LARS Contract Report 110982

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FIRST PROGRESS REPORT
AND
QUICK-LOOK ANALYSIS

Landsat-4 Image Data Quality Analysis
for quarter including
August 9 - November 9, 1982
NASA Contract NAS5-26859

To: National Aeronautics & Space Administration
Goddard Space Flight Center
Greenbelt Road
Greenbelt, MD 20771

By: P. E. Anuta and Staff
Purdue University
Laboratory for Applications of Remote Sensing
West Lafayette, IN 47906

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November 1982

Star Information Form

1. Report No. 110982	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle First Quarterly Progress Report and Quick-Look Analysis, Landsat Image Data Quality Analysis		5. Report Date November 1982
		6. Performing Organization Code
7. Author(s) P.E. Anuta and Staff		8. Performing Organization Report No. 110982
9. Performing Organization Name and Address Purdue University Laboratory for Applications of Remote Sensing 1220 Potter Drive West Lafayette, IN 47906-1399		10. Work Unit No.
		11. Contract or Grant No. NAS5-26859
12. Sponsoring Agency Name and Address NASA/Goddard Space Flight Center Greenbelt Road Greenbelt, MD 20771		13. Type of Report and Period Covered Contract
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report describes work done on evaluation of the geometric and radiometric quality of early Landsat-4 sensor data. Band-to-band and channel-to-channel registration evaluations were carried out using a line correlator. Visual blink comparisons were run on an image display to observe band-to-band registration over 512 x 512 pixel blocks. The results indicate a .5 pixel line misregistration between the 1.55 - 1.75, 2.08 - 2.35μm bands and the first four bands. Also a four 30M line-and-column misregistration of the thermal IR band was observed. Radiometric evaluation included mean and variance analysis of individual detectors and principal components analysis.

Results indicate that detector bias for all bands is very close or within tolerance. Bright spots were observed in the thermal IR band on an 18 line by 128 pixel grid. No explanation for this was pursued. The general overall quality of the TM was judged to be very high. No Landsat-4 MSS data were acquired in this period.

17. Key Words (Suggested by Author(s)) Landsat-4, Thematic Mapper, Radiometric Evaluation, Geometric Evaluation	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

*For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA - JSC

Introduction

This report covers work done at LARS/Purdue under the Landsat-D(4) Image Data Quality Analysis Contract for the period August 9 through November 9, 1982. In this period, four-band Thematic Mapper data were received on September 9 over the Detroit area and seven-band TM data from northeastern Arkansas were received on September 29. Reformatting software work had begun early so that the data could be viewed and processed at LARS/Purdue shortly after receipt. In general, the TM data appeared to be of very high quality with the expected high resolution and very low geometric and radiometric error content. No Landsat-4 MSS data were obtained in the period. Numerous readily applied analysis procedures were carried out to provide a "quick look" analysis to identify obvious problems prior to detailed parameter evaluation. These results are presented here.

Problems

The most significant problem is the lack of an acquisition of a TM/MSS frame over the prime test site, Chicago, to date. An alternate prime site is being considered for initial investigations. This would be our Priority 4 site including Jacksonville, FL, the Atlantic Coast, and numerous interstates. An acquisition is available from October.

Significant Results

This section contains the "quick look" analysis for the Detroit and Arkansas TM data. The work is divided into geometric and radiometric considerations. In general, the TM data appeared visually to be of very high quality; however, several errors were noted in some bands and these are briefly identified.

Geometric Evaluation

In the Detroit scene, several geometric problems were noted in Band 2. Significant scan line misregistration was observed in this band on a nominal cycle of 16 lines. A line correlation algorithm was developed by LARS for use in this study and was applied to the data to analyze channel-to-channel and band-to-band registration. This algorithm was applied to a block of data near downtown Detroit. The channel-to-channel and band-to-band results are all very good, averaging .02 pixel except for one detector of Band Two.* This has an indicated misregistration of 1.1 pixels to the east. In addition, when Band 2 was blink compared to Bands 1 and 3, blocks of imagery in Band 2 of approximately 16 lines by 128 columns appeared to be vertically misregistered by one to two lines. Other misregistration shifts of Band 2 relative to others were visually observed but not analyzed due to receipt of the seven-band Arkansas test scene.

The problems noted in Band 2 of the Detroit scene were not observed in the Arkansas data and it was assumed that these were obvious preprocessing problems which had been corrected and were not faults in the sensor itself. A block of 512 by 512 points in the Arkansas data was defined as a test site. This block surrounds NASA AgRISTARS test site Segment 306 which we have some familiarity with. Detailed line correlations were run on the bands and channels of this Arkansas data subscene and the results are in Table 1. The rows in the table are correlation results for each detector for the reflective bands for correlation over 100 pixels across a scan line and the result averaged down 32 lines to encompass 512 lines. The columns of the table are correlations between bands as noted at the top of the column. The bottom two rows are averages and standard deviations over all detectors for each band pair. Each detector now consists of a row of mean values and a row of standard deviations.

