INTRODUCTION

A set of procdures was developed to compare the geometry of systematic NLAPS and LPGS images. Eleven scenes were then processed and comparison results were generated. The two systems compared favorably and both were under the pre-launch specifications for systematic geodetic accuracy and band-to-band (B2B) alignment. This document gives the results obtained during testing and also gives an explanation for some of the differences found.

PROCEDURE

Software from the Image Assessment System (IAS) was used for both assessments. Grey scale correlation was used for the mensuration process during both the geometric and band-to-band assessment. The correlation routines have heritage with the Land Analysis System (LAS) correlation routines. Many of the parameters and actual code for the IAS correlation routines come from the LAS software correlation modules.

It should be noted that the LPGS system aligns the center pixel of all the bands while the NLAPS system aligns the upper left corner of all the bands. To make all the bands of the NLAPS imagery align with those of the LPGS imagery, separate NLAPS products were created for the multispectral bands and the PAN/thermal bands. This aligned all the bands between the products. The pixel sizes of corresponding bands between the two output products were processed to an equal size. All images were resampled using cubic convolution. Image products have an output projection of UTM with a WGS84 datum.

The following data sets were chosen for comparison:

Path	Row	Date
29	29	8/31/1999
30	36	4/18/2000
16	40	6/3/2000
36	35	6/15/2000
30	33	7/7/2000
39	37	7/22/2000
39	37	3/19/2001
16	40	4/3/2001
164	47	6/3/2001
29	29	7/3/2001
18	37	7/22/2001

IMAGE to IMAGE ASSESSMENT

Grey scale correlation was used to measure points between the systematic images. Only same day comparisons were made. Comparing only same day systematic images eliminated the need to remove relief or atmospheric effects since only a relative comparison was needed. Typically over 300 points were kept from the correlation

process. The radiometric differences were very small between the images being compared; this meant that there were very few outliers produced from the correlation process.

I) KNOWN DIFFERENCES

The image to image (I2I) assessment was done on the systematic PAN image. Known differences between the two products are:

1) The NLAPS system did not account for the aberration of light at the time of the testing. This accounted for approximately 15 meters along track difference between the two products.
2) The NLAPS system uses the 2nd day definitive ephemeris file while the LPGS system uses the 3rd day definitive ephemeris file. The 2nd day ephemeris file is more accurate. The actual difference between the accuracy of the two files varies. A plot of the difference for one whole day between 2nd and 3rd day definitive ephemeris files can be seen in Figure 1.

