

**PETRONAS
PETROLIAM NASIONAL BERHAD
MALAYSIA**

**QUALITY CONTROL SERVICES FOR THE
ACQUISITION AND PROCESSING OF
SYNTHETIC APERTURE RADAR (SAR) DATA
OVER SABAH AND SARAWAK, EAST MALAYSIA**

SECOND QC VISIT REPORT

THIRD & C VISIT REPORT

January 1991

March 1991

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8th January, 1991

Dear Sir

Second Quality Control Visit Report

As planned and reported in our first quality control report, our consultant visited the processing facilities of the flying contractor, Intera Technologies Limited, and carried out a quality control check of the technical processes used.

We are pleased to submit herewith his technical report on the visit which took place in the week 26th - 30th November 1990.

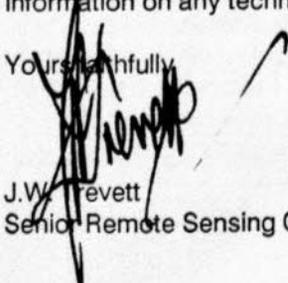
You will see from his report that the SAR system has been developed to produce a cosmetically acceptable result rather than raw digital data for analysis. As a result the various effects of processing the data in real time have to be accepted at their face value it being impossible to observe the original raw data and compare processes. The consultant therefore has drawn attention to the limitation in using the digital data for detailed analysis.

The Q.C. Consultant also undertook some investigations into the photographic processes having been guided in the technology by the HTS photographic engineer before his visit. It is however, considered that this aspect will require a further Q.C. visit when more of the photographic work is in production.

In our report on the first Q.C. visit we included on page 8 the Future Planning of Q.C. Assignments, after this second Q.C. visit we see no changes in this plan and would still expect to make the visits as described. In this respect we believe the flying should again be underway in Sabah and we would request that we are informed of the schedule in order to provide a visit to cover the end of the Sabah coverage and the start up of operations in Sarawak.

We trust this report will be acceptable and our Q.C. Consultant will be pleased to provide further information on any technical aspects that may arise.

Yours faithfully,


J.W. Revett
Senior Remote Sensing Consultant

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(b) Radiometric binning and conversion of slope is performed in preparation for mosaic generation on a STAR-I workstation.

(c) Binning of adjacent strips is performed on the STAR image analysis system.

(d) Photographic negatives are generated on a color machine at Davidson of Calgary, and simulates containing a frame and registration are generated on a plotter at Inters.

(e) Photographic positives are generated. This has been performed by Foresight of Calgary in the past but will involve Inters's subsidiary Inters Aerospace of Houston, Texas, for this project.

During the visit, it was possible to witness production steps (i) to (vi) for samples of data from various Inters mapping projects. Steps (v), (vi) and (vi) were performed during the visit on data specifically from the Malaysian acquisition (SIT 17 track).

3 THE STAR-I SYSTEM AND RAW IMAGE PRODUCTION

It is not intended here to provide a complete technical description of the STAR-I system and of the processing methods incorporated into the on-board real-time SAR processor (RTSP). Rather, those aspects of most relevance to quality control of imagery will be highlighted. A system description may be found in Nichols et al (1985), although it should be noted that Inters's data recording medium has now changed from high-density digital tapes (RDTM) to 2-hour 5000 video cassettes. Inters argue that this medium has advantages, not only in terms of weight and

1. INTRODUCTION

This document reports details of the Second QC Visit for QC Services for the Acquisition and Processing of SAR Data of Sabah and Sarawak, Malaysia.

The visit was to the production facility of the Acquisition Contractor (Intera Technologies Limited) in Calgary, Canada, and took place during the week 26th-30th November 1990. The principal aim of the visit was to report on the radar system and processing methods used in the generation of digital image products, including the formation of digital mosaics. However, the visit also allowed a preliminary opportunity to witness and discuss the facilities for the production of photographic products. The timing of the visit allowed the QC expert to follow the processing of data from the SK17 acquisition block up to and including the generation of the photographic negative of the first 1:100,000 mosaic.

The QC expert on this visit was Dr R.A. Cordy of GEC-Marconi Research Centre.

2. OUTLINE OF PROCESSING CHAIN

The following is a summary of the radar acquisition and processing steps followed by Intera in the production of digital and optical products in Calgary. Important points in the chain will be the subject of detailed description and discussion in subsequent sections.