The results for the within spectral region bands (i.e., 1,2,3) or 4,5,6 are extremely good. Averages as low as .01 pixel are seen. For correlations between band groups, the averages jump to the .5 range. All the bands indicate a significant misregistration of the thermal band with averages between 1.52 and 2.17 being observed. Individual detector shifts of over three pixels were noted. Two questions arise when carrying out these correlations: One is that as correlation between two images decreases, the variance of the misregistration estimate increases; so some of the indicated misregistration is due do this effect. This problem will be better quantified in future reports. The second question is the effect of the cubic convolution interpolation resampling on registration estimates. The geometric correction process uses this resampling method and it may blur registration differences between detectors. The "A" tape data will be free from this effect. Block correlations for the entire 512 by 512 area (Table 2) were computed to aid in determining the likely effect of misregistration estimation variance on the values in Table 1. It is interesting to note that the visible bands are rather highly correlated with the third reflective IR band and to some extent the second. Correlation is low

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* We (LARS/Purdue) have interchanged the last two TM bands on our tapes so that the thermal is Band 7 to make the wavelengths monotonically increasing. This should be noted in all future discussions.

Table 1. Means and Standard Deviations for Arkansas TM Data.

	(1,2)	13	14	15	16	17	23	24	25	26	27	34	35	36	37	45	46	47	56	57	67
CHANNEL 1 MEAN	0.01	0.06	0.08	0.71	0.58	1.64	0.03	0.10	0.59	0.44	1.13	0.01	0.73	0.50	1.58	0.75	0.47	1.65	-0.05	0.50	2.19
STD. DEV.	0.10	0.10	0.34	0.48	0.20	1.94	0.09	0.87	1.04	0.50	2.36	0.20	0.60	0.16	2.21	1.68	0.78	2.03	0.11	2.42	1.59
CHANNEL 2 MEAN	-0.00	0.03	0.01	0.53	0.54	1.98	0.00	0.15	0.33	0.49	1.78	0.02	0.55	0.51	2.13	0.17	0.32	1.42	-0.02	0.15	1.86
STD. DEV.	0.11	0.09	0.31	0.24	0.20	1.86	0.06	0.74	1.05	0.67	2.06	0.17	0.21	0.16	1.62	1.82	0.98	2.15	0.13	2.65	1.94
CHANNEL 3 MEAN	-0.01	0.01	0.00	0.65	0.50	1.97	-0.00	0.01	0.53	0.40	1.88	0.00	0.65	0.51	2.28	0.07	0.42	1.84	-0.02	0.37	1.91
STD. DEV.	0.11	0.07	0.25	0.46	0.20	1.94	0.09	0.87	0.87	0.51	2.13	0.16	0.50	0.16	1.51	2.05	1.02	1.95	0.14	2.69	2.00
CHANNEL 4 MEAN	-0.01	0.03	0.05	0.65	0.55	1.97	0.00	0.22	0.45	0.43	1.39	0.02	0.50	0.51	2.23	-0.18	0.47	1.99	-0.04	0.89	2.07
STD. DEV.	0.09	0.09	0.22	0.51	0.22	1.86	0.05	0.99	1.04	0.54	2.34	0.15	0.69	0.16	1.60	1.95	0.73	1.81	0.11	2.54	1.77
CHANNEL 5 MEAN	-0.01	-0.00	0.02	0.68	0.52	2.08	0.00	0.01	0.58	0.51	1.60	0.02	0.48	0.50	2.03	-0.17	0.48	2.22	-0.01	0.81	1.93
STD. DEV.	0.09	0.10	0.27	0.64	0.24	1.85	0.05	1.01	0.75	0.21	2.08	0.12	0.81	0.19	1.90	1.94	0.74	1.59	0.12	2.51	1.81
CHANNEL 6 MEAN	0.09	0.03	-0.02	0.56	0.52	2.07	-0.09	0.04	0.31	0.39	1.11	0.00	0.32	0.50	2.25	0.11	0.45	2.05	-0.02	1.30	2.19
STD. DEV.	0.54	0.08	0.37	0.23	0.22	1.74	0.53	0.73	1.12	0.65	2.41	0.17	0.85	0.18	1.59	2.11	0.74	1.72	0.09	2.31	1.55
