04

LANDSAT 2 PROJECT NO. 2896D

3RD QUARTERLY PROGRESS REPORT

77-10096
CR-149579

I INTRODUCTION

Title: Water Utilisation, Evapotranspiration and Soil Moisture Monitoring in the South East Region of South Australia.

Assigned Investigation No.: 2896D

Author's Name: K.R. McCloy
K. John Shepherd
J.C. Killick

Reporting Date: September 2, 1976 (FTD + 11 months)

II TECHNIQUES

1. Material Received

70 mm Format: Up to Frames 2522-23362, 2522-23364 and 2522-23371 of 27 June 76, which completes the acquisition of imagery for the study area.

9 track, 1600 BPI CCT: Frames 2342-23411 and 2359-23351

2. Status of Project

The classifier developed by McCloy and described in a paper contained in the previous report has been used for two distinct situations. The brackets indicate response values in (band 4, band 5, band 6, band 7).

(i) Bool Lagoon Bool Lagoon was classified into twenty classes ranging linearly in steps from (10, 5, 5, 2) to (14, 12, 22, 18) corresponding to a transition from water to dry bullrushes. The length of this line vector is 24.6 units so that each subclass covered a vector distance of 1.2 units. As the standard deviation in any one band, for a uniform surface is about 0.4 units, the above resolution is acceptable. The classification was compared with 1968, 1:11 000 colour aerial photography of the Lagoon, and all spectral patterns discernable on the photography were revealed as different subclasses in the classification. It is intended to analyse a classification of Bool Lagoon on the December imagery in comparison with 1:30 000 colour andfalse colour imagery of the Lagoon, also taken in December.

(ii) Coastal Dunes The coastal dunes are accompanied by varying distances of native scrub on their hinterland side. This scrub also occurs, at varying densities on the dunes. The classifier, using a line vector from (13.7, 10.1, 18.3, 21.0) for scrub to (47.0, 56.0, 55.0, 49.0) for sand, classified all pixels according to the proportion of sand and scrub within the particular picture element. The classifier worked well, but imperfectly because the sand associated with the scrub was generally very white whereas the open sand expanses tended to be

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more orangish. However McCloy independantly estimated the proportions of scrub and sand for each pixel within part of the classification and the results were:-

Symbol used in Classification		Estimated Proportion of Sand in Pixel 0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	0	24	7	-	-	-	-	-	-	-	-	-
	1	7	49	9	1	-	-	-	-	-	-	-
	2	1	2	7	7	7	1	-	1	-	-	-
	3	5	2	7	9	4	3	1	2	1	-	-
	4	-	-	1	8	8	7	13	6	5	2	-
	5	-	-	-	3	6	3	8	20	2	-	-
	6	-	-	-	-	1	6	11	18	2	1	-
	7	-	-	-	-	3	2	7	8	11	4	-
	8	-	-	-	-	-	2	1	4	2	16	6
	9	-	-	-	-	-	-	-	-	-	13	52
	$	-	-	-	-	-	-	-	-	-	1	6

Table of Correspondence between Classification and Estimation of Proportion of Sand. All pixels for which estimates were made are contained in the table.

The range of estimates for each symbol is expectedly larger at the centre because of the significance of errors in estimation. Errors in positioning will also be significant.

McCloy is currently developing a better algorithm for applying this classifier, and when this is done then more detailed results will be published.

III ACCOMPLISHMENTS

Nil this quarter

IV SIGNIFICANT RESULTS

Nil this quarter

V PUBLICATIONS

McCloy has been investigating, as part of another project, the geometric accuracy of mapping from landsat imagery, and has come to the conclusion that identification of control stations in the imagery is a significant source of error. He has therefore proposed a method of establishing control in the imagery. The proposal is contained in a paper to be offered for publication in Australia in the near future. A copy of this draft is included with this report. If there are any flaws in the understanding of the geometric characteristics of Landsat imagery, then it would be appreciated if these were pointed out so that time and effort would not be wasted in constructing the control.

It is anticipated that some control of this type may be established in South Australia as part of our Landsat-C program.