- (i) Data acquisition by STAR-1 radar.
 - SAR processing is performed on-board using a Real Time SAR Processor. The processor outputs imagery for field QC on dry silver paper and records digital data on Exabyte 8-mm video cassettes.
 - Auxiliary positional data (differential GPS measurements) are recorded for separate processing by a subcontractor (Nortech).
- (ii) Raw Imagery from individual flight lines are segmented into 30' sections on a SUN workstation at Intera.
- (iii) GPS data from Nortech are processed on a Macintosh computer at Intera to generate pseudo ground-control points.
- (iv) Segments are re-sampled onto a map grid through the use of the pseudo ground-control points, on and DIPIX image analysis system.
- (v) Radiometric balancing and correction of strips is performed in preparation for mosaic generation, on a SPARC workstation.
- (vi) Seaming of adjacent strips is performed on the DIPIX image analysis system.
- (vii) Photographic negatives are generated on a Scitex machine at DataSpan of Calgary, and surrounds containing a frame and annotation are generated on a pen-plotter at Intera.
- (viii) Photographic positives are generated. This has been performed by Fotoflight of Calgary in the past but will involve Intera's subsidiary Intera Aeroservice of Houston, Texas, for this project.

During the visit, it was possible to witness production steps (ii) to (viii) for samples of data from various Intera mapping projects. Steps (v), (vi) and (vii) were performed during the visit on data specifically from the Malaysian acquisition (SK17 block).

3. THE STAR-I SYSTEM AND RAW IMAGE PRODUCTION

It is not intended here to provide a complete technical description of the STAR-1 system and of the processing methods incorporated into the on-board real-time SAR processor (RTSP). Rather, those aspects of most relevance to quality control of imagery will be highlighted. A system description may be found in Nichols et al (1986), although it should be noted that Intera's data recording medium has now changed from high-density digital tapes (HDDTs) to Exabyte 8-mm video cassettes. Intera argue that this medium has advantages, not only in savings of space and weight, but also in the reduced "drop out" rate (i.e. a reduced data loss when they are read).

3.1 PLATFORM STABILITY

Turbulence and aircraft velocity errors are potential sources of geometric and radiometric distortions in imagery, both on small scales (focussing problems) and large scales (x, y scale errors and loss of signal power).

The effects of aircraft motions on image geometry and focussing are compensated for in a number of ways. The along-track image geometry and focussing is initially maintained by linking the radar's pulse-repetition frequency to the aircraft's ground speed, providing a constant spacing of pulses on the ground. This technique is a familiar one from other radar systems. It also serves to maintain along-track resolution in the presence of non-nominal aircraft velocities. Along-track image position and focus are further maintained by monitoring across-track aircraft velocities (through integration of accelerations measured by the Inertial Navigation System) and applying appropriate phase corrections to the radar receiver. It is expected that this technique would not necessarily be accurate by itself if slowly-varying motions have to be integrated from INS accelerations. Without additional correction, image geometry may be unacceptably distorted.

Stability of the antenna is important for maintaining maximum received power. If turbulence causes a mis-direction of the antenna from broadside then there will be a gain reduction and the appearance of a dark band running in the range direction across the image. The antenna is stabilised through a servo link to the Inertial Navigation System (INS) and, for long-term fine pointing, to a "clutterlock" system which monitors the Doppler spread of received signals to ensure that the antenna pattern is centred at zero Doppler.

Despite the various stabilisation and compensation systems it is inevitable that some errors will remain in output data. Dark turbulence bands are the most obvious and occur quite regularly with this system. It is a QC decision in the field upon receipt of quick-look printouts of imagery as to whether to re-fly strips or whether they may be cosmetically compensated for in digital post-processing in Calgary.

QC checks on the resolution of raw images are not routinely performed by Intera. A daily check on range resolution is performed indirectly through the generation of an artificial target signal which is fed back through the system. Range resolution is, anyway, not likely to be affected significantly by aircraft instability. It appears to be assumed that the motion compensation system for azimuth focussing is adequate. No imaging of known targets is performed in field operations and no post-acquisition QC of resolution in digital images is attempted on targets of opportunity. While the QC expert accepts that the focussing properties of the STAR-1 system are likely to be superior to many less-well compensated systems it nevertheless would be desirable to demonstrate this fact. At the request of the QC expert, digital imagery was displayed and small "targets of opportunity" searched for. Suitable image display and manipulation software was not available and it was only possible to conclude that, for the samples examined, the imagery was not seriously out of focus.

3.2 ON-BOARD GROUND-RANGE CONVERSION

Before being output by the RTSP, imagery is produced in slant-range format, that is the range co-ordinate is radar delay time, not ground co-ordinate. A rather crude geometrical conversion is made by discarding lines of data. It seems likely that distortions to the images of small targets may occur during this process. (Note that the assumed ground geometry is flat - i.e. conversion to ground range does not aim to remove distortions due to varying terrain height).