CHANNEL 7 MEAN	0.02	0.04	0.18	0.62	0.56	2.39	0.01	0.01	0.68	0.51	1.37	0.03	0.50	0.50	2.20	0.29	0.58	2.34	-0.03	1.43	2.11
STD. DEV.	0.10	0.06	0.56	0.49	0.18	1.53	0.07	0.92	0.63	0.20	2.41	0.16	0.74	0.15	1.77	2.07	0.75	1.50	0.11	2.11	1.31
CHANNEL 8 MEAN	-0.02	0.03	-0.06	0.62	0.59	1.94	0.04	-0.01	0.47	0.58	1.22	-0.06	0.59	0.53	2.02	0.41	0.44	2.16	-0.04	1.20	2.52
STD. DEV.	0.15	0.11	0.61	0.29	0.22	1.97	0.09	1.00	0.74	0.20	2.45	0.56	0.21	0.15	2.01	2.27	0.42	1.79	0.12	2.44	1.19
CHANNEL 9 MEAN	0.00	0.02	-0.00	0.52	0.53	2.32	0.01	0.14	0.56	0.53	1.75	0.06	0.62	0.51	2.49	0.04	0.53	2.08	-0.03	0.97	1.87
STD. DEV.	0.09	0.07	0.50	0.28	0.22	1.26	0.07	0.95	0.70	0.20	1.94	0.21	0.46	0.18	1.19	2.44	0.60	1.69	0.08	2.47	2.00
CHANNEL 10 MEAN	0.01	0.05	0.16	0.64	0.55	2.18	0.02	0.08	0.44	0.44	1.65	0.04	0.57	0.49	2.44	0.06	0.44	2.22	-0.01	1.41	2.34
STD. DEV.	0.08	0.06	0.55	0.50	0.22	1.74	0.07	1.06	0.69	0.57	2.13	0.17	0.45	0.18	1.44	2.09	0.42	1.63	0.10	2.23	1.30
CHANNEL 11 MEAN	0.01	0.05	0.03	0.42	0.59	2.31	0.02	-0.05	0.44	0.55	1.84	0.01	0.44	0.55	2.28	0.27	0.47	1.62	-0.01	1.53	1.90
STD. DEV.	0.08	0.06	0.15	0.86	0.23	1.64	0.07	0.88	0.58	0.21	1.90	0.14	0.55	0.20	1.72	1.99	0.81	2.31	0.11	2.11	2.07
CHANNEL 12 MEAN	0.03	0.05	0.05	0.56	0.57	2.24	0.01	-0.08	0.40	0.51	1.71	0.02	0.50	0.52	2.12	-0.27	0.44	1.65	0.00	1.59	2.06
STD. DEV.	0.10	0.08	0.27	0.37	0.26	1.73	0.08	0.88	0.50	0.21	2.27	0.17	0.28	0.21	1.94	1.92	1.02	2.17	0.09	2.14	1.97
CHANNEL 13 MEAN	0.03	0.05	0.09	0.58	0.59	1.91	0.01	0.11	0.52	0.53	1.57	0.02	0.47	0.52	1.91	-0.02	0.42	1.88	-0.02	1.19	2.36
STD. DEV.	0.08	0.08	0.26	0.74	0.22	2.12	0.07	0.88	0.78	0.20	2.30	0.18	0.62	0.19	2.15	2.03	0.91	2.00	0.12	2.35	1.53
CHANNEL 14 MEAN	0.04	0.06	0.08	0.55	0.60	1.91	0.00	0.03	0.56	0.54	1.25	0.02	0.51	0.54	2.08	-0.16	0.50	1.93	-0.03	0.85	2.15
STD. DEV.	0.10	0.11	0.23	0.63	0.22	2.09	0.07	0.71	0.76	0.17	2.40	0.17	0.60	0.17	1.99	2.02	0.78	2.07	0.10	2.57	1.74
CHANNEL 15 MEAN	0.01	0.05	0.05	0.57	0.59	2.49	0.02	0.04	0.50	0.44	1.41	0.00	0.41	0.50	2.17	0.04	0.34	2.37	-0.05	1.29	2.75
STD. DEV.	0.06	0.07	0.20	0.78	0.19	1.20	0.05	0.73	0.72	0.56	2.37	0.14	0.98	0.19	1.74	2.04	1.02	1.54	0.13	2.13	0.53
CHANNEL 16 MEAN	0.02	0.05	0.04	0.57	0.58	2.10	0.01	0.05	0.56	0.61	1.61	0.03	0.43	0.52	2.23	-0.44	0.44	1.93	-0.02	0.71	2.46
STD. DEV.	0.10	0.09	0.61	0.79	0.19	1.59	0.07	0.80	0.81	0.47	2.07	0.18	0.97	0.19	1.57	1.85	0.80	2.02	0.11	2.44	1.12
OVERALL AVERAGES MEAN	0.01	0.04	0.05	0.59	0.56	2.09	0.01	0.05	0.49	0.49	1.52	0.01	0.52	0.51	2.15	0.06	0.45	1.96	-0.02	1.01	2.17
STD. DEV.	0.16	0.08	0.39	0.55	0.21	1.76	0.15	0.87	0.81	0.42	2.21	0.21	0.64	0.18	1.75	2.01	0.79	1.88	0.11	2.39	1.66

Table 2. Block Correlation for 512 x 512 Points in TM Data for Arkansas Site.

Band	1	2	3	4	5	6	7
1	1.0						
2	.92	1.0					
3	.95	.94	1.0				
4	-.50	-.46	-.58	1.0			
5	.53	.54	.53	.14	1.0		
6	.80	.79	.84	-.37	.81	1.0	
7	.38	.36	.41	-.52	.19	.43	1.0

with the thermal IR. The low correlation could be due to the misregistration of the thermal band, although the effect may be small because of the 120 meter resolution.