DRAFT

GEOMETRIC FITTING OF LANDSAT IMAGERY

INTRODUCTION

Matching of field data, or other digital LANDSAT data, to a frame of LANDSAT imagery requires accurate determination of the position of that data within the frame. Work by the authors has shown that matching of co-ordinates for ground detail to corresponding position in a LANDSAT image can be achieved to better than 0.5 pixel units (40 metres).

In many areas there is little detail that can be identified reliably to the nearest picture element. This will significantly effect the accuracy of matching ground co-ordinates to LANDSAT scanner co-ordinates. A method of recording control in the imagery which will eliminate identification as a significant source of error is suggested in this paper.

Algorithm to Transform LANDSAT Scanner Coordinates to Cartesian Coordinates

There is considerable literature describing the geometric characteristics of LANDSAT imagery (1-16). The author has developed an algorithm in which the original scanner co-ordinates (P,S) are corrected for three systematic errors to give adjusted scanner co-ordinates (P^1, S^1). The adjusted scanner co-ordinates form a cartesian coordinate system which is assumed to have a fixed but unknown rotational and translational relationship with any other cartesian co-ordinate system. These rotational and translational parameters are determined by a least squares adjustment.

The systematic corrections ~~applied to the scanner co-ordinates (P,S)~~ are:

(i) Earth rotation during the satellite traverse time across a frame, which introduces a westerly shift of approximately 13 km at the equator. The correction is $C_E = -34.0 \cos(\text{latitude})$ metres, every sixth scan line.

(ii) Variable Mirror Velocity. ~~Introduces~~ Creates a maximum error in position of 425 metres at the ¼ and 3/4 positions along the scanline. The error is approximately sinusoidal, of the form

$$C_M = -425.0 \sin(2\pi * P/_{PT}) \text{ metres}$$

P = pixel co-ordinate value.
P_T = number of pixels per scan line.

(iii) Einite Scan Time. ~~causes a 216m shift in position, in the long track direction, across a scan line.~~ Shifts the pixel position in the along track direction, linearly by, to 216 metres across a whole scan line.

$$C_S = 216 * P/_{PT} \text{ metres}$$

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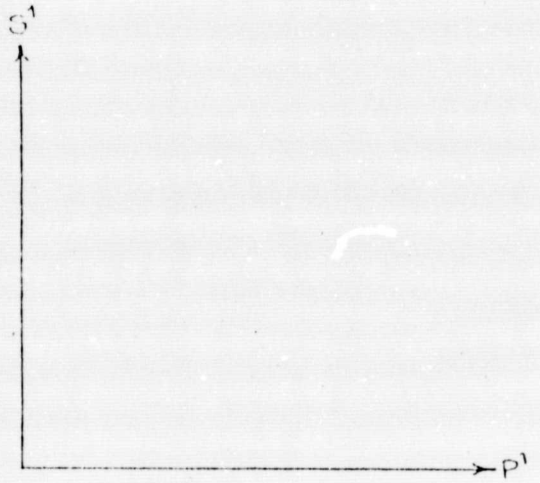
The latitude of the centre of the frame, and P_T for the frame are given in the image data, so that only (P,S) are required to complete these corrections. The adjusted scanner coordinates were inverted so that the (P^1,S^1) axes are approximately aligned with the map coordinate axes.



$$\therefore P^1 = P*P1 - 34.0 \cos(\text{latitude}) * \text{INT}(S/6) - 425.0 \text{ SIN } (2\pi * P/P_T)$$

$$S^1 = (2340 - S) * S1 - 216 * P/P_T$$

(P^1,S^1) adjusted scanner coordinates in metres

P1 = Pixel centre separation along scanline (metres)
S1 = Scanline separation (metres)
2340 = Number of scan lines in a frame.

P1 and S1 will vary with satellite orientation and elevation. Values of P1 and S1 were determined by comparing spheroidal distance to scanner coordinate separation for lines across the frame and along the centreline of the frame. The adopted values are P1 = 57.57 metres and S1 = 77.05m.

