

REVISION OF MEDIUM SCALE TOPOGRAPHIC MAPS USING SPACE IMAGERY

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ABSTRACT

The standard topographic map series covering Australia is the National Topographic Map Series. This involves the compilation of over 3,000 x 1:100 000 scale map sheets. As initial coverage of the country at this scale will be completed in 1988 the national mapping task is undergoing a transition from first cover to map revision.

Potentially, space imagery offers a cost effective approach to this large revision task, if satisfactory feature identification and position placement can be achieved to meet the required specifications.

In this paper a study area is used to compare a digital photogrammetric compilation from aerial photography with a digital compilation produced stereoscopically from panchromatic SPOT imagery. The potential of multi spectral SPOT and TM space imagery to aid in the identification of features on panchromatic SPOT imagery is also investigated.

Results show that it is feasible to plot to 1:50 000 and smaller accuracy specifications from SPOT stereoscopic, panchromatic imagery, but the identification of features is limited. This identification can be significantly improved for many of these features if multi spectral imagery is used in conjunction with the panchromatic SPOT imagery.

BACKGROUND

The Australian National Topographic Map Series (NTMS) involves the compilation of 3064 1:100 000 scale map sheets and 541 1:250 000 scale map sheets. The first cover programme for both scales is scheduled for completion in the 1988 fiscal year and the Australian Surveying and Land Information Group (SLIG) is faced with the massive ongoing task of maintaining this data base of topographic information.

Australian map revision requirements differ substantially from those of uniformly settled countries. Most of the urban development occurs in the coastal regions which make up a small percentage of the total area of the continent. Inland areas are frequently arid with sandridges and large grazing areas with sparse cultural detail. In these areas however a single new building, fence, water tank or new access road may become a significant landmark. The principle revision requirements outside the urban developments are:

- . Water resources, such as bores, wells, and tanks.
- . Land usage, such as fences and irrigation channels.

- . Specific developments such as large dams, roads, power lines, mining activity and buildings.

CURRENT REVISION TECHNIQUES

In areas of significant change, new block aerial photography is used photogrammetrically for total planimetric recompilation of cultural detail. Recompilation may also be required if the accuracy of the horizontal and/or vertical aspect of the existing map is found to be unsatisfactory. Many of the first cover compilations of Australia are based on graphical slotted template photogrammetric control extension techniques and the resultant maps are close to 1:100 000 accuracy specification limits. This presents a further revision problem (Manning 1986).

Total revision of the large number of map sheets in the national program by traditional photogrammetric techniques is heavily resource intensive.

In areas of little change the photography coverage is restricted to specific areas of development within that map sheet. The revision procedure then used is to update from this photography rather than totally recompile each area.

The imagery most used for medium scale topographic mapping in Australia is 1:80 000 high resolution panchromatic K2412 photography with a target resolution of 2-3 metres. Even with this high resolution capability, much production time is spent on feature identification as the arid inland areas have low contrast reflectance characteristics and features often merge into the background.

THE REVISION POTENTIAL OF SPACE IMAGERY

Space imagery has offered potential economy to the map maker since the launch of Landsat 1 in 1972 but limitations for medium scale map revision from MSS Landsat imagery with 80 metre pixels, have been:

- . The lack of metric accuracy of the image.
- . The problem of identification of small point features and faint linear features in low contrast reflectance backgrounds.

It has been generally accepted that a pixel size of 3-5 metres would be necessary to provide the information content required for 1:50 000 or even 1:100 000 map specifications (Doyle 1982, Welch 1985, Konecny 1987). However the use of stereoscopic or multispectral imagery may enable imagery with larger pixel sizes to produce satisfactory results.

SPOT satellite imagery is now available in Australia in both 10 metre panchromatic and 20 metre multispectral forms. Stereoscopic Russian space photography with similar resolution is also now becoming commercially available over most of Australia. In 1988 the Australian Centre for Remote Sensing will upgrade their satellite receiving capability to receive

thematic mapper imagery with 30m pixels, SPOT imagery and data from other satellites.