3.3 OUTPUT DATA

Data output by the RTSP is seven-look imagery. It is the average (in intensity) of seven images from different 30 Hz segments of the received signal bandwidth. Image sampling in azimuth is determined as follows. The initial pulse-repetition frequency is first reduced by 4 in a pre-summer then divided by 7 in the look-extraction system. For a prf of 1200 Hz at an aircraft speed of 350 knots, this results in an image sampling at 43 Hz, equivalent to a pixel spacing of 4.2 metres. Because the image sampling rate exceeds the nominal look bandwidth it might be thought that this is an adequate pixel spacing. It is not, however, since the output image is in power and

has a bandwidth doubled to 60 Hz. The consequence of this undersampling is that we may expect some distortions (e.g. loss of signal) to small targets if further manipulation of the image by resampling is attempted.

In the range direction, the pixel spacing is 5.3 metres. This implies that, on a digital display device, there will be an x, y scale distortion in these raw image produces owing to the use of non-square pixels. This is not a fundamental problem but the differences in scale must be appreciated by a potential user of raw image strips.

The numbers recorded in each pixel, although nominally power, are not on an absolute scale. The antenna's gain pattern is routinely removed before image output, together with one of a selection of ground backscatter curves (Sensitivity Time Control, STC) in order to reduce the requirement of high dynamic range output and to remove variations of backscatter with incidence angle which would otherwise degrade the cosmetic appearance of mosaics. This is not always achieved satisfactorily, and some radiometric post processing is occasionally required to correct for poor STC performance.

An error commonly seen in data output from the STAR-1 (but not unique to that system) is the presence of interference bands at near range. They are sinuous bright and dark lines running generally along-track and caused by multipath effects resulting from a reflection of radar pulses off the aircraft superstructure. These cannot be corrected by post processing and are only avoided in mosaic production by the use of alternative overlapping image strips.

The images are recorded at 1 byte (8 bits) per pixel. The maximum dynamic range of the imagery when stored as intensities is about 23 dB. Given that the image noise level is usually maintained at a few digitised units, the actual dynamic range is probably under 20 dB. There exists some rather spurious in-house claims at Intera that a 50 dB dynamic range can be usefully achieved with as few as 4-bits for a 7-look SAR such as the STAR-1. While the QC expert understands that this may be possible if numbers are recorded in logarithmic form, this is definitely not the case with the data routinely output.

4. GEOMETRICAL RECTIFICATION OF IMAGERY USING GPS

It is accepted by Intera that the nominal image geometry output by the RTSP is inadequate for mosaic production. For field operations in areas where maps do not provide a dense coverage of ground control points on which to register imagery, they have developed a variant of a standard radargrammetric approach which makes use of aircraft positional data from the Global Positioning System of satellites (GPS). The fundamental process is one of determining aircraft position at a set of times and of modelling the ground position of a scatterer whose returned signal is received at that time. This results in a pseudo ground-control point whose co-ordinate (on a given grid) may differ from that assigned to a signal by the RTSP on the aircraft. A low-order polynomial fit to the position differences is then used as the basis for resampling the raw imagery onto a geocoded grid.

Aircraft positions are generated by differential processing of GPS data relative to a base station. The base station positional accuracy is estimated by Intera to be 5-10 metres. The subcontractors, Nortech, process the GPS data, assuming a WGS84 ellipsoid. Intera believe that any errors arising from the use of this geoid (as opposed to Everest Modified) amount to only a few metres in final images. At Intera, the processed data are used to generate pseudo ground-control points using as input the radar delay to the near range swath edge (from the aircraft flight log) a radar system model and the local mean terrain height (estimated from a map at 1:1,000,000 scale). (Given a terrain height model, or one generated from stereo SAR imagery, it would be possible in principle to take out all terrain distortions. In the present project a flat ground is assumed).

Following a 2nd order polynomial fit to these pixel position errors, resampling of the raw imagery is performed. As noted in Section 3.3, resampling is undesirable if small targets are to be studied. The resampling uses a cubic convolution algorithm and takes the opportunity to force the image strips onto a 6m x 6m square grid as well as performing geometrical correction. QC is

routinely performed to exclude reliance on any obviously incorrect pseudo ground control points and outliers are eliminated from the polynomial fit. Reasons for poor points do not seem to be understood but the solution to their presence seems to produce good results.

The accuracy of the geometrical transformation is not assessed routinely for individual strips. It will be shown in Section 6 that internal consistency between strips comprising a mosaic points to an accuracy of about 250 metres. However, it seems highly desirable that we discover as soon as possible the accuracy of geometrically corrected images relative to local maps.

It is not obvious that positional accuracy would be improved by the use of more accurate GPS data. At present it is Intera's radar system model in the radargrammetric process which is believed to be the greatest error source.

5. RADIOMETRIC CORRECTIONS

Corrections to image intensities are performed with the express purpose of enhancing the cosmetic appearance of the final mosaic which will be generated from a set of strip segments. They are performed prior to mosaic formation on pairs of strips displayed simultaneously on the same screen. The criteria for acceptability are purely visual. A number of corrections to pixel intensities are made during the process. Turbulence bands are filtered out, STC errors are removed, and the means and standard deviations of strip intensities are adjusted until adjacent strips appear balanced. It is important for potential users of digital data to note that the standard-deviation-to-mean ratio for an image may have been artificially adjusted. Thus users interested in digital measures of image texture should treat these STAR-1 data with caution.

