7.9 - 1 0.0 3 5

SAR-Landsat Image Registration Study

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(E79-10035)  SAR/LANDSAT IMAGE REGISTRATION
STUDY  Final Report, Apr. 1977 - Sep. 1978            N79-13442
(International Business Machines Corp.)
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                                               G3/43   00035
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SAR—Landsat Image Registration Study

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September 1978
Final Report

Prepared under NASA contract NAS6-2827 for
Wallops Flight Center
Wallops Island, VA 23337

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Advanced Image Processing
Analysis and Development

Approved by:

Walt Dunkle, Mgr.
Space Systems

IBM-G-1

PREFACE

This is the final report on the IBM SAR-Landsat Image Registration Study performed under NASA contract NAS6-2827. It summarizes the effort and results of the entire study, and it is submitted in accordance with Item 2 of Article IX of the study contract.

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

Section 1

INTRODUCTION AND SUMMARY

1.1 PURPOSE

This is the final report on IBM's SAR-Landsat Image Registration Study. It describes the work performed under contract NAS6-2827 and satisfies Item 2 of Article IX of that contract. Some results of additional related studies outside the scope of this contract performed by IBM under its Independent Research and Development (IRAD) program are also described in this report.

1.2 SCOPE OF THE STUDY

The primary purpose of this study was to develop techniques and capabilities to assemble SAR/Landsat data sets. To accomplish this, two SAR data sets were extensively analyzed. Suitable algorithms and techniques were developed to register SAR data with corrected Landsat-MSS data. Then an example of registered SAR and Landsat-MSS data was produced. The results of this processing are presented later in this report.

A second purpose of this study was to contribute to the writing of the SAR/Landsat System Plan. This document, published by Wallops Flight Center, was edited by Purdue/LARS and jointly authored by Wallops Flight Center, Purdue/LARS, IBM Corporation, and Goodyear Aerospace Corporation.

A third purpose of this study was to design a software system that will be able to produce registered SAR and Landsat data sets. If it is approved and funded by NASA, the system will be implemented at Purdue/LARS in FY 1979. The Landsat processing portion of the system was designed in detail. Documents (Appendixes A and B) describing this design were produced.

1.3 SUMMARY OF EFFORT

During the course of this study which began in April 1977, the following results were accomplished:

a. One Landsat-MSS frame was geometrically corrected (using geodetic control points) to a 50.8-meter pixel spacing. Two subimages of this frame were corrected to a 25.4-meter pixel spacing.

b. SAR data sets were registered to each of the 25.4-meter corrected Landsat subimages.

c. An informal report that represents IBM's contribution to the SAR/Landsat System Plan was written and submitted to Purdue/LARS.

d. The Landsat-MSS portion of the SAR/Landsat Data Merging System was designed in detail. A document describing the system was written.

e. Support of NASA planning activities was provided as required by NASA.

An IRAD program of related investigations outside the scope of this contract was defined and completed. Some of the results are included in this report.

1.4 CONCLUSIONS

The primary conclusion to be drawn from the results of this study is that digital methods provide a viable technology for accurate registration of SAR and Landsat-MSS data. Existing software, developed previously by IBM, was used to produce an example of registered SAR and Landsat-MSS data. Residual RMS errors at the registration control points of this data set were on the order of 55 meters.

1.5 RECOMMENDATIONS

The results of this study lead to the following recommendations for future NASA actions:

a. NASA should implement the SAR/Landsat Data Merging System at Purdue/LARS. This will provide the means by which NASA and other users can create a data base of registered SAR and Landsat-MSS data.

b. Experiments should be conducted to determine how the addition of a registered SAR channel to the Landsat-MSS channels contributes to the information extraction process.

c. NASA should fund a study to determine the differences (if any) involved in registering digital images from Seasat-1 SAR data with corrected Landsat-MSS images. Techniques for modeling geometric distortions should be investigated thoroughly in this study.

d. The subject of registration of image data from different types of instruments (that has been shown feasible by this study) should be pursued with regard to other instruments. Sensors from both aircraft and spacecraft devices should be studied.

1.6 NEW TECHNOLOGY

No new technology was discovered during the course of this contract.

Section 2

LANDSAT PROCESSING

2.1 SUMMARY OF LANDSAT PROCESSING

The first step in the registering of aircraft SAR image data and Landsat-MSS data was the geometric correction of the Landsat data to a Universal Transverse Mercator (UTM) map projection. This included the creation of both digital and enhanced photographic images that were registered to a UTM map. The processing involved was organized into the following parts:

a. Preprocessing

b. Control-Point Location

c. Scene Correction

d. Digital Filtering

e. Film Plotting and Photographic Processing

Each of these is described below or in Section 4, following a brief summary of Landsat-MSS digital data and its sources.

2.2 SOURCES OF LANDSAT IMAGERY

A multispectral scanner (MSS) is part of the payload of each of the first three Landsat spacecraft. In addition, inclusion of an MSS device in the Landsat-D payload is currently planned by NASA. The launch dates of the Landsat satellites follow:

a. Landsat-1, July 1972

b. Landsat-2, January 1975

c. Landsat-3, March 1978

d. Landsat-D, Scheduled in 1981

The MSS instruments on these spacecraft image the surface of the earth in four (Landsat-1 and Landsat-2) or five (Landsat-3 and Landsat-D) spectral bands. This is done simultaneously through the same optical system. The first four bands operate in the solar-reflected spectral region, and the fifth band operates in the thermal (emissive) spectral region, as follows:

a. Band 1, 0.5 to 0.6 micrometers

b. Band 2, 0.6 to 0.7 micrometers

c. Band 3, 0.7 to 0.8 micrometers

d. Band 4, 0.8 to 1.1 micrometers

e. Band 5, 10.4 to 12.6 micrometers (Landsat-3 and Landsat-D only)

MSS computer compatible tapes (CCTs) may be purchased from EDC. If a user does not know which scenes he requires, he may request a computer geographic search to obtain a listing of available scenes in his area of interest. To place an order, to inquire about the availability of data, or to establish a standing order, a user may contact:

User Services Unit
EROS Data Center
Sioux Falls, South Dakota 57198

Phone 605/594-6511, extension 151

Users within the NASA community may be able to obtain MSS data directly from NASA-GSFC.

A new processing system at EDC will become operational in 1978. Digital MSS data sets obtained prior to this are in a two-pixel-interleaved (X) format. The new system will produce data sets in either band-sequential (BSQ) or band-interleaved (BIL) format.

The new EDC system will provide two levels of processing for MSS data: partial processing and full processing. Partially processed data has been radiometrically corrected. That is, decompression, gain, and offset adjustments have been applied to the image data. Fully processed data has, in addition, been geometrically corrected. That is, the image data has been resampled by either cubic convolution or nearest neighbor techniques to present the data in one of several possible map projections. Corrections due to spacecraft altitude, ground truth, etc., have been applied.

A complete description of the Landsat program, its available products, and how to acquire them may be found in the Landsat Data Users Handbook, Revised. A new version of this document is being prepared by NASA Goddard Space Flight Center (GSFC) and USGS EROS Data Center (EDC) and is expected to be available in the latter part of 1978.

2.3 PREPROCESSING

Preprocessing consisted of all work of a preparatory nature that was performed before the major parts of the geometric correction process were started. It involved reorganization, evaluation, and radiometric correction of the image data.

The first step was the reformatting of the digital image data from the X format to the BSQ format required by the existing software at IBM. There were some I/O errors on the input CCTs, but the reformatting was eventually completed for two MSS scenes: 2579-14535 (the State of Delaware and the Eastern Shore area of Maryland) and 2579-14541 (the southern part of the Delaware-Maryland-Virginia peninsula).

The reformatted data was histogrammed to obtain knowledge about the distribution of the pixel intensities in each spectral band. The histogram program was run once for each spectral band of each of the two Landsat-MSS scenes. The output from this program consisted of absolute frequency distribution, cumulative frequency distribution, arithmetic mean, standard deviation, and root of the mean of the squares (RMS). Sample output is shown in Figure 2-1.

Using the mean and standard deviation of the pixel intensity distribution of the image data and knowledge of the radiometric characteristics of the IBM Drum Scanner/Plotter,[1] gain and bias coefficients were computed for each spectral band of each scene. The data from spectral band 3 (0.7 to 0.8 micron wavelength) of each scene was radiometrically adjusted using the gain and bias coefficients in a first-degree polynomial transformation. This radiometric adjustment was merely a contrast stretch that enabled the plotting device to produce a high-quality image. The two adjusted images were plotted on film (see Section 4.2), and the resulting images were visually evaluated. The pictures appeared to be of good quality.

At this point, at the request of NASA, the Landsat processing was limited to the Delaware scene (2579-14535). All further Landsat processing was done on that scene.

It is well known that Landsat-1 and Landsat-2 MSS data often exhibit an undesirable striping pattern that occurs on a six-scan-line basis. This striping is especially evident in spectral band 1 (0.5 to 0.6 micron wavelength). A striping reduction program that uses a sweep mean and standard deviation equalization algorithm[2] was used on all four spectral bands of the Deleware scene (2579-14535). A gain and bias correction function was used to perform this radiometric correction. A new gain and bias were calculated for each image-scan-line in such a way that the mean and standard deviation of each corrected image scan line equaled those of the uncorrected six lines of that scan-mirror sweep. The resulting image data still displayed some striping, especially in the coastal regions. However, it was an improvement over the uncorrected data. The radiometrically corrected data was used as input to all of the remaining Landsat processing.

2.4 CONTROL-POINT LOCATION

In order to perform precise geometric correction of Landsat-MSS data, it was necessary to use scene data to define some of the error corrections.[2,3,4,5,6,7,8,9] In particular, UTM map coordincates and input-image pixel coordinates of several control points were needed. Twenty-five control points were found.

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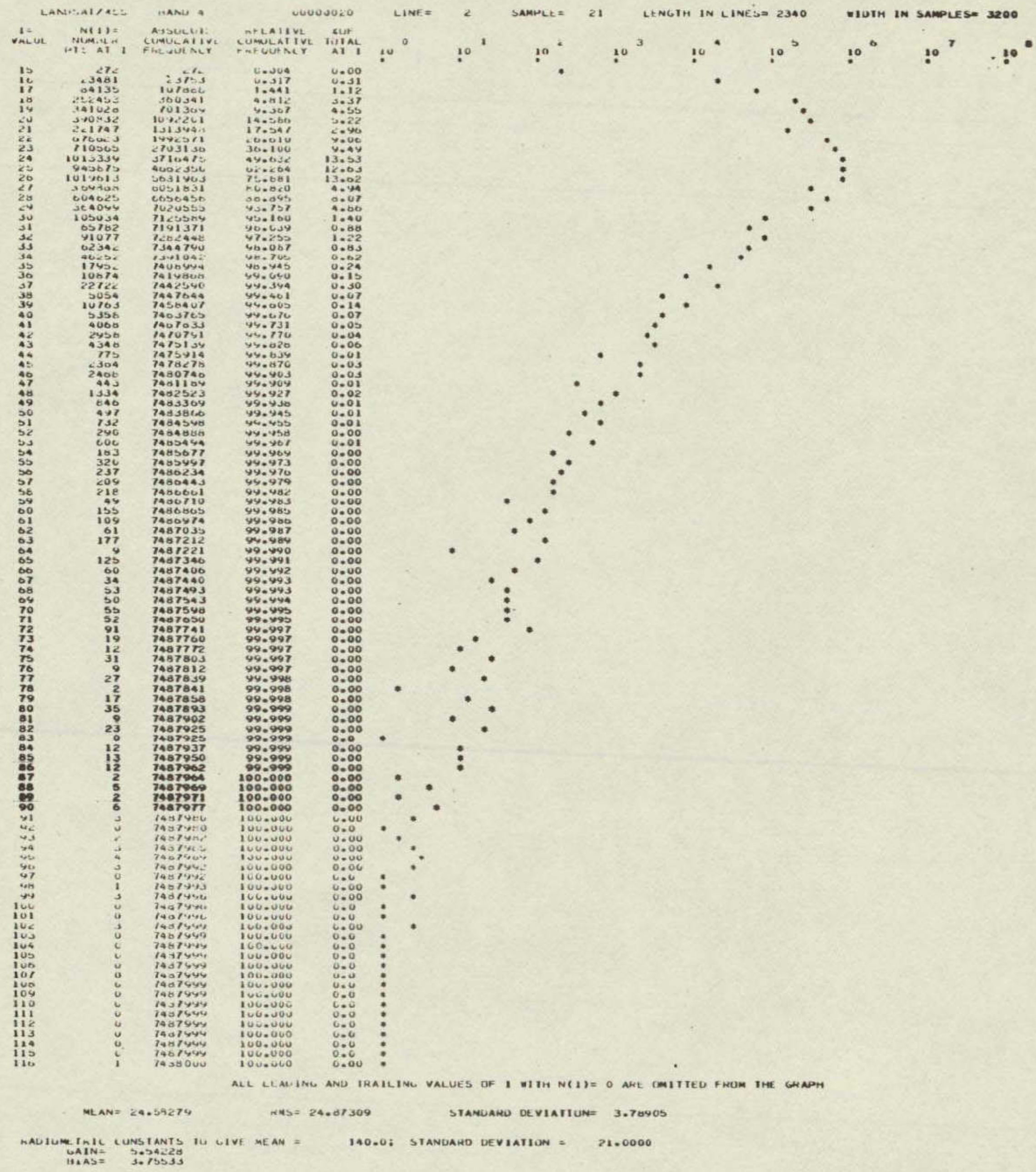

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         PTS AT I    FREQUENCY    FREQUENCY    AT I

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  20      390832      1092201       14.586     5.22
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Figure 2-1. Landsat-MSS Histograms (sheet 1 of 4)

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VALUE    NUMBER      CUMULATIVE     CUMULATIVE   TOTAL
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 19      799564      2892164         38.624     10.68
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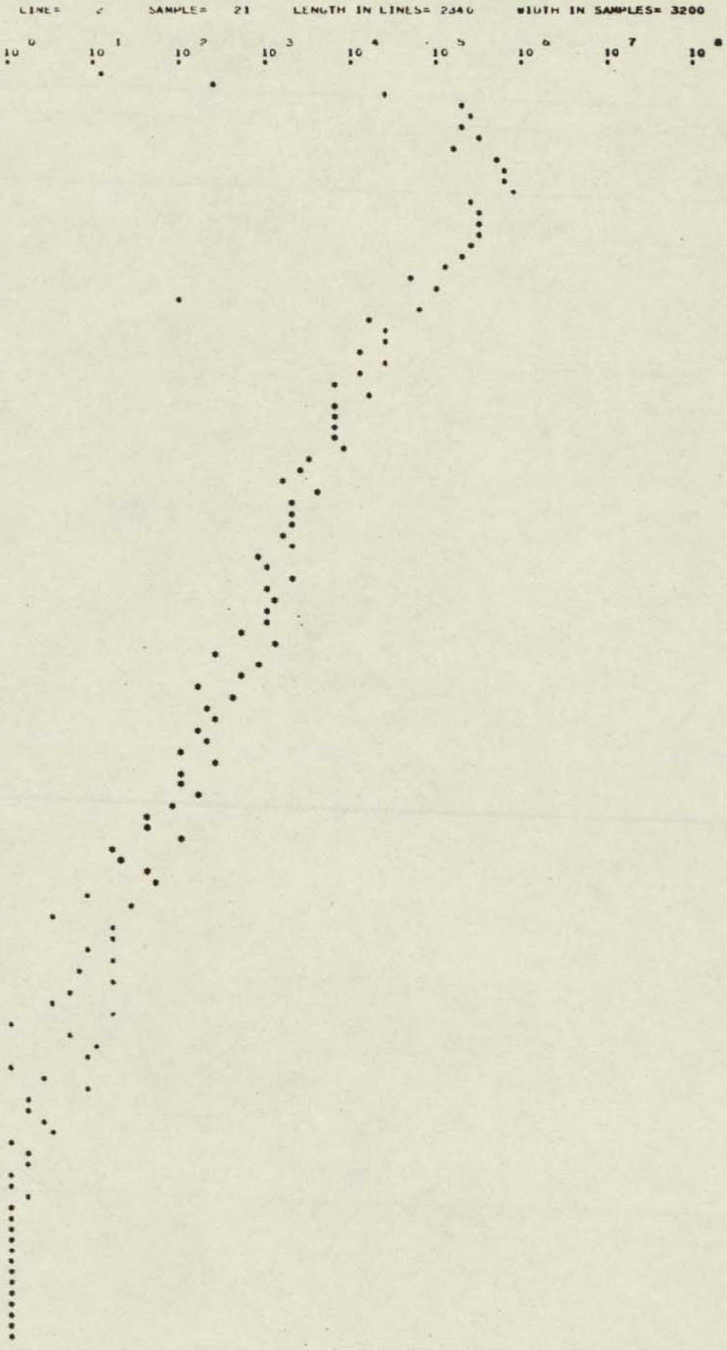

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Figure 2-1. Landsat-MSS Histograms (sheet 2 of 4)

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   25       13370       2607700        34.825      0.18
   26       16547       2624247        35.046      0.22
   27       14146       2638393        35.235      0.19
   28       23608       2662001        35.550      0.32
   29       13268       2675269        35.727      0.18
   30       25271       2700540        36.065      0.34
   31       10194       2710734        36.201      0.14
   32       35097       2745831        36.670      0.47
   33       18850       2764681        36.921      0.25
   34       38692       2803373        37.438      0.52
   35       13739       2817112        37.622      0.18
   36       33141       2850253        38.064      0.44
   37       47665       2897918        38.701      0.64
   38       35052       2932970        39.169      0.47
   39       47959       2980929        39.809      0.64
   40       67125       3048054        40.706      0.90
   41       34602       3082656        41.168      0.46
   42      115568       3198224        42.711      1.54
   43       78109       3276333        43.754      1.04
   44      123667       3400000        45.406      1.65
   45      105695       3505695        46.818      1.41
   46      202453       3708148        49.521      2.70
   47      186941       3895089        52.018      2.50
   48      187322       4082411        54.519      2.50
   49      348165       4430576        59.169      4.65
   50      122770       4553346        60.809      1.64
   51      382435       4935781        65.916      5.11
   52      272493       5208274        69.555      3.64
   53      133242       5341516        71.334      1.78
   54      472918       5814434        77.650      6.32
   55       49084       5863518        78.306      0.66
   56      315766       6179280        82.523      4.22
   57      159034       6338320        84.646      2.12
   58       89700       6428020        85.844      1.20
   59      193823       6621843        88.433      2.59
   60       98912       6720755        89.754      1.32
   61      112432       6833187        91.255      1.50
   62       88957       6922144        92.443      1.19
   63       18907       6941051        92.696      0.25
   64       91648       7032699        93.920      1.22
   65       72482       7105181        94.888      0.97
   66       42148       7147329        95.450      0.56
   67       44630       7191959        96.046      0.60
   68       54914       7246873        96.780      0.73
   69       29287       7276160        97.171      0.39
   70       67595       7343755        98.074      0.90
   71       12380       7356135        98.239      0.17
   72        4064       7360199        98.293      0.05
   73       52806       7413005        98.998      0.71
   74       15185       7428190        99.201      0.20
   75        7913       7436103        99.307      0.11
   76       20338       7456441        99.579      0.27
   77        8845       7465286        99.697      0.12
   78        4251       7469537        99.753      0.06
   79        6356       7475893        99.838      0.08
   80        6668       7482561        99.927      0.09
   81         770       7483331        99.938      0.01
   82         883       7484214        99.949      0.01
   83        1287       7485501        99.967      0.02
   84         994       7486495        99.980      0.01
   85         279       7486774        99.984      0.00
   86         270       7487044        99.987      0.00
   87         163       7487207        99.989      0.00
   88         108       7487315        99.991      0.00
   89          87       7487402        99.992      0.00
   90         133       7487535        99.994      0.00
   91          59       7487594        99.995      0.00
   92          10       7487604        99.995      0.00
   93          46       7487650        99.995      0.00
   94          70       7487720        99.996      0.00
   95          55       7487775        99.997      0.00
   96          20       7487795        99.997      0.00
   97          13       7487808        99.997      0.00
   98          17       7487825        99.998      0.00
   99          39       7487864        99.998      0.00
  100          12       7487876        99.998      0.00
  101          13       7487889        99.999      0.00
  102          21       7487910        99.999      0.00
  103          15       7487925        99.999      0.00
  104           2       7487927        99.999      0.00
  105          11       7487938        99.999      0.00
  106           7       7487945        99.999      0.00
  107          13       7487958        99.999      0.00
  108           7       7487965       100.000      0.00
  109           9       7487974       100.000      0.00
  110           3       7487977       100.000      0.00
  111           0       7487977       100.000      0.0
  112           1       7487978       100.000      0.00
  113           2       7487980       100.000      0.00
  114           1       7487981       100.000      0.00
  115           0       7487981       100.000      0.0
  116           3       7487984       100.000      0.00
  117           2       7487986       100.000      0.00
  118           0       7487986       100.000      0.0
  119           1       7487987       100.000      0.00
  120           1       7487988       100.000      0.00
  121           1       7487989       100.000      0.00
  122           1       7487990       100.000      0.00
  123           0       7487990       100.000      0.0
  124           0       7487990       100.000      0.0
  125           1       7487991       100.000      0.00
  126           4       7487995       100.000      0.00
  127           5       7488000       100.000      0.00

                         ALL LEADING AND TRAILING VALUES OF I WITH N(I)= 0 ARE OMITTED FROM THE GRAPH

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  RADIOMETRIC CONSTANTS TO GIVE MEAN =        140.0;  STANDARD DEVIATION =      21.0000
          GAIN=   1.00743
          BIAS= 101.65129
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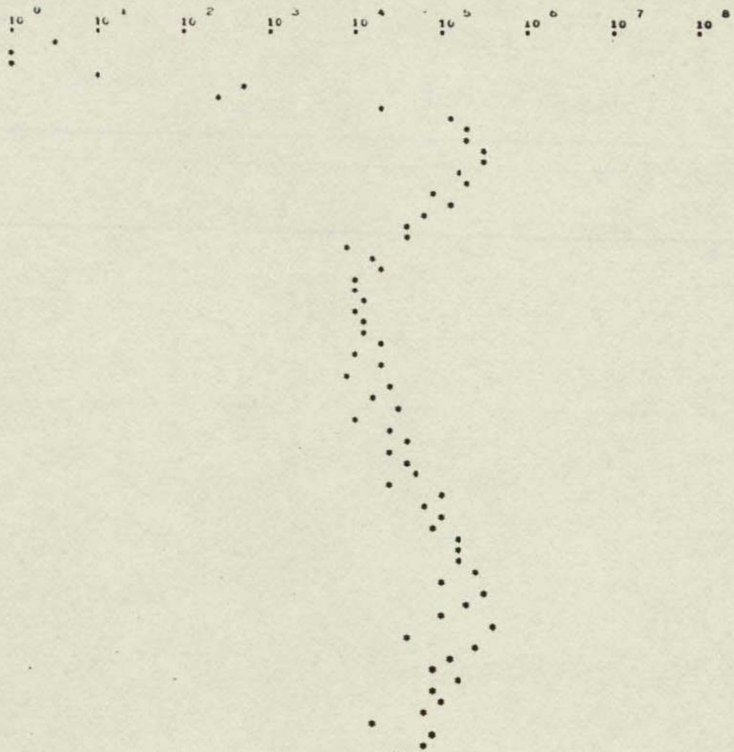
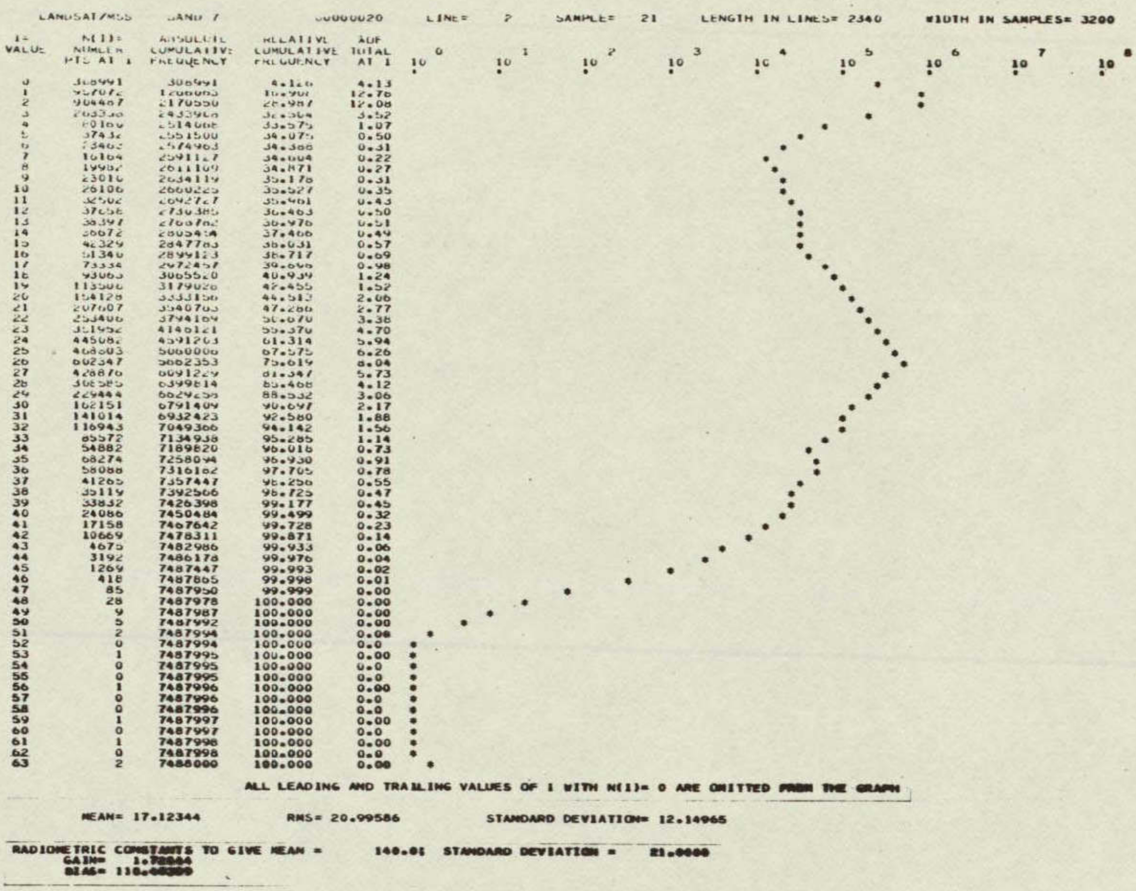