Band pairs having the approximately .5 misregistration are (1,5), (1,6), (2,5), (2,6), (3,5), (3,6), (4,6). This pattern definitely suggests that Bands 5 and 6 (1.55 - 1.75 and 2.08 - 2.35 µm) are misregistered with respect to 1,2,3,4 by about half a pixel. The correlation coefficient is quite high between the visible bands and the 2.08 - 2.35 m band, so the misregistration estimate should be reliable. LARS Bands 5 and 6 themselves appeared to be well registered.

Visual blink comparisons were run on the thermal band using the LARS Comtal digital display and it was concluded that the misregistration was four lines and columns (right and down). The line misregistrations could account for the across-track numerical correlation not producing a value of four columns of misregistration. We feel that this is a software error related to the geometric correction and cubic convolution and should pose no big problem to correct. LARS is registering the thermal band for the test site based on these results.

Considerations were made of the bow-tie and scan-line nonlinearity effects but no results were obtained on these questions in the quarter.

Radiometric Evaluations

Visual and numerical analysis was carried out on the Detroit TM data. Band 2 demonstrated radiometric errors in the form of dark multipixel spots randomly distributed over the frame. The dots have a size of up to 4 by 4 pixels and values of 10 to 40.

Receipt of the seven-band Arkansas frame prompted a more detailed analysis of the radiometric characteristics. Visual inspection was first carried out on all the bands and it was noted that the bad data spots were not present in Band 2 and all the bands appeared to be of very high quality, except for the thermal which had dot problems and rather low contrast.

The first numerical investigation was computation of means, variances, and histograms for a block of data surrounding Segment 308, as discussed above. The intention was to evaluate the channel-to-channel calibration of the 16 detectors for the first 6 bands and the 4 detectors for the thermal band. We note again that the cubic convolution may tend to alter results as compared to what would be seen in the data from "A" tapes. Histogram plots for one detector are presented in Figure 1. The data ranges for the visible bands are small. The first IR band is the only one which uses most of the 256 bin range. The thermal band has a limited range with a standard deviation of only 5.6. The data distributions appear to be skewed to the higher values for all bands. This was noted in most aircraft and Landsat 1,2,3 MSS data in past investigations. Explanation for this will not be attempted here.

The means and standard deviations for lines taken at 16-line intervals were computed in an attempt to estimate channel-to-channel calibration. These results are presented in Table 3, a through g. The means were all within .2 count of the grand mean for all detectors of all bands, except for four detectors of Band 4 which deviated from the grand mean by up to .49 count. The specification on channel-to-channel calibration is that deviation be less than the RMS noise level divided by 4. The radiometric accuracy specifications for each band are given in Table 4. The deviations in the means in Table 3 are due to sensor and calibration variations plus variations due to sampling of different areas of the scene. The 16-line interval is repeated 32 times in the 512-line block. Thus there are 32 x 512 = 16,384 samples in each mean calculation. In Table 4 we have computed a working estimate of channel-to-channel mean deviation tolerance for this quick-look analysis. Based on these rather gross assumptions, we conclude that all channels of all bands are generally within tolerances, except for about half of the detectors in Band 4. Some, such as detectors 1,2,3 and 11, are three times the tolerance. We cannot say for certain whether there is a problem here at this time in bias settings, but there is some indication from these results that there may be. No evaluation was made of the variance differences.

