

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**

**FIRST QC VISIT REPORT**

**November 1990**

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

**FIRST VISIT REPORT**

**1. INTRODUCTION**

After a number of delays due to the need to change engines on the acquisition contractors aircraft, the first quality control (QC) visit was finally undertaken from the 25th October to the 4th November by Hunting Technical Services Limited, Senior Remote Sensing Consultant/Team Leader, J.W. Trevett. Mr Trevett is defined in this Report as the QC Consultant.

**Diary**

25th October	travelling London-Kuala Lumpur
26th	Arriving Kuala Lumpur, preliminary discussions Petronas and potential data users
27th	Discussions Petronas and Intera
28th	Sunday
29th	Further discussions Petronas and Intera
30th	Discussions Petronas travel to Kota Kinabalu
31st	(In Kota Kinabalu, setting up the GPS and initial flying programem by Intera)
4th November	Travel Kota Kinabalu - Kuala Lumpur - London
5th November	Arrive London

**2. DAILY REPORT**

**2.1 26TH OCTOBER, PRELIMINARY MEETING WITH PETRONAS**

On the 26th October discussions were held with Petronas where the final wording of the contract were discussed and agreed, the changes being mainly phrasing required by the legal department which did not impinge upon the general structure and operation of the contract.

Subsequently discussion of a technical nature were held with Petronas and with the representatives of two of the concessionaires who would be using the data.

The questions from WMC Petroleum (Malaysia) Sdn Bhd were concerned with the Mosaics and Stereoscopy and are set out in their letter of the 25th October addressed to Petronas.

The concern of Idemitsu was with the number of Global Positioning System (GPS) base stations being used and the subsequent accuracy achieved. The Idemitsu representative was of the opinion that accuracy would be improved by the use of more than one GPS station.

The comments and concern were noted, some general remarks of explanation were made but the detailed answers would be sought by the QC Consultant from the Intera team.

It was explained that as a general rule most interpreters would prefer to work from the strip imagery and compile onto the mosaic, interpretation of the mosaic being only used to map major structures or broad regional trends. As in this case stereoscopic data were available the interpretation would be best under a stereoscope using the strip imagery. Note that unless the interpreter is fully experienced with radar imagery geometry in the stereoscopic mode, extreme caution should be used in making any inferences on dip slopes.

Distortion across track on a radar image is inevitable due to the method of imaging the surface obliquely, the effect is minimised in areas of low relief and its location in the image across the swath. By taking a segment of the image from about 10 per cent across to 60 per cent the

effects of such distortion are minimised to acceptable levels. To improve the data further would require the comparison with a digital elevation model constructed from reliable contour surveys, as these are not available and in any case the method would be both costly and time consuming, the differences which occur will have to be accepted.

## 2.2 27TH OCTOBER, MEETING WITH INTERA AT PETRONAS

Petronas explained their flying programme in terms of flight line patterns and timing. The timing is not an aspect of quality control only in so much as it determines the visits to be made. The Intera Quality Control Parameters are listed in Table 1.

The mosaics to be supplied are at 1:100 000 scale and 1:50 000 scale, the use of 1:100 000 scale posed a problem as the scale is not used as a publication scale by the Survey of Malaysia and therefore there is no prescribed sheet notation to be followed. It was agreed that the general 1:200 000 indexing should be used further subdivided into four sectors, to be described as NE, SE, SW or NW as appropriate, this being an accepted international practice.

The final mosaic strips to be presented would be as strips for each mosaic with end overlaps, the strips to bear the notation of the 1:200 000 scale sheet number reference, the 1:100 000 quadrant and the strip number in accordance with the overall flight plan.

Concern was expressed by Intera at the flight pattern for Sabah area which was at  $45^\circ$  to the sheet layout, this would produce strips of unequal length. The QC Consultant indicated that if the grain of the country was best imaged by a NE/SW flight pattern then this was the guiding criteria, a formula for varying the length of the strips and still maintaining stereoscopic capability along the length of the strip would have to be found.

Geological and topographic maps of the region were then examined in detail and it became evident that whilst the structures did indeed run NE/SW, the drainage, which strongly reflected the linears, was at  $90^\circ$  to this direction. This meant in effect that with the existing flight plan the main linears would be at right angles to the flight direction which is acknowledged as being undesirable for maximum expression.

It was therefore agreed that the flight plan should be redesigned to an E/W pattern, whilst this then brought the flight lines into correspondance with those in Sarawak and to the sheet layout it must be stressed that the decision was made on the assessment of the geological consideration and not for any expediency of mosaic construction.