In the examples witnessed by the QC consultant, the final strips were very closely balanced in tone and free from obvious turbulence artefacts.

6. MOSAIC GENERATION

Seaming of adjacent strips is performed interactively using proprietary software on a DIPIX image analysis system. Successful seaming relies heavily on the experience of operators to mask seam locations within suitable image regions.

Despite geometrical transformation using GPS data, individual strips are still not on a sufficiently accurate grid to overlay upon each other. The first stage in seaming is therefore to co-register overlapping strips on some small and perhaps critical feature (such as a road). This co-registering provides the only check at present on the consistency (and probably the absolute accuracy) of the GPS geometric correction. For the first SK17 mosaic, shifts of typically 30-40 pixels in X and Y were observed between strips, corresponding to 180-240 metres in positional error.

Once co-registered, images are colour coded and overlapped on a display screen. This makes any non-uniform registration of strips very clear to the operator. Along track, oscillatory drifts of up to 10 pixels (60m) in registration were seen, presumably indicative of the short-term error in the radargrammetric model.

No further re-sampling of imagery is done in forming the mosaic. Rather, each pixel's value is now selected from one or other of the two overlapping strips. A seam boundary is defined interactively according to the following criteria:

- (i) maximise mid-range content in mosaic (i.e. avoid using far range and near range data);
- (ii) in a choice, preferentially select data from the strip having the higher information content;
- (iii) avoid seaming through uniform areas which would make the seam more obvious in the mosaic;
- (iv) avoid generation of double features in a mosaic when there is local mis-registration of the two strips.

In the SK17 example witnessed, the seaming quality was very high. Even with knowledge of the seam location its presence was very difficult to detect visually.

Final mosaics are generated oversized to permit masking down to fiducial marks when photographic negatives are produced. Information on the seam boundary locations is preserved to allow for possible regeneration of the mosaic at a later date.

7. SUMMARY OF COMMENTS ON DIGITAL IMAGERY

The following summarise concerns about processing methods and caveats about the use of digital data generated by Intera.

- (i) Raw digital data have non-square pixels.
- (ii) Raw data are undersampled, and manipulation by resampling is undesirable if small targets are being studied.
- (iii) Imagery is uncalibrated, both absolutely and relatively (i.e. neither the absolute value nor the ratio of the two values is of physical significance).
- (iv) Near-range imagery is contaminated by interference bands.
- (v) No validation of image resolution is provided.
- (vi) Rectified image strips have been re-sampled (see (ii)).
- (vii) No validation of rectified image geometry against map data is provided.

The concerns about undersampling are probably of minor significance if the user's principal interest is in distributed targets. Similarly, for interpretability of extended targets, the radiometric properties of final images are probably an advantage rather than a disadvantage (i.e. the strong intrinsic variation of backscatter with incidence angle, if not suppressed, would render mosaicing difficult). Also the problem of interference band contamination of near-range data is avoidable if use is made of overlapping strips (as is done in mosaic generation).

The points about validation of resolution and geometry remain as concerns. It is still desirable to see some quantitative verification of the azimuth resolution of the STAR-1 system. Also it seems of great importance to verify the geometrical properties of images through the use of maps. While it is expected that errors will be <250 metres, this should surely be validated as soon as possible.

8. PHOTOGRAPHIC NEGATIVE PRODUCTION

Data Span of Calgary handle Intera's negative production and have been doing so for the last 4 years.

The facilities at DataSpan are centred around a Scitex laser scanner/plotter. In plotting mode, this is a continuous tone plotting device which produces photographic negatives from a digital data file. The system resolution appears to be easily capable of coping with Intera's pixel size. At 1:100,000 scale Intera's pixels are 60 μ m square, as compared to the Scitex spot size of 25 μ m.

It is claimed that the geometrical and resolution properties of the plotter/film combination are well validated and accurate. DataSpan suggest that the plotter's geometry is effectively tested by plots of seismic data (which constitute a major activity at DataSpan). The overall scale is verified by Intera through overlaying surrounds generated in-house on mylar (i.e. those to be used in the final print production). Film resolution has been investigated over some years - an Agfa product is currently preferred and is believed to be capable of resolutions even finer than the 25 μ m spot size.

Look-up tables for radiometric conversion of digital data to negative density are selected to provide an appropriate range of tones which will be usable in the final printing process. A calibration step wedge containing 17 tones is output on every negative generated for Intera. The look-up table attempts to match the dynamic range of the input data across the range of the wedge.