COMPARATIVE STUDY

To assess the technical capability and potential benefits of space imagery for revision of medium scale topographic maps, a test study was arranged under PEPS agreement project 225 (Veenstra and McMaster, 1987). The aim of the study was to compare the results of revision from panchromatic aerial photography and revision from panchromatic SPOT imagery for use in the revision of 1:50 000, 1:100 000, and 1:250 000 scale topographic maps in Australia. The main points of the study were:

- . Accuracy
- . Feature identification
- . Cost comparison

The spectral windows of the stereoscopic imagery used were:

<u>Imagery</u>	<u>Wavelength</u>
Kodak K2412	0.40-0.70um
SPOT Panchromatic	0.51-0.73um

The area selected for study was SPOT scene (K378, J396) in Central Queensland. Land use in the area is largely cattle grazing with some cropping and irrigation areas. In addition, running north-south through the area is a series of very large open cut coal mines. These relatively recent developments and associated infrastructure, such as two new towns, and road and rail links, are not shown at all on the existing 1:100 000 and 1:250 000 series topographic maps. which have reliability dates of 1972 and 1974. Consequently the existing maps were not useful as a direct basis for comparison and a reference "ground truth" was established by field survey.

STUDY METHODOLOGY

Conventional Photogrammetric Revision

Ground control was intensified in the SPOT test area and all points targetted. Mapping photography was flown in July/August 1986 and consisted of 1:80 000 panchromatic K2412 aerial photography flown at 25,000 ft.

An aerotriangulation adjustment using independent models was carried out from aerial photography using a perimeter of targetted ground control points. The fit to horizontal control for 21 ground points was 1.0 RMSE and for 93 vertical control points was 0.9 RMSE. This block adjustment provided photogrammetric model control suitable for 1:50 000 mapping.

The area was stereodigitised model by model using PG2 stereoplotters interfaced to an Automap I digital mapping system. Identification of new features was aided by the use of reference material obtained from local authorities prior to

plotting. Twenty six digital models were joined to produce a base compilation to 1:50 000 scale specifications covering the SPOT scene. The compilation consisted of raw digital information with no generalisation. A vegetation classification was also carried out with the following classifications:

Dense - More than 60% ground cover
Medium - 20-70% ground cover
Scattered - 10-30% ground cover
Clear - 0-15% ground cover

Stereoscopic SPOT Revision

Level 1A diapositives at a scale of 1:400 000 in a 23x23cm format were produced by SPOT IMAGE in France. The stereo pair consisted of a 17 degree western oblique taken on 8 June 1986 and a 26 degree eastern oblique taken 22 days later on 30 June 1986. This combination produced a 0.8 base height ratio.

The SPOT panchromatic imagery was set up in a ZEISS Planicomp 100, with fixed x6 eyepieces, to form a single model for stereo digitising. The stereomodel was set up with prototype software by Priebbenow (1987) and exhibited a strong East-West slope due to SPOT imagery being acquired at different angles to vertical. This causes a visible scale difference in the two images. The operator had no involvement with the previous plotting from aerial photography but had access to the same reference material showing some new developments in the area.

To enable a direct comparison using the same symbology, the digital data collected on the Planicomp was then transformed and replotted using the in-house digital mapping system. Duplicated features were deleted and other minor editing tasks carried out to produce a data file equivalent to that previously produced by stereodigitising from aerial photography.

ACCURACY COMPARISONS

The accuracy of the photogrammetric control produced across the SPOT area was conservatively rated at 3 metres and was used as the basis of accuracy comparisons with co-ordinates produced from the SPOT image.

The SPOT model was set up on 27 control points established by aerotriangulation. Three dimensional values for an additional 45 detail points were observed in the SPOT model and compared to values generated from aerotriangulation, producing a data set of 72 points.

The results of accuracy comparisons between aerotriangulated and SPOT generated values is shown in Table 1.

Point Feature INTERPRETATION		Mean Differences(m)				RMSE (m)			
		E	N	Plan	H	E	N	Plan	H
Very poor (VP)	5	5.9	6.0	12.2	-1.7	12.0	9.6	15.4	5.9
Poor	15	2.5	3.3	12.1	-0.5	10.1	9.7	14.0	4.9
Fair/Good (F)	52	0.4	-1.1	7.0	-0.8	6.0	5.7	8.2	4.3
Overall	72	1.1	0.3	8.5	-0.8	7.4	6.8	10.0	4.4

Table 1 : Accuracy Comparison of Spot and Aerotrig Values

In general a planimetric accuracy of about 8 metres was achieved with a slightly better value of 6m for height values.

FEATURE IDENTIFICATION

A field check of existing maps was undertaken to provide the content 'ground truth' for comparison against the data plotted from aerial photography and that plotted from SPOT imagery.

Aerial Photography

Feature identification from the high resolution K2412 1:80 000 photography for medium scale image revision was good, although reliant on the skill of the operator and to a small extent on indirect detection. Overall 90% of linear and 97% of all point features were identified on the aerial photography.