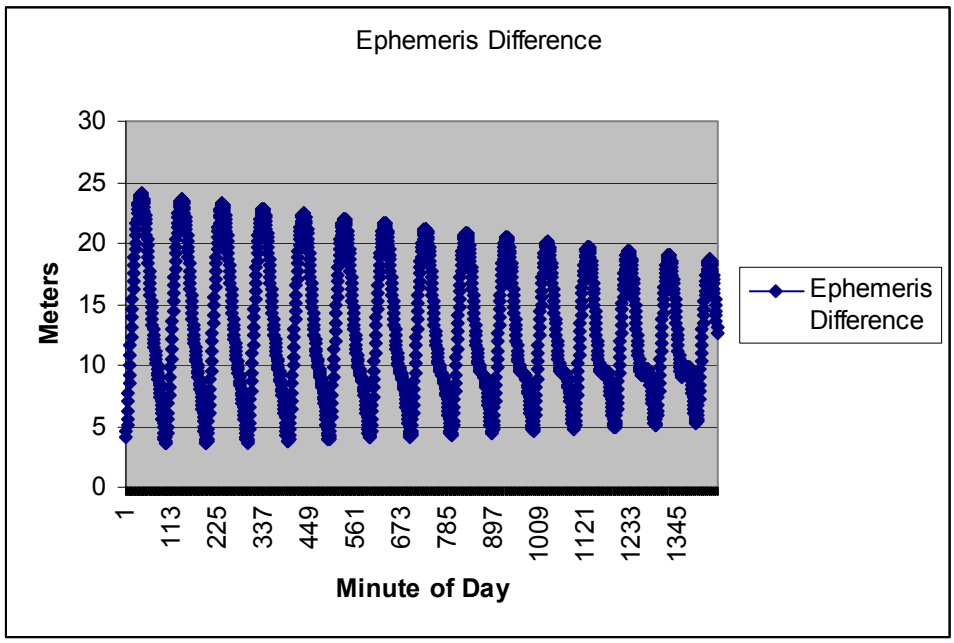

Figure 1

From the figure it can be seen that the difference can be up to 24 meters. Several of the days used in the testing procedure were checked and Figure 1 was typical of the differences. Some days, however, had a much smaller maximum difference and one had a much larger maximum difference. The largest difference found among the days tested was 70 meters. All plots had a periodic nature. The periodic nature is probably due to the satellite's orbit and the tracking information obtained for each orbit.

3) NLAPS and LPGS do not handle the quaternion, gyro and gyro drift attitude data the same way. The quaternion, gyro, and gyro drift need to be combined into one low frequency attitude state for the satellite and instrument. The LPGS system uses a Kalman filter to combine these measurements. The technique used by the NLAPS system is yet to be determined, although known to be different. The difference due to the two techniques is unknown at this time.

II) RESULTS

Figure 2 shows the overall net horizontal RMSE between the systematic images. This plot is a measure of the RMSE between PAN bands only.

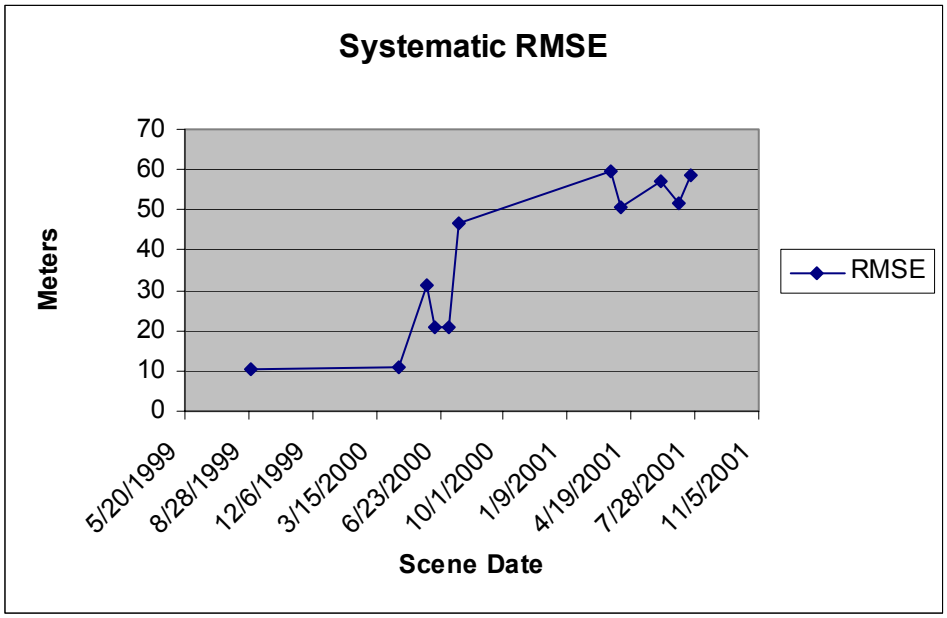

Figure 2

Figure 3 shows the standard deviation in the line and sample direction between measured points for each scene.