Figure 2-1. Landsat-MSS Histograms (sheet 3 of 4)



```
LANDSAT/MSS     BAND 7          00000020     LINE=    2    SAMPLE=   21     LENGTH IN LINES= 2340     WIDTH IN SAMPLES= 3200

 I=       N(I)=       ABSOLUTE      RELATIVE     %OF
VALUE     NUMBER     CUMULATIVE    CUMULATIVE   TOTAL     0         1         2         3         4         5         6         7         8
         PTS AT I    FREQUENCY     FREQUENCY    AT I   10        10        10        10        10        10        10        10        10

  0       308991       308991         4.126      4.13
  1       957072      1266063        16.908     12.78
  2       904487      2170550        28.987     12.08
  3       263336      2433886        32.504      3.52
  4        80182      2514068        33.575      1.07
  5        37432      2551500        34.075      0.50
  6        23463      2574963        34.388      0.31
  7        16164      2591127        34.604      0.22
  8        19982      2611109        34.871      0.27
  9        23010      2634119        35.178      0.31
 10        26106      2660225        35.527      0.35
 11        32502      2692727        35.961      0.43
 12        37658      2730385        36.463      0.50
 13        38397      2768782        36.976      0.51
 14        36672      2805454        37.466      0.49
 15        42329      2847783        38.031      0.57
 16        51340      2899123        38.717      0.69
 17        73334      2972457        39.696      0.98
 18        93063      3065520        40.939      1.24
 19       113500      3179020        42.455      1.52
 20       154136      3333156        44.513      2.06
 21       207607      3540763        47.286      2.77
 22       253406      3794169        50.670      3.38
 23       351952      4146121        55.370      4.70
 24       445082      4591203        61.314      5.94
 25       468803      5060006        67.575      6.26
 26       602347      5662353        75.619      8.04
 27       428876      6091229        81.347      5.73
 28       308585      6399814        85.468      4.12
 29       229444      6629258        88.532      3.06
 30       162151      6791409        90.697      2.17
 31       141014      6932423        92.580      1.88
 32       116943      7049366        94.142      1.56
 33        85572      7134938        95.285      1.14
 34        54882      7189820        96.018      0.73
 35        68274      7258094        96.930      0.91
 36        58088      7316182        97.705      0.78
 37        41265      7357447        98.256      0.55
 38        35119      7392566        98.725      0.47
 39        33832      7426398        99.177      0.45
 40        24086      7450484        99.499      0.32
 41        17158      7467642        99.728      0.23
 42        10669      7478311        99.871      0.14
 43         4675      7482986        99.933      0.06
 44         3192      7486178        99.976      0.04
 45         1269      7487447        99.993      0.02
 46          418      7487865        99.998      0.01
 47           85      7487950        99.999      0.00
 48           28      7487978       100.000      0.00
 49            9      7487987       100.000      0.00
 50            5      7487992       100.000      0.00
 51            2      7487994       100.000      0.00
 52            0      7487994       100.000      0.0
 53            1      7487995       100.000      0.00
 54            0      7487995       100.000      0.0
 55            0      7487995       100.000      0.0
 56            1      7487996       100.000      0.00
 57            0      7487996       100.000      0.0
 58            0      7487996       100.000      0.0
 59            1      7487997       100.000      0.00
 60            0      7487997       100.000      0.0
 61            1      7487998       100.000      0.00
 62            0      7487998       100.000      0.0
 63            2      7488000       100.000      0.00

                          ALL LEADING AND TRAILING VALUES OF I WITH N(I)= 0 ARE OMITTED FROM THE GRAPH

        MEAN= 17.12344            RMS= 20.99586            STANDARD DEVIATION= 12.14965

RADIOMETRIC CONSTANTS TO GIVE MEAN =      140.00  STANDARD DEVIATION =     21.0000
        GAIN=   1.72844
        BIAS= 110.40309
```

Figure 2-1. Landsat-MSS Histograms (sheet 4 of 4)

Several years ago, IBM produced a mosaic image of the State of New Jersey. The bottom scene (1079-15133) in that mosaic is of the same ground area as the Delaware scene. An attempt was made to correlate the control points from the older scene to the current scene. Six control points were located in this manner, using a digital correlation program. Several points in the older scene either were not found or had a correlation peak that was too small. The remaining control points were found manually.

The first step in manual control-point location was to select some potential control points. This was done by viewing the film image and locating features that were visible both on the image and on a map. Next, computer generated shadeprints were created for each potential control point. A shadeprint is a display of a subimage on a computer listing as a two-dimensional array of printed characters, on which gray levels are simulated by overstrike printing (see Figure 2-2). The shadeprints and maps were then manually compared to determine corresponding points in both pixel and map coordinates. Finally, the set of control-point locations was checked for errors by an iterative process of evaluating the geometric transformation (between corrected output space and uncorrected input space) derived from a given set of control points and mapping those control points through that transformation. Points at which the geometric errors were largest were rechecked for location errors, and the process was repeated for the refined set of points.

2.5 SCENE CORRECTION

Scene correction of Landsat-MSS data is the accurate geometric correction of the data to a UTM map projection. It involved two steps: determining the geometric transformation between the corrected and uncorrected images, and resampling (interpolating) the uncorrected data to the data samples in the corrected data set.

The geometric transformation used for the Delaware scene used fifth-degree least-squares polynomials according to algorithms and techniques[10] developed by IBM under contract NAS5-21716. Twenty-five well-distributed control points were used to generate the image error models. The error models were evaluated at a nine-by-nine array of points, and the polynomial models were obtained by fitting to these eighty-one points.

Cubic convolution[2,10] resampling incorporating a high-frequency correction technique was used to remove some horizontal geometric errors. Resampling was done at two different pixel lattices. First, the full frame was resampled to a horizontal and vertical pixel spacing of 50.8 meters. Second, two subimages (one of the Salisbury, MD area and one of the Cambridge, MD area) were resampled to a spacing of 25.4 meters. These particular spacings were chosen to give images of 1:500,000 and 1:250,000 scales when the data was plotted on the IBM Drum Scanner/Plotter with a nominal pixel spacing of .004 inches in both directions. The Salisbury SAR data was spaced at 25 meters, and this led to the selection of 25.4 meter spacing for the Landsat subimages.

Copies of all digital data sets that represent processed Landsat images were sent to NASA/WFC or to Purdue/LARS as requested by NASA.

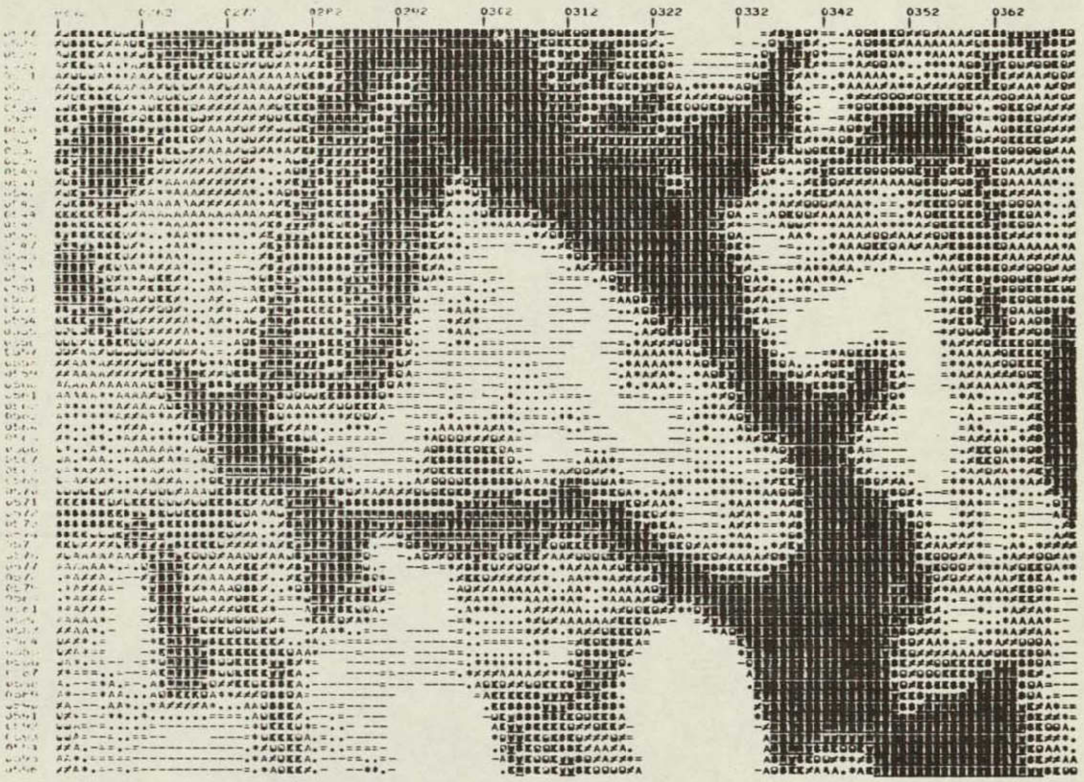


Figure 2-2. Example of Shadeprint

Section 3

SAR PROCESSING

3.1 SUMMARY OF SAR PROCESSING

Once the Landsat-MSS data was geometrically corrected to register with a UTM map, the SAR data was geometrically corrected to register with the corrected Landsat data. This included the creation of both digital and enhanced photographic images having the same geometry as the corrected Landsat images. The processing involved was organized into the following parts:

a. Preprocessing

b. Temporal Registration

c. Digital Filtering

d. Film Plotting and Photographic Processing.

Each of these is described below or in Section 4.

3.2 PREPROCESSING

Ten aircraft SAR data sets were provided at the beginning of this contract. There were two different pixel spacings of each of five ground areas. All preprocessing done on this data was for the purpose of generating film images. Histograms were created for each data set. That information was used to create radiometrically adjusted (i.e., contrast-stretched) data suitable for film plotting. That data was plotted on film, and various photographic products were created from the resulting negatives. These ten images were of very marginal quality. The data was extremely noisy, and landmarks were very difficult to distinguish. A SAR data set containing Salisbury, MD was selected to be the subject of further study.

A second SAR data set was obtained by scanning a black-and-white print of a SAR image of Cambridge, MD. The scanning was performed on the IBM Drum Scanner/Plotter. A nominally square aperture of size .004 inches was used. The pixel spacing was .004 inches in both the horizontal and the vertical directions. Although there was still some noise evident in the data, the quality of the image was considerably better than that of the Salisbury image. There were several lines in the image that appeared to be noise. They are believed to be a result of scratches in the negative used to produce the print from which the digital data was scanned.

The digital data produced by the scanning process was subjected to several preprocessing steps to prepare it for further study. Histogramming, contrast stretching, and film plotting were done as described above to verify the quality of the digital data.

3.3 TEMPORAL REGISTRATION

Temporal registration experiments were conducted with both the Salisbury and the Cambridge images. One version of temporally registered data for each of these data sets was created under IRAD funding. The Cambridge image was then subjected to further study and a second version of temporally registered data was created. The techniques used to register the SAR data were identical in each case and are described below.

3.3.1 Processing Steps for Temporal Registration of SAR Image Data

The first step was to select potential registration control points (RCPs) in both the corrected Landsat data and the uncorrected SAR data. This was done by viewing pictures made from each data set and locating features that were visible in both pictures. For the Salisbury image, this was very difficult to do. The high noise content of the SAR data resulted in few good features being visible. Selecting potential control points was much easier for the Cambridge image, since the noise content was much lower. However, there were still some regions of the image in which control points could not be found.

The second step was to generate shadeprints (i.e., display of the subimage with a computer line printer as a two dimensional array of printed characters, on which gray levels are simulated by overstrike printing) for both the uncorrected SAR and the corrected Landsat-MSS data. One shadeprint was generated for each potential control point in each of three data sets: SAR, MSS band 2, and MSS band 4. Some features visible in one MSS spectral band were not visible in another band. Bands 2 and 4 were used because they are frequently the most useful bands for control-point location.

The third step was to manually determine control-point locations (i.e., corresponding pixel coordinates in each image space) by viewing the shadeprints. This was very difficult for the Salisbury image. The noise content rendered most of the SAR shadeprints useless. For the Cambridge image, this problem was not as severe. Consequently, many more control points were located in the Cambridge image.

The fourth step can be called refinement of control-point locations. It involved checking the control-point locations for errors. This was done by obtaining the geometric transformation resulting from a set of control points, evaluating the geometric transformation at the control-point locations (in corrected Landsat-MSS space), and computing the differences between the observed and computed values of the control points (in uncorrected SAR space). These differences, or residual errors, were then studied to see if any errors in control-point location could be discovered. (Frequently the residual error for a mislocated point is larger than that of the correctly located points.) The process was iterated until a reasonable set of control points was obtained.

For Salisbury, a total of 14 control points were used. For Cambridge, a total of 73 control points were used. In this particular example, many of these control points were clustered in sets of two or three similar locations. The important factor seems to be the distribution of the control points. Wherever there was a relatively large region of the SAR image in which there were no control points, registration accuracy observed in the photographic images seemed to be lower. This was evident in the Salisbury image and in the first two processed versions of the Cambridge image.

The fifth step was the calculation of the coefficients of the geometric transformation that were used to correct the SAR data. Least-squares polynomials in two variables of degree five were used. Each point (y,x) in corrected Landsat-MSS space was mapped to the point (v,u) in uncorrected SAR space. Here $v = H(y,x)$ and $u = V(y,x)$, where H and V were fifth-degree polynomials. Each polynomial contained 21 terms and the sum of the exponents in any term was less than or equal to five. (See Section 3.3.2 for a description of the least-squares algorithm.)

The sixth, and final step was the resampling of the SAR image data. Cubic convolution[2,10] resampling was used.

3.3.2 Description of Least-Squares Fitting Algorithm

A direct polynomial fit to the registration control points was used to define the transformation between corrected Landsat space and uncorrected SAR space. This process involved the following steps:

a. Locating a set of RCPs in both the corrected Landsat data and the uncorrected SAR data, as discussed above.

b. Selecting an appropriate polynomial form to use as a geometric transformation.

c. Determining the coefficients of the polynomials by a least-squares fit.

The resulting polynomials were used by the resampling program to create a corrected SAR image.

It can be very difficult to locate RCPs in the SAR data. The high noise content in the Salisbury, MD image (see EVALUATION OF TECHNICAL RESULTS section below) made precise location of RCPs impossible for that image. The Cambridge, MD image had much lower noise content, and RCP location was much easier. The nature of SAR data itself contributes to the RCP location problem. The radiometry of a feature in an SAR image is usually totally different to that of the same feature in a Landsat image. In addition, shadowing or apparent widening of edges is present in SAR data, but not in Landsat data.

A manual technique for RCP location was used by IBM in its experiments with the Salisbury and Cambridge SAR data sets. Potential RCPs were displayed using a computer printout in which overstrikes are used to simulate gray levels. (These are called shadeprints.) RCPs were located by visually comparing Landsat and SAR shadeprints.

To discuss the least-squares technique used to obtain the polynomials that mapped corrected Landsat space into uncorrected SAR space, let

(y_i, x_i) = horizontal and vertical pixel coordinates of i^{th} RCP in corrected Landsat space.

(v_i, u_i) = horizontal and vertical pixel coordinates of i^{th} RCP in uncorrected SAR space.

$$T = \begin{bmatrix} v_1 & u_1 \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ v_n & u_n \end{bmatrix}$$

$$W = \begin{bmatrix} f_1(y_1,x_1) & \ldots & f_{21}(y_1,x_1) \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ f_1(y_n,x_1) & \ldots & f_{21}(y_n,x_n) \end{bmatrix}$$

$$R = \begin{bmatrix} H_1 & V_1 \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ H_{21} & V_{21} \end{bmatrix}$$

The columns of R will represent the coefficients of two polynomials. That is,

$$\begin{aligned}
H(y,x) = {} & H_1 + H_2x + H_3x^2 + H_yx^3 + H_5x^4 + H_6x^5 + \\
& H_7y + H_8yx + H_9yx^2 + H_{10}yx^3 + H_{11}yx^4 + \\
& H_{12}y^2 + H_{13}y^2x + H_{14}y^2x^2 + H_{15}y^2x^3 + \\
& H_{16}y^3 + H_{17}y^3x + H_{18}y^3x^2 + \\
& H_{19}y^4 + H_{20}y^4x + \\
& H_{21}y^5 \\
= {} & \sum_{i=1}^{21} H_i \, f_i(y,x)
\end{aligned}$$

$$V(y,x) = \sum_{i=1}^{21} V_i \, f_i(y,x)$$

The polynomials H and V approximate the mapping

$$(y_i,x_i) \longmapsto (v_i,u_i) \quad \text{for } i=1,2,\ldots,n$$

in the least square sense. That is,

$$\left.\begin{array}{l} H(y_i,x_i) \approx v_i \\ \\ V(y_i,x_i) \approx u_i \end{array}\right\} \text{for } i=1,2,\ldots,n$$

The coefficients of H and V are found by solving the matrix equation T = W R for R. The solution is

$$R = (W^T W)^{-1} W^T T \tag{1}$$

The equations given above are for full, fifth-degree, bivariate polynomials. This is the form selected to correct the Cambridge image. For the Salisbury image, only 12 RCPs were found. Full, third-degree, bivariate polynomials were used for that image.

In each case, the form of the polynomials was determined empirically. Several polynomials were found by performing the least-squares fit, and the resulting residual errors were computed. The ideal situation in doing a direct fit to RCPs is to have a highly overdetermined system (equation 1) and to have very low residual errors. This would indicate that the polynomials were good models of the geometric distortions. This did not happen for the two images in question. For the Salisbury image, the small number of RCPs led to a system that was only slightly overdetermined. Polynomials of degree less than that used led to unacceptably high residual errors. The Cambridge image had enough RCPs located to give a very overdetermined system, and the corresponding residual errors were acceptably small.

Full bivariate polynomials of degrees three, four, five, six, and seven were considered for the processing of the Cambridge SAR image. Those of degree five appeared to fit the control points best, especially near the edges of the SAR image data. The results of the least-squares fitting, using the final set of 73 control points, are shown in Section 5.

Section 4

IMAGE PROCESSING

Some of the processing performed on image data under this contract was identical for both SAR and Landsat data. These standard image-processing techniques include:

a. Enhancement

b. Film Plotting and Photographic Processing

c. Resampling Methods

which are discussed below.

4.1 ENHANCEMENT

It is possible to modify Landsat digital data in such a way as to enhance certain aspects of the image. Two such aspects are contrast and edge definition. The purpose of both types of enhancement is to make certain features more visible in a photographic rendition of an image. An enhanced image ususally represents a less accurate reconstruction of the true data than the original Landsat digital radiometric data. However, enhanced images generally appear to be more pleasing to view and to contain more information.

4.1.1 Contrast Enhancement

The usual purpose of contrast enhancement is to enable an image display device (such as a film plotter, a CRT display, or a computer line printer) to utilize its full dynamic range capability. Consider a 256-level plotter being used with 64-level Landsat-MSS data. Unless some contrast stretching is done to the data, the resulting image will be too dark (since only the lowest fourth of the dynamic range of the plotter is being used). Another use for contrast enhancement is to bring out the information in a particular region in an image.

A standard method of stretching the contrast of a digital image is to apply a first-degree polynomial function to the image data. That is, let

$$C(i,j) = g\ I(i,j) + b$$

where

$I(i,j)$ = intensity value of i^{th} sample in j^{th} line in the input data

g = gain coefficient.

b = bias coefficient.

$C(i,j)$ = intensity value of i^{th} sample in j^{th} line in the contrast-stretched data.

It is assumed that the values $C(i,j)$ have been clipped to fit the dynamic range of the display device.

The gain and bias coefficients can be determined through a very simple statistical technique:

$$g = {}^{S}/_{s}$$

$$b = M - g\,m$$

where

m = mean of the subimage of input data that is of interest.

s = standard deviation of the subimage of input data.

M = desired mean of the subimage of output data.

S = desired standard deviation of the subimage of output data.

The values of the statistical parameters of the subimage of output data are determined empirically. However, reasonable values may be estimated by letting M be the midpoint of the effective dynamic range of the image display device and by letting S be one sixth the length of the effective dynamic range of the device.

For example, consider a plotter that accepts pixel values in the range 0,1,...,255 and that plots the same gray level for all values in the range 0,1,...,55. In the range 56,57,...,255 assume that the response (gray level versus pixel value) is approximately linear. The effective dynamic range of this hyopthetical plotter is 56,57,...,255. Then M=155 and S=33 should be reasonable values to obtain a good plot with this plotter. Experience would enable these values to be refined.

4.1.2 Digital Filtering for Edge Enhancement

Edge enhancement is an artificial sharpening of the features of a digital image. It is often used to accentuate boundaries of features or to bring out linear features of an image. Pictures of edge enhanced images are generally more appealing than those of unenhanced images (although this is very subjective).

Digital edge enhancement can be performed by a digital filter (discrete convolution) function of the form

$$E(i,j) = \sum_{m=1}^{3} \sum_{n=1}^{3} I(i+m-2,j+n-2)\ F(m,n)$$

where

$I(i,j)$ = intensity value of i^{th} sample in j^{th} line in the input data

$F(*,*)$ = 3 x 3 matrix of filter weights

$E(i,j)$ = intensity value of i^{th} sample in j^{th} line in the edge-enhanced data.

The particular algorithm depends only on the matrix of filter weights

To perform edge enhancement, the filter matrix F must define some kind of high-pass filter. Four examples of Laplacian-type, high-pass filters are:

$$F_1 = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix} \qquad F_2 = \begin{bmatrix} -1 & -2 & -1 \\ -2 & 13 & -2 \\ -1 & -2 & -1 \end{bmatrix}$$

$$F_3 = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix} \qquad F_4 = \begin{bmatrix} 1 & -2 & 1 \\ -2 & 5 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

Each of these examples has the property that the sum of the weights is one. This results in an image that is the sum or the original image plus a Laplacian-filtered image. Therefore, the resulting radiometry of an edge-enhanced image will be somewhat comparable (statistically) to that of the original image.

4.1.3 Enhancement Processing

The Salisbury subimage, corrected to 25.4-meter pixel spacing, was digitally filtered for edge enhancement in two ways. First, a Laplacian filter was used on the data and the result added to the image data. Numerically, this amounted to multiplying a given pixel value by five and subtracting each of its four (horizontal and vertical) neighboring pixel values (filter F_1 above). The resulting image contained enhanced edges and also contained the intensity distribution of the original data.

The second method involved using a Laplacian filter on the data and adding a constant to the result. This amounted to multiplying a given pixel value by four and subtracting each of its four neighboring pixel values. The resulting image contained only edge information.

In addition, contrast enhancement (as described in Section 4.1.1) was performed on all Landsat and SAR images that were created under this contract. The purpose of this processing was to obtain digital data that was compatible with and well-suited to the film plotting device that was used to make photographic negatives.

4.2 FILM PLOTTING AND PHOTOGRAPHIC PROCESSING

Digital images were converted to film negatives on the IBM Drum Scanner/Plotter[1]. From these negatives, two basic photographic products were made: black-and-white contact prints, and false-color contact prints. The false-color prints used MSS spectral bands 1, 2, and 4 to give yellow, magenta, and cyan colors on the prints.

Copies of all photographic products have been delivered to Dr. Harold Maurer (NASA/WFC). Some pictures were also sent to Paul Anuta (Purdue/LARS) for his use in a related effort.

In addition, 35 mm slides and other transparencies were prepared and sent to Dr. Harold Maurer as requested.

4.3 RESAMPLING METHODS

One of the requirements normally imposed upon image processing when the image is in digital form is that the output pixel lattice be regular, or equispaced, in the output space. This is needed for two reasons: compact data storage, and the limitations of many film recorders. If the output pixel lattice is not regular, then additional information must be carried to specify pixel location. The last requirement precludes the simple repositioning of the original image pixels. The only way to change geometry and specify the target pixel location, too, is to "resample" the orignal image. Resampling here consists of calculating the location of a particular target pixel in the original image and interpolating over the surrounding original pixels to determine the output intensity. During processing, the target pixels are considered output and the original pixels are considered input. Figure 4-1 shows the relationship between input and output pixels.

In the following discussion, the calculation of the output pixel location in the input image is presumed.