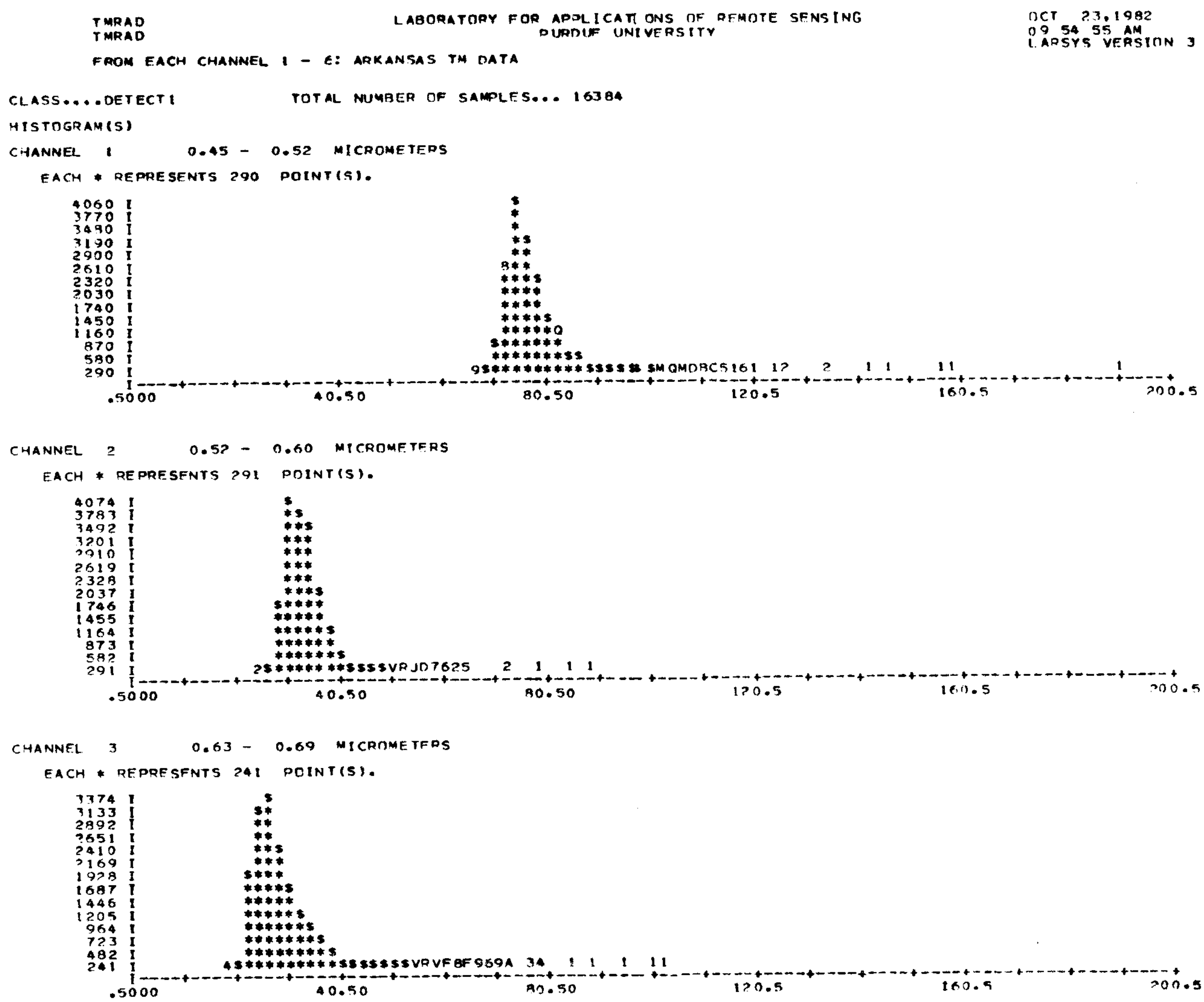

Figure 1. Histograms for TM bands for one detector for 512 x 512 point area from Arkansas test frame.

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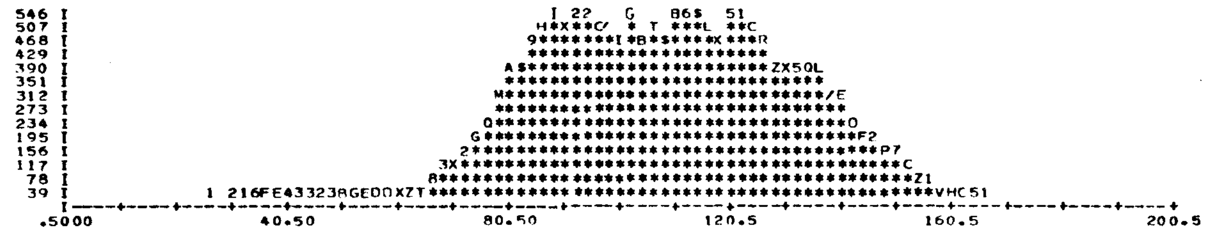
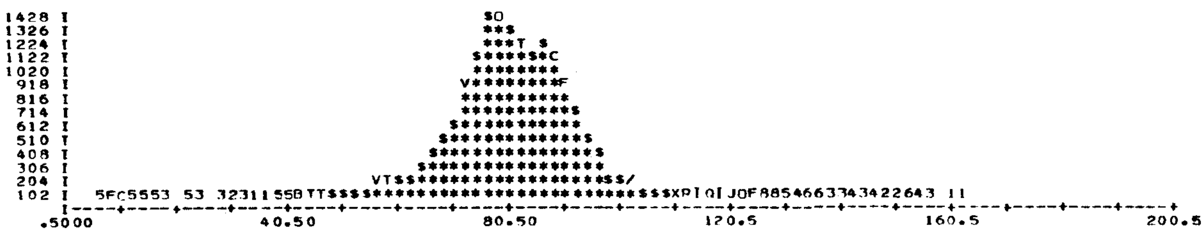
TMRAD                    LABORATORY FOR APPLICATIONS OF REMOTE SENSING          OCT  23,1982
TMRAD                                  PURDUE UNIVERSITY                        09 54 55 AM
                                                                                LARSYS VERSION 3
FROM EACH CHANNEL 1 - 6: ARKANSAS TM DATA