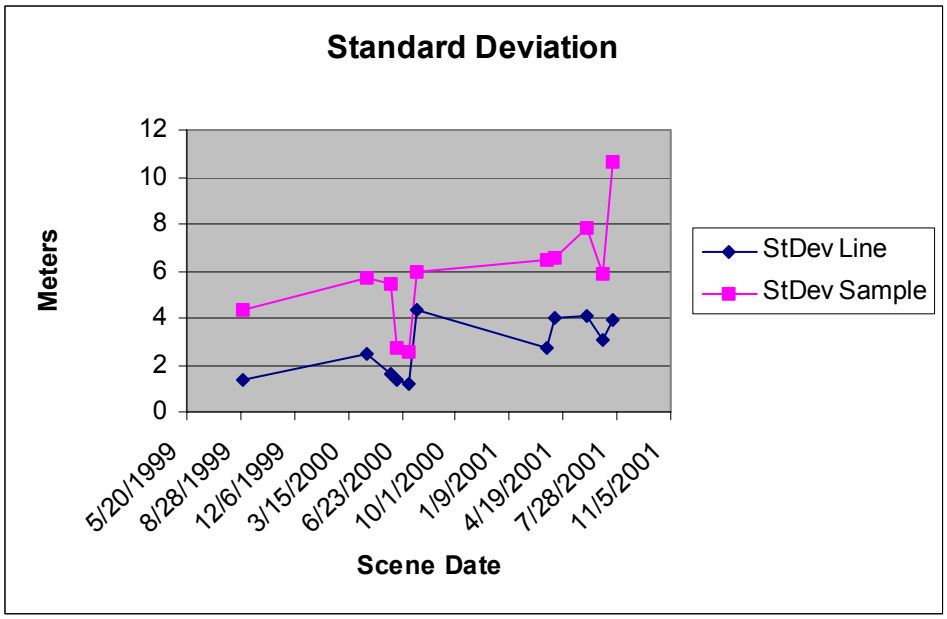

Figure 3

The small standard deviation in the difference between the products shows how the majority of the difference between the two products is due to a small shift between images. Shifting one image with respect to the other would remove the majority of the difference. The slightly higher standard deviation in the sample direction could be due to small differences in how the scanning mirror is modeled between the two systems or due to differences in how the attitude data are processed. Figures 4 and 5 show the RMSE and standard deviation with a threshold of 250 meters RMSE and 50 meters standard deviation for I2I. These thresholds are those that will be used by the Earth Resource Observation Systems (EROS) Data Center for comparing the Landsat data between International Ground Stations (IGS) to those produced by the USGS.