SPOT Panchromatic Imagery

Feature definition of the 10 metre panchromatic SPOT imagery was dependent to a certain extent on the spectral difference between features and background reflectance. The identification of features was also reliant on the skill of the operator using indirect detection, for example the vegetation difference between paddocks often indicated fence lines.

Major linear features such as urban street patterns, aircraft landing grounds, railways, cleared lines and major power lines were mostly visible and correctly interpreted. Minor linear features and point features however provided more of a problem. Overall 70% of linear and 36% of point features were identified from the SPOT imagery.

Operator comments on feature identification from SPOT panchromatic imagery were:

Linear Features

Railway lines - easily recognised due to the nature of railway layout. Difficulty occurred when other linear features or areas of cultural congestion occurred adjacent to the railway line, as definition of individual features was impaired.

Power lines - with the aid of good reference material it was possible to identify the path of a power line. This feature, particularly the low voltage lines, would be very difficult to correctly identify on the SPOT imagery without prior reference material.

Roads - Major roads are easily interpreted where they are a stand alone feature but are difficult to position accurately where two or more linear features followed the same general path. Classification of road surface was difficult because of large variations in spectral reflectance characteristics due to variations in soil type and vegetation cover across the study area.

Tracks - Good vehicle tracks were easily interpreted where they produced a clear change in reflectance from the surroundings. Fair and poor vehicle tracks were very difficult to identify particularly when crossing areas of mottled vegetation or cleared areas where the track and the background exhibited similar reflectance characteristics.

Fences - In general, major fence patterns were easy to locate and identify due to vegetation changes, however, internal patterns were often only partially visible or were not visible at all.

Cleared lines - These features usually had a strong visual appearance and were generally easy to plot from SPOT imagery. Only those cleared lines having landmark value or not associated with another feature such as a power line, were selected.

Point Features

Buildings - Large buildings particularly in the mining areas were able to be interpreted but where clusters of buildings b0s12v10h0Pand associated features occurred it was not possible to identify separate entities.

Tanks/earth dams - Large earth dams were identified by indirect detection where they constitute a stand alone feature, however, in areas of congested detail they were difficult to see. Smaller corrugated iron tanks and some small concrete tanks were not directly visible.

Townships - Two new townships, Tieri and Middlemount, were easily identified and basic street patterns were able to be plotted.

Bridges - It was very difficult to identify any bridges in the Study area.

Gravel scrapes/Quarries - Generally these were relatively easy to locate and identify due to strong reflectance between disturbed and natural earth. Some errors of commission were encountered with earth dams.

Microwave Towers/Grids/Gates - None of these features were identified from the SPOT imagery.

Landing grounds - Most of the landing areas exhibited a difference in reflectance characteristics to the surrounding earth and were relatively easily located and identified.

Vegetation - Where a defined boundary exists between one vegetation classification and another the delineation was easily seen on the panchromatic SPOT imagery, however difficulty arose when assessing the percentage of ground cover. Dark patchy ground appeared very similar in nature to patches of heavy vegetation. Canopy details lost due to the resolution of the SPOT imagery made identification of the type of vegetation very difficult.

Statistical Results

The feature identification statistical summaries are shown in Tables 2 and 3. These classify features seen on the imagery as:

- . Correctly identified.
- . Misidentified (errors of commission).
- . Not seen (errors of omission).

Type of Feature	AERIAL PHOTOGRAPHY					SPOT IMAGERY			
	No. of Features	Features Identified	% of Ground Truth	Mis-identified Features	Omitted Features	Features Identified	% of Ground Truth	Mis-identified Features	Omitted Features
Buildings	417	450	100	33	0	163	39	46	254
Microwave Tower	1	0	0	0	1	0	0	0	1
Conveyor	9	9	100	0	0	1	11	0	8
Bridge	9	9	100	0	0	0	0	0	9
L/G	10	10	100	1	0	10	100	1	0
Quarry	63	63	100	2	0	47	75	7	16
Yards	30	24	80	0	6	0	0	0	30
Landmark Features	77	66	86	0	11	0	0	0	77
Stockpiles	53	53	100	0	0	50	95	0	3
Waterhole	29	27	93	0	2	0	0	0	29
Tank or Small Dam	334	331	99	13	3	100	30	13	234
Spillway	2	2	100	0	0	0	0	0	2