The Geometric Corrections listed in Table G.2-3 of the LANDSAT Users Handbook[1] will introduce distortions that can be modelled using the relationships

$$p^1 = a_0 + a_1x + a_2y + a_3xy + a_4x^2 + a_5y^2$$

$$s^1 = b_0 + b_1x + b_2y + b_3xy + b_4x^2 + b_5y^2$$

Changes in scale will be allowed for by these relationships so that values of P1, S1 can be set and not redefined for each frame. However accurate values of P1 and S1 are required because the proposed control depends on these quantities.
The above relationships are used to form observation equations for the least squares adjustment, using a minimum of six control points.

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MAP NOT AVAILABLE YET

MAP 1

B & W print from S.A. Dept. of Lands 1: 59000 Topographical Map and overlay from LANDSAT digital print out (Line Printer)

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Results Achieved

Two areas have been studied. An area of approximately 1/16 of a frame, to the north of Adelaide (Map 2) and subsequently an area of approximately ¼ of a frame in the south east of South Australia (Map 3).

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MAP NOT AVAILABLE YET

Map 2 Frame 1115-00060 (Yorke Peninsula)

MAP NOT AVAILABLE YET

Map 3 Frame 1129-23494 (Hastings)

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With results:-

(i) Area 1

Point	Scanner Coords		Cartesian coords (Clarke)		Residuals	
	P	S	E (m)	N (m)	P	S
1	2636	45	167940	825670	-0.12	0.61
2	2986	83	188970	818430	0.13	-0.49
3	3135	146	196970	811400	-0.01	-0.06
4	2446	280	151530	807120	0.20	-1.14
5	2819	316	174210	800250	0.14	-0.35
6	2982	310	184460	799130	-0.23	0.70
7	2486	378	152260	798400	-0.13	0.52
8	2519	490	152220	788490	-0.09	0.80
9	2775	558	166920	780050	0.08	-0.80
10	3052	461	185910	785540	0.03	0.21

Standard Deviations of Residuals

Across track = 0.14 (8.06m)

Along track = 0.68 (52.43m)

(ii) Area 2

Point	Scanner Coords		Cartesian Coords (AMG)		Residuals	
	P	S	E (m)	N (m)	P	S
1	1326.0	1961.5	489060	5802510	-0.36	+0.32
2	1264.0	1764.2	489480	5818490	0.91	0.07
3	946.0	1763.0	471440	5822300	-0.57	-0.80
4	816.5	1843.0	462420	5817750	0.02	0.34
5	894.0	2082.0	461970	5798330	-0.30	0.03
6	1302.9	1478.7	497560	5840030	0.31	-0.22
7	1182.7	1298.2	494455	5855410	-0.87	0.04
8	1026.9	931.0	493000	5885610	0.57	0.08
9	989.5	1482.0	479640	5843530	0.03	-0.23
10	306.0	1737.4	435710	5832820	1.10	-0.39
11	626.0	1601.0	456610	5838720	0.04	0.86
12	279.0	1385.0	441530	5859350	-1.16	0.00
13	103.2	1187.3	435580	5876625	0.64	-0.43
14	421.1	1210.9	452980	5871180	0.66	0.18
15	34.0	1656.0	422200	5841220	-0.74	0.39
16	670.0	914.0	473390	5890220	-0.57	0.04
17	580.7	2028.6	445310	5806190	0.29	-0.30

Standard Deviations of Residuals

Across track = 0.66 (38m)

Along track = 0.38 (29m)

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Identification of Control

The general location of control points was initially done on 1:250,000 photographs of the LANDSAT imagery. The area selected was then printed from the digital data and discernable patterns on all four bands were combined onto one line printer image. These patterns and boundaries discerned on the imagery were then digitised and plotted at 1:50,000 or the most suitable map scale. An overlay was then prepared for the corresponding topographic map and a control point was selected within the area (as in Map 1).

In both areas, a systematic distribution of the control was sacrificed to achieve higher reliability in identification.
Identification should be better in Area 2 than in Area 1 because of the greater contrasts between the pinus radiata plantations and adjacent detail, either cultural, such as roads or grazing areas. Of the control points in Area 2, more than half have residuals that are approximately 1 pixel in size, either along or at right angles to the scan line (see Map 4). Analysis using better control would be required to ascertain the significance of this observation.