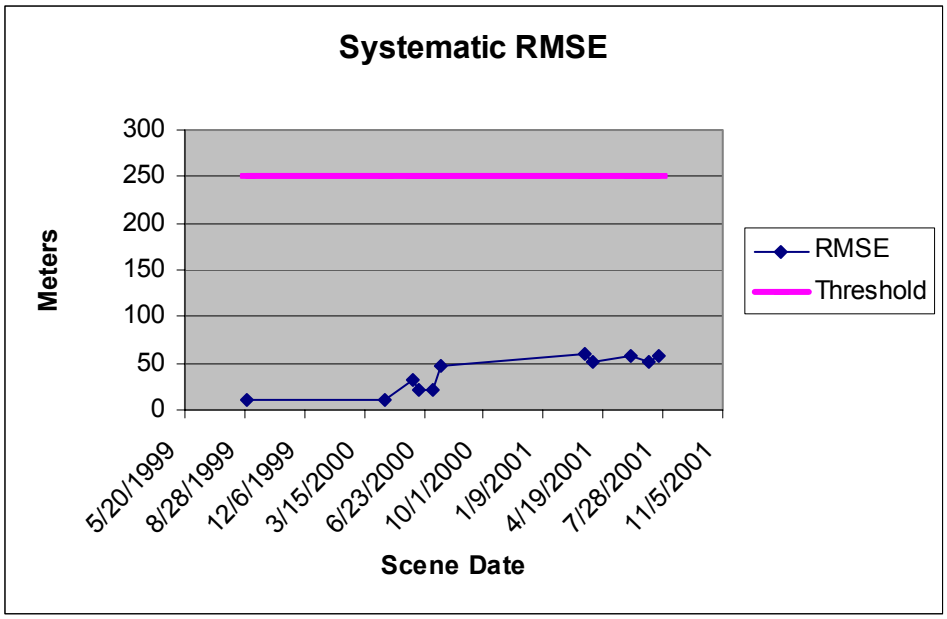

Figure 4

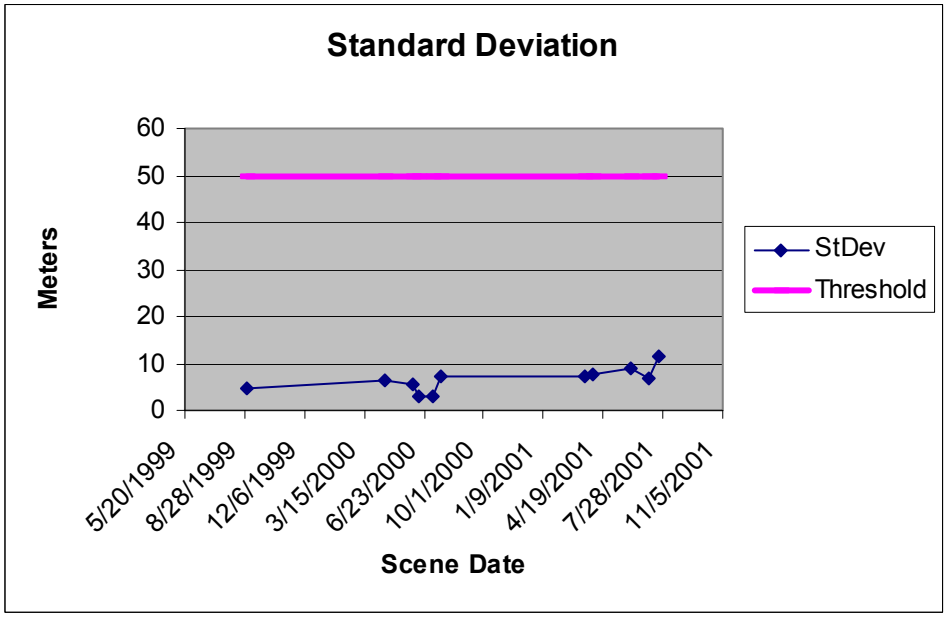

Figure 5

A vector plot of the residuals helps to show the "systematic" nature of the difference between the two products. Figure 6 is a vector plot of the difference at each point measured between the images for path 39 row 37 from March 19, 2001.

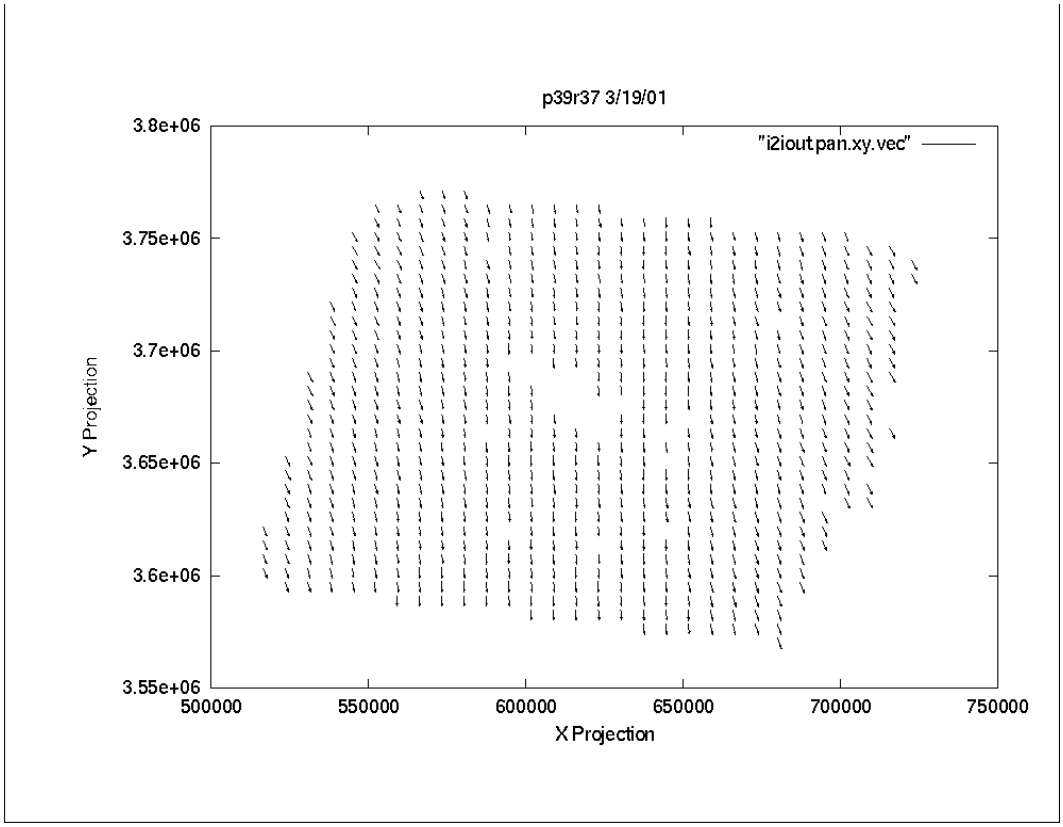

Figure 6

The vector plots of the scenes from after July 7, 2000 all show a consistent direction, down and to the right. Further investigations are being done to try to determine the nature of this offset.

