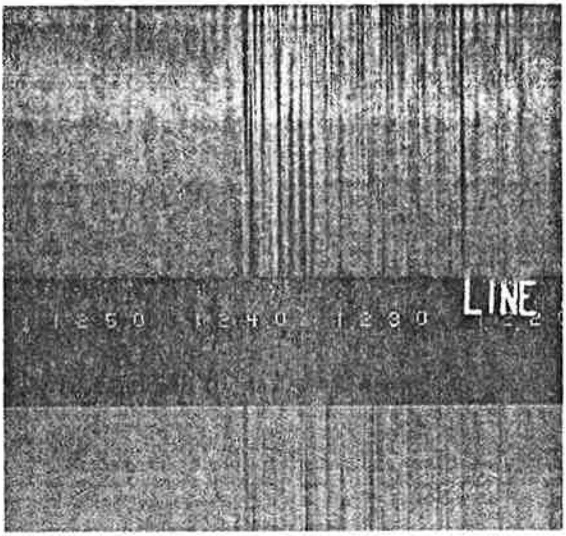

Figure 5 c.
Transversal distortional banding

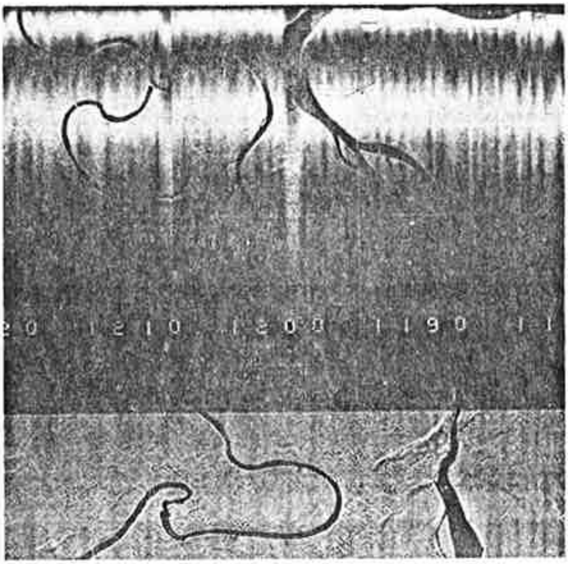

Figure 5 d.
Malfunction of automatic gain control

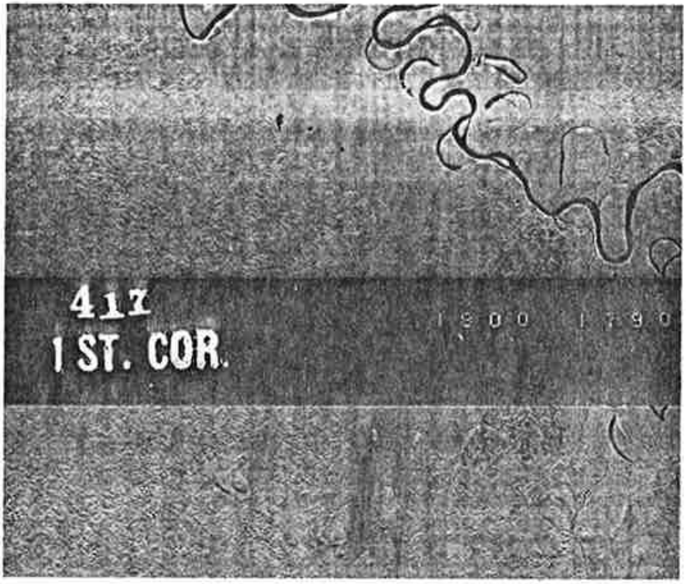

Figure 5 e.
Near range 'speckle'

In order to be sure of an image which is of a density range desirable for image interpretation it was recommended that Aero Service Corporation be requested to provide copies of individual SLAR–strips with different ranges of density, so that an optimum can be established experimentally by a comparison of various alternatives.

4.3 Results of the Evaluation of Image Quality

Due to the fact that the first correlations produced on the field correlator all demonstrated longitudinal banding, which occurred to a lesser degree in recorrelations produced in the laboratory correlation, almost all strips were rejected with a request for recorrelation to reduce banding.