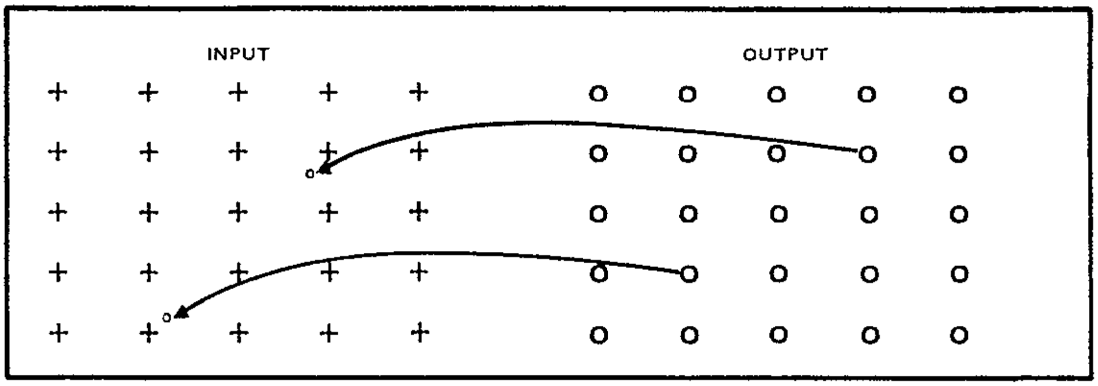


Figure 4-1. Locating Output Points in Input Space

Cubic convolution is a family of resamplers that approximate the SINC, or SINE (x)/x function. The SINC function is the theoretical perfect resampler, but it requires an infinite number of terms. Cubic convolution substitutes a truncated piecewise cubic approximation to the SINC function, so that the amount of processing is feasible for large image data sets. Cubic convolution is a one-dimensional process that must be repeated to provide for two-dimensional resampling. This is illustrated in Figure 4-2, where four horizontal resamplings provide the values for a final vertical resampling. The final vertical resampling then provides the output intensity. This is for a so-called four-point resampler.

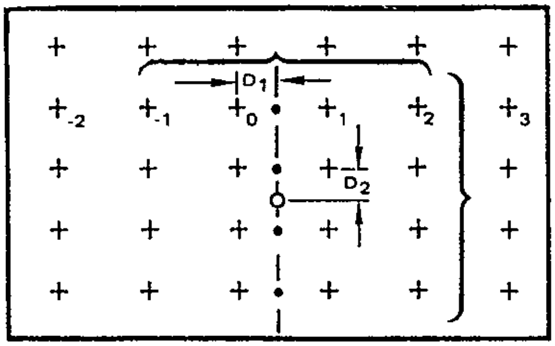


Figure 4-2. Two-Way Cubic Convolution Resampling

The equation of the classic four-point cubic-convolution resampling algorithm used for this contract is

$$I_{OUT} = D\{D[D(-I_{-1}+I_0-I_1+I_2) + (2I_{-1}-2I_0+I_1-I_2)] + (I_1-I_{-1})\} + I_0 \qquad (2)$$

An experimental program that evaluates this equation five times for each output pixel and that uses 32-bit floating point arithemetic was used to resample both Landsat and SAR data.

For SAR data, each of the four one-dimensional horizontal resamplings used the same value for D in Equation 1. That is, $D = D_1$ as in Figure 4-2. For Landsat-MSS data, each one-dimensional resampling used a distinct value for D. This is due to the use of the resampling program to remove high-frequency geometric errors that occur in the horizontal direction in MSS data.

Section 5

TECHNICAL EVALUATIONS

In this section, the evaluations of the geometry of the corrected Landsat-MSS image and the corrected Salisbury SAR image, and the final version of the corrected Cambridge SAR image are described.

5.1 LANDSAT PROCESSING EVALUATION

Under contract NAS6-2827, IBM processed Landsat-2 MSS scene number 2579-14535. The processing performed was scene correction. That is, the image was geometrically corrected to a Universal Transverse Mercator (UTM) map projection using geodetic control points to model scene dependent errors (attitude and altitude). Digital data at two scales was produced. First, the entire scene was processed, resulting in an image with pixels at a spacing of 50.8 meters in both the horizontal and the vertical directions. Second, two subimages of the scene were processed with pixels spaced at 25.4 meters in both directions.

The geometric accuracy of the corrected Landsat images was evaluated by checking the errors at the locations of the geodetic control points (GCPs) that were used to correct the image. For each GCP, a nominal input-space location was found by the following transformations:

a. Mapping the UTM coordinates into output-space pixel coordinates using the elementary rotation, translation, and scale-change transformation which exists between the two coordinate systems

b. Mapping the output-space coordinates into input-space pixel coordinates using the mapping polynomials that define the geometric transformation for the scene.

These nominal input-space locations were compared with the corresponding observed input-space locations that were found manually from the input data. The resulting errors in meters were found. The RMS of these errors, as shown in Table 5-1, was 77.3 meters.

The corrected digital data was recorded on film. The resulting photographic image products were of good quality.

5.2 SAR IMAGE PROCESSING EVALUATION

5.2.1 Salisbury SAR Image

A subset of the SAR image containing Salisbury, MD was chosen to be temporally registered to the corrected Landsat data from MSS scene 2579-14535. This SAR data had very high noise content which hindered the finding of registration control-point (RCP) locations. Due to the sparsity of suitable visible features in the SAR data, only 14 RCPs were located.

Table 5-1. Results of Accuracy Check for Landsat Data

	Measured UTM Map Coordinates			Observed Input-Space Coordinates		Nominal Input-Space Coordinates		Input-Space Differences In Pixels		Radial Error In Meters
GCP	NORTHING	EASTING	ZONE	YOBS	XOBS	YNOM	XNOM	DELY	DELX	RSSM
1	4368380	399200	18	361.00	729.00	359.69	730.32	1.3081	-1.3200	128.517
2	4319160	370820	18	91.00	1402.00	90.57	1402.00	0.4348	-0.0004	24.843
3	4264533	450858	18	1618.00	1623.00	1618.81	1622.84	-0.8133	0.1637	48.244
4	4281320	465530	18	1883.00	1625.00	1883.10	1625.06	-0.0990	-0.0551	7.145
5	4265817	477486	18	2155.00	1784.00	2156.48	1784.25	-1.4757	-0.2456	86.537
6	4269440	407370	18	945.00	1915.00	944.69	1917.11	0.3063	-2.1149	168.413
7	4249185	379330	18	554.00	2236.00	554.46	2236.31	-0.4646	-0.3072	36.014
8	4235348	419500	18	1303.00	2304.00	1303.69	2303.83	-0.6935	0.1690	41.826
9	4238490	420600	18	1308.00	2262.00	1308.49	2262.53	-0.4887	-0.5264	50.181
10	4243210	370290	18	425.00	2333.00	425.45	2332.68	-0.4459	0.3172	35.783
11	4241985	375720	18	524.00	2333.00	524.59	2333.89	-0.5905	-0.8859	77.853
12	4390075	399120	18	261.00	465.00	260.61	465.84	0.3899	-0.8435	70.425
13	4382940	408410	18	454.00	529.00	453.25	529.51	0.7472	-0.5134	58.959
14	4377045	413810	18	573.00	586.00	572.66	587.82	-0.3373	-1.8218	145.569
15	4350880	387920	18	244.00	971.00	243.51	972.12	0.4946	-1.1209	93.167
16	4378540	449910	18	1185.00	478.00	1183.88	478.70	1.1172	-0.6984	84.470
17	4381505	451450	18	1196.00	438.00	1197.01	438.67	-1.0054	-0.6745	78.452
18	4372495	453540	18	1273.00	543.00	1272.57	543.26	0.4295	-0.2598	32.022
19	4367605	453665	18	1298.00	599.00	1298.92	599.61	-0.9172	-0.6115	71.356
20	4379950	425480	18	760.00	523.00	760.06	522.99	-0.0573	0.0066	3.314
21	4373880	422460	18	736.00	604.00	735.36	604.63	0.6420	-0.6303	61.952
22	4357310	493810	18	2026.00	626.00	2025.99	626.98	0.0140	-0.9799	77.609
23	4319340	516745	18	2589.00	1031.00	2588.68	1031.95	0.3244	-0.9549	77.866
24	4317620	511740	18	2510.00	1067.00	2510.85	1066.76	-0.8480	0.2375	51.979
25	4273070	494460	18	2414.00	1652.00	2414.46	1652.81	-0.4622	-0.8053	69.032
					MEAN OF EACH COLUMN:			-0.0726	-0.5790	67.261
					RMS OF RSSM:					77.301

Full, bivariate, cubic, least-squares polynomials were used to define the transformation between corrected and uncorrected SAR data. The RSS residual errors (in pixels) of the least-squares fit at the RCP locations are shown in Table 5-2. These results seem reasonable.

The resulting image that was produced using the least-squares fit summarized in Table 5-2 had reasonable registration at the 14 RCP locations. However, some severe misregistration is evident at locations between the RCPs For example, US Route 50 east of Salisbury is clearly visible in both the SAR and the Landsat data. In the corrected SAR image, that road is displaced to the north of its proper location. RCPs above (lake) and below (airport) the misregistered road are properly registered.

The conclusion that can be drawn is that the distortions in the SAR data are too severe to be modeled by cubic polynomials. Since the maximum number of terms in a least-squares polynomial is directly related to the number of points being fitted, it would be difficult to obtain significant improvement in the correction accuracy of the Salisbury SAR image.

5.2.2 Cambridge SAR Image

Exactly the same procedure as was used on the Salisbury image was used on the Cambridge image. However, 73 control points and fifth-degree polynomials were used for the least-squares fitting process. The results from the least-squares fit are shown in Table 5-3. The mean RSS error of about 5 pixels is quite acceptable, since the pixels in the Cambridge image are much smaller (about 10 meters) than were those in the Salisbury image.

A visual check of false-color composite photographic images of this SAR image merged with corrected Landsat-MSS data indicated that the SAR data were suitably registered to the Landsat data. The visual check is evidently necessary. The first two attempts at correcting the Cambridge SAR image used some incorrectly located control points, but a similar mean RSS error of about 5 pixels at the control-point locations was attained in each case. Each of these first two versions was easily found to be misregistered by visual inspection of false-color composite pictures.

It can also be seen from the photographic products that the SAR data added information that was not present in the Landsat data. For example, highly detailed information in the Cambridge urban area was present in the SAR data, but not in the Landsat data.

Table 5-2. Results of Accuracy Check for Salisbury SAR Data

Observed Output-Space Coordinates		Observed Input-Space Coordinates		Mapped Input-Space Coordinates		Input-Space Differences In Pixels		Radial Error in Pixels
Y(I)	X(I)	YP(I)	XP(I)	YEVAL	XEVAL	DY	DX	RSS
1037.0000	1359.0000	393.0000	2058.0000	393.0143	2058.0349	-0.0143	-0.0349	0.0377
1163.0000	1847.0000	663.0000	2488.0000	662.3030	2486.4555	0.6970	1.5445	1.6945
870.0000	1853.0000	367.0000	2570.0000	366.6809	2569.6435	0.3191	0.3565	0.4785
775.0000	2068.0000	326.0000	2804.0000	327.0820	2804.3825	-1.0820	-0.3825	1.1476
1105.0000	2170.0000	685.0000	2812.0000	685.0728	2811.0775	-0.0728	0.9225	0.9254
655.0000	2203.0000	244.0000	2976.0000	243.3904	2976.2905	0.6096	-0.2905	0.6752
583.0000	2446.0000	240.0000	3265.0000	240.1656	3264.9272	-0.1656	0.0728	0.1809
653.0000	2607.0000	358.0000	3402.0000	357.9502	3402.0932	0.0498	-0.0932	0.1057
1153.0000	1861.0000	655.0000	2502.0000	655.8181	2503.6869	-0.8181	-1.6869	1.8748
1101.0000	2197.0000	685.0000	2925.0000	684.6824	2925.9988	0.3176	-0.9988	1.0385
998.0000	2150.0000	562.0000	2830.0000	562.1898	2830.0688	-0.1898	-0.0688	0.2019
917.0000	2182.0000	501.0000	2879.0000	498.9147	2879.7736	2.0853	-0.7736	2.2312
954.0000	2213.0000	542.0000	2899.0000	543.6066	2898.0484	-1.6066	0.9516	1.8673
687.0000	2246.0000	286.0000	3011.0000	286.1294	3010.5073	-0.1294	0.4927	0.5094
				MEAN_OF_EACH_COLUMN		-0.0000	0.0001	0.9263

Table 5-3. Results of Accuracy Check for Final Cambridge SAR Data

```
LEAST-SQUARES FIT EVALUATION BY SURROUTINE LS22EV:

  RESULTS OF LEAST SQUARES FIT:                                                                                          Radial
          Observed                          Observed                           Mapped                    Input-Space Differences        Errors       I
   Output-Space Coordinates         Input-Space Coordinates          Input-Space Coordinates                 in Pixels               in Pixels
   300.0000       246.0000         254.0000        132.0000         257.5887       131.2214         -3.5887         0.7786          3.6722        1
   339.0000       261.0000         358.0000        146.0000         360.8242       147.9109         -2.8242        -1.9109          3.4100        2
   235.0000       290.0000         114.0000        293.0000         119.2300       292.2046         -5.2300         0.7954          5.2902        3
   856.0000       369.0000        1696.0000        150.0000        1690.9051       148.7788          5.0949         1.2212          5.2392        4
   871.0000       509.0000        1795.0000        523.0000        1795.5433       516.7302         -0.5433         6.2698          6.2933        5
   608.0000       654.0000        1229.0000       1083.0000        1229.9474      1085.1252         -0.9474        -2.1252          2.3268        6
   284.0000       809.0000         534.0000       1713.0000         533.8438      1715.6005          0.1562        -2.6005          2.6052        7
   560.0000       901.0000        1254.0000       1798.0000        1251.0308      1805.0605          2.9692        -7.0605          7.6594        8
   483.0000       899.0000        1062.0000       1846.0000        1061.5174      1843.5278          0.4826         2.4722          2.5189        9
   734.0000      1110.0000        1797.0000       2280.0000        1796.1665      2280.5016          0.8335        -0.5016          0.9728       10
   759.0000       975.0000        1779.0000       1892.0000        1780.1392      1891.3306         -1.1392         0.6694          1.3213       11
   359.0000       236.0000         408.0000         68.0000         397.4642        66.8744         10.5358         1.1256         10.5957       12
   486.0000       263.0000         717.0000         70.0000         719.0023        63.7837         -2.0023         6.2163          6.5308       13
   531.0000       270.0000         830.0000         54.0000         830.5994        55.8656         -0.5994        -1.8656          1.9595       14
   575.0000       316.0000         957.0000        156.0000         961.8519       158.9751         -4.8519        -2.9751          5.6914       15
   633.0000       345.0000        1120.0000        203.0000        1118.3321       205.6423          1.6679        -2.6423          3.1247       16
   701.0000       319.0000        1271.0000         97.0000        1269.6223        91.6778          1.3777         5.3222          5.4976       17
   293.0000       364.0000         302.0000        460.0000         302.3310       460.6248         -0.3310        -0.6248          0.7070       18
   339.0000       375.0000         420.0000        461.0000         422.6584       463.9647         -2.6584        -2.9647          3.9820       19
   387.0000       445.0000         579.0000        632.0000         580.5310       631.9028         -1.5310         0.0972          1.5341       20
   832.0000       424.0000        1659.0000        309.0000        1657.3208       309.9711          1.6792        -0.9711          1.9398       21
   853.0000       481.0000        1731.0000        448.0000        1738.2924       452.1903         -7.2924        -4.1903          8.4105       22
   653.0000       434.0000        1222.0000        444.0000        1217.9625       442.6389          4.0375         1.3611          4.2608       23
   538.0000       450.0000         951.0000        562.0000         948.8824       556.6725          2.1176         5.3275          5.7329       24
   606.0000       544.0000        1164.0000        779.0000        1165.1026       778.2956         -1.1026         0.7044          1.3084       25
   384.0000       527.0000         621.0000        866.0000         619.2737       864.2419          1.7263         1.7581          2.4640       26
   177.0000       509.0000         102.0000        946.0000          97.2767       939.5709          4.7233         6.4291          7.9776       27
   162.0000       547.0000          80.0000       1051.0000          82.3850      1056.2534         -2.3850        -5.2534          5.7695       28
   352.0000       614.0000         593.0000       1128.0000         589.6485      1128.4620          3.3515        -0.4620          3.3832       29
   457.0000       618.0000         847.0000       1073.0000         845.5150      1075.8355          1.4850        -2.8355          3.2008       30
   623.0000       685.0000        1281.0000       1165.0000        1283.5201      1162.8799         -2.5201         2.1201          3.2933       31
   138.0000       625.0000          61.0000       1283.0000          68.7962      1290.5445         -7.7962        -7.5445         10.8489       32
   153.0000       717.0000         154.0000       1541.0000         160.0308      1539.1999         -6.0308         1.8001          6.2937       33
   363.0000       755.0000         691.0000       1513.0000         693.6051      1516.1993         -2.6051        -3.1993          4.1258       34
   346.0000       854.0000         714.0000       1809.0000         707.6408      1801.5317          6.3592         7.4683          9.8090       35
   250.0000       781.0000         431.0000       1660.0000         435.6761      1659.0509         -4.6761         0.9491          4.7715       36
   115.0000       828.0000         131.0000       1861.0000         130.3736      1866.8811          0.6264        -5.8811          5.9144       37
   782.0000       991.0000        1842.0000       1920.0000        1840.8372      1919.2020          1.1628         0.7980          1.4103       38
   716.0000      1011.0000        1701.0000       2016.0000        1700.3201      2020.3301          0.6799        -4.3301          4.3832       39
   538.0000       987.0000        1251.0000       2059.0000        1246.6647      2056.3888          4.3353         2.6112          5.0610       40
    93.0000      1039.0000         185.0000       2480.0000         190.8386      2472.9708         -5.8386         7.0292          9.1378       41
   337.0000      1015.0000         777.0000       2250.0000         775.4284      2256.2954          1.5716        -6.2954          6.4886       42
   581.0000      1096.0000        1410.0000       2334.0000        1415.0974      2335.2392         -5.0974        -1.2392          5.2459       43
   645.0000      1112.0000        1581.0000       2341.0000        1583.4768      2342.4251         -2.4768        -1.4251          2.8575       44
   644.0000      1147.0000        1601.0000       2439.0000        1598.2350      2439.4632          2.7650        -0.4632          2.8035       45
   742.0000      1116.0000        1817.0000       2292.0000        1817.2169      2291.1661         -0.2169         0.8339          0.8616       46
   181.0000       459.0000          82.0000        800.0000          78.1625       795.8773          3.8375         4.1227          5.6323       47
   423.0000       299.0000         588.0000        200.0000         586.4248       202.5256          1.5752        -2.5256          2.9766       48
   450.0000       361.0000         683.0000        359.0000         686.5083       359.7038         -3.5083        -0.7038          3.5782       49
   224.0000       543.0000         732.0000       1010.0000         733.9790      1006.7988         -1.9790         3.2012          3.7635       50
   793.0000       337.0000        1501.0000         86.0000        1511.4117        91.1485        -10.4117        -5.1485         11.6151       51
   758.0000       458.0000        1493.0000        444.0000        1490.0465       445.5479          2.9535        -1.5478          3.3345       52
   878.0000       636.0000        1864.0000        845.0000        1868.9024       853.7769         -4.9024        -8.7769         10.0532       53
   271.0000       968.0000         583.0000       2171.0000         592.3213      2166.5158         -9.3213         4.4842         10.3438       54
   170.0000       837.0000         274.0000       1862.0000         272.3522      1862.5066          1.6478        -0.5066          1.7239       55
   170.0000       841.0000         282.0000       1870.0000         274.6802      1873.5924          7.3198        -3.5924          8.1538       56
   117.0000       819.0000         133.0000       1851.0000         130.1549      1841.0735          2.8451         9.9265         10.3261       57
   255.0000       783.0000         451.0000       1660.0000         448.9608      1661.5024          2.0392        -1.5024          2.5329       58
   125.0000       626.0000          38.0000       1298.0000          37.2706      1300.9089          0.7294        -2.9089          2.9989       59
   694.0000       312.0000        1253.0000         76.0000        1248.3004        75.9457          4.6996         0.0543          4.6999       60
   220.0000       293.0000          86.0000        308.0000          84.0232       310.0602          1.9768        -2.0602          2.8552       61
   379.0000       443.0000         560.0000        629.0000         559.8094       631.0028          0.1906        -2.0028          2.0119       62
   879.0000       514.0000        1824.0000        531.0000        1817.1143       525.3256          6.8857         5.6744          8.9225       63
   166.0000       578.0000          94.0000       1030.0000          87.0087      1028.3595          6.9913         1.6405          7.1812       64
   143.0000       708.0000         127.0000       1523.0000         129.9369      1519.8341         -2.9369         3.1659          4.3184       65
   618.0000       743.0000        1299.0000       1329.0000        1303.4091      1328.8923         -4.4091       — 0.1077          4.4104       66
   745.0000       833.0000        1670.0000       1506.0000        1664.7515      1501.6169          5.2485         4.3831          6.8380       67
   768.0000       912.0000        1769.0000       1713.0000        1764.4490      1708.3789          4.5510         4.6211          6.4858       68
   726.0000      1020.0000        1723.0000       2038.0000        1729.2489      2038.8225         -6.2489        -0.8225          6.3028       69
   572.0000       889.0000        1270.0000       1760.0000        1273.6395      1764.8179         -3.6395        -4.8179          6.0381       70
   487.0000       897.0000        1069.0000       1840.0000        1070.0979      1835.6632         -1.0979         4.3368          4.4736       71
   105.0000      1037.0000         227.0000       2454.0000         220.8415      2461.9611          6.1585        -7.9611         10.0651       72
   542.0000      1128.0000        1337.0000       2452.0000        1333.6481      2447.6371          3.3519         4.3629          5.5019       73

                                                                     MEAN OF EACH COLUMN             -0.0000        -0.0000          5.0113



                                                                     RMS OF RSS ERRORS                                                5.7230
                                                                     ID NUMBER OF POINT WITH LARGEST RESIDUAL ERROR                     51

RETURNING NORMALLY FROM SUBROUTINE LS22EV
```

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Section 6

SAR/LANDSAT PROCESSING CAPABILITY

Under this contract, a SAR/Landsat Data Merging System (SLDMS) was designed. The documentation produced during this effort is included in the appendixes of this report:

a. Appendix A - Functional Description of the SAR/Landsat Data Merging System

b. Appendix B - Detailed Design of SAR/Landsat Data Merging System

Section 7

SUPPORT TO NASA PLANNING ACTIVITIES

7.1 DOCUMENTATION

IBM generated documentation, as required by NASA, to support its planning activities. In particular, inputs were provided to support the 1978 RTOP on SAR/Landsat Data Merging.

7.2 PHOTOGRAPHIC PRODUCTS FOR PRESENTATIONS

At various times during the course of this contract, IBM generated photographic products of the SAR and Landsat-MSS data being investigated. Some of these products were produced in color transparency, 35 mm slide, or lantern slide format for use as visual aids for oral presentations by NASA investigators.

Section 8

RESULTS AND CONCLUSIONS

8.1 FEASIBILITY OF SAR/LANDSAT REGISTRATION

The results from the experiment on the Cambridge SAR image indicate that temporal registration of SAR data with Landsat-MSS data is both feasible (from a technical viewpoint) and useful (from an information-content viewpoint). Multi-sensor temporal registration is likely to be a very desirable process in the future. It will enable users to make use of varied sources of information to solve their problems. This experiment shows the viability of using SAR data in this way.

8.2 CONTROL-POINT LOCATION RESULTS

This investigation confirmed that the greatest difficulty in registering aircraft SAR data to corrected Landsat-MSS data is control-point location. The difficulties occur in the following areas:

a. Feature selection

b. Distribution of control points

c. Comparing Landsat and SAR features

d. Correctness of control-point locations.

The results and conclusions regarding control-point location that are implied by this study are described below.

The selection of features that will serve as good control points is made difficult by the differences in SAR and MSS data. Features that are usually high-quality control points in the MSS data (such as road intersections) were often unusable in the SAR data. Features of normally lower quality in MSS data (such as agricultural field boundaries) had to be used. This problem is compounded by the fact that features often looked quite different in the data from the two sensors. For example, the shadowing in the SAR data did not occur in the MSS data.

The experiments on the Salisbury and Cambridge SAR images clearly demonstrated the importance of having a set of control points that is well-distributed throughout the image. In every case tried during this contract (and the related IRAD work), there were geometric errors in any relatively large areas that contained no control points.

The experience on this contract indicates that SAR and Landsat-MSS data are unsuitable for automatic computer correlation of digital control-point data. It is clear that the gray-level data cannot be compared by computer, due to the different response characteristics of the MSS and SAR images. The image data could be processed by an edge-detection algorithm prior to machine correlation, but the SAR shadowing would likely cause this method to be ineffective. However, the high noise content of the SAR data makes edge detection very difficult, if not impossible. The rotational difference between the SAR and Landsat-MSS data precluded any attempt at machine correlation of control points during this study.

All of the problems normally associated with checking for errors in control-point location are present in the SAR/Landsat registration problem. However, extreme care must be taken to avoid obvious errors. All points near the edges should be double checked, since errors in these points can easily go undetected. Errors in control-point coordinates caused the first two versions of the corrected Cambridge SAR data to have severe geometric errors. Most of these control-point location errors were on points near the border of the SAR image. When a set of control points that contained only correctly-located points was used, the resulting corrected image had good registration with the corrected Landsat-MSS image.

Section 9

REFERENCES

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APPENDIX A

FUNCTIONAL DESCRIPTION
OF THE
SAR/LANDSAT DATA MERGING SYSTEM

September 1978

By

Stephen W. Murphrey

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

A.1 GENERAL SYSTEM REQUIREMENTS

A.1.1 Functional

The SAR/Landsat Data Merging System (SLDMS) will have the capability of producing SAR and Landsat MSS images that are registered to each other and to a Universal Transverse Mercator (UTM) map projection. A SLDMS user will accomplish this by processing the Landsat data to his own specifications and then processing the SAR data to register with the corrected Landsat data. He then can use the corrected SAR and Landsat data for multispectral classification and other information extraction processes.