BAND to BAND ASSESSMENT

Grey scale correlation was used to measure between bands within an image product. Grey scale correlation was performed on every band combination. The higher resolution bands were reduced to match the lower resolution bands. Outliers were determined during the correlation process by looking at the correlation characteristics and further reduced by performing a student-t distribution test on the offset values. Over 700 points were correlated However, the number of valid points were much smaller once outliers were removed. Dry arid regions with little vegetation were found to produce the best correlation among all bands.

I) RESULTS

Tables 2 and 3 show the RMSE and standard deviation measured from the B2B assessment for the LPGS product. The value for the line direction is the top number for each entry while the value for the sample direction is the bottom number. Tables 4 and 5 show the same measurements for the NLAPS product. All values are in pixel

size relative to the coarsest resolution of the bands being paired. The values correspond to path 39 row 37 March 19, 2001.

Band	2	3	4	5	61	62	7	8
1	0.0210 0.0363	0.0314 0.0475	0.0467 0.0541	0.0673 0.0699	0.1003 0.1420	0.1059 0.1166	0.0679 0.0678	0.0320 0.0476
2		0.0192 0.0240	0.0344 0.0467	0.0573 0.0544	0.1068 0.1145	0.1033 0.1086	0.0577 0.0528	0.0266 0.0485
3			0.0267 0.0415	0.0508 0.0454	0.0879 0.1101	0.0903 0.1202	0.0502 0.0487	0.0253 0.0364
4				0.0500 0.0493	0.0906 0.1285	0.0876 0.1229	0.0597 0.0592	0.0283 0.0290
5					0.05589 0.09733	0.0529 0.0996	0.0220 0.0337	0.0410 0.0489
61							0.0621 0.0818	0.1043 0.1293
62							0.0604 0.0821	0.1113 0.1226
7								0.0585 0.0585

Table 2 LPGS RMSE (Line,Sample)

Band	2	3	4	5	61	62	7	8
1	0.0210 0.0363	0.0313 0.0475	0.0467 0.0541	0.0599 0.0664	0.0987 0.1380	0.1056 0.1126	0.0570 0.0606	0.0299 0.0464
2		0.0192 0.0240	0.0344 0.0468	0.0500 0.0488	0.1054 0.1136	0.1031 0.1059	0.0472 0.0488	0.0265 0.0468
3			0.0261 0.0414	0.0409 0.0386	0.0860 0.1060	0.0892 0.1117	0.0372 0.0423	0.0252 0.0360
4				0.0434 0.0430	0.0901 0.1250	0.0860 0.1210	0.0524 0.0527	0.0283 0.0279
5					0.0557 0.0958	0.0529 0.0974	0.0218 0.0337	0.0262 0.0381
61							0.0604 0.0630	0.1000 0.1253
62							0.0593 0.0626	0.1033 0.1190
7								0.0460 0.0534

Table 3 LPGS Standard Deviation

Band	2	3	4	5	61	62	7	8
1	0.0222 0.0363	0.0301 0.0493	0.0461 0.0579	0.0813 0.1603	0.1456 0.3205	0.1406 0.3219	0.0834 0.1440	0.0468 0.0555

2		0.0243 0.0356	0.0351 0.0540	0.0688 0.1522	0.1389 0.3101	0.1230 0.3104	0.0752 0.1333	0.0334 0.0648
3			0.0280 0.0467	0.0657 0.1352	0.1607 0.3130	0.1195 0.3044	0.0684 0.1184	0.0263 0.0516
4				0.0667 0.1596	0.1129 0.3059	0.1162 0.2992	0.0757 0.1422	0.0337 0.0454
5					0.0797 0.2338	0.0992 0.2403	0.0304 0.0451	0.0802 0.1689
61							0.0924 0.2538	0.1613 0.3335
62							0.0889 0.2618	0.1567 0.3339
7								0.0803 0.1555