The use of the GPS base and aircraft station was discussed in detail and Intera outlined their method of operation. The GPS ground station is first established over a point of known location, it is stressed that this must ideally be a permanently established primary triangulation monument approved by the Survey of Malaysia who should provide the position both in U.T.M. or equivalent grid terms and in terms of Latitude and Longitude of the Graticule.

Averaged reading at the monument over a 12 hour period will provide a location obtained from the satellite positioning data to be compared with the surveyed position, the difference between the two readings is taken to be the regional positioned variation. The station is then moved to a more convenient location, in the case of Sabah this is scheduled to be the roof of the Hyatt Hotel which will enable a cable to be run to the operators room where regular readings throughout the campaign will be made. The first series of readings at the Hotel will be adjusted to take into consideration positional differences measured at the surveyed monument, thereby establishing the location of this secondary control station.

Global positioning satellites although maintained in a stable orbital position can be re-located or moved as may be required by principal users (these are mainly military), the base station being permanently located for the project and related to a known survey point, monitors the relevant satellites in view and records any faults or gaps in transmission or changes which can be

related to the positional information being received and recorded at 1 second intervals on board the aircraft.

## TABLE 1 STAR - 1 QUALITY CONTROL PARAMETERS

### PETRONAS PROJECT

OCTOBER 26TH 1990

#### 1. Line Positioning

Lines will be flown with 60 per cent mean overlap  $\pm$  5 per cent. Quality control will be provided in field using dry silver paper. Nominal line spacing on this project is 9.25 km. Lines not conforming to this specification will be reflown.

#### 2. Data Positioning

Differential GPS will be acquired for all data. Lines will be reflown if GPS data is incomplete.

#### 3. Reflights

Flight lines which have to be reflown will be done so with a minimum endlap of 10 per cent of swath width.

#### 4. Lead In/Lead Out

At start of line, there will be a 10 km lead-in where data is acquired. At end of line, a 10 km lead-out will be made. The preceding will be subject to ATC and national sovereignty regulations. In the areas of look direction change, a 10 km overlap will be provided.

#### 5. Geometric Accuracy

Excluding crosstrack terrain displacement effects, geometric accuracy will be better than 1 per cent when referenced to a 30 nautical mile line.

#### 6. Radiometrics

- a. Antenna pattern and/or fall off in near range where stereo interpretation is still possible will be considered to be acceptable. Bad or questionable antenna pattern/falloff will be rejected and reflown.
- b. Rain shadows which cause loss of data will be reflown. If these rain artifacts exist in shadow areas, the line will not be reflown. If less than 1 per cent of the swath is affected by a rain shadow which does not significantly affect data interpretation, the line may be accepted.
- c. Turbulence banding: If severe, the data will be immediately rejected in the field. Slight turbulence is normally accepted on advisement of mission coordinator and corrected with post-processing software.

#### 7. Loss of Data

Any loss of data in contract area will be subject to a reflight (for example, bad tape, radar problem, navigation problem).

Then the main function of the base GPS is to provide data on any changes in the satellite data, provided the base monument is primary or secondary triangulation and reliable, and adequate stabilising or base establishment readings are taken, then using more than one base station to provide correction curves will not necessarily improve the aircraft positioned data to any extent that will significantly effect the final mosaic accuracy, given the inherent geometry of SAR.

It should be noted that primary triangulation stations are not individually fixed and located but are themselves part of an adjusted network. Somewhere in Borneo there will be base triangulation stations, normally ends of a precisely measured base line with the station positions fixed by precise astronomical observations. Thus there may well be triangulation adjustments made to the monument to ensure overall triangulation harmony but given the potential precision of modern satellite measuring systems. all that this method of operation is set out to do is to ensure coincidence between the two data bases. In global positioning terms there is no guarantee that the primary triangulation point is any more accurately defined than the GPS readings will achieve.

### **2.3 29TH OCTOBER, FURTHER DISCUSSIONS WITH INTERA AND PETRONAS**

Intera explained that the airborne navigation system was now controlled by the GPS rather than the Inertial Navigation System (INS) previously used, although INS is still used for initial positioning. The flight line plan of regular parallel lines will be flown using the GPS to maintain course through the autopilot. The mosaics are then constructed based upon the GPS position of the data and the sheet lines, which are also graticules not grid, will be calculated from the data and applied.