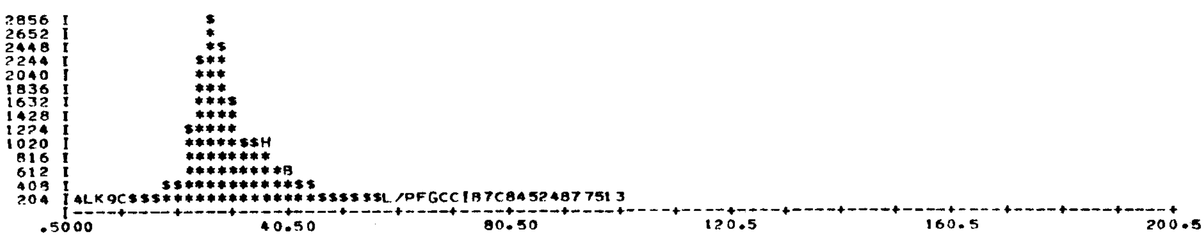
CLASS....DETECT1            TOTAL NUMBER OF SAMPLES...  16384
HISTOGRAM(S)
CHANNEL  4       0.76 -  0.90  MICROMETERS
   EACH * REPRESENTS  39  POINT(S).
```




```
CHANNEL  5       1.55 -  1.75  MICROMETERS
   EACH * REPRESENTS 102  POINT(S).
```




```
CHANNEL  6       2.08 -  2.35  MICROMETERS
   EACH * REPRESENTS 204  POINT(S).
```




```
FROM BAND 7 (THERMAL IR) : ARKANSAS TM DATA

CLASS....TDETECT1           TOTAL NUMBER OF SAMPLES...   4096
HISTOGRAM(S)
CHANNEL  7      10.40 - 12.50  MICROMETERS
   EACH * REPRESENTS  46  POINT(S).
```

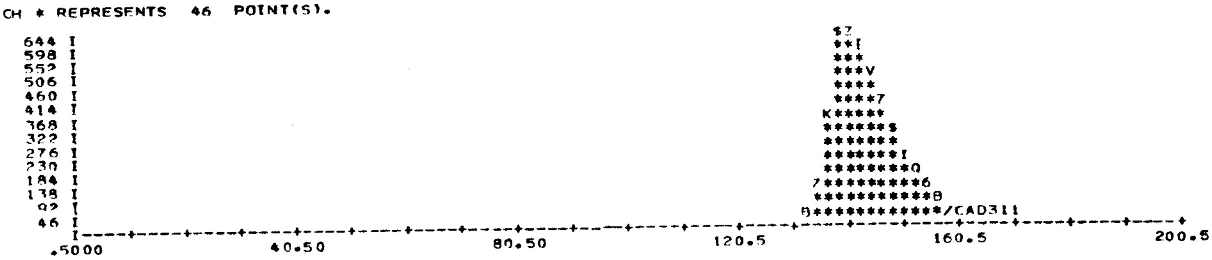


Figure 1. (Continued)

Other radiometric observations were made in the thermal data. There are vertical rows of bright dots in this band. The dots have a vertical interval of 17 to 18 lines and are spaced 128 pixels apart horizontally. The value of the dots is approximately 157. The size of the dots is one pixel wide and up to 3 pixels vertically.

This radiometric and geometeric quick-look analysis hopefully identifies obvious problems and to some extent evaluates the key performance parameters of registration and channel-to-channel calibration.

Publications

No publications were produced in the quarter.

Recommendations

Two technical recommendations arise out of this early analysis. One is to further check and adjust the registration of Bands 5, 6, and 7 if they prove to be out of registration as is suggested by our results. The second is to examine the thermal IR processing stream to find and correct the cause of the bright pixels in the data. A third recommendation is to interchange TM Bands 6 and 7 so that wavelength increases monotonically with band number.

Funds Expended

The funds expended on the project are reported periodically by the Purdue Office of Contract and Grant Business Affairs to the sponsor on NASA Form 533M. These are issued monthly. Specific disclosure of funds expended in this form of technical report is not permissible. If a quarterly summary is required, it can be prepared as a separate document by Purdue OCGBA.

Data Utility

Data utility conclusions as a result of these initial investigations are, first, that Band 2 of the Detroit data has some problems and should be used with caution. Similarly, the thermal IR band of the Arkansas frame appears to be significantly out of registration and should be used with caution in conjunction with the other bands.

Finally, it was of interest to examine the dimensionality of the new seven-band TM data relative to what had been available from the

Landsat MSS for the past ten years. Principal components analysis was conducted of the 512 by 512 block in the Arkansas data using three sets of bands: The first four, the first six, and then all seven. We felt the first four would reasonably represent the MSS bands as we did not have MSS data for this scene. Again we emphasize that our Band 7 is the thermal IR. The eigenvectors and eigenvalues for the three cases are listed in Table 4. The results for the four-band case are similar to those for previous MSS bands even though there is only one IR band and a blue band is present here. There typically are two components for vegetated scenes in this wavelength