11. REFERENCE

9. PRINT PRODUCTION

For the production of Malaysian prints, Intera intend making use of their subsidiary Intera Aeroservice of Houston, Texas. However, they have routinely used a Calgary based company, Fotoflight, in previous projects and this company was visited to demonstrate the processing method and quality procedure. While at Fotoflight, a number of Intera mosaics of other surveys were in production.

Intera supply Fotoflight with a frame plotted on semi-transparent mylar film, containing co-ordinate, titling an archiving information. The mosaic negative, produced by DataSpan, is masked down to its correct size by Intera and supplied to Fotoflight. Fotoflight produce a negative of the frame and routinely remove blemishes by masking. They also routinely appear to re-mask the mosaic negative to improve its fit to the frame.

Printing is by contact onto paper. Fotoflight suggest that choice of paper is very limited and shrinkage is inevitable, especially if storage conditions are humid. Storage is in fact not considered either at Fotoflight or at Intera. Rather, prints are generally sent to customers within about 3 days of production. The paper's spatial resolution is claimed to result in minimal degradation for contact printing. Intera suggested a change in effective pixel size from 60 to 65 μ m might be expected. There appears to be no means by which this can be quantified.

Following QC at Intera, requirements for re-touching of the negative are specified. Fotoflight paint regions of negatives with a dye to lighten regions of the final print. An example was seen of a very obvious seam in a particular mosaic separating a light image strip from a dark strip. It was hoped that painting would improve the appearance of that mosaic and lessen the seam's impact on interpretation.

Final QC of photoproduction is by Intera's Production Manager. He uses an 11-point comment sheet (Figure 1) on which to note image defects. Examples were seen of prints of various qualities ranging from ones with barely perceptible defects to one containing serious turbulence banding and which were rejectable.

10. CONCLUSIONS

Data from the STAR-1 radar and the production methods used at Intera's processing facility in Calgary are aimed at producing a cosmetically high-quality photographic product.

Users of digital data must, however, be aware of the points listed in Section 7. These images are probably unsuitable for the detailed digital analysis with which scientific users may be familiar.

A validation of azimuth (along track) resolution is desirable but has not been performed. During the remainder of the campaign it would be very helpful to demonstrate azimuth resolution by the imaging of a point target.

Validation of geometrical accuracy has been performed by internal consistency checks and is estimated to be better than 250 metres for targets of equal elevation. However, an independent external check, through superposition of imagery on maps (e.g. at a scale of 1:50,000) in a highly desirable addition to this.

11. REFERENCE

Nichols, A.D., Wilhelm, J.W., Gaffield, T.W., Inkster, D.R., and Leving, S.K. "A SAR for Real-Time Ice Reconnaissance", IEEE Trans. Grossi, Remote Sensing, Vol. GE-24, pp383-387, 1986.

QUALITY CONTROL SERVICES FOR THE ACQUISITION AND PROCESSING

OF SYNTHETIC CONTENTS RADAR IN 1990

THIRD QC VISIT REPORT

1. INTRODUCTION 1

The first quality control (QC) visit was undertaken by the Consultants' representative Mr J.M. Taylor.

2. IMAGE ACQUISITION 1

2.1 Sabah 1

2.2 Sarawak 2

The visit was scheduled to coincide with the completion of the second data acquisition phase, which was also scheduled to coincide with the completion of the second data acquisition phase. The data received from this second phase had been reviewed by Sarawak and were made available for the QC.

3. DISCUSSIONS IN KUALA LUMPUR 3

4. FUTURE PROGRAMME 4

2. IMAGE ACQUISITION

With the exception of the priority areas acquired under Phase One of the flying programme, all the cover was examined together with the internal control records. Thus it was possible to assess which data had been rejected for reliability and ensure that the relevant data were satisfactory.

FIGURES

1. Gaps in SAR Data Coverage in map pocket
2. Area F Shown at Strip and Large Mosaic Scales in map pocket

In the course of the inspection, it was noted that the flying contractors had not provided a comment on image rejection as a result of low ground positioning system (GPS) data; such rejection has to be accepted as a valid decision by the flying contractors and it must be assumed that all accepted data have valid GPS information.

2.1 SABAH

All the images for the Sabah area were laid out and checked for overlap, regularity of flying, accuracy of re-flights and general coverage of territory. It should be pointed out that the QC was hampered by the lack of suitable survey maps. In fact, it had been unable to obtain any maps at a reasonable scale (1:250 000 or larger). Subsequent enquiries at the survey office failed to locate any for sale or loan.

All of the cover was found to be up to specification, although, without precise maps of the international boundary of Malaysia, it is impossible to be sure that cover is complete, especially with regard to all the off-shore islands. Using the geographical coordinates shown on the individual strips it would appear that the boundary with Indonesia is well covered, whereas flying had been required to the limit west to the original flight line and demonstrated the overall accuracy of the GPS and the navigational system.