Table 4 NLAPS RMSE

Band	2	3	4	5	61	62	7	8
1	0.0222 0.0363	0.0301 0.0474	0.0461 0.0563	0.0655 0.0799	0.1340 0.1664	0.1217 0.1583	0.0577 0.0770	0.0423 0.0528
2		0.0243 0.0333	0.0351 0.0528	0.0524 0.0590	0.1253 0.1433	0.1114 0.1347	0.0523 0.0533	0.0278 0.0614
3			0.0280 0.0399	0.0443 0.0467	0.0875 0.1378	0.0977 0.1317	0.0392 0.0498	0.0229 0.0448
4				0.0449 0.0551	0.0962 0.1407	0.1007 0.1437	0.0624 0.0705	0.0276 0.0454
5					0.0734 0.1196	0.0928 0.1225	0.0304 0.0385	0.0491 0.0623
61							0.0851 0.0979	0.1379 0.1454
62							0.0810 0.1059	0.1315 0.1396
7								0.0479 0.0759

Table 5 NLAPS Standard Deviation

The NLAPS product appears to have a slightly larger offset than the LPGS product in the sample direction when comparing the warm focal plane (bands 1-4,8) to the cold focal plane (5,61,62,7). Due to the nature of band 6, lower resolution, emissive thermal sensor, it did not correlate quite as well with the other bands. From Tables 3 and 5 it can be seen that the same band combinations had similar standard deviations between the two products during mensuration. This helps show that the quality of measurement made during the process for both products were essentially the same. Figures 7 and 8 show vector plots of the measured RMSE for the LPGS and NLAPS products respectively. The plots represent the measurements made when comparing

band 3 to band 5. The vectors are scaled by a factor of 500 in both plots. From the plots it can be seen that the LPGS vectors have a much more randomness than the NLAPS vectors. The vectors show a slight offset associated with the NLAPS product. The threshold for band to band registration when comparing Landsat IGS products is 0.17 pixels.

