STARMAP Processing of SAR Imagery for Petroleum Exploration in Irian Jaya*

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ABSTRACT

In this paper we present the results of the first major commercial implentation of the process known as STARMAP by which topographic mapping information is extracted from airborne Synthetic Aperture Radar (SAR) data. A SAR survey using the STAR-2 system, was conducted in the Warim block of Irian Jaya, Indonesia, in 1988. The SAR data were supplemented by GPS data for navigation improvement and for flight line recovery. STARMAP products in the form of ortho-rectified Radar Image Maps at 1:50,000 scale, Digital Elevation Models (DEM's) and contour maps were created. These products can be used as planimetrically accurate base maps, topographic representations and as source data for thematic extraction (eg geological). They were used in Conoco's exploration program for logistical support, for geological interpretation and for creation of sub-surface geological profiles. In this paper we describe the data acquisition and STARMAP processing methodology. Verification of accuracies, to the extent possible, are summarised. Examples are not available within this manuscript but will be incorporated into a more complete revision available at presentation time.

1.0 INTRODUCTION

Support of exploration programs in areas of the world which are habitually cloud or haze covered is often ineffective using traditional methods of aerial photography or satellite data. Considerable use has been made of radar data over the years in these circumstances, but usually for interpretive geology and coarse-grained mapping applications. These applications have not addressed the requirement for extraction of elevation data in a quantitative, systematic fashion, nor do they allow for horizontal accuracies better than about 200 meters in most cases. STARMAP is the name of a recently developed process in which topographic mapping products are created from radar images acquired by Intera's STAR-1 or STAR-2 airborne Synthetic Aperture Radar (SAR) systems. Mapping products include Digital Elevation Models (DEM's) and rectified ortho-images mosaiced into 1:50,000 scale Radar Image Maps. Achievement of accuracies of the order of 30 meters (RMS) has been the short term goal.

The first major application of STARMAP was in support of an exploration program conducted by Conoco Warim Inc in the Warim block of Irian Jaya, Indonesia, commencing in 1989. The STARMAP products were to be utilised:

(1) by the planning teams and field crews for laying out seismic lines in the foothills,
(2) by the helicopter-borne geological parties performing field sampling in the mountains,
(3) by the geophysical engineers using the Digital Elevation Models (DEM's) for interpretive purposes culminating in well-siting recommendations.

The purpose of this paper is to present the STARMAP methodology used for the project. A companion paper at this conference describes the utilization of the STARMAP products and particularly the interpretive aspects noted above.

The radar data were acquired by the STAR-2 system. Differentially-processed GPS data were used in the STARMAP process because of the absence of adequate ground control in the area. Some ground control points were acquired in order to check accuracies. In this paper we will summarise the acquisition parameters and STARMAP process and will show some examples of the resulting products and accuracies.

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2.0 DATA ACQUISITION

2.1 The Radar System

STAR-2 is a fully-focussed, digital, real-time, X-Band SAR system flown in a Cessna Conquest. In 'narrow-swath' mode, STAR-2 has a resolution-limited pixel size of 5.4 m x 4.2 m in slant range, 4096 pixels across the swath, corresponding to a ground swath of about 18 km width. Usually the pixels are resampled to 6 m size during post-processing. Speckle reduction is achieved through multi-looking (seven independent azimuthal samples of each pixel are incoherently summed).

In the tropics STAR-2 typically flies at altitudes of 8-9 km at speeds of 240 knots and with maximum operating range of about 2500 km. The radar can view to either side of the aircraft upon command. For STARMAP applications it is desireable to keep the viewing geometry as steep as possible which corresponds to depression angles varying from 40 to 15 degrees across the swath.

The real time digital imagery, accompanied by annotation information, was recorded onto High Density Digital Tape (HDDT) and subsequently transcribed onto Computer Compatible Tapes (CCT's).

2.2 Global Positioning System (GPS)

GPS information were utilised for three elements of the program as described below. A pair of Canadian Marconi CMA 786 receivers were used. These were two-channel sequencing types , designed for aircraft navigation purposes, but with differential processing capability. Data were logged on lap-top computer and though independent of the radar system, could be time referenced to the radar data through event marks and cross-correlation with the INS data. In single point mode accuracy was advertised as 25 m RMS , assuming PDOP~2. Static results were generally consistent with this figure.