The specific Landsat processing functions that the SLDMS will have are radiometric correction and geometric correction. Radiometric correction is defined to be a striping reduction process that is performed on MSS data that has been radiometrically calibrated but not resampled. Geometric correction is defined to be the resampling of MSS data to a UTM map projection. The user will be able to specify both the spacing between pixels in the output UTM image and the orientation of the image (i.e., the direction of north relative to the image scan lines).

The specific SAR processing function that the SLDMS will have is registration. Registration is defined to be the resampling of SAR data to have the same geometry as a corrected Landsat-MSS data set. That is, the SAR data will be resampled to the same lattice of pixels as was the geometrically corrected Landsat-MSS data.

A.1.2 Hardware

The SLDMS will run on the IBM 370/148 computer at LARS. The only hardware requirements for the system are the tape drives needed for image data sets and sufficient virtual memory for the resampling program. The system will be designed to minimize the use of disk space by using tapes wherever it is reasonable to do so.

The resampling program will require an internal input buffer large enough to store the maximum number of input image lines that will be needed to create one output image line. This is a function of the rotational difference between the input and output images. Therefore, the memory requirement varies from image to image.

A.1.3 Software

The SLDMS will be written in Fortran IV and IBM 370 Assembler Language. Generally, Fortran will be used wherever it is reasonable to do so. However, Assembler Language will be used for those programs that would be significantly more inefficient if written in Fortran.

The programs will use some local LARS programs to perform certain standard functions. For example, the program TAPOP will be used to perform image data set I/O.

A.2 IMPLEMENTATION AT LARS

A.2.1 Landsat-MSS

Landsat-MSS processing software which will be implemented at LARS will be defined in this section. Full use of techniques, algorithms, and software developed under the Master Data Processor (NAS5-22999) and the Landsat-C Return Beam Videcon (RBV) Software and Interactive Ground Control Point (GCP) System (NAS5-23790) contracts will be made in implementing the SLDMS. In particular, the Control Point Library Copy Tape, which is a back-up copy of NASA's control point library, will be used by the SLDMS.

The Landsat-MSS software will consist of five programs:

a. Reformatting Program
b. Automatic Control-Point Location Program
c. Manual Control-Point Location Program
d. Geometric Transformation Program
e. Resampling Program.

The inputs, functions, and outputs of each of these programs are described below.

There are three kinds of input MSS data that can be processed by the SLDMS:

a. Uncorrected Data -- This consists of four bands of MSS data in the X format. The image data has been radiometrically corrected and line-length adjusted, but no other corrections have been applied. Ancillary data includes no geometric transformation.

b. Partially Processed Data -- This consists of four or five bands of MSS data in the BSQ format. The only correction applied to the image data is radiometric correction. Ancillary data includes geometric transformation information.

c. Fully Corrected Data -- This consists of four or five bands of MSS data in the BSQ format. Both radiometric correction and geometric correction have been applied to the data.

The SLDMS will be able to geometrically correct and perform a striping reduction on both uncorrected and partially processed data. It will also be able to resample fully corrected data in order to change the pixel spacing.

As shown in Figure A-1, there are three paths through the software. The first path involves the reformatting, automatic control-point location, geometric transformation, and resampling programs. This path would normally be used for an uncorrected MSS scene for which a corresponding control-point library exists. The result from this path is a fully corrected MSS scene with user-selected orientation and pixel spacing. This would be the most desirable path for processing uncorrected data. It can also be used to correct partially processed data. If no control-point library exists for an uncorrected MSS scene that is to be processed, there are two alternate paths through the system that can be used.

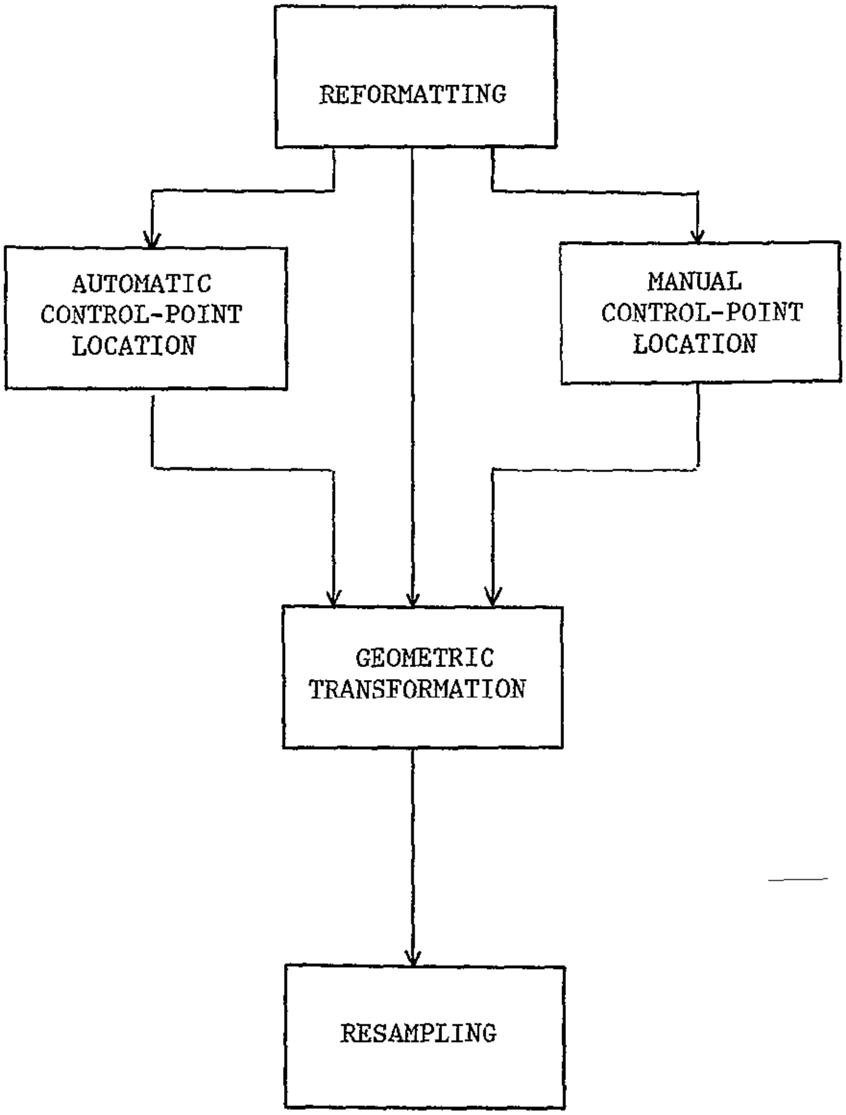

Figure A-1. Software Paths

The second path involves the reformatting, geometric transformation, and resampling programs. This path would normally be used for an uncorrected MSS scene for which no control-point library exists or for a partially processed MSS scene. The result from using this path on an uncorrected MSS scene would be a systematically corrected MSS scene with user-selected orientation and pixel spacing. From a partially processed scene, a fully corrected MSS scene that has been either systematically corrected or scene corrected (depending on the original ancillary data) can be produced with this path through the software.

The third path involves the reformatting, manual control-point location, geometric correction, and resampling programs. This path would normally be used for an uncorrected MSS scene for which no corresponding control-point library exists or for a fully corrected MSS scene. The result from this path would be a fully corrected MSS scene in either case. For a fully corrected input scene, only the reformatting and the resampling portion of the manual control-point location program are used. In this case, the result is a fully corrected scene with different pixel spacing.

A.2.2 Aircraft SAR

The aircraft SAR processing software which will be implemented at LARS will be defined in this section. The techniques and algorithms were developed by IBM under contract NAS6-2827.

The aircraft SAR software will consist of three programs:

a. Manual Control-Point Location Program
b. Geometric Transformation Program
c. Resampling Program.

These programs have the same functions as the corresponding Landsat programs.

The Geometric Transformation Program is a least-squares fitting program. It will be a modification of an existing LARS program. This modification will be performed by LARS, and it is not included in this document.

The other two programs are minor modifications of the corresponding Landsat programs. That is, the MSS high-frequency corrections must be removed in order to process SAR data. These are included in this document.

The input to this portion of the SLDMS consists of digital image data from aircraft SAR instruments. The first step is the location of control points in both the SAR data and the corrected Landsat data. Then a geometric transformation that maps points (X,Y) in the corrected Landsat image to points (U,V) in the SAR image is obtained in the form of 21-term fifth-degree polynomials u(X,Y) and v(X,Y) such that U = u(X,Y) and V = v(X,Y). Finally, the SAR data is resampled using the above geometric transformation. The result is a corrected SAR data set that is registered to the corrected Landsat data set.

A.2.3 Seasat SAR

The only difference between the Seasat and aircraft SAR processing software is the Geometric Transformation Program. The Manual Control-Point Location Programs and the Resampling Program used for aircraft SAR data will also be usable for Seasat SAR data (assuming that it is 8-bit data).

The Geometric Transformation Program will use the algorithms defined in the Seasat SAR Investigation described above.

The input to the Seasat SAR portion of the SLDMS is digital image data from the Seasat SAR instrument and the corresponding Seasat ancillary parameters. The output is a corrected SAR data set that is registered to the corrected Landsat data set.

A.3 USER CONSIDERATIONS

Users of the SAR/Landsat Data Merging System (SLDMS) have several choices to make when processing a Landsat data set. These user options are discussed in this section.

In some cases, a user will have a choice of using partially processed or fully corrected input MSS data. Since fully corrected data is already resampled to a standard map projection, further resampling may not be necessary. A common reason for further resampling would be the need to have the corrected Landsat data at a different pixel spacing than the 57 meters (horizontal and vertical) of the fully corrected data set. Although resampling the data only once is clearly desirable, a recent study (Bi-resampled Data Study; Final Report for Contract NAS5-23708; R. Benner, W. Young; IBM Corp., March 1977) has indicated that a second resampling will degrade the data only slightly and will not essentially change multispectral classification results.

When processing uncorrected MSS data and some partially processed MSS data, a SLDMS user must decide whether to use geodetic control points in determining the geometric transformation between the corrected and uncorrected spaces. If a systematic correction will provide satisfactory geometric accuracy to meet a user's needs and if no control-point library exists for a particular scene, then the expense of control-point location can be avoided by using systematic correction.

The SLDMS will have the capability to resample with nearest neighbor or cubic convolution. Although cubic convolution is widely regarded as a better algorithm than nearest neighbor, it is considerably more expensive to perform on a general purpose computer. Computer expense for resampling is directly proportional to the number of pixels that are being created.

Pixel spacing in the corrected Landsat data is a user option in the SLDMS. MSS input data is spaced at about 57 meters horizontally and at about 79 meters vertically. Fully corrected MSS data produced by the MDP will be spaced at 57 meters in both directions. A particular spacing may be chosen because the SAR data has a similar spacing. A second factor that a user must consider when choosing the pixel spacing is resampling cost. The number of output pixels that are created in the resampling step is inversely proportional to the pixel spacing.

Another user option for Landsat MSS processing is the orientation of the image. Orientation is the angle between North and an image scan line at some point in the image. The standard orientation is such that the spacecraft velocity vector is approximately perpendicular to the image scan lines. That is, input-space scan lines are nearly parallel to output-space scan lines. Orientation affects the resampling step. The memory required for the resampling program is directly proportional to the angle between the input-space scan lines and the output-space scan lines.

A.4 FUNCTIONAL REQUIREMENTS OF SLDMS PROGRAMS

A.4.1 Reformatting Program

The reformatting program converts Landsat MSS computer compatible tapes (CCTs) into LARS Multispectral Image Storage Tape (MIST) format. The inputs, functions, and outputs of this program are stated in Table A-2. It is important to note that the reformatting program performs different functions on each of the different kinds of input data. The different possibilities are shown in Table A-1.

Table A-1. Reformatting Program Functions

Uncorrected	Partially Processed	Fully Corrected
Convert to MIST	Convert to MIST	Convert to MIST
Remove LCC pixels		
Detector histograms	Detector histograms	
Striping red. tables	Striping red. tables	
Striping reduction	Striping reduction	
Extract ancillary	Extract ancillary	Extract ancillary

A.4.2 Automatic Control-Point Location Program

The automatic control-point location program is used to locate the input-space coordinates of a set of points whose geodetic coordinates are known. The output from this program is a set of pixel coordinates of control points. These coordinates are specified to a fraction of a pixel, and the location accuracy is assumed to be within one tenth of a pixel for a good control point.

The specific functions of this program are shown in Table A-3. Basically, the program extracts suitable prototype control points from a tape, creates corresponding search areas from an image tape, correlates the data, and determines the search-area coordinates of the control points. The tape containing the control points is a Control Point Library Copy Tape, which is a back-up copy of NASA's control-point library. It is also possible to obtain prototype control points from an image tape.

Table A-2. Reformatting Program Functions

Input	Process	Output
1. MSS computer tapes:	1. Convert uncorrected MSS data from X format to MIST format.	1. MIST format tape.
a. Uncorrected	2. Convert partially processed MSS data from BSQ format to MIST format.	2. Ancillary data set.
b. Partially processed		3. Printer listing.
c. Fully corrected	3. Convert fully corrected MSS data from BSQ format to MIST format.	
2. User's requests.	4. Remove line-length correction (LLC) pixels from uncorrected data.	
	5. Compute detector histograms.	
	6. Compute striping reduction tables.	
	7. Perform striping reduction.	
	8. Extract ancillary data from input tapes.	

Table A-3. Automatic Control-Point Location Program Functions

Input	Process	Output
1. Control Point Library Copy Tape.	1. Extract prototype control points from: a. Control Point Library Copy Tape b. MIST format image tape	1. Enlarged ancillary data set containing control point locations.
2. Ancillary data set (from Reformatting).	2. Extract search areas from image tape.	2. Printer listing.
3. MIST format tape (from Reformatting).	3. Horizontally resample search areas (and control points, if from image tape) to correct high-frequency errors.	
4. User's requests.	4. Obtain correlation surface for each control point.	
	5. Fit correlation surface to find control point location to sub-pixel accuracy.	
	6. Evaluate quality of each control point.	

A.4.3 Manual Control-Point Location Program

The basic function of the manual control point location program is to process image data in a way that will enable a user to determine control-point coordinates manually. The specific functions of this program are listed in Table A-4.

In order to assist a user to determine control-point coordinates manually, this program produces two kinds of output. First, it generates a resampled image data set for each control point. Second, it displays a control-point data set on a computer listing by simulating pixel gray levels with printer overstrikes.

The resampling that is performed for a control-point location task has two purposes. First, horizontal geometric distortions that are high-frequency in nature are removed during the resampling process. These distortions are listed in Table A-5. Second, a change of scale is performed. This is done to enlarge the control-point subimage so that a user may determine the control-point coordinates to a sub-pixel accuracy level.

A.4.4 Geometric Transformation Program

The geometric transformation program has the following basic functions for uncorrected or partially processed scenes:

a. To define the transformation between the corrected output space and the high-frequency-corrected input space.

b. To assess the accuracy of the geometric transformation.

The resulting geometric transformation is added to the ancillary data set that corresponds to the scene. It is specified as a finite, tabular function. A set of output-space grid points is defined, and the corrected input-space coordinates are determined. This grid-point correspondence is the primary output of the program.

Table A-4. High-Frequency Horizontal Geometric Errors

Line length variations
Earth rotation errors
Sampling delay errors
Band-to-band offset
Mirror velocity errors

The specific functions of this program are shown in Table A-5. For uncorrected data for which no control points exist, models that correct all known systematic errors are used. If control point locations are available for an uncorrected or a partially processed data set, models that correct all known systematic and scene-dependent errors are used. These error models are then used to determine grid point correspondence.

Table A-5. Manual Control-Point Location Program

Input	Process	Output
1. MIST format tape (from Reformatting).	1. Extract small subimages to computer memory.	1. MIST format tape.
2. User's requests.	2. Resample small subimages including: a. Scale change b. High-frequency error correction	2. Shadeprints on listing data set.
	3. Histogram small subimages.	3. Printer listing.
	4. Obtain translate tables using histograms.	
	5. Print shadeprint on listing with overstrikes.	

In the case of scene correction, this program also provides an assessment of the geometric errors. This is done using the covariance matrix of the attitude/altitude fitting process, as described in section LANDSAT MSS IMAGE TO MAP REGISTRATION.

This program can also create a grid point correspondence from the ancillary data for a partially processed scene.

A.4.5. Resampling Program

The resampling program creates a geometrically corrected image data set from an input image data set. It can resample the data using nearest-neighbor or cubic-convolution resampling algorithms.

The resampling program can process the following kinds of data:

a. Uncorrected or partially processed Landsat MSS data.

b. Fully processed Landsat MSS data.

c. SAR image data.

The program operates in essentially the same way for all three kinds of data. However, when uncorrected or partially processed Landsat MSS data is resampled, the program removes horizontal, high-frequency, geometric errors as part of the resampling process.

The specific inputs, functions, and outputs are shown in Table A-6. A checkpoint-restart capability is included because cubic-convolution resampling is a computationally bound process.

Table A-6. Geometric Transformation Program

Input	Process	Output
1. Ancillary data set.	2. Systematic error modeling for uncorrected MSS data.	1. Enlarged ancillary data set containing grind-point correspondence.
2. User's requests.	2. Scene error modeling for uncorrected or partially processed MSS data.	2. Printer listing.
	3. Output space definition.	
	4. Interpolation grid point creation from error models.	
	5. Interpolation grid point creation from ancillary data (for partially processed scenes).	
	6. Geometric error assessment from error models.	

Table A-7. Resampling Program

Input	Process	Output
1. Ancillary data set from geometric transformation program.	1. Set up interpolation grid point arrays	1. MIST format tape.
2. MIST format tape from uncorrected or partially processed scene.	2. Horizontal, high-frequency error correction	2. Printer listing.
3. User's requests.	3. Cubic convolution resampling.	3. Checkpoint restart data set.
4. Checkpoint restart data set.	4. Nearest neighbor resampling.	
	5. Checkpoint restart capability.	

APPENDIX B

DETAILED DESIGN
OF THE
SAR/LANDSAT DATA MERGING SYSTEM

September 1978

by

Stephen W. Murphrey

CONTENTS

ILLUSTRATIONS

TABLES

B.1 INTRODUCTION

This document describes in detail the software that comprises the SAR/LANDSAT (SLDMS). Its primary purpose is to specify the software in sufficient detail so that a competent, image-processing programmer can write the SLDMS programs. It is assumed that the programmer will be somewhat familiar with the IBM existing image-processing software and that he (or she) will use or modify existing code wherever possible.

A second purpose of this document is to provide NASA with enough knowledge to be able to understand the characteristics of the SLDMS.

The design of each SLDMS program is described by a module hierarchy diagram and a set of program specifications (one for each module). In general, the program specifications are independent of the particular programming language chosen for implementation.

B.2 SYSTEM DATA SETS

The SLDMS software uses various input and output data sets. These data sets are described in this section at a system level. A cross-reference of the data sets and programs used in the SLDMS is contained in Table B-1. Each of these data sets is described below in some detail. While it is expected that the formats of some data sets will be changed during the SLDMS implementation effort, the descriptions in this document should give a reasonable indication of the amounts and kinds of data that will be used by the SLDMS.

B.2.1 X-Format CCT

This tape, purchased from EROS Data Center (EDC) or obtained from NASA/GSFC, contains uncorrected MSS image data. There are five files on this tape. The format is completely described in the following:

> "Generation and Physical Characteristics of the Landsat 1 and 2 MSS Computer Compatible Tapes," Goddard Space Flight Center, November 1975, NASA Publication X-563-75-223.

B.2.2 BSQ-Format CCT

Partially processed MSS data and fully corrected MSS data can be produced on CCTs by the MDP. The formats of these tapes are defined in the following Interface Control Documents between the Image Processing Facility and EDC Digital Image Processing System for Landsat:

> "Fully Processed Multispectral Scanner Computer Compatible Tape (CCT-PM)," IBM/FSD, Contract NAS5-22999

> "Partially Processed Multispectral Scanner Computer Compatible Tape (CCT-AM)," IBM/FSD, Contract NAS5-22999

B.2.3 BIL-Format CCT

No documentation on BIL-format CCTs is currently available.

B.2.4 MIST-Format CCT

The MIST format will be used for all image files created by the SLDMS. It is a BIL format in which one record contains data from all spectral bands of a given line. The format is completely described in the following:

> "LARSYS System Manual," Pages 5-52 through 5-58.

Table B-1. Data Set/Program Cross Reference

Data Set	Program				
	MRFT	ACPL	MCPL	GTRN	RSPL
X-Format CCT	I				
BSQ-Format CCT	I				
BIL-Format CCT	I				
MIST-Format CCT	O	I	I O		I O
CPL Copy Tape		I			
Checkpoint Tape					I O
Ancillary Data Set	O	I O		I O	I
Shadeprint Data Set			O		—
User-Request Data Set	I	I	I	I	I
Temporary Data Set	X				

B.2.5 CPL Copy Tape

The Control-Point Library (CPL) Copy Tape provides a copy of either the operational sub-library or the delta sub-library of a library residing on a given MDP system. Its use in NASA's Control-Point Library Building System (CPLBS) is to transfer the operational library to the other system, to restore the operational library, to update operational libraries on both systems, or to restore the delta library.

The CPL Copy Tape will provide prototype control points (windows) to users of the SLDMS. For those Landsat MSS scenes that have corresponding control points on the tape, an SLDMS user will be able to perform precise geometric correction (to his particular scale and orientation) with an automatic process.

The format of the CPL Copy Tape is currently under review at IBM. The format described below is not necessarily the actual format that will be used.

The tape contains in the following order:

a. Library Control Record

b. All directory records

c. All control-point records

The directories and control points are copies of the corresponding CPLBS disk files. In general, the data will require more than one tape reel. Each reel will contain the Library Control Record followed by the remaining data. The Library Control Record will insure that the reel is part of the sequence. Detailed descriptions of the above records follow.

The directory file and the control-point files on the CPL Copy Tape contain data blocked at five records per block. Record lengths and block lengths are shown in Table B-2. In the case of the control-point file, block size is not a multiple of record length. Record formats are shown in Tables B-3, B-4, and B-5.