The results of this test are better than those reported by other workers. WONG[7] and DEROUCHE[8] claim standard deviations of 40-45m along track and 42-55m across track, however both were fitting a whole LANDSAT frame to control compared to the part frame areas considered in this paper. TRINDER[9] claims standard deviations of 66m and believes that control identification on the smaller scale maps used for this purpose significantly contributed to the larger error.

The work described here suggests that:

(i) Misidentification is probably a major cause of error.

(ii) In areas of relatively indistinguishable detail, as in the case with large areas of Australia, mis-identification will be a more serious error than occurred here.

(iii) Provision of control will allow detailed analysis of residual errors. This analysis may justify further refinement of the algorithms used.

(iv) Mapping to within 1:100,000 standards can be achieved for portions of a frame and may be possible for larger areas if mis-identification can be eliminated as a significant source of error.

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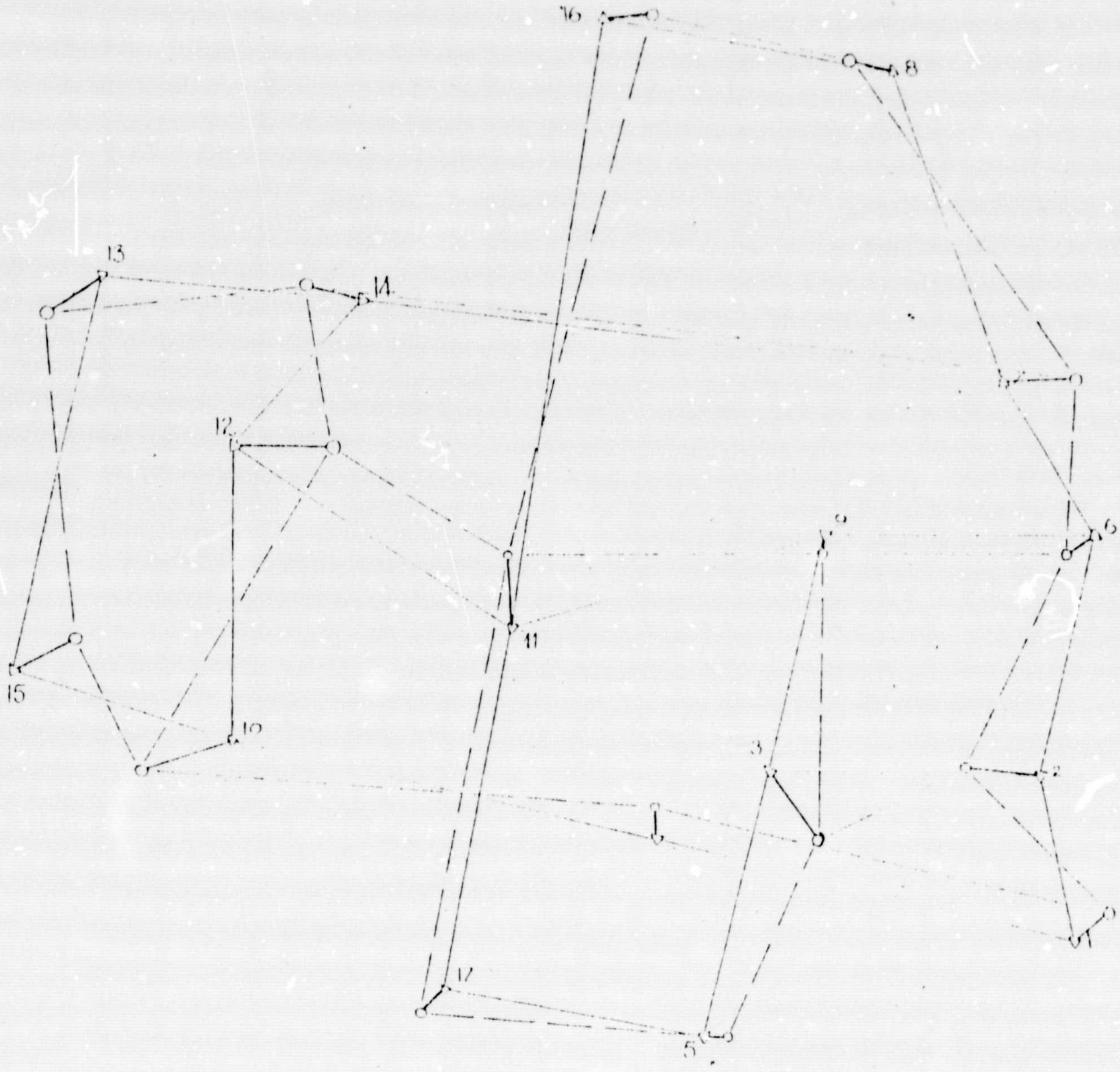