Table 6 contains part of a summary of the evaluation of image quality, with only the most relevant information per image strip (such as quality defects occurring), the reason for rejection, and the area in which the effect causing rejection occurs. This indication of area uses the number of range marks in the centre between near and far range.

BT	:	Transversal banding
BL	:	Longitudinal banding
BD	:	Distortional banding
S	:	Speckle
C	:	Lack of contrast
CT	:	Change of tone
O	:	Underexposure
FC	:	Field correlator
LC	:	Laboratory correlator
LL	:	Rain
(S)	:	Strong
(m)	:	Medium
(l)	:	Slight
NR	:	Near range
FR	:	Far range

Table 6 a.
List of abbreviations used in summary of image quality evaluation

Line Nr.	View	Corr.	Acc	REJECTED Due to	Between Marks
1½	NR	F.C.		Maladj. of antenna	Total
	FR	F.C.		BT, BL (l)	Total
1	NR	F.C.		BT, BL (l)	Total
	FR	F.C.		BT, BL (l)	Total
2	NR	F.C.		S (s)	1160–1250
(FLT 26/L2)				BT, BL (l)	Total
	FR	F.C.		C(l), C.T(l), BL, BT	Total
2 (FLT 26/L2)	FR	L.C.		C(l), BT(l)	Total
3	NR	F.C.		C(s), BL,	Total
(FLT 01/L3)	FR	F.C.		BL, BT	Total
3	NR	F.C.		S(s), BL(m), BT(m)	Total
(FLT 29/L1)	FR	F.C.		BL, BT(l)	Total
4	NR	F.C.		S(s), BT, BL	Total
(FLT 29/L2)	FR	F.C.		BT, BL	Total
4 (FLT 29/L4)	NR	F.C.		O, BT, BL, LL	Total
	FR	F.C.		O, BT, BL, LL	Total
4	NR	F.C.		O, LL, BT	Total
(FLT 01/L1)	FR	F.C.		O, LL, BT	Total
5	NR	F.C.		S(m), BL	Total
(FLT 29/L1)	FR	F.C.		BL, O.(l)	Total
5	NR	F.C.		BT, BL	Total
(FLT 01/L2)	FR	F.C.		BT, BL	Total
6	NR	F.C.		BT, BL	Total
	FR	F.C.		BT, BL	Total
	NR	L.C.		BT, BL, O	Total
	FR	L.C.		BT	Total
7	NR	F.C.		BT, BL	Total
	FR	F.C.		BT, BL	Total
	NR	L.C.		BT, O	Total
	FR	L.C.		BT, O	Total

Table 6b.
Summary of evaluation of quality

In general, an attempt should be made to reduce quality defects by careful recorrelation. For a number of strips, especially far range views, it is expected that recorrelations would be acceptable. For others, however, this might be impossible to achieve merely by correlation.

5. IMAGE GEOMETRY

5.1 Method of Evaluation

As pointed out in section 2.6, a large number of measurements (about 3000) were made of 'tie points' connecting overlapping strips geometrically. This connection was done with the computer programme 'STRITA' which transformed each strip in the blocksystem using a linear conformal transformation.

As a result of the computation co-ordinate errors were obtained for each point in every strip of imagery. Table 7 demonstrates the typical output of the computation. These co-ordinate errors were then used to evaluate each individual geometric specification.

The evaluation was split into mechanical and interpretative aspects. The mechanical aspect consisted of the computation of differences and sums of co-ordinate errors, aiming at the evaluation of each individual specification. It was found that interpretation of the mechanically elaborated indications of defects of image geometry had to be done with the greatest awareness of what was involved.

Since there was a specification particularly requiring an invariable image scale in range direction, there was also a procedure devised to check its fulfilment (b in table 3). But it was obvious that scale errors in range direction were hardly to be expected except in case of serious electronic malfunction. So when an apparent scale change in range direction was detected, it could usually be verified that it was actually a curvature of the flightline rather than a real scale defect in range direction.

In addition to evaluating the fulfilment of technical specifications, the quantitative method applied permitted quantitative conclusions on the amount of geometry defects. Consequently graphs could be prepared for the scale changes and curvatures of image strips. These plots can be used to rectify the present imagery. It is, however, recommended that delay be observed in the use of these data until after they have been recomputed with the inclusion of ground control points. This offers the advantage of absolute verified geometry, not only relative as heretofore.