This apparently produces sheets of the highest precision in respect to location, however whilst coincidence between the mosaics and any sheet may well be achieved to acceptable standards the methodology used does not set out to achieve this and no reference is normally made to existing maps.

The QC Consultant expressed concern over this attitude from a quality control point of view. It is accepted that there may be shortcomings in the precision of some of the map sheets, especially those in the more remote regions where precise ground control and survey will be difficult to achieve. In the more developed areas, around the coastline, the precision of mapping will be higher. It is inevitable that users will wish to relate their interpreted data to data from other sources. These sources may be geological maps, geophysical surveys, geochemical data or seismic data, if the two bases are not on the same basic projection and do not relate within acceptable cartographic limits commensurate with the scale, then users will have no confidence in the data and will not be able to use it for their exploration analysis.

It was agreed that Intera would obtain copies of the 1:50 000 map sheets and would relate to these when constructing their mosaics. The quality control would, in the case of the 1:100 000 series, select features that were common to both mosaic and the 1:50 000 map and whose position and representation were not in doubt and measure the location in terms of latitude and longitude for comparison. In general a correlation of 1-2mm would be expected provided the point chosen was in the near range area of the SAR along track. In other areas correlation between features would be observed by tracing features off the 1:50 000 series, reducing them to 1:100 000 and overlaying the mosaics. It is accepted that correspondence in detail, along rivers for example, may not be precise due to differences in mapping methods but there should be general agreement in configuration and location. These parameters cannot be defined in precise measurement terms but must be the judgement of the quality control observer based upon their experience of mapping methods and tolerances. In the case of the 1:50 000 mosaic sheets direct overlay with the maps will be made, corresponding accuracies will be expected and given the general fit of the map data correspondence with the sheet cut lines will be expected.

The physical parameters of the SAR were then discussed, the questions concerning the processing methods, methods of calibration and determination of the SAR parameters were not possible to resolve. The system used by Intera means that all the processing of the data is carried

out in near real time on board the aircraft, as a result there is no record of the raw data and therefore no means of checking the quality control of processing.

It should be pointed out at this stage that synthetic aperture radar produces an initial record which is a radar hologram and as such is totally unreadable as an image. Subsequent processing selects the optimum signal for recording and seeks to correct for various radar artefacts of the system such as antenna pattern, signal to noise ratio, slant range to ground range and so on, from this a final record is selected which can produce an image. Other such systems, for example ERS-1 satellite data will be received as raw data and much emphasis will be made on methods of processing and evaluating the data, introducing certain calibration and validation methodologies. One method used is to set up good radar targets, corner reflectors, of known dimensions, orientation and position which are imaged daily and used to evaluate the imagery.

The Intera system builds standard correction factors into the system to produce a normalised image, in general with experience this produces an image of acceptable visual quality. In order to deduce whether the system is capable of the performance claimed, it is necessary for the quality control to have an understanding of the parameters and corrections used. Where one is dealing with the visual image then the cosmetic appearance is the main judgement, in other words the image looks right. Such an evaluation is however subjective and depending upon the experience of the person viewing the image. In this case there is a request to be supplied with the digital data, this implies that at some time the digital data will be used for analysis which in turn will be more critical of the quality of the data, it therefore becomes even more desirable to understand the various corrections and adjustments made.

It was agreed that the quality control team would supply a list of relevant questions which would be sent to Intera Canada for consideration by their system experts, the radar system physicist of the quality control team would then be able to evaluate the parameters and further evaluate the data during his visit to Calgary.

As a further consideration the use of corner reflectors would normally be used to ensure the contract requirement for six metre resolution data has been met, because of the difference between radar resolution and optical imagery resolution this can be difficult to check using normal ground objects. The method of establishing the resolution criteria within the system will be evaluated and reported upon by the quality control radar scientist.

The criteria for accepting or rejecting data were discussed, Intera explained how the quick look data are examined after every sortie in order to establish whether the area has been covered within the tolerances established by a 60 per cent overlap, whether there is evidence of precipitation from clouds and whether a resulting rain shadow has occurred, whether flight turbulence or other factors have degraded the data and if any other radar related artefacts have occurred on the data. It can be demonstrated that by subsequent data processing the effects of certain artefacts can be cosmetically corrected, it is desirable that such measures are kept to a minimum again especially since digital data may subsequently be used.