Table B-2. Control Point Library Copy Tape Record Formats

Record Type	Record Length	Block Length	Maximum # Records
Library Control Record	400	400	1 per reel
Directory Record	360	1800	6250
Control-Point Record	1244	6232	125000

TABLE B-3. LIBRARY CONTROL RECORD

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
DMCFFNAM	ALPHANUMERIC SYSTEM NAME OF FILE	1 - 8	C8
DMCFPROG	NAME OF PROGRAM THAT WROTE THIS RECORD	9 - 12	C4
DMCFDATE	DATE RECORD WAS LAST WRITTEN	13 - 16	C4
DMCFTIME	TIME RECORD WAS LAST WRITTEN	17 - 22	C6
DMCFSTAT	RECORD STATUS	23 - 24	X2
DMCFVALD	SUB-LIBRARY VALID INDICATOR	25 - 26	Y2
DMCFSYSI	SYSTEM ON WHICH THIS SUB-LIBRARY RESIDES	27 - 28	I2
DMCFREC#	CONTROL RECORD NUMBER IN DMTL	29 - 30	I2
DMCFGPNM	GROUP NAME (PRODUCTION OR DEVELOPMENT)	31 - 32	C2
DMCFLBNM	LIBRARY NAME (MSS OR RBV)	33 - 34	C2
DMCFSLNM	SUB-LIBRARY NAME (OPERATIONAL OR DELTA)	35 - 36	C2
DMCFLBDT	DATE LIBRARY INITIALIZED	37 - 44	C8
-	SPARE	45 - 48	A4
DMCFINSV	INDEX FILE SNT VALUE	49 - 50	I2
DMCFINNM	INDEX FILE NAME	51 - 58	C8
DMCFDRSV	DIRECTORY FILE SNT VALUE	59 - 60	I2
DMCFDRNM	DIRECTORY FILE NAME	61 - 68	C8
DMCFCPSV	CONTROL POINT FILE SNT VALUE	69 - 70	I2
DMCFCPNM	CONTROL POINT FILE NAME	71 - 78	C8
-	ALIGNMENT	79 - 80	A2
-	SPARE	81 - 84	A4
DMCFDRA#	NEXT AVAILABLE DIRECTORY RECORD NUMBER	85 - 88	I4
DMCFDR#D	NUMBER OF DELETED DIRECTORY RECORDS	89 - 92	I4
DMCFCPA#	NEXT AVAILABLE CONTROL POINT RECORD NUMBER	93 - 96	I4
DMCFCP#D	NUMBER OF DELETED CONTROL POINT RECORDS	97 - 100	I4
-	SPARE	101 - 104	A4
DMCFSLUP	DATA WRITTEN TO SUB-LIBRARY SINCE LAST COPY TAPE?	105 - 106	Y2
DMCFCTS#	TAPE NUMBER OF LAST COPY TAPE PRODUCED	107 - 108	I2
DMCFRINP	RESTORE-IN-PROGRESS (YES OR NO)	109 - 110	Y2
DMCFRT#	SEQUENTIAL TAPE # OF TAPE USED IN LAST RESTORE	111 - 112	I2
DMCFRT#I	SYSTEM ID (A OR B)	113 - 114	I2
DMCFRT#A	SEQ. TAPE # OF LAST RESTORE TAPE FROM SYSTEM A	115 - 116	I2
DMCFRT#B	SEQ. TAPE # OF LAST RESTORE TAPE FROM SYSTEM B	117 - 118	I2
-	ALIGNMENT	119 - 120	A2
-	SPARE	121 - 124	A4
DMCFPMUR	NEXT PAGE NUMBER FOR PMUR REPORT	125 - 128	I4
DMCFPBSV	PERFORMANCE DATA FILE SNT	129 - 130	I2
DMCFUINP	UPDATE-IN-PROGRESS (YES OR NO)	131 - 132	Y2
DMCFUT#	SEQUENTIAL TAPE # OF TAPE USED IN LAST UPDATE	133 - 134	I2
DMCFUT#I	SYSTEM ID (A OR B)	135 - 136	I2
DMCFUT#A	SEQ. TAPE # OF LAST UPDATE TAPE FROM SYSTEM A	137 - 138	I2
DMCFUT#B	SEQ. TAPE # OF LAST UPDATE TAPE FROM SYSTEM B	139 - 140	I2
-	SPARE	141 - 144	A4
DMCFRS#	REEL NUMBER	145 - 146	I2
DMCFTAPC	CONTENTS OF TAPE (DELTA, OPERATIONAL, PERFORMANCE)	147 - 158	C12
-	ALIGNMENT	159 - 160	A2
-	SPARE	161 - 400	A240

TABLE B-4. CONTROL POINT LIBRARY DIRECTORY RECORD

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
DMDRFNAM	ALPHANUMERIC SYSTEM NAME OF FILE	1 - 8	C8
DMDRPROG	NAME OF PROGRAM THAT WROTE THIS RECORD	9 - 12	C4
DMDRDATE	DATE RECORD WAS LAST WRITTEN (YDDD)	13 - 16	C4
DMDRTIME	TIME RECORD WAS LAST WRITTEN (HHMMSS)	17 - 22	C6
DMDRSTAT	RECORD STATUS	23 - 24	X2
DMDRCHAN	CHAIN POINTER - RELATIVE RECORD NUMBER	25 - 28	I4
-	SPARE	29 - 32	A4
DMDRSNSR	SENSOR	33 - 34	I2
-	SPARE	35 - 36	A2
DMDRPATH	WRS PATH NUMBER	37 - 38	I2
DMDRROWN	WRS ROW NUMBER	39 - 40	I2
DMDRQUAD	RBV IMAGE QUADRANT	41 - 42	I2
DMDRREGT	REGISTRATION TYPE	43 - 44	I2
DMDRMISN	LANDSAT MISSION	45 - 46	C2
DMDROBSV	IMAGE OBSERVATION TIME: DDDDHHMMS	47 - 56	C10
DMDRUPDL	UPDATE LEVEL OF CONTROL POINT SET	57 - 58	I2
DMDRMODL	MODIFICATION LEVEL OF CONTROL POINT SET	59 - 60	I2
DMDRCPCT	# OF ENTRIES IN CONTROL POINT ID AND POINTER LISTS	61 - 62	I2
-	SPARE	63 - 64	A2
DMDRCIDS	CONTROL POINT ID NUMBER LIST	65 - 124	30I2
DMDRCRBS	CONTROL POINT POINTER LIST	125 - 244	30I4
DMDRLRU1	INPUT-SPACE LINE (UTM/PS) - CORNER 1 (RBV ONLY)	245 - 246	I2
DMDRLRU2	INPUT-SPACE LINE (UTM/PS) - CORNER 2 (RBV ONLY)	247 - 248	I2
DMDRLRU3	INPUT-SPACE LINE (UTM/PS) - CORNER 3 (RBV ONLY)	249 - 250	I2
DMDRLRU4	INPUT-SPACE LINE (UTM/PS) - CORNER 4 (RBV ONLY)	251 - 252	I2
DMDRSRU1	INPUT-SPACE SAMPLE (UTM/PS) - CORNER 1	253 - 254	I2
DMDRSRU2	INPUT-SPACE SAMPLE (UTM/PS) - CORNER 2	255 - 256	I2
DMDRSRU3	INPUT-SPACE SAMPLE (UTM/PS) - CORNER 3	257 - 258	I2
DMDRSRU4	INPUT-SPACE SAMPLE (UTM/PS) - CORNER 4	259 - 260	I2
DMDRLRH1	INPUT-SPACE LINE (HOM) - CORNER 1 (RBV ONLY)	261 - 262	I2
DMDRLRH2	INPUT-SPACE LINE (HOM) - CORNER 2 (RBV ONLY)	263 - 264	I2
DMDRLRH3	INPUT-SPACE LINE (HOM) - CORNER 3 (RBV ONLY)	265 - 266	I2
DMDRLRH4	INPUT-SPACE LINE (HOM) - CORNER 4 (RBV ONLY)	267 - 268	I2
DMDRSRH1	INPUT-SPACE SAMPLE (HOM) - CORNER 1	269 - 270	I2
DMDRSRH2	INPUT-SPACE SAMPLE (HOM) - CORNER 2	271 - 272	I2
DMDRSRH3	INPUT-SPACE SAMPLE (HOM) - CORNER 3	273 - 274	I2
DMDRSRH4	INPUT-SPACE SAMPLE (HOM) - CORNER 4	275 - 276	I2
DMDRLWU	INPUT-SPACE LINE POSITION (UTM/PS) - WRS CENTER	277 - 278	I2
DMDRSWU	INPUT-SPACE SAMPLE POSITION - WRS CENTER	279 - 280	I2
DMDRLWH	INPUT-SPACE LINE POSITION (HOM) - WRS CENTER	281 - 282	I2
DMDRSWH	INPUT-SPACE SAMPLE POSITION (HOM) - WRS CENTER	283 - 284	I2
DMDRNGLA	GEODETIC LATITUDE OF NADIR	285 - 292	D8
DMDRNLON	LONGITUDE OF NADIR	293 - 300	D8
DMDRBETA	BETA ANGLE OF REFERENCE IMAGE	301 - 308	D8
DMDCCNCT	CONTROL POINT ID NUMBER COUNTER	309 - 310	I2
-	SPARE	311 - 312	A2
DMDCUDAT	DATE OF UPDATE FOR LATEST UPDATE LEVEL	313 - 316	I4
DMDCUUID	ID OF USER WHO ENTERED UPDATE	317 - 324	C8
DMDCUSYS	ID OF SYSTEM WHERE UPDATE PERFORMED	325 - 326	I2
DMDCUTAP	SEQUENTIAL TAPE NUMBER OF UPDATE TAPE	327 - 328	I2
DMDCMDAT	DATE OF UPDATE FOR LATEST MODIFICATION LEVEL	329 - 332	I4
DMDCMUID	ID OF USER WHO ENTERED MODIFICATION	331 - 340	C8
DMDCMSYS	ID OF SYSTEM WHERE MODIFICATION PERFORMED	341 - 342	I2
DMDCMTAP	SEQUENTIAL TAPE NUMBER OF UPDATE TAPE	343 - 344	I2
-	SPARE	345 - 360	A16

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TABLE B-5. LIBRARY CONTROL POINT RECORD

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
DMCPFNAM	ALPHANUMERIC SYSTEM NAME OF FILE	1 - 8	C8
DMCPPROG	NAME OF PROGRAM THAT WROTE THIS RECORD	9 - 12	C4
DMCPDATE	DATE RECORD WAS LAST WRITTEN (YDDD)	13 - 16	C4
DMCPTIME	TIME RECORD WAS LAST WRITTEN (HHMMSS)	17 - 22	C6
DMCPSTAT	RECORD STATUS	23 - 24	X2
DMCPSNSR	SENSOR	25 - 26	I2
-	SPARE	27 - 28	A2
DMCPPATH	WRS PATH NUMBER	29 - 30	I2
DMCPRCWN	WRS ROW NUMBER	31 - 32	I2
DMCPQUAD	RBV IMAGE QUADRANT	33 - 34	I2
DMCPREGT	REGISTRATION TYPE	35 - 36	I2
DMCPMISN	LANDSAT MISSION	37 - 38	C2
DMCPOBSV	IMAGE OBSERVATION TIME: DDDDHHMMS	39 - 48	C10
DMCPUPDL	UPDATE LEVEL OF CONTROL POINT SET	49 - 50	I2
DMCPMODL	MODIFICATION LEVEL OF CONTROL POINT SET	51 - 52	I2
DMCPCNCT	CONTROL POINT ID NUMBER WITHIN SET	53 - 54	I2
DMCPWTYP	WINDOW TYPE (M, C, F, OR P)	55 - 56	C2
DMCPLOLI	FEATURE LOCATION IN WINDOW IN LINES	57 - 60	E4
DMCPLOSM	FEATURE LOCATION IN WINDOW IN SAMPLES	61 - 64	E4
DMCPPXMN	MEAN OF WINDOW PIXEL VALUES (DECIMAL AFTER BIT 8)	65 - 66	I2
DMCPSHFT	SHIFT FACTOR (P0)	67 - 68	I2
DMCPPXVR	VARIANCE OF WINDOW PIXEL VALUES X WINDOW SIZE	69 - 72	E4
DMCPMMAG	MEAN MAGNITUDE OF CONDITIONED WINDOW (P1)	73 - 74	I2
DMCPLSBR	# LEADING SIGN BITS IN LARGEST ROW FFT COMPONENT (P2)	75 - 76	I2
DMCPLSBC	# LEADING SIGN BITS IN LARGEST COL FFT COMPONENT (P3)	77 - 78	I2
-	SPARE	79 - 80	A2
DMCPWNDW	WINDOW ARRAY (32-BY-32 ARRAY OF 8-BIT PIXELS)	81 - 1104	
DMCPCOFS	ORDER OF SELECTION BY EDIT; 1 - N	1105 - 1106	I2
DMCPSPBD	SPECTRAL BAND NUMBER	1107 - 1108	I2
DMCPLXEC	GEOCENTRIC RECTANGULAR X COORD OF CONTROL POINT	1109 - 1116	D8
DMCPLYEC	GEOCENTRIC RECTANGULAR Y COORD OF CONTROL POINT	1117 - 1124	D8
DMCPLZEC	GEOCENTRIC RECTANGULAR Z COORD OF CONTROL POINT	1125 - 1132	D8
DMCPEROT	VELOCITY OF CONTROL POINT DUE TO EARTH ROTATION	1133 - 1140	D8
-	SPARE	1141 - 1144	A4
DMCSCOBS	SOURCE IMAGE ID: A.DDDD.HHMMS	1145 - 1156	C12
DMCSGIDC	GENERIC IDENTIFICATION CODE	1157 - 1160	C4
DMCSMPSC	MAP SCALE CODE	1161 - 1164	I4
DMCSNODE	NODE;DESCENDING/ASCENDING	1165 - 1166	I2
DMCS7ACR	# IMAGES IN WHICH CP VIOLATED 7-ACROSS RESTRICTION	1167 - 1168	I2
DMCSOUTS	# IMAGES IN WHICH EST. CP LOC. OUTSIDE AVAIL. DATA	1169 - 1170	I2
DMCSEDGE	# IMAGES IN WHICH LOC. OF PEAK TOO NEAR EDGE OF SA	1171 - 1172	I2
DMCSNIMG	# IMAGES FOR WHICH CORRELATION WAS ATTEMPTED	1173 - 1176	I4
DMCSNCOR	NUMBER OF SUCCESSFUL CORRELATIONS	1177 - 1180	I4
DMCSPEAK	MEAN OF PEAK CORRELATION VALUES OBSERVED	1181 - 1184	E4
DMCSCURV	MEAN, OBS. VALUES OF MIN. CURVATURE OF COR SURF.	1185 - 1188	E4
DMCSSPEK	PEAK CORRELATION VALUE	1189 - 1192	E4
DMCSSCRV	CURVATURE OF CORRELATION SURFACE AT PEAK	1193 - 1196	E4
DMCSLOLT	FEATURE LOCATION IN GEODETIC LATITUDE	1197 - 1204	D8
DMCSICLN	FEATURE LOCATION IN LONGITUDE	1205 - 1212	D8
DMCSELEV	ELEVATION OF FEATURE (METERS ABOVE REF ELLIPSOID)	1213 - 1216	E4
DMCSERAT	AXIS 90% ERROR ELLIPSE EST. ALONG TRACK (METERS)	1217 - 1220	E4
DMCSERCT	AXIS 90% ERROR ELLIPSE EST. ACROSS TRACK (METERS)	1221 - 1224	E4
DMCSUSER	ID OF USER WHO CREATED THIS POINT	1225 - 1232	C8
DMCSCDAT	CREATION DATE - YDDD (JULIAN DAY)	1233 - 1236	I4
DMCSMCID	NASA CP ID # FROM MAP CP DESCRIPTION DATA TAPE	1237 - 1238	C2
DMCSCSYS	ID OF SYSTEM ON WHICH CREATED	1239 - 1240	I2
DMCSCTAP	ID OF TAPE WHICH ENTERED INTO OPER'L LIB.	1241 - 1242	I2
-	SPARE	1243 - 1244	A2

B.2.6 Checkpoint Tape

The Checkpoint Tape is created and used by the Resampling Program (RSPL). Its purpose is to save data whenever a checkpoint is taken. Whenever a computer failure occurs, this data set can be used to restart RSPL at the last checkpoint. This reduces the amount of lost computer time in the event of a failure during the expensive resampling program.

The format of the Checkpoint Tape will be defined during the implementation of the SLDMS.

B.2.7 Ancillary Data Set

Every MSS scene that is processed by the SLDMS will have an associated Ancillary Data Set (ADS). It contains information that completely describes the associated scene as well as information produced by one SLDMS program for use by another program.

The ADS will be a sequential data set consisting of 80-byte records. It will usually reside on a direct-access device, although it may be a tape data set. It is organized into sections, each consisting of a title record followed by one or more data records. All data in a single section is functionally related. Figure B-1 shows the layout of the ADS.

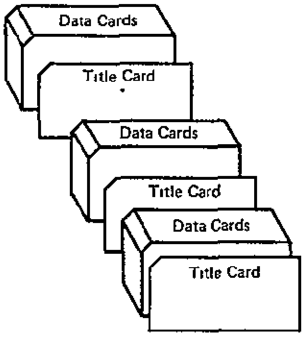

Figure B-1. Organization of Ancillary Data Set

Most of the data on the ADS is expected to be in printable character form. This will permit SLDMS users to easily determine what data is on an ADS by viewing it at a terminal or printing it with a standard utility. The basic formats of the two types of ADS records are shown in Tables B-6 and B-7.

The formats of the data cards in each "section" will be determined during the implementation of the SLDMS. Preliminary definitions of all ADS "sections" follow in Tables B-8 through B-20.

TABLE B-6. ANCILLARY DATA SET: TITLE CARD FORMAT

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	A UNIQUE DESCRIPTIVE IDENTIFIER THAT DEFINES A "SECTION" OF THE ADS (IN PRINTABLE CHARACTER FORM) FORM).	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION".	61 - 70	I10
NCARD	SEQUENCE NUMBER OF THIS CARD WITHIN THE ADS (NOT REQUIRED TO BE USED).	73 - 80	I8

TABLE B-7. ANCILLARY DATA SET: DATA CARD FORMAT

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
-	BLANK CHARACTER (X'40').	1	C1
-	DATA FIELDS (IN PRINTABLE CHARACTER FORM IF POSSIBLE).	2 - 72	-
NCARD	SEQUENCE NUMBER OF THIS CARD WITHIN THE ADS (NOT REQUIRED TO BE USED).	73 - 80	I8

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TABLE B-8. FORMAT OF ANCILLARY DATASET

```
X-FORMAT CCT HEADER DATA:                                                  3
         SCENE             ACQDATE   ACQSITE     DIRECT/RECORDED
        NADLAT    NADLON     FCLAT     FCLON

CCT STAT DATA:                                                            13
        NATEST    NALEST     ALFER     DELVV    AMSNLT    AMSNLN
       ATTTIM1   AMSROL1   AMSPIT1   AMSYAW1   ALTTIM1   AMSALT1
       ATTTIM2   AMSROL2   AMSPIT2   AMSYAW2   ALTTIM2   AMSALT2
       ATTTIM3   AMSROL3   AMSPIT3   AMSYAW3   ALTTIM3   AMSALT3
       ATTTIM4   AMSROL4   AMSPIT4   AMSYAW4   ALTTIM4   AMSALT4
       ATTTIM5   AMSROL5   AMSPIT5   AMSYAW5   ALTTIM5   AMSALT5
       ATTTIM6   AMSROL6   AMSPIT6   AMSYAW6   ALTTIM6   AMSALT6
       ATTTIM7   AMSROL7   AMSPIT7   AMSYAW7   ALTTIM7   AMSALT7
       ATTTIM8   AMSROL8   AMSPIT8   AMSYAW8   ALTTIM8   AMSALT8
       ATTTIM9   AMSROL9   AMSPIT9   AMSYAW9   ALTTIM9   AMSALT9
                                              ALTTIM10  AMSALT10
                                              ALTTIM11  AMSALT11

DETECTOR-BY-DETECTOR HISTOGRAM:                                         1281
        B1D1V0    B1D2V0    B1D3V0    B1D4V0    B1D5V0    B1D6V0        B1V0
        B1D1V1    B1D2V1    B1D3V1    B1D4V1    B1D5V1    B1D6V1        B1V1
             .         .         .         .         .         .           .
             .         .         .         .         .         .           .
             .         .         .         .         .         .           .
      B1D1V255  B1D2V255  B1D3V255  B1D4V255  B1D5V255  B1D6V255      B1V255
        B2D1V0    B2D2V0    B2D3V0    B2D4V0    B2D5V0    B2D6V0        B2V0
        B2D1V1    B2D2V1    B2D3V1    B2D4V1    B2D5V1    B2D6V1        B2V1
             .         .         .         .         .         .           .
             .         .         .         .         .         .           .
             .         .         .         .         .         .           .
      B2D1V255  B2D2V255  B2D3V255  B2D4V255  B2D5V255  B2D6V255      B2V255
        B3D1V0    B3D2V0    B3D3V0    B3D4V0    B3D5V0    B3D6V0        B3V0
        B3D1V1    B3D2V1    B3D3V1    B3D4V1    B3D5V1    B3D6V1        B3V1
             .         .         .         .         .         .           .
             .         .         .         .         .         .           .
             .         .         .         .         .         .           .
      B3D1V255  B3D2V255  B3D3V255  B3D4V255  B3D5V255  B3D6V255      B3V255
        B4D1V0    B4D2V0    B4D3V0    B4D4V0    B4D5V0    B4D6V0        B4V0
        B4D1V1    B4D2V1    B4D3V1    B4D4V1    B4D5V1    B4D6V1        B4V1
             .         .         .         .         .         .           .
             .         .         .         .         .         .           .
             .         .         .         .         .         .           .
      B4D1V255  B4D2V255  B4D3V255  B4D4V255  B4D5V255  B4D6V255      B4V255
        B5D1V0    B5D2V0                                                B5V0
        B5D1V1    B5D2V1                                                B5V1
             .         .                                                   .
             .         .                                                   .
             .         .                                                   .
      B5D1V255  B5D2V255                                              B5V255

DETECTOR-BY-DETECTOR STATISTICAL PARAMETERS:                              11
         B1D1M     B1D2M     B1D3M     B1D4M     B1D5M     B1D6M         B1M
         B1D1S     B1D2S     B1D3S     B1D4S     B1D5S     B1D6S         B1S
         B2D1M     B2D2M     B2D3M     B2D4M     B2D5M     B2D6M         B2M
         B2D1S     B2D2S     B2D3S     B2D4S     B2D5S     B2D6S         B2S
         B3D1M     B3D2M     B3D3M     B3D4M     B3D5M     B3D6M         B3M
         B3D1S     B3D2S     B3D3S     B3D4S     B3D5S     B3D6S         B3S
         B4D1M     B4D2M     B4D3M     B4D4M     B4D5M     B4D6M         B4M
         B4D1S     B4D2S     B4D3S     B4D4S     B4D5S     B4D6S         B4S
         B5D1M     B5D2M     B5D3M     B5D4M     B5D5M     B5D6M         B5M
         B5D1S     B5D2S     B5D3S     B5D4S     B5D5S     B5D6S         B5S

OUTPUT-SPACE DEFINITION:                                                   3
        HSPACO    VSPACO   HEADING    OSWIDP    OSLENP   MAPPROJ
           FDH       FCV     FCLAT     FCLON    FCMAP1    FCMAP2      FCMAP3
```

TABLE B-8. FORMAT OF ANCILLARY DATASET (CONTINUED)

```
ERROR MODELS:                                                          5
      ROLL0     ROLL1      ROLL2      ROLL3
     PITCH0    PITCH1     PITCH2     PITCH3
       YAW0      YAW1       YAW2       YAW3
      DELH0     DELH1

ERROR ASSESSMENT:                                                    N+1
       OSH1       OSV1       CTPH1      CTPV1     AESTH1     AESTV1
       OSH2       OSV2       CTPH2      CTPV2     AESTH2     AESTV2
         .          .          .          .          .          .
         .          .          .          .          .          .
         .          .          .          .          .          .
       OSHN       OSVN       CTPHN      CTPVN     AESTHN     AESTVN

CCT HEADER DATA:                                                       8
      SCENE   ASC/DSC     WRSPTH     WRSROW
     SENSOR   MISSION      ORBIT     ADSTAT     NUMDET      ISWID
     WRSLIN    WRSPIX     CPYEAR      CPDAY     CPHOUR      CPMIN      CPSEC
      MFANN     MFANC      GCFLG     GCDFLG      RCFLG     RCDFLG
      ISLIN   IFORMAT     ILTYPE      ILCNT     RSTYPE     MAPROJ
     WRSOFF    IDJUST     UBANDS     MBNDNO
   PASSTYPE   CALTYPE

CCT ANCILLARY RECORD NUMBER 1 DATA:                                   12
      ISWID     ISLEN     ISPACH     ISPACV
      OSWID     OSLEN     OSPACH     OSPACV     SCALTM     ISWIDM
                MIRR0                 MIRR1                 MIRR2
                MIRR3                MAXMIR
               SCSKEW                 TBTWN               TACTIVE
                    A                     B                 ECCON
       SD11      SD12       SD13       SD14       SD15       SD16
       SD21      SD22       SD23       SD24       SD25       SD26
       SD31      SD32       SD33       SD34       SD35       SD36
       SD41      SD42       SD43       SD44       SD45       SD46
       SD51      SD52     BBOFF1     BBOFF2     BBOFF3     BBOFF4

CCT ANCILLARY RECORD NUMBER 2 DATA:                                   11
     WRSFRM    WRSORB     WRSLAT     WRSLON    FCXCTIM
               NADLAT                NADLON
               NADIRX                NADIRY                NADIRZ
                 BETA               INADLIN               INADSPL
                DELVV                 ERVEL                ERPARM
      ROLL0     ROLL1      ROLL2      ROLL3
     PITCH0    PITCH1     PITCH2     PITCH3
       YAW0      YAW1       YAW2       YAW3
      DELH0     DELH1
     NUMGCP

HRS POINTS FROM ANCILLARY RECORDS 3 - 10:                            K+1
      NHOR       NVER           ( K = NHOR B1V1 NVER )
   H1  H2  H3  H4  H5  H6  H7  H8  H9 H10 H11 H12 H13 H14 H15 H16
  H17 H18 H19 H20 H21 H22 H23 H24 H25 H26 H27 H28 H29 H30 H31 H32
   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
   .   .   .       .   .   .   .   .   .   .   .   .   .   .   .
   .   .   .  HK     ( NOTE: STORED ROW BY ROW )

VRS POINTS FROM ANCILLARY RECORDS 3 - 10:                            L+1
      NHOR       NVER           ( L = NHOR B1V1 NVER )
   V1  V2  V3  V4  V5  V6  V7  V8  V9 V10 V11 V12 V13 V14 V15 V16
  V17 V18 V19 V20 V21 V22 V23 V24 V25 V26 V27 V28 V29 V30 V31 V32
   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
   .   .   .       .   .   .   .   .   .   .   .   .   .   .   .
   .   .   .  VL     ( NOTE: STORED COLUMN BY COLUMN )

CCT ANCILLARY RECORD 10 DATA:                                          2
     WRSPIX    WRSOFF     ORIENT
```

TABLE B-9. ANCILLARY DATA SET FIELDS (X-FORMAT CCT HEADER DATA)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	X-FORMAT CCT HEADER DATA:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 3)	61 - 70	I10
-	BLANK CHARACTER	1	C1
SCENE	NASA SCENE IDENTIFIER	2 - 11	C10
ACQDATE	DATE OF ACQUISITION OF SCENE	12 - 21	C10
ACQSITE	SITE OF ACQUISITION OF SCENE	22 - 31	C10
DIRREC	DIRECT OR RECORDED DATA INDICATOR	32 - 41	C10
-	BLANK CHARACTER	1	C1
NADLAT	LATITUDE OF SPACECRAFT NADIR (RADIANS)	2 - 11	F10
NADLON	LONGITUDE OF SPACECRAFT NADIR (RADIANS)	12 - 21	F10
FCLAT	LATITUDE OF FORMAT CENTER (RADIANS)	22 - 31	F10
FCLON	LONGITUDE OF FORMAT CENTER (RADIANS)	32 - 41	F10