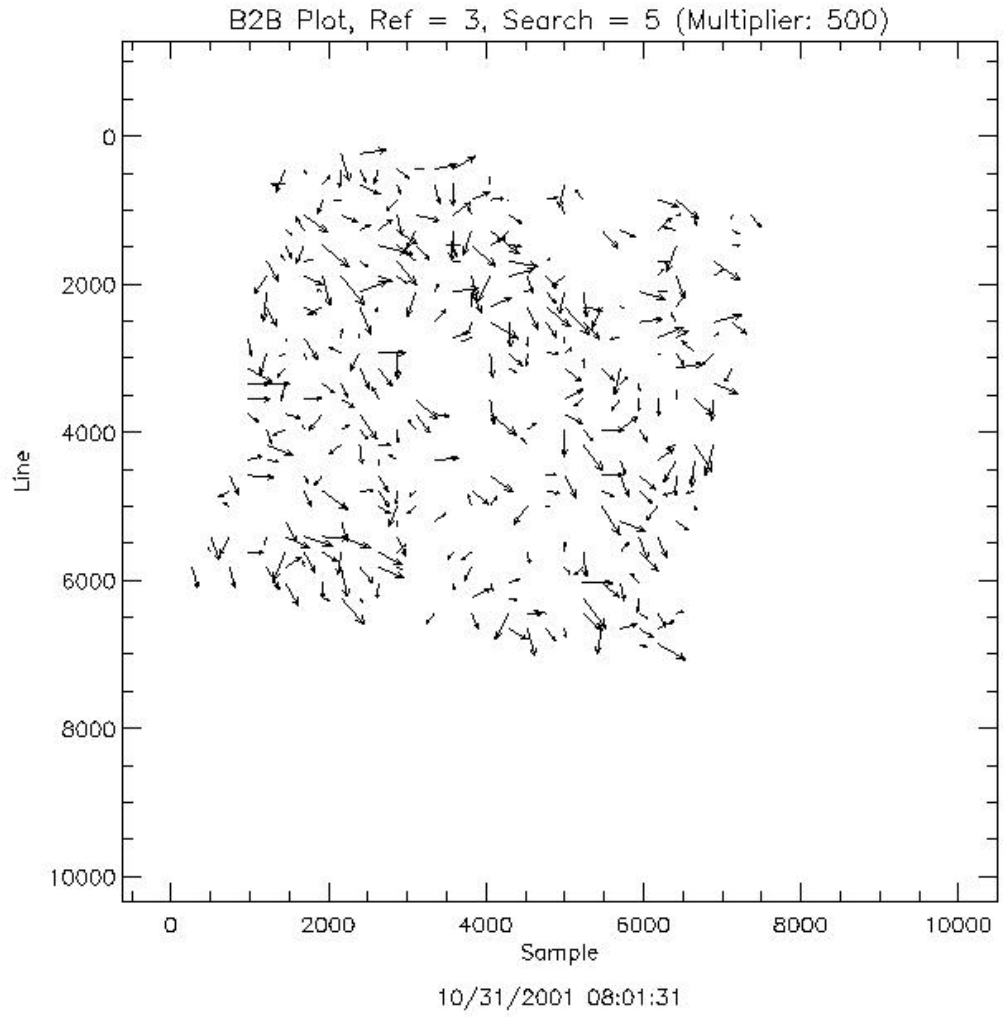

Figure 7 LPGS RMSE band 3 to 5

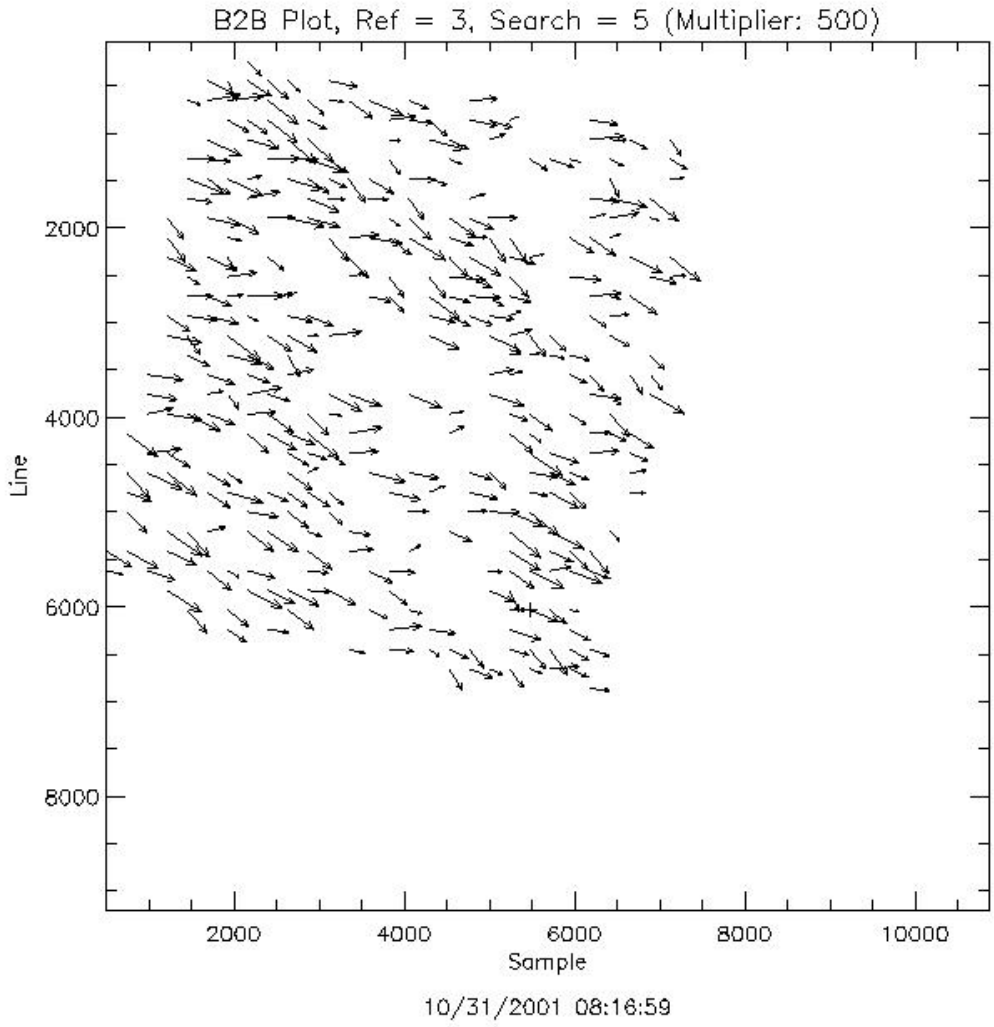

Figure 8 RMSE NLAPS band 3 to 5

Tables 6 and 7 show the LPGS and NLAPS RMSE calculated for the band-to-band assessment using the image for path 36 row 35 acquired on June 15, 2000.

Band	2	3	4	5	61	62	7	8
1	0.0244 0.0300	0.0469 0.0467	0.1006 0.0735	0.0508 0.0489	0.1226 0.0974	0.1510 0.1171	0.0659 0.0390	0.0727 0.0519
2		0.0320 0.0371	0.0663 0.0555	0.0650 0.0515	0.1460 0.1230	0.1449 0.1259	0.0603 0.0534	0.0442 0.0405
3			0.0424 0.0328	0.0660 0.0476	0.1546 0.1370	0.1320 0.1520	0.0572 0.0388	0.0204 0.0157
4				0.0722 0.0513	0.1424 0.2001	0.1410 0.2058	0.0743 0.0622	0.0245 0.0201
5					0.1371	0.0546	0.0136	0.0743

					0.1553	0.1237	0.0193	0.0513
61							0.1370 0.1472	0.1323 0.1246
62							0.1248 0.1544	0.1604 0.1406
7								0.0700 0.0456

Table 6 RSME LPGS

Band	2	3	4	5	61	62	7	8
1	0.0240 0.0252	0.0476 0.0501	0.0993 0.0697	0.0742 0.1415	0.1535 0.2952	0.1515 0.3022	0.0821 0.1200	0.0787 0.0697
2		0.0275 0.0384	0.0684 0.0529	0.0799 0.1373	0.1555 0.2762	0.1474 0.2421	0.0631 0.1204	0.0546 0.0512
3			0.0385 0.0259	0.0804 0.1355	0.1889 0.3007	0.2161 0.2974	0.0713 0.1231	0.0372 0.0416
4				0.0946 0.1611	0.2257 0.2916	0.2339 0.2818	0.0835 0.1379	0.0249 0.0364
5					0.1529 0.2464	0.1536 0.2858	0.0146 0.0294	0.0983 0.1684
61							0.1256 0.3089	0.1650 0.3079
62							0.1469 0.3200	0.1712 0.2538
7								0.0847 0.1491

Table 7 RMSE NLAPS

Tables 6 and 7 show similar results to 2 and 4. Tables of the standard deviation and vector plots are not shown, however they also showed similar results as those from path 39 row 37 March 19, 2001.

CONCLUSION

The test results in this document show that systematic products from NLAPS and LPGS compare favorably. Both systems are also within the pre-launch specifications. The majority of the geodetic difference between the images tested can be removed by applying an offset in the line and/or sample direction to one of the images. Only a few control points would need to be measured between the images and then a simple bias could be applied to one of the scenes to adjust one scene to the other. Most image processing software packages have tools available for this type of procedure.

After these testing procedures were done, NLAPS was modified to account for the aberration of light. There are also plans to modify LPGS to use the 2nd day definitive ephemeris file. Once this change has been made to LPGS, rerunning the data sets using the same test procedures should produce even better results.

SUMMARY

A set of eleven scenes were chosen for comparing systematic products from the NLAPS and LPGS Landsat 7 processing systems. Relative geodetic accuracy was compared among all eleven scenes. This was done by performing an image-to-image assessment between same day image pairs. Band-to-band alignment was assessed on two of the eleven scenes produced from each system. The systematic products compared favorably between the systems. Both systems also met the threshold for band alignment that will be used when assessing Landsat 7 products from the International Ground Stations.