MAP 4

CONTROL DIAGRAM FOR FRAME 1129-23494

KEY

Control Stations

Adjusted control position relative to OBSERVED position.

NOTE Residuals ○⟶ plotted at X100 enlargement of Control Diagram.

0 1 2 3 4

Residual Scale

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Establishment of Ground Control for LANDSAT Imagery

EVANS[10] has shown that a 22 inch slightly convex mirror makes a readily identifiable record on LANDSAT Imagery. A single mirror is adequate for identifying the control to the nearest picture element. However, the results given earlier suggest that the identification of control needs to be to better than 1/10 of a picture element for mis-identification to be eliminated as a serious source of error.

Two sets of mirrors, set up in a similar manner to retrograde verniers[1] would be located parallel, and perpendicular, to the scan lines (DIAGRAM 1)

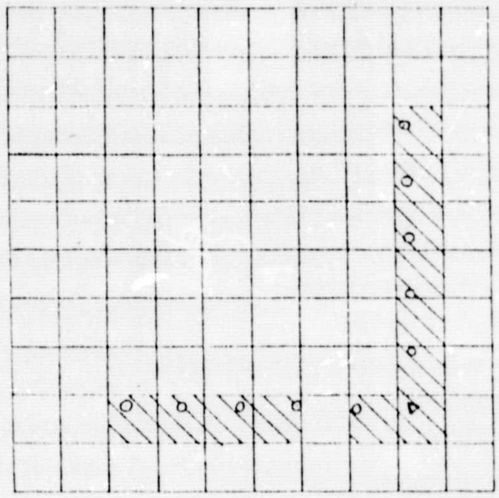

DIAGRAM 1: Simplified diagram of Vernier Setup.

Δ Corner Mirror (Control Point)
o Auxiliary (Vernier) Mirrors
▧ High Value Pixels (Due to Mirror)

The corner mirror is the control point. The separation between the mirrors is greater than the pixel separation so that within the vernier all pixels, except one, will contain a mirror and consequently have much higher response values than the surrounding pixels. The position of the pixel within the vernier that does not contain a mirror is related to the position of the control mirror within its pixel.

Let R_M be the response by those pixels containing a mirror, and R_S be the surface response. As shown by EVANS, pixels do not change sharply from one response level to the other, due to the sensor sampling characteristics, and atmospheric conditions. As a mirror moves from one pixel to the adjacent pixel, the response of the pixel can be expected to change as an ogive similar to that shown in Diagram 2.

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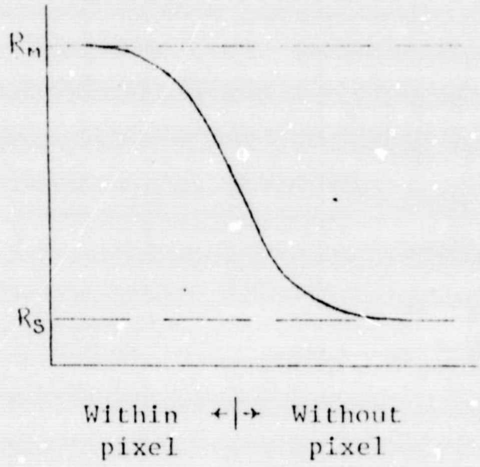

Diagram 2: Response against Mirror position in pixel.