Flight coverage is an important item, the Intera flight plan is based upon a common flying height and regular equal parallel flight lines. These are predetermined to provide the required 60 per cent overlap, it is possible that topographic factors due to long and sustained changes in ground height along track could result in less than the desired 60 per cent overlap, it was eventually established that should this arise the flight plan would be modified in those areas to correct the phenomenon. The quality control team will wish to see the quick look imagery and, having due regard to its diminished quality compared with the final product and the operational limitations of the reproducing equipment, will satisfy themselves that the data are to the standard required.

The mosaicing of the data are carried out using digital image analysis equipment, the systems used will be evaluated and reported upon during the Calgary visit. It is noted that the negatives are written onto film at full size so that no photographic enlarging is required and that

each negative will carry its own grey scale wedge. These will be checked using a densitometer. It is also noted that the 1:50 000 series are a re-plot of the basic data at the new scale and not a photographic enlargement of the 1:100 000 data, this is welcomed as it will further ensure maximum fidelity of the photographic data.

The 1:500 000 composite mosaic was discussed as a further requirement. Intera propose that this shall be constructed by normal photographic mosaicing means. It is understood that re-sampling the data to give fewer pixels before plotting in a single matrix cell would be too time consuming. It is accepted that the smaller scale composite mosaic will be to less exacting criteria on content but it is perhaps even more essential to ensure that the final composite is in accord with any 1:500 000 series that may exist. To this end there is a benefit in photographic laydown mosaicing since this should be done to any 1:500 000 map to ensure compatibility. The HTS photographic engineer will comment further on these aspects.

It is noted that some of the mosaic construction processing for the 1:100 000 series will be undertaken in Kuala Lumpur by the local counterparts. Staff will be sent to Canada for appropriate training, it is however essential that a Canadian expert returns with the trained personnel to Kuala Lumpur to ensure the newly installed system and the trained staff are performing to specification. It is understood that this procedure is partly to provide technical transfer and also for expediency to obviate any delays that could occur due to pressure on processing in Canada.

There is concern that suitable plotting equipment of the same calibre as that used in Calgary may not be available in Kuala Lumpur. It is considered that any attempt to use equipment at a smaller plotting format and subsequent photographic enlargement should be discouraged if the full significance of acquiring 6 metre resolution data is to be maintained.

The security aspects of transferring data between Malaysia and Canada were discussed and it was ascertained that this was not expected to present a problem, a security officer was to be aboard the aircraft on each survey flight and a security officer would go with the data and be present during processing in Canada.

Other security problems were also discussed, these were mainly concerned with obtaining coverage near international borders. The re-orientation of flight lines E-W in Sabah has to a large extent removed the border problem with Indonesia, although the problem with turning would occur along the Sarawak/Kalimantan border. The border with Brunei, it was hoped that clearance would be granted but if not it is accepted that should difficulties occur with operating near or over the borders then it is possible that gaps in the data will occur in those regions.

Intera presented their own quality control parameters and these were discussed and agreed. In particular the reasons for data rejection were demonstrated and accepted.

#### **2.4 30TH OCTOBER.**

Discussions HTS/Petronas concerning aspects of the contract. The QC Consultant then travelled to Kota Kinabalu to await the aircraft.

#### **2.5 31ST OCTOBER**

In Kota Kinabalu, remainder of Intera party arriving also aircraft, some discussions with Intera party leader.

#### **2.6 1ST NOVEMBER.**

Intera setting up the GPS station and preparing the aircraft. The QC Consultant held discussions with the GPS operators, the primary station had been set up over a monument that had been located and identified by a member of the Survey of Malaysia. This was a secondary triangulation point but nevertheless was approved and recommended by the Survey as reliable, all

relevant positional data were also supplied thus we are satisfied that a good base station has been used. It is understood a second base station has been identified and will be used as a further check.

After some initial minor problems with the SAR, a test sortie was flown in the afternoon and the resulting imagery examined in conjunction with the Intera team leader. Certain adjustments to the SAR and the recorder had been made during the flight and the merits of each data setting were discussed and the optimum settings agreed.

It should be understood that such methods mean that the final selection of the data parameters are empirical and dependent upon the judgement of the observers. Subsequent maintenance of the required visual standards may result in changes in the gain etc., being made during flight, whilst this will produce a visually acceptable result the balances cannot be quantified in the digital data. It is accepted that this is not a research operation but a practical application of SAR data, in which case the interpretability of the data is the prime consideration but any limitations or constraints on the digital data for more detailed analysis must be recognised and understood.

## **2.7 NOVEMBER 2ND. COMMENCEMENT OF FLYING**

First two operational flights carried out, data examined on the quick looks and deemed to be of apparent acceptable quality with the required amount of overlap. The stereoscopic view of the images was also found to be of good perception. A second, secondary triangulation monument identified by the survey department was used to record GPS data and added into the base referencing data. The establishment of the GPS is considered satisfactory.