range. Adding the two middle IR bands increases the dimensionality to three, indicating significant correlation of these two bands; but as a pair, they are relatively uncorrelated with the visible and near IR regions. Adding the thermal increases the dimensionality to about four. These are expected results and indicate that the intrinisic dimensionality of the .4 to 14 μm range is about four for vegetated scenes, which is what was observed early in the remote sensing research using twelve-band aircraft MSS data.

The general conclusion on data utility is that no severe problems exist in any of the TM bands. The thermal band appears to be misregistered to the right and down by four 30M pixels and this should be investigated further. Slight misregistrations of the 1.55 - 1.75 and 2.08 - 2.35 bands may exist. The data should be used with these problems in mind.

Table 3. Calibration Accuracy Specifications for TM Bands.

Band	Accuracy Specification	Spec. X Grand Mean	Channel-to-Channel Error Tolerance
1	.8% NEP	.61	.15
2	.5% NEP	.16	.04
3	.5% NEP	.14	.04
4	.5% NEP	.54	.13
5	1.0% NEP	.80	.20
6	2.4% NEP	3.42	.85
7	.5° K NETD	.24 **	.06

** Assuming a scene mean temperature of 294° K

Table 3a. Arkansas TM Data.
Stats of All Detectors in Each Band.

BAND 1

Detector	Mean	Std.Dev.	Dev.of Mean	Dev.of Std.
1	76.35	5.71	-0.05	0.02
2	76.29	5.51	-0.11	-0.22
3	76.33	5.64	-0.07	-0.09
4	76.37	5.77	-0.03	0.04
5	76.35	5.78	-0.05	0.05
6	76.30	5.65	-0.10	-0.08
7	76.35	5.56	-0.05	-0.17
8	76.43	5.66	0.03	-0.07
9	76.46	5.82	0.06	0.09
10	76.48	5.86	0.08	0.13
11	76.52	5.93	0.12	0.20
12	76.49	5.86	0.09	0.13
13	76.45	5.80	0.05	0.07
14	76.46	5.84	0.06	0.11
15	76.39	5.56	-0.01	-0.08
16	76.37	5.70	-0.03	-0.03
Total	1222.39	91.74		

Grand Mean: 1222.39/16 = 76.40

Aver. Std. Dev.: 91.74/16 = 5.73

Table 3b. Arkansas TM Data.

BAND 2

Detector	Mean	Std.Dev.	Dev.of Mean	Dev.of Std.
1	32.45	3.89	0.01	-0.01
2	32.40	3.78	-0.04	-0.12
3	32.40	3.83	-0.04	-0.07
4	32.38	3.88	-0.06	-0.02
5	32.40	3.95	-0.04	0.05
6	32.43	3.88	-0.01	-0.02
7	32.41	3.83	-0.03	-0.07
8	32.43	3.84	-0.01	-0.06
9	32.50	3.95	0.06	0.05
10	32.49	3.94	0.05	0.04
11	32.52	3.95	0.08	0.05
12	32.54	3.97	0.10	0.07
13	32.48	3.94	0.04	0.04
14	32.46	3.96	0.02	0.06
15	32.41	3.86	-0.03	-0.04
16	32.41	3.89	-0.03	-0.01
Total	519.11	62.34		

Grand Mean: 519.11/16 = 32.44

Aver. Std. Dev.: 62.34/16 = 3.90

Table 3c. Arkansas TM Data.

BAND 3

Detector	Mean	Std.Dev.	Dev.of Mean	Dev.of Std.
1	27.99	6.48	-0.03	-0.10
2	27.95	6.37	-0.07	-0.21
3	27.95	6.46	-0.07	-0.12
4	27.92	6.55	-0.10	-0.03
5	27.97	6.62	-0.05	0.04
6	28.01	6.57	-0.01	-0.01
7	28.02	6.50	0.00	-0.08
8	28.03	6.56	0.01	-0.02
9	28.11	6.72	0.09	0.14
10	28.13	6.76	0.11	0.18
11	28.15	6.77	0.13	0.19
12	28.12	6.71	0.10	0.13
13	28.04	6.64	0.02	0.06
14	28.07	6.64	0.05	0.06
15	27.96	6.50	-0.06	-0.08
16	27.91	6.45	-0.11	-0.13
Total	448.33	105.3		

Grand Mean: 448.33/16 = 28.02

Aver. Std. Dev.: 105.3/16 = 6.58

Table 3d. Arkansas TM Data.

BAND 4

Detector	Mean	Std.Dev.	Dev.of Mean	Dev.of Std.
1	107.83	21.69	0.42	-0.11
2	107.90	21.54	0.49	-0.26
3	107.80	21.58	0.39	-0.22
4	107.68	21.55	0.27	-0.25
5	107.57	21.50	0.16	-0.3
6	107.43	21.58	0.02	-0.22
7	107.30	21.67	-0.11	-0.13
8	107.22	21.75	-0.19	-0.05
9	107.23	21.93	-0.18	0.13