Therefore the response values for the pixels along the vernier will not exhibit a sharp drop at the particular pixel, but instead approximate a continuous curve, the shape of which depends upon the position of the mirrors within the pixels. This characteristic could be used to improve the resolution of a vernier for a given mirror count. This is illustrated in Diagram 3 in which the pixel separation is 100m, least count = 10m so that that the vernier interval is 110m. In this diagram, three positions of the control mirror within the pixel are illustrated, 0.70, 0.75 and 0.80. The author believes that the pixel response will be similar to that shown in which case a least count of 0.05 pixels should be achieved, or alternatively 5 mirrors should ~~be~~ given ~~position~~ position to 0.10 pixels.

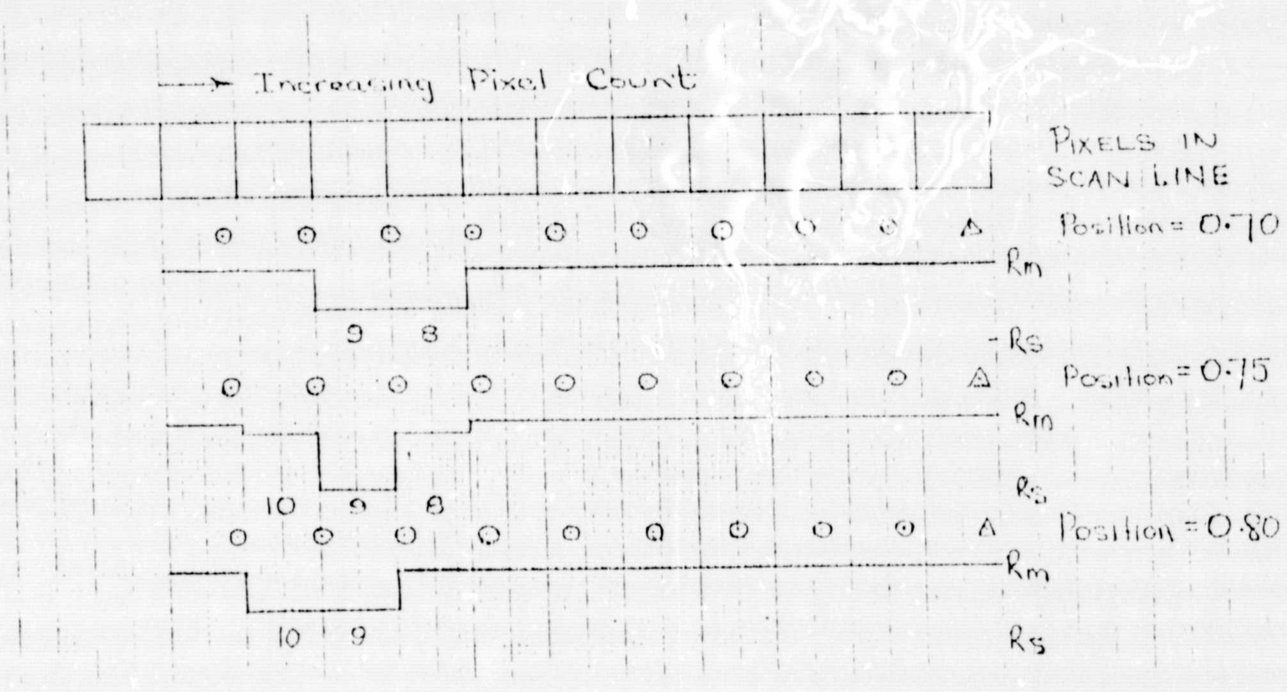

DIAGRAM 3: Changes in pixel response with changes in Vernier Location

In LANDSAT there is insignificant overlap along track, but about 30% overlap across track, requiring quite different approaches to establishing the verniers in either direction.