## **2.8 NOVEMBER 3RD. ONE FLIGHT.**

Segmented data examined in block form by laying down strips to check overlap which was all found to be within the 60 per cent tolerances prescribed; most being greater than 60 per cent. The selected imagery was examined and agreed and the parameters for rejection discussed.

Where imagery was rejected the reasons for rejection were agreed and the rectifying procedures for re-flying approved.

It is noted that two priority concession areas exist S17 and SB6, the flights examined to date represent parts of area S17 which are requested by Idemitsu.

Bad weather precluded any further flights being undertaken on this day.

## **2.9 NOVEMBER 4TH. CONTINUATION OF FLYING**

The remaining data up to the end of the morning's flight were examined, this effectively completed S17 the Idemitsu block. The overall visual quality of the data as adjudged from examination of the quick look data was acceptable. The cover check showed that the average of 60 per cent lateral overlap was maintained and that adequate lead in data were available to cover the block.

The afternoon flight was started on the second priority area, although the data were not available before the QC Consultant's departure there were indications that the aircraft had encountered unfavourable weather conditions and the flight programme was terminated earlier than expected.

The weather on the 3rd and 4th was most unsettled with numerous storms common to the monsoon season, in the circumstances there is surprisingly little evidence of turbulence affecting the data, what minor events did occur should be removable in the image processing. On coastal areas some point targets appear which will enable subsequent detailed analysis of the SAR system.

### **3. FUTURE PLANNING OF QC ASSIGNMENTS**

The future operation timing was discussed with the Intera team leader, the Terracontrol representative and the Petronas representative. It is understood the priority area digital data will be processed in Calgary in the last half of November. This was the period originally scheduled for a quality control visit to the processing location, since it is considered essential to monitor the processes to be used. Taking into consideration the need to be assured that the fixed, on-board, processing parameters are valid, it is intended to send a radar system expert to Calgary within this period.

It is not expected that, following periods in Singapore and Indonesia, re-flying of Sabah, Sarawak will commence before the beginning of January. It is felt desirable that the third QC Consultant visit, or second field visit, would be best undertaken at the completion of the Sabah block and the commencement of the Sarawak block. This timing will enable the QC Consultant to ensure Sabah is adequately covered and that the control for Sarawak is satisfactory.

The fourth QC visit would then be timed for the end of February, when Sarawak is completed. This visit will complete QC of all the flying phases, it will also include examination of all local processing and any completed deliverables.

At present the programme envisages a fifth QC visit. However it is understood that the production of mosaics will continue until the end of 1991 as a result of the number of sheets involved. At the same time a composite mosaic for both States is called for, this will require special production.

Products will be delivered progressively and it will not, therefore, be possible to monitor and control all deliverables during the fifth QC visit. It is therefore proposed that a further quality control visit is approved by Petronas, making a total of six rather than five. The fifth visit would be to Calgary around March/April when a suitably substantive number of mosaics of Sabah are ready for final acceptance and, more importantly, some of the 1:50 000 series ready for checking.

The final QC visit would be in Kuala Lumpur on completion of all deliveries of photographic, base materials and digital data to ensure all deliverables are to standard. This visit will also include preparation of the final project appraisal report.

### **4. REPORTING ARRANGEMENTS**

Reports will be issued after each QC mission describing the activities and the data examined. It is proposed that after the first visit to Calgary a short commentary on the use and limitation of the data be prepared as a guideline to users and potential purchasers.

As the data flow improves and supply of hard copy becomes available for more general supply, we propose to issue a second set of guidelines to use for inclusion with the data. These guidelines will call attention to some of the general limitations of SAR data and the particular attributes of the STAR 1 system, this is not intended to be critical but it is hoped will enable users to derive the maximum positive benefit from the data.

The QC Consultants have a copy of the flight plan for the project and the sector notation, thus it is possible to mark and monitor progress. It is therefore requested that we be supplied with the Intera progress reports in order that we can be aware of the progress, in all aspects, and schedule our inputs to the best advantage.

At the meetings with Petronas and Intera it was stated that although the QC Consultants had received a copy of the original call for tender for the data acquisition, it would be most helpful to have the final, agreed, contractual requirements and the segment of Intera's submission setting out the specifications of the equipment and methodologies they intend to use. It was agreed these should be made available at the meetings held.