TABLE B-10. ANCILLARY DATA SET FIELDS (CCT SIAT DATA)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	CCT SIAT DATA:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 13)	61 - 70	I10
-	BLANK CHARACTER	1	C1
NATEST	LATITUDE OF SPACECRAFT NADIR (RADIANS)	2 - 11	F10
NALEST	LONGITUDE OF SPACECRAFT NADIR (RADIANS)	12 - 21	F10
ALFER	EARTH ROTATION ANGLE (RADIANS)	22 - 31	F10
DELVV	NORMALIZED VELOCITY CHANGE	32 - 41	F10
AMSNLT	LATITUDE OF SPACECRAFT NADIR (RADIANS)	42 - 51	F10
AMSNLN	LONGITUDE OF SPACECRAFT NADIR (RADIANS)	52 - 61	F10
-	BLANK CHARACTER	1	C1
ATTTIM1	TIME OF ATTITUDE MEASUREMENT 1	2 - 11	F10
AMSRCL1	AMS ROLL MEASUREMENT 1	12 - 21	F10
AMSPIT1	AMS PITCH MEASUREMENT 1	22 - 31	F10
AMSYAW1	AMS YAW MEASUREMENT 1	32 - 41	F10
ALTTIM1	TIME OF ALTITUDE MEASUREMENT 1	42 - 51	F10
AMSALT1	AMS ALTITUDE MEASUREMENT 1	52 - 61	F10
⋮	⋮	⋮	⋮
-	BLANK CHARACTER	1	C1
ATTTIM9	TIME OF ATTITUDE MEASUREMENT 9	2 - 11	F10
AMSRCL9	AMS RCLL MEASUREMENT 9	12 - 21	F10
AMSPIT9	AMS PITCH MEASUREMENT 9	22 - 31	F10
AMSYAW9	AMS YAW MEASUREMENT 9	32 - 41	F10
ALTTIM9	TIME OF ALTITUDE MEASUREMENT 9	42 - 51	F10
AMSALT9	AMS ALTITUDE MEASUREMENT 9	52 - 61	F10
-	BLANK CHARACTER	1	C1
-	SPARE	2 - 51	F10
ALTTIM10	TIME OF ALTITUDE MEASUREMENT 10	42 - 51	F10
AMSALT10	AMS ALTITUDE MEASUREMENT 10	52 - 61	F10
-	BLANK CHARACTER	1	C1
-	SPARE	2 - 51	F10
ALTTIM11	TIME OF ALTITUDE MEASUREMENT 11	42 - 51	F10
AMSALT11	AMS ALTITUDE MEASUREMENT 11	52 - 61	F10

TABLE B-11. ANCILLARY DATA SET FIELDS (DETECTOR-BY-DETECTOR HISTOGRAMS)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	DETECTOR-BY-DETECTOR HISTOGRAMS:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 1281)	61 - 70	I10
-	BLANK CHARACTER	1	C1
B1D1V0	NUMBER OF BAND-1, DETECTOR-1 PIXELS WITH VALUE 0	2 - 11	I10
B1D2V0	NUMBER OF BAND-1, DETECTOR-2 PIXELS WITH VALUE 0	12 - 21	I10
B1D3V0	NUMBER OF BAND-1, DETECTOR-3 PIXELS WITH VALUE 0	22 - 31	I10
B1D4V0	NUMBER OF BAND-1, DETECTOR-4 PIXELS WITH VALUE 0	32 - 41	I10
B1D5V0	NUMBER OF BAND-1, DETECTOR-5 PIXELS WITH VALUE 0	42 - 51	I10
B1D6V0	NUMBER OF BAND-1, DETECTOR-6 PIXELS WITH VALUE 0	52 - 61	I10
B1V0	NUMBER OF BAND-1 PIXELS WITH VALUE 0	62 - 71	I10
-	BLANK CHARACTER	1	C1
B1D1V1	NUMBER OF BAND-1, DETECTOR-1 PIXELS WITH VALUE 1	2 - 11	I10
B1D2V1	NUMBER OF BAND-1, DETECTOR-2 PIXELS WITH VALUE 1	12 - 21	I10
B1D3V1	NUMBER OF BAND-1, DETECTOR-3 PIXELS WITH VALUE 1	22 - 31	I10
B1D4V1	NUMBER OF BAND-1, DETECTOR-4 PIXELS WITH VALUE 1	32 - 41	I10
B1D5V1	NUMBER OF BAND-1, DETECTOR-5 PIXELS WITH VALUE 1	42 - 51	I10
B1D6V1	NUMBER OF BAND-1, DETECTOR-6 PIXELS WITH VALUE 1	52 - 61	I10
B1V1	NUMBER OF BAND-1 PIXELS WITH VALUE 1	62 - 71	I10
⋮	⋮	⋮	⋮
-	BLANK CHARACTER	1	C1
B1D1V255	NUMBER OF BAND-1, DETECTOR-1 PIXELS WITH VALUE 255	2 - 11	I10
B1D2V255	NUMBER OF BAND-1, DETECTOR-2 PIXELS WITH VALUE 255	12 - 21	I10
B1D3V255	NUMBER OF BAND-1, DETECTOR-3 PIXELS WITH VALUE 255	22 - 31	I10
B1D4V255	NUMBER OF BAND-1, DETECTOR-4 PIXELS WITH VALUE 255	32 - 41	I10
B1D5V255	NUMBER OF BAND-1, DETECTOR-5 PIXELS WITH VALUE 255	42 - 51	I10
B1D6V255	NUMBER OF BAND-1, DETECTOR-6 PIXELS WITH VALUE 255	52 - 61	I10
B1V255	NUMBER OF BAND-1 PIXELS WITH VALUE 255	62 - 71	I10
⋮	⋮	⋮	⋮
-	BLANK CHARACTER	1	C1
B4D1V255	NUMBER OF BAND-4, DETECTOR-1 PIXELS WITH VALUE 255	2 - 11	I10
B4D2V255	NUMBER OF BAND-4, DETECTOR-2 PIXELS WITH VALUE 255	12 - 21	I10
B4D3V255	NUMBER OF BAND-4, DETECTOR-3 PIXELS WITH VALUE 255	22 - 31	I10
B4D4V255	NUMBER OF BAND-4, DETECTOR-4 PIXELS WITH VALUE 255	32 - 41	I10
B4D5V255	NUMBER OF BAND-4, DETECTOR-5 PIXELS WITH VALUE 255	42 - 51	I10
B4D6V255	NUMBER OF BAND-4, DETECTOR-6 PIXELS WITH VALUE 255	52 - 61	I10
B4V255	NUMBER OF BAND-4 PIXELS WITH VALUE 255	62 - 71	I10
-	BLANK CHARACTER	1	C1
B5D1V0	NUMBER OF BAND-5, DETECTOR-1 PIXELS WITH VALUE 0	2 - 11	I10
B5D2V0	NUMBER OF BAND-5, DETECTOR-2 PIXELS WITH VALUE 0	12 - 21	I10
-	SPARE	22 - 61	I10
B5V0	NUMBER OF BAND-5 PIXELS WITH VALUE 0	62 - 71	I10
⋮	⋮	⋮	⋮
-	BLANK CHARACTER	1	C1
B5D1V255	NUMBER OF BAND-5, DETECTOR-1 PIXELS WITH VALUE 255	2 - 11	I10
B5D2V255	NUMBER OF BAND-5, DETECTOR-2 PIXELS WITH VALUE 255	12 - 21	I10
-	SPARE	22 - 61	I10
B5V255	NUMBER OF BAND-5 PIXELS WITH VALUE 255	62 - 71	I10

TABLE B-12. ANCILLARY DATA SET FIELDS (DETECTOR-BY-DETECTOR STATISTICAL DATA)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	DETECTOR-BY-DETECTOR STATISTICAL PARAMETERS:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 11)	61 - 70	I10
-	BLANK CHARACTER	1	C1
B1D1M	MEAN OF BAND-1, DETECTOR-1 PIXELS	2 - 11	F10
B1D2M	MEAN OF BAND-1, DETECTOR-2 PIXELS	12 - 21	F10
B1D3M	MEAN OF BAND-1, DETECTOR-3 PIXELS	22 - 31	F10
B1D4M	MEAN OF BAND-1, DETECTOR-4 PIXELS	32 - 41	F10
B1D5M	MEAN OF BAND-1, DETECTOR-5 PIXELS	42 - 51	F10
B1D6M	MEAN OF BAND-1, DETECTOR-6 PIXELS	52 - 61	F10
B1M	MEAN OF BAND-1 PIXELS	62 - 71	F10
-	BLANK CHARACTER	1	C1
B1D1S	STANDARD DEVIATION OF BAND-1, DETECTOR-1 PIXELS	2 - 11	F10
B1D2S	STANDARD DEVIATION OF BAND-1, DETECTOR-2 PIXELS	12 - 21	F10
B1D3S	STANDARD DEVIATION OF BAND-1, DETECTOR-3 PIXELS	22 - 31	F10
B1D4S	STANDARD DEVIATION OF BAND-1, DETECTOR-4 PIXELS	32 - 41	F10
B1D5S	STANDARD DEVIATION OF BAND-1, DETECTOR-5 PIXELS	42 - 51	F10
B1D6S	STANDARD DEVIATION OF BAND-1, DETECTOR-6 PIXELS	52 - 61	F10
B1S	STANDARD DEVIATION OF BAND-1 PIXELS	62 - 71	F10
⋮	⋮	⋮	⋮
-	BLANK CHARACTER	1	C1
B5D1M	MEAN OF BAND-5, DETECTOR-1 PIXELS	2 - 11	F10
B5D2M	MEAN OF BAND-5, DETECTOR-2 PIXELS	12 - 21	F10
B5D3M	MEAN OF BAND-5, DETECTOR-3 PIXELS	22 - 31	F10
B5D4M	MEAN OF BAND-5, DETECTOR-4 PIXELS	32 - 41	F10
B5D5M	MEAN OF BAND-5, DETECTOR-5 PIXELS	42 - 51	F10
B5D6M	MEAN OF BAND-5, DETECTOR-6 PIXELS	52 - 61	F10
B5M	MEAN OF BAND-5 PIXELS	62 - 71	F10
-	BLANK CHARACTER	1	C1
B5D1S	STANDARD DEVIATION OF BAND-5, DETECTOR-1 PIXELS	2 - 11	F10
B5D2S	STANDARD DEVIATION OF BAND-5, DETECTOR-2 PIXELS	12 - 21	F10
B5D3S	STANDARD DEVIATION OF BAND-5, DETECTOR-3 PIXELS	22 - 31	F10
B5D4S	STANDARD DEVIATION OF BAND-5, DETECTOR-4 PIXELS	32 - 41	F10
B5D5S	STANDARD DEVIATION OF BAND-5, DETECTOR-5 PIXELS	42 - 51	F10
B5D6S	STANDARD DEVIATION OF BAND-5, DETECTOR-6 PIXELS	52 - 61	F10
B5S	STANDARD DEVIATION OF BAND-5 PIXELS	62 - 71	F10

TABLE B-13. ANCILLARY DATA SET FIELDS (OUTPUT-SPACE DEFINITION)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	OUTPUT-SPCE DEFINITION:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 3)	61 - 70	I10
-	BLANK CHARACTER	1	C1
HSPACO	DISTANCE BETWEEN OUTPUT-SPACE PIXEL CENTERS (METERS)	2 - 11	F10
VSPACO	DISTANCE BETWEEN OUTPUT-SPACE PIXEL CENTERS (METERS)	12 - 21	F10
HEADING	SPACECRAFT HEADING ANGLE	22 - 31	F10
OSWIDP	WIDTH OF OUTPUT SPACE (PIXELS)	32 - 41	F10
OSLENP	LENGTH OF OUTPUT SPACE (PIXELS)	42 - 51	F10
MAPPROJ	MAP PROJECTION	52 - 71	C20
-	BLANK CHARACTER	1	C1
FCH	FORMAT CENTER COORDINATE (HORIZONTAL)	2 - 11	F10
FCV	FORMAT CENTER COORDINATE (VERTICAL)	12 - 21	F10
FCLAT	FORMAT CENTER LATITUDE (RADIANS)	22 - 31	F10
FCLON	FORMAT CENTER LONGITUDE (RADIANS)	32 - 41	F10
FCMAP1	FORMAT CENTER MAP COORDINATE	42 - 51	F10
FCMAP2	FORMAT CENTER MAP COORDINATE	52 - 61	F10
FCMAP3	FORMAT CENTER MAP COORDINATE	62 - 71	F10

TABLE B-14. ANCILLARY DATA SET FIELDS (ERROR MODELS)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	ERROR MODELS:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 5)	61 - 70	I10
-	BLANK CHARACTER	1	C1
ROLL0	CONSTANT-TERM COEFFICIENT OF ROLL MODEL	2 - 11	F10
ROLL1	DEGREE-1-TERM COEFFICIENT OF ROLL MODEL	12 - 21	F10
ROLL2	DEGREE-2-TERM COEFFICIENT OF ROLL MODEL	22 - 31	F10
ROLL3	DEGREE-3-TERM COEFFICIENT OF ROLL MODEL	32 - 41	F10
-	BLANK CHARACTER	1	C1
PITCH0	CONSTANT-TERM COEFFICIENT OF PITCH MODEL	2 - 11	F10
PITCH1	DEGREE-1-TERM COEFFICIENT OF PITCH MODEL	12 - 21	F10
PITCH2	DEGREE-2-TERM COEFFICIENT OF PITCH MODEL	22 - 31	F10
PITCH3	DEGREE-3-TERM COEFFICIENT OF PITCH MODEL	32 - 41	F10
-	BLANK CHARACTER	1	C1
YAW0	CONSTANT-TERM COEFFICIENT OF YAW MODEL	2 - 11	F10
YAW1	DEGREE-1-TERM COEFFICIENT OF YAW MODEL	12 - 21	F10
YAW2	DEGREE-2-TERM COEFFICIENT OF YAW MODEL	22 - 31	F10
YAW3	DEGREE-3-TERM COEFFICIENT OF YAW MODEL	32 - 41	F10
-	BLANK CHARACTER	1	C1
DELH0	CONSTANT-TERM COEFFICIENT OF ALTITUDE-CHANGE MODEL	2 - 11	F10
DELH1	DEGREE-1-TERM COEFFICIENT OF ALTITUDE-CHANGE MODEL	12 - 21	F10

TABLE B-15. ANCILLARY DATA SET FIELDS (ERROR ASSESSMENT)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	ERROR ASSESSMENT:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= N+1)	61 - 70	I10
-	BLANK CHARACTER	1	C1
OSH1	OUTPUT-SPACE COORDINATE OF POINT 1	2 - 11	F10
OSV1	OUTPUT-SPACE COORDINATE OF POINT 1	12 - 21	F10
CTPH1	CORRECTED TANGENT-PLANE COORDINATE OF POINT 1	22 - 31	F10
CTPV1	CORRECTED TANGENT-PLANE COORDINATE OF POINT 1	32 - 41	F10
AESTH1	ERROR ESTIMATE FOR POINT 1	42 - 51	F10
AESTV1	ERROR ESTIMATE FOR POINT 1	52 - 61	F10
⋮	⋮	⋮	⋮
-	BLANK CHARACTER	1	C1
OSHN	OUTPUT-SPACE COORDINATE OF POINT N	2 - 11	F10
OSVN	OUTPUT-SPACE COORDINATE OF POINT N	12 - 21	F10
CTPHN	CORRECTED TANGENT-PLANE COORDINATE OF POINT N	22 - 31	F10
CTPVN	CORRECTED TANGENT-PLANE COORDINATE OF POINT N	32 - 41	F10
AESTHN	ERROR ESTIMATE FOR POINT N	42 - 51	F10
AESTVN	ERROR ESTIMATE FOR POINT N	52 - 61	F10

TABLE B-16. ANCILLARY DATA SET FIELDS (CCT HEADER DATA)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	CCT HEADER DATA:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 8)	61 - 70	I10
-	BLANK CHARACTER	1	C1
SCENE	NASA SCENE IDENTIFIER	2 - 11	C10
ASCDSC	ASCENDING OR DESCENDING NODE	12 - 21	C10
WRSPTH	WRS PATH NUMBER	22 - 31	I10
WRSROW	WRS ROW NUMBER	32 - 41	I10
-	BLANK CHARACTER	1	C1
SENSOR	SENSOR IDENTIFIER	2 - 11	C10
MISSION	MISSION IDENTIFIER	12 - 21	C10
ORBIT	SPACECRAFT ORBIT NUMBER	22 - 31	I10
ADSTAT	ACTIVE DETECTOR STATUS	32 - 41	X10
NUMDET	NUMBER OF ACTIVE DETECTORS	42 - 51	I10
ISWID	WIDTH OF INPUT SPACE (PIXELS)	52 - 61	I10
-	BLANK CHARACTER	1	C1
WPSLIN	LINE NUMBER OW WRS FORMAT CENTER	2 - 11	I10
WPSPIX	PIXEL NUMBER OF WRS FORMAT CENTER	12 - 21	I10
CPYEAR	CENTER PICTURE EXPOSURE TIME (YEAR)	22 - 31	I10
CPDAY	CENTER PICTURE EXPOSURE TIME (JULIAN DAY OF YEAR)	32 - 41	I10
CPHOUP	CENTER PICTURE EXPOSURE TIME (HOUR)	42 - 51	I10
CPMIN	CENTER PICTURE EXPOSURE TIME (MINUTES)	52 - 61	F10
-	BLANK CHARACTER	1	C1
MFANN	NUMBER OF MAJOR FRAMES OF ANNOTATION DATA	2 - 11	I10
MFANC	NUMBER OF MAJOR FRAMES OF ANCILLARY DATA	12 - 21	I10
GCFLG	GEOMETRIC CORRECTION FLAG	22 - 31	C10
GCDFLG	GEOMETRIC CORRECTION DATA FLAG	32 - 41	C10
PCFLG	RADIOMETRIC CORRECTION FLAG	42 - 51	C10
RCDFLG	RADIOMETRIC CORRECTION DATA FLAG	52 - 61	C10
-	BLANK CHARACTER	1	C1
ISLIN	NUMBER OF MAJOR FRAMES (LINES) OF IMAGE DATA	2 - 11	I10
IFORMAT	IMAGE DATA FORMAT	12 - 21	C10
ILTYPE	TYPE OF INTERLEAVING	22 - 31	C10
ILCNT	LINE INTERLEAVING COUNT	32 - 41	I10
FSTYPE	TYPE OF RESAMPLING APPLIED	42 - 51	C10
MAPRCJ	MAP PROJECTION APPLIED	52 - 61	C10
-	BLANK CHARACTER	1	C1
WRSOFF	WRS OFFSET FROM FULLY PROCESSED IMAGE CENTER	2 - 11	I10
IDJUST	IMAGE DATA JUSTIFICATION	12 - 21	C10
UBANDS	NUMBEWR OF USABLE SPECTRAL BANDS	22 - 31	I10
MBNDNC	MSS SPECTRAL BAND NUMBER	32 - 41	I10
-	BLANK CHARACTER	1	C1
PASSTYPE	TYPE OF PASS (DAY / NIGHT)	2 - 11	C10
CAITYPE	MODE OF CALIBRATION WEDGE	12 - 21	C10

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TABLE B-17. ANCILLARY DATA SET FIELDS (CCT ANCILLARY RECORD NUMBER 1 DATA)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	CCT ANCILLARY RECORD NUMBER 1 DATA:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 12)	61 - 70	I10
-	BLANK CHARACTER	1	C1
ISWID	WIDTH OF INPUT SPACE (PIXELS)	2 - 11	F10
ISLEN	LENGTH OF INPUT SPACE (PIXELS)	12 - 21	F10
ISPACH	HOR. SPACING BETWEEN INPUT-SPACE PIXELS (METERS)	22 - 31	F10
ISPACV	VER. SPACING BETWEEN INPUT-SPACE PIXELS (METERS)	32 - 41	F10
-	BLANK CHARACTER	1	C1
OSWID	WIDTH OF OUTPUT SPACE (PIXELS)	2 - 11	F10
OSLEN	LENGTH OF OUTPUT SPACE (PIXELS)	12 - 21	F10
OSPACH	HOR. SPACING BETWEEN OUTPUT-SPACE PIXELS (METERS)	22 - 31	F10
OSPACV	VER. SPACING BETWEEN OUTPUT-SPACE PIXELS (METERS)	32 - 41	F10
SCALTM	NOMINAL SPACECRAFT ALTITUDE (METERS)	42 - 51	F10
ISWIDM	WIDTH OF INPUT SPACE (METERS)	52 - 61	F10
-	BLANK CHARACTER	1	C1
MIRR0	CONSTANT COEFFICIENT OF MIRROR-VELOCITY MODEL	2 - 21	D20
MIRR1	DEGREE-1 COEFFICIENT OF MIRROR-VELOCITY MODEL	22 - 41	D20
MIRR2	DEGREE-2 COEFFICIENT OF MIRROR-VELOCITY MODEL	42 - 61	D20
-	BLANK CHARACTER	1	C1
MIRR3	DEGREE-3 COEFFICIENT OF MIRROR-VELOCITY MODEL	2 - 21	D20
MAXMIR	MAXIMUM SCAN-MIRROR ANGLE (RADIANS)	22 - 41	D20
-	BLANK CHARACTER	1	C1
SCSKEW	SCAN-SKEW PARAMETER	2 - 21	D20
TBTWN	TIME BETWEEN CONSECUTIVE MIRROR SWEEPS	22 - 41	D20
TACTIVE	TIME FOR AN ACTIVE MIRROR SCAN (SECONDS)	42 - 61	D20
-	BLANK CHARACTER	1	C1
A	SEMIMAJOR AXIS OF EARTH-SPHEROID MODEL (METERS)	2 - 21	D20
B	SEMIMINOR AXIS OF EARTH-SPHEROID MODEL (METERS)	22 - 41	D20
ECCON	EARTH-CURVATURE CONSTANT	42 - 61	D20
-	BLANK CHARACTER	1	C1
SD11	SAMPLING-DELAY CORRECTION FOR BAND 1, DETECTOR 1	2 - 11	F10
SD12	SAMPLING-DELAY CORRECTION FOR BAND 1, DETECTOR 2	12 - 21	F10
SD13	SAMPLING-DELAY CORRECTION FOR BAND 1, DETECTOR 3	22 - 31	F10
SD14	SAMPLING-DELAY CORRECTION FOR BAND 1, DETECTOR 4	32 - 41	F10
SD15	SAMPLING-DELAY CORRECTION FOR BAND 1, DETECTOR 5	42 - 51	F10
SD16	SAMPLING-DELAY CORRECTION FOR BAND 1, DETECTOR 6	52 - 61	F10
⋮	⋮	⋮	⋮
-	BLANK CHARACTER	1	C1
SD41	SAMPLING-DELAY CORRECTION FOR BAND 4, DETECTOR 1	2 - 11	F10
SD42	SAMPLING-DELAY CORRECTION FOR BAND 4, DETECTOR 2	12 - 21	F10
SD43	SAMPLING-DELAY CORRECTION FOR BAND 4, DETECTOR 3	22 - 31	F10
SD44	SAMPLING-DELAY CORRECTION FOR BAND 4, DETECTOR 4	32 - 41	F10
SD45	SAMPLING-DELAY CORRECTION FOR BAND 4, DETECTOR 5	42 - 51	F10
SD46	SAMPLING-DELAY CORRECTION FOR BAND 4, DETECTOR 6	52 - 61	F10
-	BLANK CHARACTER	1	C1
SD51	SAMPLING-DELAY CORRECTION FOR BAND 5, DETECTOR 1	2 - 11	F10
SD52	SAMPLING-DELAY CORRECTION FOR BAND 5, DETECTOR 2	12 - 21	F10
BBOFF5	BAND-TO-BAND OFFSET FOR BAND 5	22 - 31	F10
BBOFF6	BAND-TO-BAND OFFSET FOR BAND 6	32 - 41	F10
BBOFF7	BAND-TO-BAND OFFSET FOR BAND 7	42 - 51	F10
BBOFF8A	BAND-TO-BAND OFFSET FOR BAND 8A	52 - 61	F10
BBOFF8B	BAND-TO-BAND OFFSET FOR BAND 8B	62 - 71	F10

TABLE B-18. ANCILLARY DATA SET FIELDS (CCT ANCILLARY RECORD NUMBER 2 DATA)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	CCT ANCILLARY RECORD NUMBER 2 DATA:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 11)	61 - 70	I10
-	BLANK CHARACTER	1	C1
WRSFRM	WRS FRAME	2 - 11	F10
WRSORB	WRS ORBIT	12 - 21	F10
WRSLAT	GEODETIC LATITUDE OF WRS FORMAT CENTER (RADIANS)	22 - 31	F10
WRSLON	LONGITUDE OF WRS FORMAT CENTER (RADIANS)	32 - 41	F10
FCXCTIM	SPACECRAFT TIME OF FRAME CENTER	42 - 61	C20
-	BLANK CHARACTER	1	C1
NADLAT	GEODETIC LATITUDE OF SPACECRAFT NADIR (RADIANS)	2 - 21	D20
NADLON	LONGITUDE OF SPACECRAFT NADIR (RADIANS)	22 - 41	D20
-	BLANK CHARACTER	1	C1
NADIRX	EARTH-FIXED COORDINATE OF SPACECRAFT NADIR (METERS)	2 - 21	D20
NADIRY	EARTH-FIXED COORDINATE OF SPACECRAFT NADIR (METERS)	22 - 41	D20
NADIRZ	EARTH-FIXED COORDINATE OF SPACECRAFT NADIR (METERS)	42 - 61	D20
-	BLANK CHARACTER	1	C1
BETA	HEADING ANGLE	2 - 21	D20
INADLIN	INPUT-SPACE LINE NUMBER OF SPACECRAFT NADIR	22 - 41	D20
INADSPL	INPUT-SPACE SAMPLE NUMBER OF SPACECRAFT NADIR	42 - 61	D20
-	BLANK CHARACTER	1	C1
DELVV	NORMALIZED VELOCITY CHANGE OF SPACECRAFT	2 - 21	D20
ERVEL		22 - 41	D20
ERPARM	EARTH-ROTATION PARAMETER	42 - 61	D20
-	BLANK CHARACTER	1	C1
ROLL0	CONSTANT-TERM COEFFICIENT OF ROLL MODEL	2 - 11	F10
ROLL1	DEGREE-1-TERM COEFFICIENT OF ROLL MODEL	12 - 21	F10
ROLL2	DEGREE-2-TERM COEFFICIENT OF ROLL MODEL	22 - 31	F10
ROLL3	DEGREE-3-TERM COEFFICIENT OF ROLL MODEL	32 - 41	F10
-	BLANK CHARACTER	1	C1
PITCH0	CONSTANT-TERM COEFFICIENT OF PITCH MODEL	2 - 11	F10
PITCH1	DEGREE-1-TERM COEFFICIENT OF PITCH MODEL	12 - 21	F10
PITCH2	DEGREE-2-TERM COEFFICIENT OF PITCH MODEL	22 - 31	F10
PITCH3	DEGREE-3-TERM COEFFICIENT OF PITCH MODEL	32 - 41	F10
-	BLANK CHARACTER	1	C1
YAW0	CONSTANT-TERM COEFFICIENT OF YAW MODEL	2 - 11	F10
YAW1	DEGREE-1-TERM COEFFICIENT OF YAW MODEL	12 - 21	F10
YAW2	DEGREE-2-TERM COEFFICIENT OF YAW MODEL	22 - 31	F10
YAW3	DEGREE-3-TERM COEFFICIENT OF YAW MODEL	32 - 41	F10
-	BLANK CHARACTER	1	C1
DELH0	CONSTANT-TERM COEFFICIENT OF ALTITUDE-CHANGE MODEL	2 - 11	F10
DELH1	DEGREE-1-TERM COEFFICIENT OF ALTITUDE-CHANGE MODEL	12 - 21	F10
-	BLANK CHARACTER	1	C1
NUMGCP	NUMBER OF GCPS USED TO GET ERROR MODELS	2 - 11	F10

TABLE B-19. ANCILLARY DATA SET FIELDS (HRS POINTS FROM ANC. RECORDS 3 - 10)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	HRS POINTS FROM ANCILLARY RECORDS 3 - 10:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= K+1)	61 - 70	I10
-	BLANK CHARACTER	1	C1
H1	HRS POINT NUMBER 1	2 - 5	R4
H2	HRS POINT NUMBER 2	6 - 9	R4
⋮	⋮	⋮	⋮
H16	HRS POINT NUMBER 16	62 - 65	R4
-	BLANK CHARACTER	1	C1
H17	HRS POINT NUMBER 17	2 - 5	R4
H18	HRS POINT NUMBER 18	6 - 9	R4
⋮	⋮	⋮	⋮
H32	HRS POINT NUMBER 32	62 - 65	R4
⋮	⋮	⋮	⋮

TABLE B-20. ANCILLARY DATA SET FIELDS (VRS POINTS FROM ANC. RECORDS 3 - 10)

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
TITLE	VRS POINTS FROM ANCILLARY RECORDS 3 - 10:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= L+1)	61 - 70	I10
-	BLANK CHARACTER	1	C1
V1	VRS POINT NUMBER 1	2 - 5	R4
H2	VRS POINT NUMBER 2	6 - 9	R4
⋮	⋮	⋮	⋮
V16	VRS POINT NUMBER 16	62 - 65	R4
-	BLANK CHARACTER	1	C1
V17	VRS POINT NUMBER 17	2 - 5	R4
V18	VRS POINT NUMBER 18	6 - 9	R4
⋮	⋮	⋮	⋮
V32	VRS POINT NUMBER 32	62 - 65	R4
⋮	⋮	⋮	⋮

B.2.8 Shadeprint Data Set

The shadeprint data set is a computer listing on which image data is displayed. Gray levels are simulated by overstrike printing. Each printed character position represents a single pixel. An example of a shadeprint data set is shown in Figure B-2.