TABLE 2 : ANALYSIS OF POINT FEATURES

Type of Feature	No. of Features	Features Identified	% of Ground Truth	Mis-identified Features	Omitted Features	Features Identified	% of Ground Truth	Mis-identified Features	Omitted Features
Roads	100units	100units	100	0	0		96	0	4units
VT's	100units	99units	99	1unit	3units	45units	45	20units	55units
Railways	6	6	100	0	0	6	100	0	0
Power L = Major	6	6	100	0	0	6	100	0	0
= Minor	22	2	10			2	10		
Fences	435	430	99	4	1	335	77	57	95
Channel, Drain	20	20	100	0	0	0	0	0	20
Water pipeline	3	1	33	2	0	0	0	0	20
Sewerage plant	4	1	25	3	0	0	0	0	4

TABLE 3 : ANALYSIS OF LINEAR FEATURES

There were in addition 59 unidentified point features plotted from SPOT imagery. Fifteen of these proved to be non existent features when checked with ground truth. Details of these unidentified features are shown in Table 4.

Feature	Number
Tanks	16
Buildings	4
Stacks of pipes (Water pipeline under construction at time of imagery)	23
Motorcross track	1
Non Existent feature	<u>15</u>
Total	59

Table 4 : Unidentified Features Plotted from SPOT

COST COMPARISON

Imagery Costs

A "one off" direct comparison of imagery costs is difficult as although a SPOT scene and a 1:100 000 map sheet cover approximately the same area the geographical map sheet lines do not align with the SPOT orbital path. Where a 1:100 000 map sheet is used as the basic unit a number of partial SPOT scenes will be required. The number of scenes required depends on the total coverage available but for costing purposes an average figure of 3.3 SPOT scenes to stereoscopically cover a 1:100 000 map sheet has been used. The cost per map sheet then becomes 3.3 @ Aus \$1,500 approximately Aus \$5,000. The local price of 1:80 000 photography has been assessed at a similar cost of Aus \$5,000 from existing market rates.

A SPOT alternative would be to utilize the special products option whereby images can be obtained anywhere along track, however the resulting price per special scene of Aus \$3,750 for each of two scenes would raise the total cost of stereoscopic coverage.

Compilation Costs

Compilation from aerial photography involved the use of a Kern PG2 stereoplotter interfaced to a digital mapping system. Compilation from SPOT imagery necessitated the use of an analytical plotter set up with suitable software for space imagery and interfaced to a digital mapping system. No costs for equipment have been included although the compilation from aerial photography would have been carried out much quicker on an analytical plotter rather than the 26 models set up in a PG2.

The results show a clear savings in production man days for the stereodigitising from SPOT imagery over conventional stereodigitising, providing that sufficient, well identified ground control or photogrammetric control, is already available.

	<u>Aerial Photography</u>	<u>SPOT</u>
Imagery Acquisition	Aus \$5,000	Aus \$5,000
Stereodigitising/Editing	32 man days	16 man days
Model Joins Editing	8 man days	4 man days
Aerotriangulation	<u>8 man days</u>	-
Total	<u>50 man days</u>	<u>20 Man days</u>

If the different cost of the capital equipment is ignored and the operator is costed at \$100 a day then the cost of using SPOT imagery for revision of the 1:100 000 area was \$5,000 + \$2,000 = \$7,000 as against \$5,000 + \$5,000 = \$10,000 for aerial photography.

EXTENDED STUDY WITH MULTISPECTRAL IMAGERY

The initial comparative study of stereoscopic panchromatic imagery showed that although the requisite accuracy for medium scale mapping was achievable from SPOT imagery, feature identification was inadequate. The results showed that although the 1A panchromatic imagery (spectral window 0.51-0.73 um) was used stereoscopically the resolution of the 10 metre pixel was not sufficient by itself to identify features to meet the Australian mapping specifications.

However the potential exists to make use of multi spectral space imagery to enhance feature definition and assist in feature identification. With SPOT imagery the use of multi spectral 20 metre pixel imagery may however slightly degrade the achievable accuracy. The combined use of this data with 10 metre panchromatic has the potential to significantly increase feature identification whilst maintaining accuracy.

SPOT Multi Spectral Imagery

To examine this concept MSS 1B near nadir colour 1:50 000 composite photographic prints of SPOT bands 1, 2 and 3 were used. This extended the spectral window to 0.50 - 0.89 um. The methodology employed was to use an overlay from the panchromatic digital file. The MSS print was then examined monoscopically with a simple magnifier and any additional features not on the original plot were marked up. Positional accuracy was not considered in the extended study, only the information content.