10	107.17	21.99	-0.24	0.19
11	107.08	22.01	-0.33	0.21
12	107.11	22.06	-0.3	0.26
13	107.18	22.15	-0.23	0.35
14	107.33	22.08	-0.08	0.28
15	107.39	21.98	-0.02	0.18
16	107.37	21.79	-0.04	-0.01
Total	1718.59	348.55		

Grand Mean: 1718.59/16 = 107.41

Aver. Std. Dev.: 348.85/16 = 21.8

Table 3e. Arkansas TM Data.

BAND 5

Detector	Mean	Std.Dev.	Dev.of Mean	Dev.of Std.
1	80.02	12.47	0.19	-0.21
2	79.95	12.36	0.12	-0.32
3	79.94	12.41	0.11	-0.27
4	79.91	12.56	0.08	-0.12
5	79.91	12.67	0.08	-0.01
6	79.87	12.77	0.04	0.09
7	79.79	12.83	-0.04	0.15
8	79.73	12.80	-0.1	0.12
9	79.77	12.82	-0.06	0.14
10	79.77	12.86	-0.06	0.18
11	79.77	12.97	-0.06	0.29
12	79.81	12.90	-0.02	0.22
13	79.84	12.79	0.01	0.11
14	79.86	12.68	0.03	0.00
15	79.69	12.57	-0.14	-0.11
16	79.68	12.42	-0.13	-0.26
Total	1277.31	202.88		

Grand Mean: 1277.31/16 = 79.83

Aver. Std. Dev.: 202.88/16 = 12.68

Table 3f. Arkansas TM Data.

BAND 6 (2.08 - 2.35μm)

Detector	Mean	Std.Dev.	Dev.of Mean	Dev.of Std.
1	29.37	8.85	0.02	-0.24
2	29.32	8.81	-0.03	-0.28
3	29.34	8.86	-0.01	-0.23
4	29.37	9.03	0.02	-0.06
5	29.35	9.11	0.00	0.02
6	29.37	9.25	0.02	0.16
7	29.34	9.21	-0.01	0.12
8	29.39	9.18	0.04	0.09
9	29.35	9.28	0.00	0.19
10	29.38	9.39	0.03	0.3
11	29.44	9.41	0.09	0.32
12	29.45	9.28	0.1	0.19
13	29.38	9.17	0.03	0.08
14	29.31	9.04	-0.04	-0.05
15	29.27	8.85	-0.08	-0.24
16	29.23	8.72	-0.12	-0.37
Total	469.66	145.44		

Grand Mean: 469.66/16 = 29.35

Aver. Std. Dev.: 145.44/16 = 9.09

Table 3g. Arkansas TM Data.

BAND 7 (Thermal IR)

Detector	Mean	Std.Dev.	Dev.of Mean	Dev.of Std.
1	142.45	5.60	-0.02	0.03
2	142.42	5.46	-0.05	-0.11
3	142.45	5.53	-0.02	-0.04
4	142.55	5.69	0.08	0.12
Total	569.87	22.28		

Grand Mean: 569.87/4 = 142.47

Aver. Std. Dev: 22.28/4 = 5.57

Table 4. Principal Components Results for Arkansas TM Data.

Results Based on Bands 1, 2, 3, 4

EIGENVALUE	% OF VAR.	CUM. %	MSE
514.02	89.04	89.04	10.96
59.71	10.34	99.38	0.62
2.20	0.38	99.76	0.24
1.38	0.24	100.00	-0.00

EIGENVECTORS

-0.14020	0.59589	-0.78599	-0.086.49
-0.08969	0.39904	0.40832	-0.81609
-0.18197	0.65220	0.46407	0.57110
0.96912	0.24560	0.01122	0.01920

Results Based on Bands 1 Through 6

EIGENVALUE	% OF VAR.	CUM. %	MSE
531.55	64.98	64.98	35.02
255.59	31.24	96.22	3.78
22.15	2.71	98.93	1.07
5.22	0.64	99.57	0.43
2.28	0.28	99.85	0.15
1.27	0.15	100.00	-0.00

EIGENVECTORS

-0.14702	0.22285	0.55788	-0.24762	0.73151	0.14515
-0.09673	0.15352	0.34346	-0.22426	-0.54468	0.70862
-0.19021	0.25512	0.53271	-0.05115	-0.40691	-0.66840
0.94779	0.19079	0.23642	0.09562	-0.01416	-0.00716
0.00501	0.77333	-0.47996	-0.40977	0.00471	-0.06029
-0.18579	0.47669	0.02749	0.84186	0.04924	0.16232

Results Based on All Bands

EIGENVALUE	% OF VAR.	CUM. %	MSE
525.81	63.29	63.29	36.71
253.98	30.57	93.87	6.13
24.89	3.00	96.86	3.14
18.08	2.18	99.04	0.96
4.69	0.57	99.60	0.40
2.03	0.24	99.85	0.15
1.28	0.15	100.00	-0.00

EIGENVECTORS

-0.15027	0.21962	0.44266	0.35203	-0.27705	-0.72814	0.04857
-0.09889	0.14870	0.28840	0.18877	-0.19872	0.45909	0.77397
-0.19642	0.24846	0.44461	0.28585	-0.03336	0.49591	-0.61095
0.93437	0.21823	0.10208	0.24650	0.08734	0.02031	-0.01032
-0.00834	0.77004	-0.30538	-0.38372	-0.40432	0.01311	-0.05322
-0.19541	0.47233	0.00950	0.03598	0.83933	-0.10347	0.14885
-0.13326	0.06513	-0.64763	0.741.24	-0.08404	0.04271	-0.01591