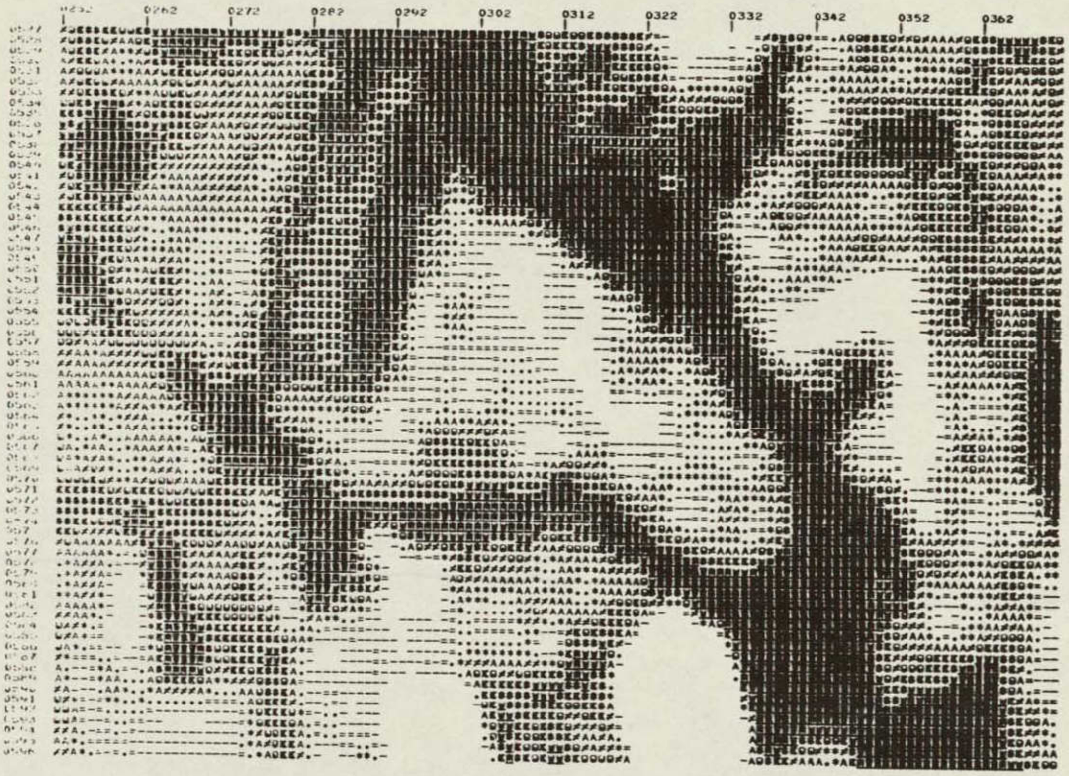

Figure B-2. Example of a Shadeprint

B.2.9 User-Request Data Set

Each of the SLDMS programs has its own User-Request Data Set (URDS). It is used to allow a user to supply any optional or necessary data to the program.

The general formats of all URDSs are similar. Each will consist of a FORTRAN NAMELIST followed by formatted data. The records on a URDS are 80-byte card images.

B.3 REFORMATTING PROGRAM (MRFT)

B.3.1 Statement of Problem

MSS data, as obtained from NASA or EDC, can be in any of several formats. The LARSYS System uses a particular Multispectral Image Storage Tape (MIST) format that facilitates multispectral processing. This format is defined on pages 5-52 through 5-58 of the LARSYS System Manual. Reformatting, as defined here, is the reorganization of the image data into the MIST format.

During the reformatting process, it is convenient to perform several other preliminary processing tasks. These include removing line-length-correction pixels, histogramming, striping reduction, and ancillary-data extraction.

B.3.2 Data Flow

There is a severe limit on the amount of temporary disk storage available on the LARS computer. This restriction has influenced the way data will flow through the reformatting program. In particular, temporary image data sets will be stored on tape data sets. This will require somewhat more I/O than would be necessary on a system that had available about 35 million bytes of temporary disk space. In order to minimize tape-drive utilization, the X-format and BSQ-format tapes will be reformatted so as to use a maximum of three tape drives at one time.

B.3.3 Non-Image Data Considerations

The non-image data that is contained on the Landsat MSS computer tapes will be used by other programs in the SLDMS. For X-format CCTs, the non-image data fields are completely defined (see "Generation and Physical Characteristics of the Landsat 1 and 2 MSS Computer Compatible Tapes," GSFC, November 1975, X-563-75-223). The format of the BSQ and BIL tapes that will be produced by EROS Data Center are apparently not yet officially defined. These will be specified in the new edition of the Landsat Data User's Guide (expected to be published in January, 1979). Actual coding of some sections of the reformatting program cannot be started until those formats are defined. Currently, definitions of only X format and BSQ format (from MDP) are available to IBM.

B.3.4 Program Description

The design of the Reformatting Program is described in Figure B-3 and the nine program specifications that flow.

```
                                        |---- MRFTXA
                 |---- MRFTX   -----|---- MRFTXI
                 |                      |---- MRFTXS
                 |
                 |
MRFT -----|
                 |                      |---- MRFTBA
                 |---- MRFTBS -----|
                 |                      |---- MRFTBII
                 |
                 |
                 |                      |---- MRFTBA
                 |---- MRFTBI -----|
                                        |---- MRFTBII
```

FIGURE B-3. MODULE HIERARCHY FOR LANDSAT MSS REFORMATTING PROGRAM.

****** SAF/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MRFT

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS IS THE TOP-LEVEL DRIVER FOR THE LANDSAT MSS REFORMATTING PROGRAM.

INPUTS .... 1. AN IMAGE TAPE IN X, BSQ, OR BIL FORMAT.
2. A DATA SET CONTAINING USER'S REQUESTS (ON CARD IMAGES).

OUTPUTS .... 1. AN IMAGE TAPE IN MIST FORMAT.
2. AN SLDMS ANCILLARY DATA SET FOR THE SCENE TO BE PROCESSED.
3. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... NOT APPLICABLE.

PDL (PROGRAM OUTLINE)

```
  PRINT PROGRAM-ENTRY MESSAGE
  READ USER'S REQUESTS
  PRINT PARAMETERS DEFINING THIS RUN
  CASENTRY
      CASE 1
          REFORMAT X-FORMAT DATA
      CASE 2
          REFORMAT BSQ-FORMAT DATA
      CASE 3
          REFORMAT BIL-FORMAT DATA
  ENDCASE
  IF   DATA IS UNCORRECTED OR PARTIALLY-PROCESSED DATA   THEN
      DETERMINE STRIPING-REDUCTION TABLES
      IF   STRIPING REDUCTION WAS REQUESTED   THEN
          PERFORM STRIPING REDUCTION
      ENDIF
  ENDIF
  PRINT PROGRAM-EXIT MESSAGE
```

****** END OF SPECIFICATION ******

```
******      SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION       ******
NAME ........... MRFTBS
DESIGNER ....... STEPHEN W. MURPHREY
FUNCTION ....... REFORMATS IMAGE DATA IN BSQ FORMAT.
INPUTS ......... 1. SEE CALLING SEQUENCE.
OUTPUTS ........ 1. SEE CALLING SEQUENCE.
COMMON BLOCKS ..
RESTRICTIONS ...
CALLING SEQ. ... CALL MRFTBS (     )
  VARIABLE  TYPE  I/O  DIM    DESCRIPTION                        UNITS
  ------    ---   -   ------  ------------------------------     ------
PDI (PROGRAM OUTLINE)
  OPEN FIRST INPUT DATA SET    (I,1)
  OPEN FIRST OUTPUT DATA SET   (O,1)
  READ AND PROCESS NON-IMAGE RECORDS
  WRITE ID RECORD
  DO FOR EACH IMAGE RECORD
      READ ONE INPUT RECORD   (I,1)
      PROCESS INPUT DATA AND PLACE IT IN OUTPUT BUFFER
      INITIALIZE NON-IMAGE FIELDS IN OUTPUT BUFFER
      WRITE ONE OUTPUT RECORD  (O,1)
  ENDDO
  WRITE END-OF-TAPE RECORD
  CLOSE DATA SETS (I,1) AND (O,1)
  DO FOR EACH REMAINING INPUT DATA SET   (I,N)
      OPEN NEXT INPUT DATA SET     (I,N)
      OPEN LAST OUTPUT DATA SET    (O,N-1)  FOR INPUT
      OPEN NEXT OUTPUT DATA SET    (O,N)
      READ AND PROCESS NON-IMAGE RECORDS
      COPY ID RECORD FROM  (O,N-1)  TO  (O,N)
      DO FOR EACH IMAGE RECORD
          READ ONE INPUT RECORD   (I,N)
          READ ONE RECORD    (O,N-1)
          PROCESS INPUT DATA AND PLACE IT IN OUTPUT BUFFER
          WRITE ONE OUTPUT RECORD  (O,N)
      ENDDO
      WRITE END-OF-TAPE RECORD
      CLOSE DATA SETS  (I,N)  AND  (O,N-1)  AND  (O,N)
  ENDDO
******                    END OF SPECIFICATION                          ******
```

```
******       SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION        ******

NAME ........... MRFTXA

DESIGNER ....... STEPHEN W. MURPHREY

FUNCTION ....... READS AND PROCESSES X-FORMAT NON-IMAGE RECORDS.

INPUTS ......... 1. SEE CALLING SEQUENCE.

OUTPUTS ........ 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL MRFTXA (      )

  VARIABLE  TYPE  I/O  DIM    DESCRIPTION                       UNITS

  ------    ---    -  ------ -------------------------------    -------

PDL (PROGRAM OUTLINE)

  READ 40-BYTE ID RECORD FROM INPUT DATA SET
  READ 624-BYTE ANNOTATION RECORD FROM INPUT DATA SET
  DETERMINE FORMAT LEVEL
  PRINT FIELDS FROM ID RECORD:
      SCENE/FRAME ID
      CCT SEQUENCE NUMBER
      DATA RECORD LENGTH
      IAT IDENTIFICATION
      MSS ADJUSTED LINE LENGTH = LLA
      MSS DATA MODE/CORRECTION CODE
  PRINT FIELDS FROM ANNOTATION RECORD:
      DATE OF ACQUISITION
      FORMAT CENTER LATITUDE AND LONGITUDE
      NADIR LATITUDE AND LONGITUDE
      ORBIT DIRECTION
      NOMINAL PATH AND ROW
      SENSOR AND SPECTRAL BAND SPECIFIC INFORMATION
      DIRECT OR RECORDED TRANSMISSION
      SUN ELEVATION AND AZIMUTH ANGLES
      TYPE OF CORRECTIONS ON DATA
      SCALE OF IMAGE
      MAP PROJECTION
      RESAMPLING ALGORITHM
      PREDICTED OR DEFINITIVE EPHEMERIS DATA
      PROCESSING PROCEDURE
      EARTH IMAGE OR RBV CALIBRATION IMAGE
      SENSOR GAIN OPTIONS
      TYPE OF MSS TRANSMISSION
      TYPE OF MSS DATA PROCESSING
      FRAME IDENTIFICATION NUMBER
      NDPF IDENTIFICATION CODE
      DIRECT OR RECORDED MSS DATA
      MSS DATA ACQUISITION SITE
      TICK-MARK LOCATION DATA
  IF   THIS IS FROM FIRST STRIP   THEN
      WRITE ID DATA TO ANCILLARY DATA SET
      WRITE ANNOTATION DATA TO ANCILLARY DATA SET
  ENDIF

******                  END OF SPECIFICATION                        ******
```

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****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MRFTX

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... REFORMATS X-FORMAT DATA.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL MRFTX (   )

```
  VARIABLE  TYPE  I/O  DIM     DESCRIPTION                      UNITS
  ------    ---    -  ------   ------------------------------   -------
```

PDL (PROGRAM OUTLINE)

```
  OPEN FIRST INPUT DATA SET    (I,1)
  OPEN FIRST OUTPUT DATA SET   (O,1)
  READ AND PROCESS NON-IMAGE RECORDS
  WRITE ID RECORD
  DO FOR EACH IMAGE RECORD
      READ ONE INPUT RECORD    (I,1)
      PROCESS INPUT DATA AND PLACE IT IN OUTPUT BUFFER
      INITIALIZE NON-IMAGE FIELDS IN OUTPUT BUFFER
      WRITE ONE OUTPUT RECORD  (O,1)
  ENDDO
  WRITE END-OF-TAPE RECORD
  CLOSE DATA SETS (I,1) AND (O,1)
  DO FOR EACH REMAINING INPUT DATA SET    (I,N)
      OPEN NEXT INPUT DATA SET    (I,N)
      OPEN LAST OUTPUT DATA SET   (O,N-1)   FOR INPUT
      OPEN NEXT OUTPUT DATA SET   (O,N)
      READ AND PROCESS NON-IMAGE RECORDS
      COPY ID RECORD FROM   (O,N-1)   TO   (O,N)
      DO FOR EACH IMAGE RECORD
          READ ONE INPUT RECORD   (I,N)
          READ ONE RECORD    (O,N-1)
          PROCESS INPUT DATA AND PLACE IT IN OUTPUT BUFFER
          WRITE ONE OUTPUT RECORD   (O,N)
      ENDDO
      WRITE END-OF-TAPE RECORD
      CLOSE DATA SETS   (I,N)   AND   (O,N-1)   AND   (O,N)
  ENDDO
  READ AND PROCESS SLAT FILE
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MRFTBA

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... READS AND PROCESSES NON-IMAGE RECORDS FROM BSQ-FORMAT OR BIL-FORMAT TAPE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL MRFTBSA (   )

```
  VARIABLE  TYPE  I/O  DIM     DESCRIPTION                         UNITS

  ------    ---    -  ------  ------------------------------   -------
```

PDL (PROGRAM OUTLINE)

```
  DO UNTIL END-OF-DATA IS REACHED
      READ ONE NON-IMAGE RECORD
  ENDDO
  IF   THIS IS FIRST FILE OF INPUT TAPE   THEN
      PRINT DIRECTORY RECORD
      WRITE DIRECTORY DATA TO ANCILLARY DATA SET
  ELSE
      PRINT TRAILER RECORD
      WRITE TRAILER DATA TO ANCILLARY DATA SET
  ENDIF
  PRINT HEADER RECORD
  PRINT ANCILLARY RECORDS
  PRINT ANNOTATION RECORDS
  WRITE HEADER DATA TO ANCILLARY DATA SET
  WRITE ANCILLARY DATA TO ANCILLARY DATA SET
  WRITE ANNOTATION DATA TO ANCILLARY DATA SET
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MRFTBII

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... PROCESSES ONE LINE OF BSQ-FORMAT OR BIL-FORMAT IMAGE DATA.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL MRFTBI (   )

```
  VARIABLE  TYPE  I/O  DIM    DESCRIPTION                        UNITS
  ------    ---    -  ------ ------------------------------     -------
```

PDL (PROGRAM OUTLINE)

```
  MOVE IMAGE DATA INTO CURRENT-BAND AREA OF OUTPUT BUFFER
  IF   THIS IS PARTIALLY-PROCESSED DATA   THEN
      DO FOR EACH IMAGE PIXEL
          OBTAIN V = PIXEL VALUE
          INCREMENT V COUNTER FOR CURRENT DETECTOR BY 1
      ENDDO
  ENDIF
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MRFTBI

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... REFORMATS BIL-FORMAT DATA.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL MRFTBI (   )

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS

PDL (PROGRAM OUTLINE)

```
OPEN INPUT DATA SET
OPEN OUTPUT DATA SET
READ AND PROCESS NON-IMAGE RECORDS
WRITE ID RECORD
DO FOR EACH IMAGE LINE
    INITIALIZE NON-IMAGE FIELDS IN OUTPUT BUFFER
    DO   FOR EACH SPECTRAL BAND
        READ ONE INPUT RECORD
        PROCESS INPUT DATA AND PLACE IT IN OUTPUT BUFFER
    ENDDO
    WRITE ONE OUTPUT RECORD
ENDDO
WRITE END-OF-TAPE RECORD
CLOSE INPUT AND OUTPUT DATA SETS
```

****** END OF SPECIFICATION ******

B.4 AUTOMATIC CONTROL-POINT LOCATION PROGRAM

B.4.1 Statement of Problem

The objective of this program is to determine the locations of a set of control points in a Landsat MSS image. These locations are pixel coordinates in the high-frequency-corrected input space (see Figure B-6 in Section B.6). They are to be used as inputs to the Geometric Transformation Program.

In order to locate a particular control point in a given high-frequency-corrected input space, it is necessary to know the location of that control point in some high-frequency-corrected input space. A search area is defined to be a 128-by-128 pixel subimage of the given high-frequency-corrected input space. The control point is assumed to be contained in the search area, but its precise location within the search area is not known. A window is defined to be a 32-by-32 pixel subimage of a high-frequency-corrected input space. The control point is near the center of the window, and its location within the window is precisely known.

The Automatic Control-Point Location Program uses cross correlation to compare the window with all possible 32-by-32 pixel subimages of the search area. This results in a 97-by-97 array of regularly spaced points on a correlation surface. The location of the peak of the correlation surface represents the location of the control point. Therefore it is the function of this program to locate the peak of the correlation surface for each control point.

This program is required to determine control-point locations in an automatic process that requires no manual effort by the user.

B.4.2 Data Flow

The data flow through the Automatic Control-Point Location Program involves both image data and ancillary data. Windows and search areas are obtained and horizontally resampled to remove high-frequency errors, if necessary. Some ancillary parameters are used to determine locations of the search areas. The results from this program are added to the ancillary data set.

B.4.3 Program Description

The design of the Automatic Control-Point Location Program is described in Figure B-4, the eight program specifications that follow, and five of the program specifications from the Manual Control-Point Location Program.

```
               |---- ACPLCT
               |
               |---- ACPLSA
               |
               |                      |---- MCPLEX
               |                      |
               |---- ACPLRS ------|---- MCPLGP ----------- MCPLHF
               |                      |
ACPL ----      |                      |---- MCPLVR ----------- MCPLHR
               |
               |---- ACPLCS
               |
               |---- ACPLSF
               |
               |---- ACPLSP
               |
               |---- ACPLPQ
```

FIGURE B-4. MODULE HIERARCHY FOR AUTOMATIC CONTROL-POINT LOCATION PROGRAM.

```
******        SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION        ******

NAME ........... ACPL

DESIGNER ....... STEPHEN W. MURPHREY

FUNCTION ....... THIS IS THE TOP-LEVEL DRIVER FOR THE AUTOMATIC CONTROL POINT
                 LOCATION PROGRAM.

INPUTS ......... 1. CONTROL POINT LIBRARY COPY TAPE  OR  MIST-FORMAT TAPE.
                 2. AN SLDMS ANCILLARY DATA SET FOR THE SCENE TO BE PROCESSED.
                 3. A DATA SET CONTAINING USER'S REQUESTS ( ON CARD IMAGES ).

OUTPUTS ........ 1. THE UPDATED SLDMS ANCILLARY DATA SET.
                 2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... NOT APPLICABLE.

PDL (PROGRAM OUTLINE)

  PRINT PROGRAM-ENTRY MESSAGE
  READ USER'S REQUESTS
  IF  CONTROL-POINT WINDOWS COME FROM CPL COPY TAPE THEN
      EXTRACT 32-BY-32 PIXEL WINDOWS FROM CPL COPY TAPE INTO MEMORY
  ELSE
      RESAMPLE 32-BY-32 PIXEL WINDOWS FROM A MIST FORMAT TAPE INTO MEMORY
  ENDIF
  FIND INPUT-SPACE COORDINATES OF SEARCH AREAS
  RESAMPLE 128-BY-128 PIXEL SEARCH AREAS FROM THE MIST-FORMAT TAPE INTO MEMORY.
  OBTAIN 5-BY-5 CORRELATION SURFACE CENTERED AT NEAREST PIXEL TO EACH GCP.
  COEFFICIENTS OF DEGREE-4 LEAST SQUARES POLYNOMIAL FIT TO SURFACE OF EACH GCP.
  LOCATE PEAK OF EACH GCP SURFACE BY NEWTON'S METHOD.
  ESTIMATE QUALITY EACH GCP (VALUE OF SURFACE AND MINIMUM CURVATURE AT PEAK).
  WRITE RESULTS TO ANCILLARY DATA SET
  PRINT PROGRAM-EXIT MESSAGE

******                      END OF SPECIFICATION                           ******
```

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ACPLCT

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... EXTRACTS WINDOWS FROM A CONTROL POINT LIBRARY COPY TAPE

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL ACPLCT (   )

```
  VARIABLE  TYPE  I/O  DIM     DESCRIPTION                        UNITS
  ------    ---    -  ------  --------------------------------   -------
```

PDL (PROGRAM OUTLINE)

```
  SET $WRS AND $EOF FLAGS TO FALSE
  OPEN DIRECTORY FILE OF CPL COPY TAPE
  DO UNTIL   $WRS IS TRUE   OR   $EOF IS TRUE
      READ ONE DIRECTORY RECORD INTO BUFFER
      IF   A TAPE MARK WAS READ   THEN
          SET $EOF FLAG TO TRUE
          PRINT MESSAGE THAT SUITABLE CONTROL POINTS WERE NOT FOUND
      ENDIF
      IF   WRS ROW, WRS PATH, AND REGISTRATION TYPE ARE AS REQUESTED   THEN
          IF   A SPECIFIC LANDSAT MISSION WAS REQUESTED BY THE USER   THEN
              IF   LANDSAT MISSION IS AS REQUESTED BY THE USER   THEN
                  SET $WRS FLAG TO TRUE
              ENDIF
          ELSE
              SET $WRS FLAG TO TRUE
          ENDIF
      ENDIF
  ENDDO
  CLOSE DIRECTORY FILE OF CPL COPY TAPE
  IF   $WRS IS TRUE   THEN
      PRINT INFORMATION FROM CURRENT DIRECTORY RECORD
  ENDIF
  OPEN CONTROL-POINT FILE ON REEL 1 OF CPL COPY TAPE
  SET N = 1
  DO FOR EACH CONTROL-POINT POINTER PI
      K = PI - N
      DO WHILE   K > 0
          READ (SKIP) ONE CONTROL POINT RECORD
          IF   END-OF-DATA IS REACHED   THEN
              CLOSE CONTROL-POINT FILE ON CURRENT REEL OF CPL COPY TAPE
              OPEN CONTROL-POINT FILE ON NEXT REEL OF CPL COPY TAPE
              READ (SKIP) ONE CONTROL POINT RECORD
          ENDIF
          K = K - 1
          N = N + 1
      ENDDO
      READ ONE CONTROL POINT RECORD INTO MEMORY
      IF   END-OF-DATA IS REACHED   THEN
          CLOSE CONTROL-POINT FILE ON CURRENT REEL OF CPL COPY TAPE
          OPEN CONTROL-POINT FILE ON NEXT REEL OF CPL COPY TAPE
          READ ONE CONTROL POINT RECORD INTO MEMORY
      ENDIF
      N = N + 1
      PRINT ANCILLARY DATA FROM CONTROL POINT RECORD
  ENDDO
  CLOSE CURRENT CONTROL-POINT FILE
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ACPLSA

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... ESTIMATES THE LOCATIONS IN THE INPUT SPACE OF THE INPUT MAP CONTROL POINTS.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS .. ERTHCONS, MSSCONS

RESTRICTIONS ...