It was evident that many features missed on the panchromatic SPOT imagery were able to be identified. In particular water features became far easier to identify using the MSS imagery. The method used was to

systematically examine the imagery and to annotate the SPOT detail plot with additional features. The new product was then compared to ground truth.

Operator comments were:

- . **Tanks** - (and other small water features). Much easier to see and plot. Many unidentified features from previous plot were identified.
- . **Buildings** - Clearer definitions between building and background; however not many new buildings seen.
- . **Fences** - Some continuation, some new patterns (additional ones).
- . **Tracks** - Little additional information available.
- . **Gravel scrapes** - Several previously unidentified features were identifiable as scrapes.
- . **Townships** - Both regular grid patterns and curvilinear road patterns were better defined. Individual areas of large buildings and water features became more identifiable.

The results showed an increase in feature identification over the panchromatic imagery (see Table 5).

Type of Feature	No. of Additional Features	Correctly Identified	Features Misidentified
Tanks	139	96	43
Buildings	20	11	9
Fences	29	18	11
Dams	19	17	2
Tracks	7	3	4
Gravel Scrapes	6	3	3
Waterholes	3	2	1
L/G	1	0	1

Table 5 : Additional Features on SPOT Multi Spectral Imagery

In general the identification of point water features such as tanks and dams were doubled. The vegetation classification improved and the classification of roads was also enhanced. A high level of errors of commission existed where features were sighted but incorrectly categorized. Overall 20% more features were identified on the MSS than had been recorded from the panchromatic imagery.

Landsat Thematic Mapper Data

Thematic Mapper (TM) data with 30 metre pixel resolution from the Australian experimental project was also recorded over the test area and two photographic composite colour prints at 1:100 000 scale were produced.

The first was a composite of bands 2, 3 and 4, the second was a composite of bands 2, 3 and 5. The Australian TM products were of experimental quality only and quality can be expected to be considerably improved when the ACRES upgrade is completed in 1989.

On the imagery used for the study, feature identification was generally inferior to that using the multi spectral SPOT imagery, and feature identification was not as good.

ANALYSIS

Metric Accuracy

The study results indicated that accuracy specifications for 1:100 000 and 1:250 000 scale topographic mapping (+/- 0.5 mm of publication scale at 90% confidence level) were adequately achieved using the 10 metre panchromatic SPOT imagery. 1:50 000 metric accuracy standards were also achieved by using the dense control network of 27 points available over the test area.

Information Content

On SPOT, as with any imagery, the ability to correctly identify features was greatly enhanced by the quality of reference material available prior to plotting which gave an indication of where to look for certain features.

Most major linear features were identified on SPOT panchromatic 1A imagery but the identification of minor features or features located in difficult terrain or unfavourable vegetation cover, proved difficult. Only a low percentage of point features were visible on the SPOT imagery. In general only features that were large or had a strong variation in spectral reflectance variation, or had indirect detection assistance were identifiable on the panchromatic imagery.

The vegetation classification assessment showed that clearly defined vegetation boundaries can be plotted accurately from panchromatic SPOT imagery but the interpretation of percentage ground cover was difficult. The classification achieved was far more general than from aerial photography but still suitable for 1:50 000 or 1:100 000 revision mapping.

The use of SPOT MSS data demonstrated the benefit in using this data to assist in feature definition on the panchromatic imagery. Vegetation classification was improved using multi spectral imagery. Its success

raised the question of repeating the stereoscopic study using MSS imagery instead of panchromatic. This approach would have feature content identification benefits but could suffer from an accuracy degradation. Another solution would be the merging of both data sets with accurate correlation of pixels as is proposed in future SPOT systems.

Cost Comparison

SPOT was found to be cheaper in producing an initial revision compilation, providing sufficient existing ground or photogrammetric control was available at no extra cost. Although the SPOT panchromatic revision compilation was cheaper to produce, it had significant shortcomings in information content which would require increased field checking or more aerial photography to identify details required by mapping specifications.

The cost of this information upgrade would in turn be greater than the savings in the initial compilation phase, so no clear overall economy was found in the use of panchromatic SPOT imagery.

CONCLUSIONS

The test study showed that panchromatic SPOT imagery can meet the accuracy requirements for medium scale map revision. However feature identification of point features was not adequate to meet current specifications without the use of additional material.

The use of multi spectral imagery significantly improved feature identification under Australian conditions, even though only standard photographic composite processing was used. A greater benefit can be expected if digital data is optimised and geocoded on an image analysis system before producing composite film products.

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