There is another important advantage in awaiting rectification data derived with ground control. More time is available for checking the measured data on measuring errors, for carrying out remeasurements, and for experimenting with different methods of computing the triangulation.

It should however be said that the results obtained so far are perfectly usable, and can be improved directly by a very simple procedure as soon as ground control points are available, without any further programming or measuring efforts. More will be said about this in the recommendations (section 6).

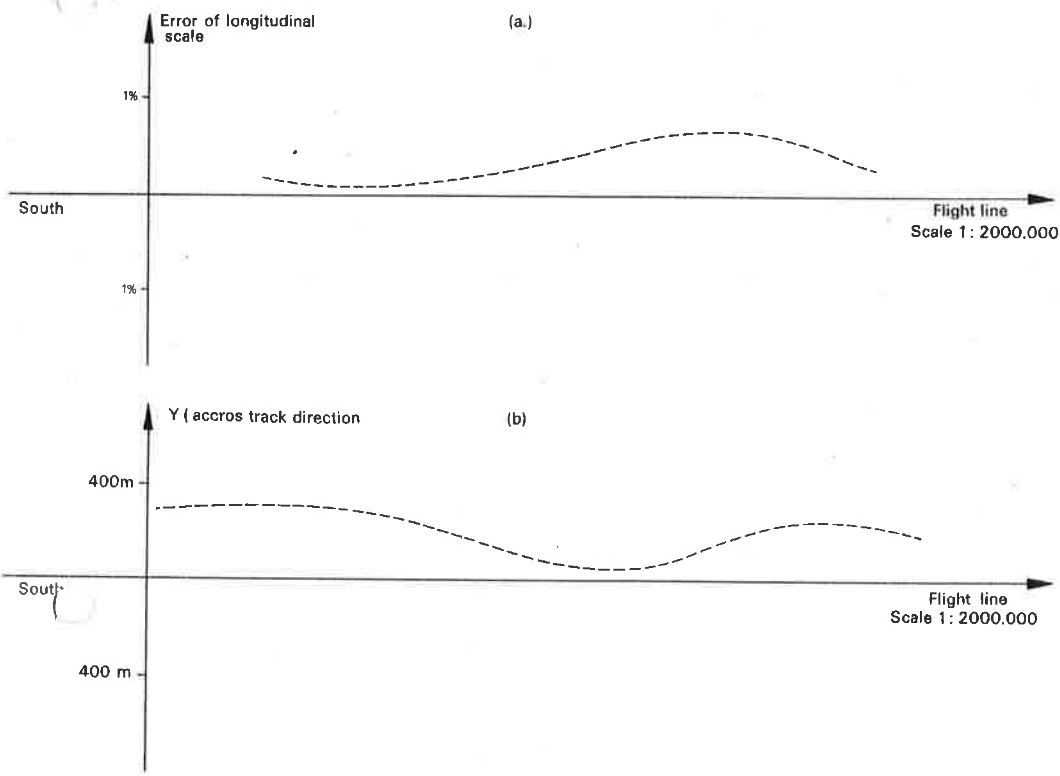

Figure 6.

Errors of longitudinal scale (a) and curvature of flightline (b)

Modelnr. = - 1412.

PTN.	VX	VY	X	Y
456	0.662	1.797	- 749.461	- 944.341
468	0.212	2.663	- 771.470	- 988.527
469	0.524	- 0.544	- 578.171	- 989.617
457	0.334	- 0.428	- 580.934	- 945.371
458	0.035	- 1.010	- 458.352	- 947.425
471	- 0.184	- 1.517	- 449.590	- 991.684
472	- 0.804	- 1.264	- 302.266	- 992.986
459	- 0.383	- 1.641	- 287.635	- 949.051
460	- 0.498	- 1.434	- 101.189	- 953.270
473	- 0.163	- 0.397	- 107.948	- 997.381
474	0.246	0.993	181.934	- 999.715
461	0.150	0.872	176.043	- 959.882
462	0.126	1.261	367.057	- 964.870
475	0.048	1.081	341.405	- 1000.938

Modelnr. = - 41412.