The cover was then examined for quality of data, as readily demonstrated from the quick look images, although there are signs of inferior product when compared with the final photographic products. In general the data quality met the specifications, although the effects of low sun angle and other factors could be identified. It was decided that wherever visible areas that could be expected to be eliminated during the final digital processing.

Examination of the laid down data indicated that the decision to re-align the flight lines to E-W had been correct. The structures are all well expressed and the imagery appear to be well balanced. The flight lines in the original direction would have resulted in unbalanced shadow effects in many of the valleys.

The excessive height and the formation of Mount Kinabalu does result in a substantial radar shadow and a consequent loss of data. To verify the area with a different look direction may have supplied data in the shadow area, but the resulting images could not have been used either for stereoscopic viewing or for the construction of the mosaic.

**QUALITY CONTROL SERVICES FOR THE ACQUISITION AND PROCESSING
OF SYNTHETIC APERTURE RADAR IN 1990**

THIRD QC VISIT REPORT

1. INTRODUCTION

The third quality control (QC) visit was undertaken by the Consultants' representative Mr J.W. Trevett, from the 16th February to the 25th February 1991 in Kuching, Sarawak and Kuala Lumpur.

The visit was scheduled to coincide with the completion of the second data acquisition phase, which was also the final phase of flying. At the request of Petronas all the dry silver images from this second phase had been retained by Intera and were made available for the QC.

2. IMAGE ACQUISITION

With the exception of the priority areas acquired under Phase One of the flying programme, all the cover was examined together with the Intera control records. Thus it was possible to assess which data had been rejected for re-flying and ensure that the re-flown data were satisfactory.

In this respect it was only possible to assess overall image quality, and any variations resulting from antenna stability, meteorological conditions and shadows. It was not possible to comment on image rejection as a result of bad global positioning system (GPS) data; such rejection has to be accepted as a valid decision by the flying contractors and it must be assumed that all accepted data have valid GPS referencing.

2.1 SABAH

All the images for the Sabah area were laid out and checked for overlap, regularity of flying, accuracy of reflights and general coverage of territory. It should be pointed out that the QC was impeded by the lack of suitable survey maps; Intera had been unable to obtain any maps at a reasonable scale (1:250 000 or larger). Subsequent enquiries at the survey office failed to locate any for sale or loan.

All of the cover was found to be up to specification, although, without precise maps of the international boundary of Malaysia, it is impossible to be sure that cover is complete, especially with regard to all the off-shore islands. Using the geographical coordinates shown on the individual strips it would appear that the boundary with Indonesia is well covered. Where re-flying had been required, this fitted well to the original flight lines and demonstrated the overall accuracy of the GPS and the navigational system.

The cover was then examined for quality of data, as visually determined from the quick look images, although these are always an inferior product when compared with the final photographic products. In general the data quality met the specifications. Where the effects of turbulence and other factors could be identified, it was decided that all were within limits that could be expected to be eliminated during the final digital processing.

Examination of the laid down data indicated that the decision to re-align the flight lines to E-W had been correct. The structures are all well expressed and the linears appear to be well balanced. The flight lines in the original direction would have resulted in unbalanced shadow effects in many of the valleys.

The excessive height and the formation of Mount Kinabalu does result in a substantial radar shadow and a consequent loss of data. To re-fly the area with another look direction may have supplied data in the shadow area, but the resulting image could not have been used either for stereoscopic viewing or for the construction of the mosaic.

One of the strips that misses the top of the mountain does provide some data in the shadow areas. It is therefore important that, at the mosaic stage, all of this strip is incorporated and not just the central section that is normally used. This will ensure that a minimum of radar shadow is included; the resulting straight line cut off across the shadow must be then accepted even though it may not be visually pleasant.

No further significant shadow effects were observed in other sections of the images. In flying a survey of this type it is necessary to select a depression angle that will give some expression to features in low relief area whilst not causing excessive radar shadows in the high relief areas. A depression angle suitable for providing shadow - free images of Mount Kinabalu would have meant sacrificing detail in most other areas.

The SAR data for Sabah were therefore found to be satisfactory and no further re-flying was recommended as necessary.

2.2 SARAWAK

In Sarawak similar QC procedures were adopted. Some flying was still being carried out so that the final data sets were actually examined just as the flying sorties were completed.

It was evident that in Sarawak less favourable weather conditions had been encountered, with the result that there was a great deal of turbulence, especially over the land/sea interface. This in turn meant that the flying contractor had rejected a higher proportion of data and had ordered more re-flights. All of the data and the re-flights were considered satisfactory, with the exception of two areas where the combination of turbulence and antenna pattern affected the images significantly. It was decided that these artefacts could not be removed by image processing without some loss of overall image quality. Re-flying was requested for these areas; the new data were, however, deemed to be acceptable.

A major problem in Sarawak occurred in the Brunei boundary region, especially in the area of Brunei nearest to Sabah and the enclave between the two areas of Brunei. In the first flying phase full overflight permission had still to be granted. Data were however obtained for the priority area, although this included much of Brunei in error. In the second phase restricted overflight permission was granted, so long as the aircraft did not obtain data.