Along Track

Scan Line separation $= 77.05\text{m} = d_s$

Vernier Least Count $= \frac{d_s}{10} = 7.705\text{m}$

Vernier Interval $= \frac{11}{10} d_s = 84.76\text{m}$

This vernier would work in the same way as previously described, with the control mirror at the southerly end of the vernier.

Across Track

The spacing of the pixels along a scan line is shown in DIAGRAM 4.

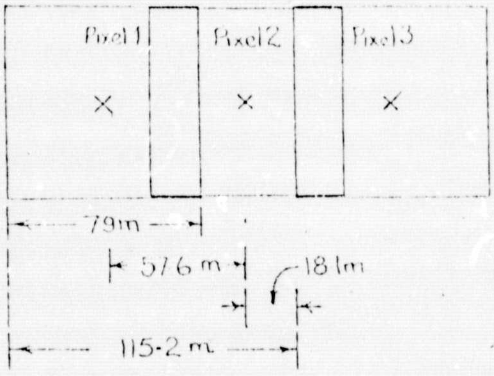

DIAGRAM 4

Using 57.57 as the pixel separation would mean that the Vernier interval would be 63.32m so that every pixel would contain a mirror.
Instead use the alternate pixels by setting the separation at $115.2\text{m} = d_p$.

Vernier Least Count $= \frac{d_p}{10} = 11.52\text{m}$

Vernier Interval $= \frac{11}{10} d_p = 126.72\text{m}$

The responses from each set of pixels (even and odd sets) will be complimentary to the other as illustrated in Diagram 5 and suitable modelling using both sets would be required.

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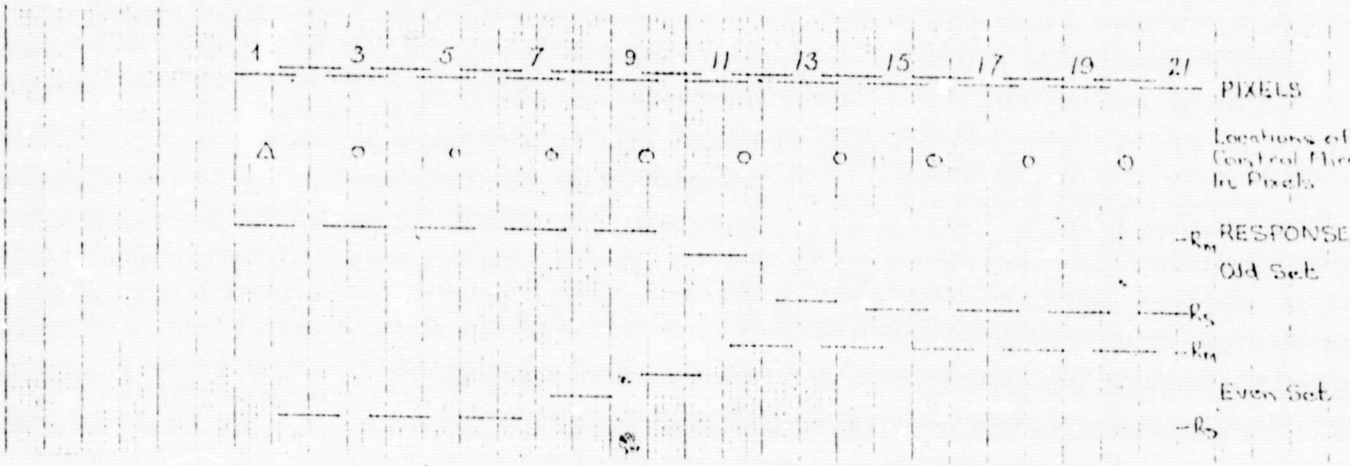

DIAGRAM 5.

CONCLUSION

As pointed out by EVANS, the repeatability of LANDSAT makes establishment and maintenance of mirror control stations a relatively simple astronomical problem. Provision of control will eliminate mis-identification as a significant source of error in matching field data to the imagery, in temporal analysis, and in plotting from the imagery. The accuracy in this matching should be within 1:100,000 mapping specifications, thereby significantly impr~~ess~~oving the value ~~in~~ of LANDSAT imagery to Australia.

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