2.2.1 Navigation

Flight line navigation is normally implemented through INS control of the auto-pilot. However INS drifts can create positional uncertainties up to several km during the coarse of a mission. Because of the relatively close tolerances placed on the overlapping image swaths it was found advantageous to use the on-board, single-point GPS to provide updates to the INS at least at the beginnings of each flight line.

2.2.2 Precise Flight Line Recovery

In the absense of a dense collection of Ground Control Points (GCP's), STARMAP processing requires input of the sensor position, desireably to sub-pixel accuracy, and sampled over time increments small with respect to flight line dynamics. To achieve this objective, GPS data were differentially post-processed. One GPS unit was was tied in to control at the airport base of operations at Sentani near Jayapura while the other unit was, of course, aboard the aircraft. Data were collected over baselines up to 600 km with intervening mountains. Previous experiments had provided expectations of about 4-7 m RMS acuracies along each axis with accuracy degradation no more than a few meters owing to long baselines.

2.2.3 GCP Collection

In order to check STARMAP accuracies, a few GCP's were acquired through use of the same GPS receivers. When the STAR-2 imagery had been acquired, several points were identified on the imagery, at places accessible to helicopter or small aircraft where the 'mobile' GPS unit now removed from the STAR-2 aircraft, could be deployed. Normally these were small airstrips cut in the jungle for missionary support of local villages. In two cases these coincided with previously surveyed monuments, enabling consistency checks to be attempted.

2.3 Operations

Stereo imagery were acquired over an area of 27,000 kmsq. during March-April of 1988. Flight lines wer oriented East-West with viewing direction to the north. The terrain in the southern portion of the WARIM area is relatively flat but the northern portion consists of extremely rugged, high mountainous terrain. In the mountain areas, shadowing was prevalent so that area of the block, was also acquired with South viewing imagery which enabled more than 90% of the shadow areas to be recovered. The eastern extreme of the block borders with Papua New Guinea which created air coverage problems. These were resolved by flying that portion in a North-South orientation with East viewing radar.

Data QA and GPS post-processing were conducted at the completion of each mission at the airport base of operations in Sentani.

3.0 STARMAP PROCESSING

STARMAP processing took place in Calgary and Boulder. Processing steps include:

- Digital Radiometric Correction, GPS Cleanup, etc
- Creation of Film Diapositives
- Analytical Plotter Work - relative orientation of diapositives, tiepoint creation, data acquisition(grid points, breaklines, drainage lines)
- Flight Line Adjustment
- DEM and Contour Creation
- Image Rectification (Removal of Terrain Displacement, Register to Map Projection, Resample)
- Digitally Mosaic
- Create Final Products (Radar Image Map at 1:50,000 scale, Contour Overlays, Composite DEM from Two Viewing Directions Where Applicable), QA, Editing

4.0 RESULTS SUMMARISED

Radar Image Maps were created for each of the viewing directions. These maps are the radar equivalents of ortho-photo maps. They were presented with and without overlaid contours. Contours were created at 50 or 100 meter intervals depending on terrain. The DEM's were also created for each of the viewing directions. Composite DEM's were created in the regions of dual coverage. The resulting contours were thus composite contours as well.

Geometric accuracies are summarised below. It should be noted that the few GCP's were not used in the solution except to provide where desireable, a global offset to a complete mapsheet.

4.1 GPS: Based upon comparison with a single reliable (ie intact) survey monument established by the Royal Australian Survey Corps and located near one of the GCP's at Iwur about 500 km from the reference station, northing, easting and height differences were three, six, and five meters respectively.

4.2 STARMAP Planimetric: Based upon four GCP's the mean difference was about 20 m in both axes.

4.3 STARMAP Vertical: Vertical uncertainties in the 30-40 m RMS range were observed from:

- Internal tie point consistency checks,
- Comparison with the forementioned GCP's,
- Comparison with results of seismic line surveys in the western portion of the block.

5.0 CONCLUSIONS

In this extended summary we have presented the background to and results achieved from the first major commercial use of SAR for extraction of topographic information. The products include DEM's and ortho-rectified Radar Image Maps with overlaid contours presented at 1:50,000 scale and from which larger scale maps have been generalised . GPS has been integrated into the process in a fundamental way, thus eliminating the need for GCP's except as checks.

This technology has its niche particularly in those areas of the world where the standard technologies using air photos or SPOT data are too slow or too expensive due to cloud and haze cover. It should also be noted that the work reported is now three years old and significant developments have occurred to STARMAP in the interim which will improve accuracy, throughput and cost. These will be reported elsewhere.