Flying near international borders always presents problems, especially if one is acquiring data. It is surprising, therefore, to learn that there is apparently no proviso in the contract calling attention to the fact that images could only be acquired provided that diplomatic/security clearances had been obtained. As it stands it would appear that the agreement with Petronas to obtain data 10 kms over the border still applies. It is, however, clear that the acquisition of these data could present a severe risk to the flying contractors and a compromise has to be agreed.

It was necessary, therefore, to establish the extent of any shortfall of data. For this a map showing the border and sufficient planimetric detail was required. A suitable map, at 1:250 000 scale, was obtained on loan from the geological survey and this was used to plot the extent of available cover and indicate the gaps. Figure 1 shows a sketch map of the area of Brunei concerned with the gaps shaded.

Areas A, B, C, D, E, are not regarded as significant. Given the irregular nature of the boundary it would be impossible to re-fly and improve on coverage without risking infringing Brunei territory. Area F is thought to have been covered in a reflight and any remaining gap is insignificant. Area H is similarly thought to have been covered in the first phase but this remains to be proven. Area G has no known cover but, again, any reflight would be risky and not certain to make a significant improvement. Flying in a different direction is not the answer, it would have no greater certainty of success and the data would not be suitable for inclusion in the mosaics or for stereoscopic inspection.

To put the problem into context, Figure 2 shows area F enlarged to two scales. The first at 1:125 000 scale is that used for the strip images and the second is the maximum mapping scale of 1:50 000. In this context neither problem can be regarded as worth putting the contractor at risk. As far as can be determined the gaps are not in areas of major geological significance.

When all the imagery had been examined and the final acquisitions checked, including reflights, it was agreed that the main contract requirements had been met and the aircraft was free to leave the project area.

Cover is again dependent upon final check against reliable maps which were not available at this time. In the case of the Indonesian boundary it would appear that no constraints on flying were imposed and cover extends across the frontier.

The GPS in Sarawak was established to the same standard as the station in Sabah using reliable local control as reference points. The available GPS windows were reduced and it was necessary to carry out flying at night to maximise GPS time.

3. DISCUSSIONS IN KUALA LUMPUR

Discussions were held in Kuala Lumpur both with Petronas and with Petronas and Intera combined.

4. FUTURE PROGRAMME

The problems related to the Brunei data were discussed and it was learnt that Intera were discussing with the Brunei government the possibility of obtaining SAR data for their territories. If this does occur then the Sarawak gaps could be filled.

It was agreed that the mosaics where the gaps occur should not be finally produced for five months. If during this period the Brunei acquisition is agreed, and obtained, the mosaics can be completed using these data. If the agreement is not concluded, then the mosaics will be completed with the maximum use of available data, irrespective of the normal policy of restricting mosaicing to the central area of each image strip.

The policy on the construction of mosaics of the Mount Kinabalu, as outlined earlier, was agreed.

A problem had arisen on the sizing of the 1:100 000 scale mosaics. Borders produced by Petronas did not agree with that of the mosaic supplied by Intera; a subsequent sheet plot produced by Terra Control Technologies did not agree with either. At the meeting a new plot from Petronas was produced on a more stable medium and this showed an agreeable coincidence. It was opined that much of the error as demonstrated was the result of a mixture of plotter error and material instability. The most valid comparison would be to calculate the sheet dimensions on both computers and to compare these mathematical results. Should any difference of significance still occur then the Survey of Malaysia should be requested to supply an independent set of figures which should be regarded as the definitive set.

There was a worry that the wrong spheroid had been used, but the difference between figures for the spheroid used and those given by reliable surveyors/cartographers is not of great significance in an area of the size involved. In general the difference is in the oblateness which occurs at the polar regions, at the equator, where the Earth is closer to a sphere, the difference should not be significant. If a final error or difference still occurs, it should be possible to identify the source by comparison of all the figures and formulae used.

It was agreed that both parties would make the calculations for comparison.

The problems in obtaining maps was discussed, these are essential if the mosaics are to be checked for reliability especially on major features. Whilst it can be argued that this problem should have been identified at the contract stage, it would now be advantageous if Petronas could assist Intera to obtain suitable maps or copies from the Survey Departments. Maps will be essential to the QC if the final cover is to be checked and the overall accuracy and resolution quantified.

Copies of the first mosaics were available for inspection. From a visual inspection the results appeared to be fully up to specification and should provide a valuable data base for geological and other analysis. The internal accuracy and resolution does remain to be verified.

It was noted that for security requirements various zones have had to be masked out on the photographic products. It is pointed out that these same areas cannot be masked on the digital data and so they will be visible to anyone using the digital tapes.