PTN.	VX	VY	X	Y
461	- 0.296	- 1.454	176.489	- 957.556
474	0.159	- 1.290	182.022	- 997.432
475	0.028	0.138	341.425	- 999.995
462	- 0.213	0.516	367.396	- 964.125
452	0.235	- 0.570	600.144	- 962.755
463	0.161	0.847	605.949	- 982.541
476	0.370	0.709	595.684	- 1006.159
477	- 0.001	0.785	732.226	- 1008.276
464	- 0.108	1.274	741.969	- 979.149
465	- 0.013	1.322	908.773	- 983.839
478	0.006	0.599	908.503	- 1012.115
479	0.141	- 1.804	1145.431	- 1017.174
467	0.130	- 1.013	1139.210	- 992.078
466	- 0.056	- 0.874	1142.984	- 975.205

Modelnr. = - 1411.

PTN.	VX	VY	X	Y
468	0.216	2.572	- 771.473	- 988.436
482	0.197	6.389	- 796.988	- 1008.986
483	1.262	- 1.064	- 574.000	- 1006.851
469	0.748	- 0.588	- 578.395	- 989.573
471	0.116	- 1.566	- 449.891	- 991.634
484	- 1.255	- 3.164	- 425.366	- 1009.518
496	- 1.662	- 2.308	- 434.365	- 1037.640
485	- 1.314	- 2.352	- 299.365	- 1015.012
472	- 0.843	- 1.624	- 302.228	- 992.627
473	- 0.095	- 0.873	- 108.016	- 996.905
486	- 0.322	- 0.244	- 130.972	- 1023.961
488	0.633	1.793	212.140	- 1038.991
474	0.157	0.886	182.024	-. 999.608
475	- 0.228	0.756	341.681	- 1000.613

Table 7.

Typical output of computation to be used for evaluation of geometry

5.2 Results of the Evaluation of Image Geometry

A number of strips were found with typical sinusoidal changes of longitudinal scale due to the inertial schuler frequency, but in excess of the 1% specified in the contract. Scale errors generally do have an average different from zero. Table 8 shows part of a summary of the results of the geometric evaluation. Figure 6a presents a graph for the rectification of longitudinal scale defects. Graphs were also prepared for the curvatures of image strips and a sample is shown at figure 6b. The typical schuler period can be observed in these curvatures also. They are however not as often a reason for rejection of a strip as are scale defects.

In addition to incorrect longitudinal scale and curvature of the flightline, no other purely geometric specifications (i – m) were violated. It soon became obvious that specifications (i) and (k) are only an insurance against electronic failure, but the types of errors noted in these specifications fortunately are seldom expected.

With the presently applied computed evaluation specification (l) also loses its significance. When a defect of longitudinal scale is detected in a strip through checking specification (j), a check of specification (l) does not produce new information.

Apart from evaluating the purely geometric specifications (i) – (m), the fulfilment of the flightplan was also checked. Taking into account the modification of the contract, some small defects were discovered in specifications (a) and (c), concerning the stereoscopic coverage of the whole area.

Line Nr.	View	Corr.	Acc.	REJECTED	
				Due to	Between marks
27			x		
27 A					
28				Escala longitudinal y distancia entre homologos	
28 A					
29			x		Error de medicion pto 335
29 A					
30				Escala longitudinal	
31			x		
32				Distorsion angular	
33			x		
33 A			x		
34				Escala longitudinal	
35				Escala longitudinal	
36			x		
37			x		

Table 8
Summary of evaluation of image geometry

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The evaluation of image quality and geometry was based on a complete set of copies of the SLAR imagery on film and on single weight paper. The scale of the imagery to be evaluated was 1:400,000.

The evaluation of image quality revealed that hardly any of the strips presented fulfilled the contract strictly, as there was electronic noise and transversal banding in the majority of strips. Fortunately, however, the far range views, which are going to be used for the preparation of the mosaics, will be of acceptable quality after careful recorrelation.

The most serious defects of image quality noted consisted of 'speckle' or electronic noise in the near range views. It will have to be decided, after recorrelation, whether PRORADAM can obtain improvements through recorrelation satisfactorily, or whether reflights are required.