There was discussion on the border titles as to which sheets should be labelled Sabah and which labelled Sarawak, it was suggested that a project title should be used with both names included for all sheets.

4. FUTURE PROGRAMME

A requirement for two further QC visits was identified. The first will be scheduled when a reasonable amount of variety of data in mosaic and strip form have been completed; this is likely to take place in June and should be in Calgary. The other visit would be to Kuala Lumpur to review the local contractor Terra Control Technologies to ensure that the systems in use are compatible with those in Intera. August was proposed for this visit. In the interest of ensuring continuity of quality control procedures and maintaining an overview of all aspects of the projects it was requested that the Consultants' QC specialist should make all remaining visits.

Any requirement for additional QC inputs will be discussed as the programme develops, either before the current schedule of visits or during the August visit to Kuala Lumpur.

FIGURE 2 Missing SAR Data - Area F
Shown at Strip and Large Mosaic Scales

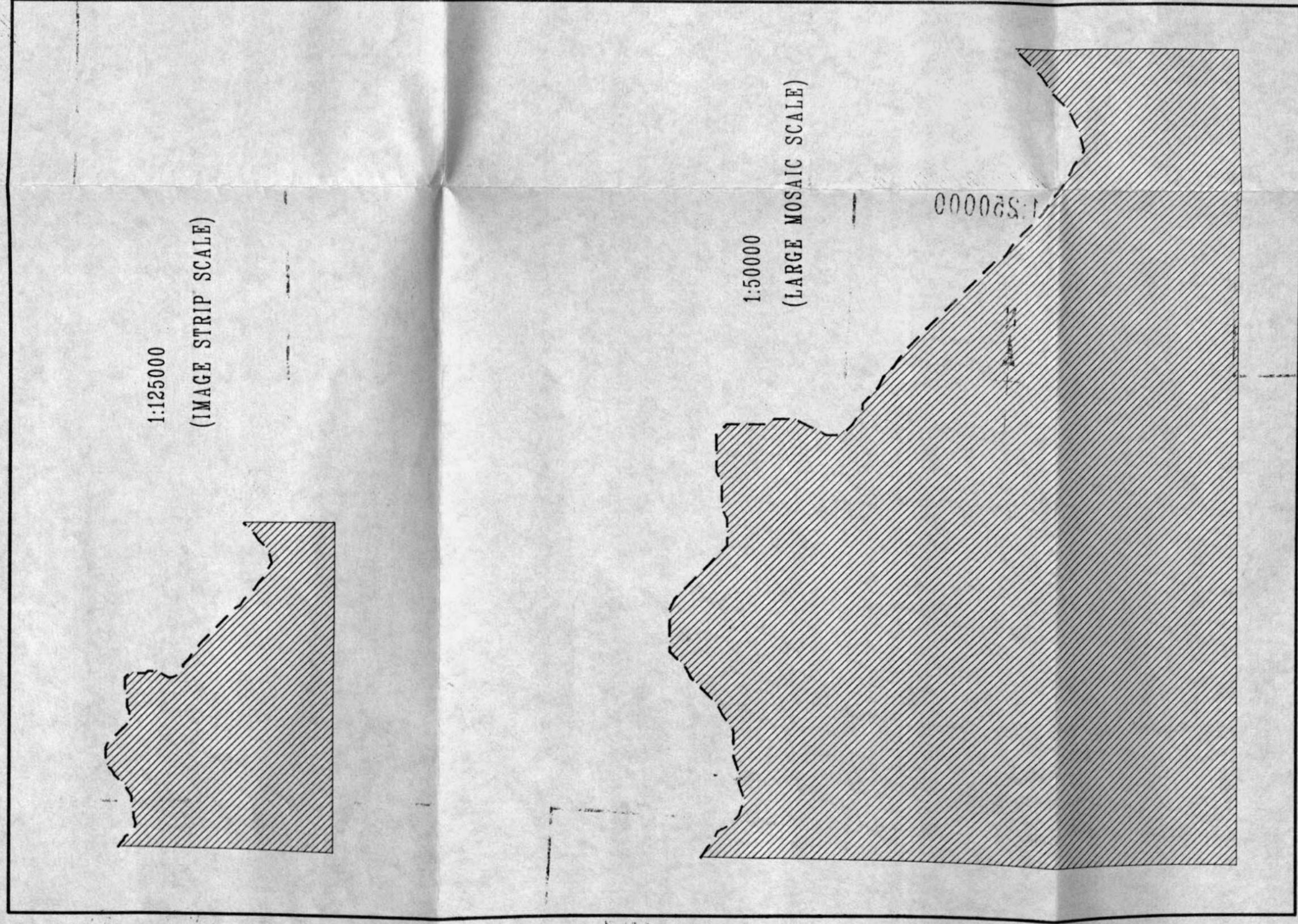


FIGURE 1 Gaps in SAR Data Coverage