On a number of occasions violations of the specifications concerning the overlap between adjacent strips were noted. Usually, however, these violations are rather insignificant.

Apart from the above quality defects due to banding and 'speckle', no other significant instances of unsatisfactory quality were detected.

Image geometry evaluation produced a more satisfactory result than image quality. A majority of strips was found to be acceptable. Reasons for rejection were only errors of longitudinal scale in excess of 1%, and in a few cases excessive bending of the flight-line. The method used for the geometric evaluation was new, and based on principles of photogrammetric block formation. Consequently many aspects of the work were still experimental. But the advantage of the approach is twofold: an evaluation of image geometry (as well as determination of radargrammetric ground control) is possible. It can therefore be concluded, that the first exercise – the evaluation of image geometry – was successful.

Determination of radargrammetric ground control will be possible after having access to geodetic ground control. But the same measurements can be used as for the evaluation, so that triangulation requires only a minimum of extra work. The combination of these two purposes was not foreseen in the compilation of the contract, which only provided for 30 days to evaluate the imagery. This period is definitely too short if triangulation is to be done in the same time. Consequently the work had to be finished under pressure.

6.2 Recommendations

From these conclusions it is recommended that in future, projects with SLAR must have more time for evaluation of the imagery in order to carry out a thorough evaluation and prepare good triangulation with checks of possible measuring errors, and eventual remeasurements.

The training of counterparts for evaluation and triangulation should preferably not be done within the evaluation period, as it is time-demanding.

Specifications for future projects should be established with advance knowledge of the further data processing applied. In PRORADAM, specifications were drawn up without consideration of the process of the cartographic treatment of the imagery. Consequently the geometric specifications were not well considered. Basing the evaluation on triangulation with the imagery requires specifications in terms of point or co-ordinate errors. For rectification or correlation purposes also changes of longitudinal scale can be indicated as an output of the evaluation.

As concerns further cartographic processing of the imagery, it is suggested that the production of mosaics is delayed so as to be able to incorporate Doppler ground control points and radargrammetric block adjustment results. This block adjustment should be carried out using the measurements for the geometric evaluation. Geographical ground co-ordinates of properly identified control points are required for these computations, as are also their image co-ordinates. It would be expected that the results of the triangulation would be available not later than 2 weeks after receiving the control point co-ordinates.

The production of mosaics, and the evaluation of the geometry, are very much simplified by the use of radargrammetric control points: for each strip of imagery a large number of these secondary points will be obtained, so that the strips have to be rectified only in part to adjust to these points.

The geometric evaluation of the mosaics should then encompass the measurement of the radargrammetric control points ('minor control points') and transformation into the ground co-ordinate system. Differences between transformed and radargrammetric ground co-ordinates are then due to imperfections in mosaicing. Another important element in checking the geometry of the mosaics is to evaluate whether there are gaps or double coverages along the boundaries of adjacent mosaics, and whether or not linear features are continuous along the cutting lines of adjacent strips used within a mosaic.

It is further suggested that the cartographic end product – the map – should be produced not only by tracing details on the mosaics, but by incorporating also stereoradargrammetry to derive form lines or contours in the areas with relief. For this purpose, stereoradargrammetry should make use of the radaraltimeter profiles given along all flightlines. Details about such a process are, however, beyond the scope of the present report.

ACKNOWLEDGEMENTS

Thanks to the enthusiastic support of Dr. RODOLFO LLINÁS, and the efforts of Dr. JULIO MURILLO, Tte. Coronel ALVARO HERRERA and Dr. GERMÁN RODRIGUEZ, it was possible to do this work in the incredibly short time of 3 weeks.

I further acknowledge the co-operation of the photogrammetric operators of the Instituto Geográfico 'Agustín Codazzi', and of the staff of the computing centre of the Ministerio de Hacienda, under its Director, Sr. M. PINILLA.

I appreciate the enthusiasm and involvement in the work and confirm that I stayed with pleasure and interest in Colombia.

This section of the Journal contains shorter contributions, particularly articles of a general nature which are not necessarily scientific or original in character.
Reviews and announcements, news of former students of the ITC, forthcoming conferences and current literature: these and other items of topical interest will also appear in these pages, though perhaps not in every quarterly issue