CALLING SEQ. ... CALL ACPLSA (NATEST, ATTTIM, AMSROL, AMSPIT, AMSYAW, NALEST, ALTTIM, AMSALT, AMSNLD, AMSNLN, DELVV, RNOMLL, NMCP, RLDR, RLNR, ELEV, BETANR, XEC, YEC, ZEC, VN, VAN, VCN, VELROT, VA, VC, CTPV, CTPH, ESTL, ESTS)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
NATEST	I*2	I	-	NUMBER OF AMS ATTITUDE VALUES	-
ATTTIM	R*8	I	NATEST	TIME OF ATTITUDE VALUES	SECONDS
ATTROL	R*8	I	NATEST	AMS ROLL VALUES	RADIANS
ATTPIT	R*8	I	NATEST	AMS ROLL VALUES	RADIANS
ATTYAW	R*8	I	NATEST	AMS ROLL VALUES	RADIANS
NALEST	I*2	I	-	NUMBER OF ALTITUDE VALUES	-
ALTTIM	R*8	I	NALEST	TIME OF ALTITUDE VALUES	SECONDS
AMSALT	R*8	I	NATEST	EPHEMERIS ALTITUDE VALUES	METERS
AMSNLD	R*8	I	-	NADIR GEOCENTRIC LATITUDE	RADIANS
AMSNLN	R*8	I	-	NADIR LONGITUDE	RADIANS
DELVV	R*8	I	-	NORMALIZED S/C VELOCITY ERROR	RADIANS
RNOMLL	R*8	I	-	NOMINAL LINE LENGTH IN INPUT	SAMPLES
NMCP	I*2	I	-	NUMBER OF INPUT MAP CONTROL POINTS	-
RLDR	R*8	I	NMCP	GEODETIC LATITUDE OF CP'S	RADIANS
RLNR	R*8	I	NMCP	LONGITUDE OF CP'S	RADIANS
ELEV	R*8	I	NMCP	ELEVATION OF CONTROL POINTS	METERS
BETANR	R*8	I	-	S/C HEADING ANGLE	RADIANS
XEC	R*8	I	NMCP	EARTH CENTERED X COORDINATE OF CP	METERS
YEC	R*8	I	NMCP	EARTH CENTERED Y COORDINATE OF CP	METERS
ZEC	R*8	I	NMCP	EARTH CENTERED Z COORDINATE OF CP	METERS
VN	R*8	I	-	EARTH ROTATION VELOCITY OF NADIR	MET/SEC
VAN	R*8	I	-	ALONG TRACK COMPONENT OF VN	MET/SEC
VCN	R*8	I	-	ACROSS TRACK COMPONENT OF VN	MET/SEC
VELROT	R*8	I	NMCP	EARTH ROTATION VEL OF CP'S	MET/SEC
VA	R*8	I	NMCP	ALONG TRACK COMPONENT OF VELROT	MET/SEC
VC	R*8	I	NMCP	ACROSS TRACK COMPONENT OF VELROT	MET/SEC
CTPV	R*8	I	NMCP	CTP VERTICAL COORDINATE OF CP'S	METERS
CTPH	R*8	I	NMCP	CTP HORIZONTAL COORDINATE OF CP'S	METERS
ESTL	R*8	I	NMCP	ESTIMATED LINE COORDINATE OF CP'S	II LINE
ESTS	R*8	I	NMCP	ESTIMATED SAMPLE COORDINATE	II SAMP

PDL (PROGRAM OUTLINE)

```
COMPUTE ATTITUDE / ALTITUDE MODELS FROM AMS DATA  <ADTAAMOD>
COMPUTE THE ANGLE BETA (S/C GROUND TRACK INCLINATION) <CPBETA>
COMPUTE THE EARTH CENTERED COORDINATES OF THE NADIR   <LLEC>
COMPUTE EARTH-ROTATION VELOCITY VECTORS AT THE NADIR  <VETHROT>
MAP THE INPUT CONTROL POINTS FROM LAT/LON TO EARTH CENTERED  (LLEC>
MAP THE INPUT CONTROL POINTS FROM EARTH CENTERED TO CTP  <ECCTP>
COMPUTE EARTH-ROTATIONAL VELOCTITY VECTORS FOR THE CONTROL POINTS
MAP THE INPUT CONTROL POINTS FROM CTP TO UTP  <CTPUTP>
MAP THE INPUT CONTROL POINTS FROM UTP TO II   <UTPII>
```

****** END OF SPECIFICATION ******

C-2

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ACPLRS

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... RESAMPLES 32-BY-32 OR 128-BY-128 PIXEL AREAS FROM A MIST-FORMAT MSS TAPE. THE ONLY CHANGE RESULTING FROM THE RESAMPLING IS THE REMOVAL OF HIGH-FREQUENCY, HORIZONTAL GEOMETRIC ERRORS.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL ACPLRS(   )

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS

PDL (PROGRAM OUTLINE)

```
  EXTRACT ALL SUBIMAGES TO COMPUTER MEMORY (MCPLEX).
  DO FOR EACH EXTRACTED SUBIMAGE.
     COMPUTE GRID-POINT CORRESPONDENCE AND OTHER CONSTANTS (MCPLGP).
     RESAMPLE SUBIMAGE CORRECTING ONLY HIGH-FREQUENCY ERRORS (MCPLVR).
  ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ACPLCS

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... COMPUTES 97-BY-97 CORRELATION SURFACE, AND FINDS THE PEAK THAT DETERMINES THE 5-BY-5 CORRELATION SURFACE THAT WILL BE USED TO LOCATE THE CONTROL POINT.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL ACPLCS(C,A)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
C	R*8	I	25X1	5-BY-5 CORRELATION MATRIX	-

PDL (PROGRAM OUTLINE)

```
DO FOR EACH CONTROL POINT.
    PLACE 32-BY-32 WINDOW IN THE CENTER OF A 128-BY-128 ARRAY.
    INITIALIZE ALL OTHER PIXELS IN THIS ARRAY TO ZERO.
    NORMALIZE WINDOW ARRAY BY SUBTRACTING WINDOW MEAN FROM EACH ELEMENT.
    CALCULATE THE VARIANCE OF THE WINDOW.
    CALCULATE 97-BY-97 ARRAY OF 32-BY-32 SEARCH-AREA VARIANCES.
    DO FOR EACH ROW OF 128-BY-128 SEARCH-AREA ARRAY.
        CALCULATE COOLEY-TUKEY FAST FOURIER TRANSFORM OF CURRENT ROW.
    ENDDO
    DO FOR EACH COLUMN OF 128-BY-128 TRANSFORMED SEARCH-AREA ARRAY.
        CALCULATE COOLEY-TUKEY FAST FOURIER TRANSFORM OF CURRENT COLUMN.
    ENDDO
    DO FOR EACH ROW OF 128-BY-128 WINDOW ARRAY.
        CALCULATE COOLEY-TUKEY FAST FOURIER TRANSFORM OF CURRENT ROW.
    ENDDO
    DO FOR EACH COLUMN OF 128-BY-128 TRANSFORMED WINDOW ARRAY.
        CALCULATE COOLEY-TUKEY FAST FOURIER TRANSFORM OF CURRENT COLUMN.
    ENDDO
    DOT PRODUCT: (SEARCH-AREA TRANSFORM) (COMPLEX-CONJUGATE WINDOW TRANSFORM)
    DO FOR EACH COLUMN OF 128-BY-128 PRODUCT ARRAY.
        CALC. COOLEY-TUKEY INVERSE FAST FOURIER TRANSFORM OF CURRENT COLUMN.
    ENDDO
    DO FOR EACH ROW OF 128-BY-128 TRANSFORMED PRODUCT ARRAY.
        CALCULATE COOLEY-TUKEY INVERSE FAST FOURIER TRANSFORM OF CURRENT ROW.
    ENDDO
    DO FOR CENTER 97-BY-97 ELEMENTS OF FINAL TRANSFORMED ARRAY.
        CORRELATION-SURFACE ELEMENT = REAL**2 / SAVARIANCE * 16384.
    ENDDO
    SET C = 5-BY-5 SUBMATRIX CENTERED AT MAXIMUM OF CORRELATION SURFACE.
ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ACPLSF

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... COMPUTES COEFFICIENTS OF A DEGREE 4 (15-TERM) LEAST-SQUARES POLYNOMIAL THAT FITS THE 5-BY-5 CORRELATION SURFACE. THIS IS DONE FOR EACH CONTROL POINT.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL ACPLSF(C,A)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
M	R*8	-	25X15	INTERNAL MATRIX	-
P	R*8	-	15X25	INTERNAL LEAST-SQUARES MATRIX	-
C	R*8	I	25X1	5-BY-5 CORRELATION MATRIX	-
A	R*8	O	15X1	POLYNOMIAL COEFFICIENT MATRIX	-

PDL (PROGRAM OUTLINE)

```
K = 1
DO FOR I = -2 TO 2 BY 1
    DO FOR J = -2 TO 2 BY 1
        M(K,1 ) = 1.
        M(K,2 ) = J
        M(K,3 ) =          I
        M(K,4 ) = J**2
        M(K,5 ) = J      * I
        M(K,6 ) =          I**2
        M(K,7 ) = J**3
        M(K,8 ) = J**2 * I
        M(K,9 ) = J      * I**2
        M(K,10) =          I**3
        M(K,11) = J**4
        M(K,12) = J**3 * I
        M(K,13) = J**2 * I**2
        M(K,14) = J      * I**3
        M(K,15) =          I**4
        K = K + 1
    ENDDO
ENDDO

P = ( M^T M )^-1 M^T          ( MATRIX EQUATION; P IS 15-BY-25 MATRIX )

DO FOR EACH CONTROL POINT.

    A = P C                   ( MATRIX EQUATION )

ENDDO
```

****** END OF SPECIFICATION ******

ORIGINAL PAGE IS
OF POOR QUALITY

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ACPLSP

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... COMPUTES LOCATION OF THE CORRELATION-SURFACE PEAK USING NEWTON'S METHOD.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

CALLING SEQ. ... CALL ACPLSP(C,A)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
NGCP	I*4	-	-	NUMBER OF CONTROL POINTS	-
F	R*8	-	2X1	1ST PARTIALS	-
S	R*8	-	2X1	FRACTIONAL CORRELATION PEAK COORDS.	-
N	R*8	-	2X2	2ND PARTIALS	-
IH	R*8	I	NGCP	INTEGER CORRELATION PEAK COORDINATE	-
IV	R*8	I	NGCP	INTEGER CORRELATION PEAK COORDINATE	-
WH	R*8	I	NGCP	WINDOW COORDINATE OF GCP FEATURE	-
WV	R*8	I	NGCP	WINDOW COORDINATE OF GCP FEATURE	-
H	R*8	O	NGCP	INPUT-SPACE GCP COORDINATE	-
V	R*8	O	NGCP	INPUT-SPACE GCP COORDINATE	-

PDL (PROGRAM OUTLINE)

```
DO FOR EACH CONTROL POINT L = 1 TO NGCP BY 1
    INITIALIZE X = Y = 0.
    DO FIVE TIMES.
        $F(1) = A_1 + 2A_3X + A_4Y + 3A_6X^2 + 2A_7XY + A_8Y^2 + 4A_{10}X^3 + 3A_{11}X^2Y + 2A_{12}XY^2 + A_{13}Y^3$
        $F(2) = A_2 + 2A_4X + A_5Y + 3A_7X^2 + 2A_8XY + A_9Y^2 + 4A_{11}X^3 + 3A_{12}X^2Y + 2A_{13}XY^2 + A_{14}Y^3$
        $N(2,2) = DF1DX = 2A_3 + 6A_6X + 2A_7Y + 12A_{10}X^2 + 6A_{11}XY + 12A_{12}Y^2$
        $N(1,2) = -DF1DY = -A_4 - 2A_7X - 2A_8Y - 3A_{11}X^2 - 4A_{12}XY - 3A_{13}Y^2$
        $N(2,1) = -DF2DX = -DF1DY$
        $N(1,1) = DF2DY = 2A_5 + 2A_8X + 6A_9Y + 2A_{12}X^2 + 6A_{13}XY + 12A_{14}Y^2$
        $D = 1. / ( DF1DX * DF2DY - DF1DY * DF2DX )$
        $S = S - D N F$          ( MATRIX EQUATION )
        $X = S(1)$
        $Y = S(2)$
    ENDDO
    $H(L) = S(1) + IH(L) + WH(L)$
    $V(L) = S(2) + IV(L) + WV(L)$
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ACPLPQ

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... COMPUTES ESTIMATES OF THE QUALITY OF THE CORRELATION-SURFACE PEAKS.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

CALLING SEQ. ... CALL ACPLPQ( )

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
NGCP	I*4	-	-	NUMBER OF CONTROL POINTS	-
MAXCOR	R*8	-	NGCP	VALUE OF SURFACE AT PEAK	-
MINCURV	R*8	-	NGCP	MINIMUM CURVATURE AT SURFACE PEAK	-
N	R*8	I	2X2	2ND PARTIALS	-
S	R*8	I	2X2	FRACTIONAL CORRELATION PEAK COORDS.	-

PDL (PROGRAM OUTLINE)

```
DO FOR EACH CONTROL POINT L = 1 TO NGCP BY 1
    R = DF1DX = N(2,2)
    S = DF1DY = -N(1,2)
    T = DF2DY = N(1,1)
    U = SQRT( (R-T)**2 + (2*S)**2 )
    MINCURV = ( R + T + U ) / 2.0
    X = S(1)
    Y = S(2)
    MAXCOR = $A_0 + A_1X + A_2Y + A_3X^2 + A_4XY + A_5Y^2 + A_6X^3 + A_7X^2Y + A_8XY^2 +$
             $A_9Y^3 + A_{10}X^4 + A_{11}X^3Y + A_{12}X^2Y^2 + A_{13}^{34}XY + A_{14}Y$
    PRINT RESULT
ENDDO
```

****** END OF SPECIFICATION ******

B.5 MANUAL CONTROL-POINT LOCATION PROGRAM

B.5.1 Statement of Problem

The objective of this program is to produce digital image data sets in which the scale has been changed or horizontal, high-frequency geometric errors have been removed. These two geometric changes are optional, and no other kinds of geometric changes will be performed.

The geometric changes are produced by resampling the digital image data using cubic convolution. The concept of resampling is discussed in detail in Section B.7. The algorithm described there is also used in this program. The scale change is required to be a digital enlargement by an integral factor (input-pixel spacing is an integral multiple of output-pixel spacing). This simplifies the resampling process and guarantees that output-pixel coordinates can easily be converted to input-pixel coordinates.

B.5.2 Data Flow

One pass through an input MIST-format data set is made by this program. During this pass, all subimages are extracted and stored in the computer's (virtual) memory. This obviously places some limit on the amount of data that may be processed. The program is designed to process a maximum of 100 subimages. The buffer that contains the input subimage data is obtained dynamically at execution time. Therefore, the effective maximum number of subimages depends on the amount of virtual memory available and the size of the subimages being processed. It will be fewer than 100 in some cases.

If histograms of the subimages have been requested by the user, input (unresampled) data will be used. These histograms may be used to generate character sets for the line-printer displays (shadeprints) of the subimages.

B.5.3 User-Specified Inputs to MCPL

The user-specified input parameters for MCPL are contained in a data set consisting of 80-byte records. This data set contains the following:

a. A FORTRAN NAMELIST

b. A shadeprint character set (optional)

c. One or more Subimage Descriptor Records.

These are described in Tables B-21, B-22, and B-23.

TABLE B-21. MCPL NAMELIST

PARAMETER	DESCRIPTION	UNITS	DEFAULT
NWID	WIDTH OF A SUBIMAGE	PIXELS	-
NLEN	LENGTH OF A SUBIMAGE	PIXELS	-
NSTRK	NUMBER OF OVERSTRIKES TO BE USED FOR SHADEPRINTS	-	4
BANDS	LIST OF SPECTRAL BANDS TO BE PROCESSED	-	1,2,3,4,5
$HIST	INDICATES THAT HISTOGRAMS OF SUBIMAGES ARE WANTED	-	F
$RDCHR	INDICATES THAT USER WILL SUPPLY SHADEPRINT CHARACTER SET	-	F
$SHDPT	INDICATES THAT SHADEPRINTS OF SUBIMAGES ARE WANTED	-	F
$RSPL	INDICATES THAT RESAMPLING WILL BE PERFORMED ON EACH SUBIMAGE	-	F
$HFCOR	INDICATES THAT HIGH-FREQUENCY HORIZONTAL ERRORS WILL BE CORRECTED	-	F
$ISUBW	INDICATES THAT A TAPE COPY OF UNCORRECTED SUBIMAGES WILL BE MADE	-	F
$OSUBW	INDICATES THAT A TAPE COPY OF RESAMPLED SUBIMAGES WILL BE MADE	-	F
HSPACO	HORIZONTAL SPACING BETWEEN PIXEL CENTERS OF RESAMPLED SUBIMAGE	METERS	-
VSPACO	VERTICAL SPACING BETWEEN PIXEL CENTERS OF RESAMPLED SUBIMAGE	METERS	-
HSPACI	HORIZONTAL SPACING BETWEEN PIXEL CENTERS OF INPUT IMAGE	METERS	-
VSPACI	VERTICAL SPACING BETWEEN PIXEL CENTERS OF INPUT IMAGE	METERS	-
HSCFAC	HORIZONTAL SCALE FACTOR = HSPACI/HSPACO	-	-
VSCFAC	VERTICAL SCALE FACTOR = VSPACI/VSPACO	-	-

TABLE B-22. SHADEPRINT CHARACTER SET

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
$CHAR	PRINTABLE CHARACTERS FOR PIXEL VALUES 0 - 63 USED FOR 1ST OVERSTRIKE	1 - 64	64C1
$CHAR	PRINTABLE CHARACTERS FOR PIXEL VALUES 64 - 127 USED FOR 1ST OVERSTRIKE	1 - 64	64C1
$CHAR	PRINTABLE CHARACTERS FOR PIXEL VALUES 128 - 191 USED FOR 1ST OVERSTRIKE	1 - 64	64C1
$CHAR	PRINTABLE CHARACTERS FOR PIXEL VALUES 192 - 255 USED FOR 1ST OVERSTRIKE	1 - 64	64C1
$CHAR	PRINTABLE CHARACTERS FOR PIXEL VALUES 0 - 63 USED FOR 2ND OVERSTRIKE	1 - 64	64C1
$CHAR	PRINTABLE CHARACTERS FOR PIXEL VALUES 64 - 127 USED FOR 2ND OVERSTRIKE	1 - 64	64C1
$CHAR	PRINTABLE CHARACTERS FOR PIXEL VALUES 128 - 191 USED FOR 2ND OVERSTRIKE	1 - 64	64C1
$CHAR	PRINTABLE CHARACTERS FOR PIXEL VALUES 192 - 255 USED FOR 2ND OVERSTRIKE	1 - 64	64C1
⋮	⋮	⋮	⋮

TABLE B-23. SUBIMAGE DESCRIPTOR RECORD

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
CENSAM	INPUT-SPACE HORIZONTAL COORDINATE OF CENTER PIXEL OF SUBIMAGE	1 - 5	I4
CENLIN	INPUT-SPACE VERTICAL COORDINATE OF CENTER PIXEL OF SUBIMAGE	6 - 10	I4
WIDTH	WIDTH OF SUBIMAGE IN PIXELS	11 - 15	I4
LENGTH	LENGTH OF SUBIMAGE IN PIXELS	16 - 20	I4
BANDS	LIST OF SPECTRAL BAND NUMBERS	21 - 25	5I1
TITLE	PRINTABLE TITLE FOR THE SUBIMAGE	26 - 72	47C1

The NAMELIST allows the user to define the functions to be performed and to specify certain constants. The shadeprint character set may be specified by the user, if desired. There must be a Subimage Descriptor Record for each subimage to be processed.

B.5.4 Program Description

The design of the Manual Control-Point Location Program is described in Figure B-5 and the program specifications that follow.

```
               |---- MCPLRD
               |
               |---- MCPLEX
               |
               |---- MCPLWI
               |
               |---- MCPLAH
               |
               |---- MCPLPH
MCPL ------|
               |---- MCPLCS
               |
               |---- MCPLGP ---------- MCPLHF
               |
               |---- MCPLVR ---------- MCPLHR
               |
               |---- MCPLWR
               |
               |---- MCPLPS
```

FIGURE B-5. MODULE HIERARCHY FOR MANUAL CONTROL-POINT LOCATION PROGRAM.

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPL

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS IS THE TOP LEVEL DRIVER FOR THE MANUAL CONTROL-POINT LOCATION PROGRAM.

INPUTS .... 1. A DATA SET CONTAINING USER'S REQUESTS (ON CARD IMAGES).
2. A MIST-FORMAT DATA SET

OUTPUTS .... 1. A PRINTER LISTING DATA SET.
2. MIST-FORMAT TAPE(S) CONTAINING EXTRACTED SUBIMAGES.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... NOT APPLICABLE.

PDL (PROGRAM OUTLINE)

```
PRINT SEPARATOR PAGE TO INDICATE START OF RUN.
READ USER'S REQUESTS AND INITIALIZE CONSTANTS AND ARRAYS.
EXTRACT ALL SUBIMAGES TO COMPUTER MEMORY.
IF   TAPE COPY OF EXTRACTED DATA WAS REQUESTED   THEN
    WRITE ALL EXTRACTED SUBIMAGES TO TAPE
ENDIF
DO FOR EACH EXTRACTED SUBIMAGE.
   IF   HISTOGRAM WAS REQUESTED   THEN
       ACCUMULATE HISTOGRAM DATA.
       PRINT HISTOGRAM STATISTICS.
   ENDIF
   IF   SHADEPRINT WAS REQUESTED   AND   CHARACTER SET NOT GIVEN   THEN
       CREATE A CHARACTER SET FROM THE HISTOGRAM.
   ENDIF
   IF   RESAMPLING WAS REQUESTED   THEN
       COMPUTE GRID-POINT CORRESPONDENCE AND OTHER CONSTANTS.
       RESAMPLE SUBIMAGE (CHANGING SCALE OR CORRECTING HIGH-FREQUENCY ERRORS)
       IF   TAPE COPY OF RESAMPLED DATA WAS REQUESTED   THEN
           WRITE RESAMPLED DATA SET TO TAPE.
       ENDIF
   ENDIF
   IF   SHADEPRINT WAS REQUESTED   THEN
       DO FOR EACH REQUESTED SPECTRAL BAND
           PRINT THE SHADEPRINT.
       ENDDO
   ENDIF
ENDDO
PRINT SEPARATOR PAGE TO INDICATE END OF RUN.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLEX

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... EXTRACTS ALL SUBIMAGES FROM INPUT MIST-FORMAT DATA SET

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

CALLING SEQ. ... CALL MCPLEX (CHGFLG,CHGLIN,SUBPTR,LINPTR,MAXLIN,TBYTES,NUMSUB)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
CHGFLG	I*2	O	2X200	SUBIMAGE INDEX / CHANGE TYPE	-------
CHGLIN	I*4	O	200	LINE NUMBER OF CORRESP. CHANGE	PIXELS
SUBPTR	I*4	O	100	ADDRESS OF SUBIMAGE IN BUFFER	-------
LINPTR	I*4	O	100	ADDRESS OF NEXT LINE IN BUFFER	-------
MAXLIN	I*4	O	-	NUMBER OF INPUT RECORDS TO USE	-------
TBYTES	I*4	O	-	SIZE OF BUFFER	BYTES
NUMSUB	I*4	O	-	NUMBER OF SUBIMAGES TO EXTRACT	-------

PDL (PROGRAM OUTLINE)

```
OBTAIN VIRTUAL MEMORY FOR SUBIMAGE BUFFER ( GETMAIN ).
DO FOR EACH SUBIMAGE ( N = 1,NUMSUB )
    SUBPTR(N) = SUBPTR(N) + ADDRESS OF BUFFER
    LINPTR(N) = SUBPTR(N)
ENDDO
OPEN INPUT MIST-FORMAT DATA SET
READ CONTROL RECORD
SET LINE#, NLIVE TO 0
DO WHILE  LINE# < MAXLIN
    LINE# = LINE# + 1
    READ ONE IMAGE RECORD
    UPDATE ARRAYS THAT CONTROL PROCESSING CHANGES
    DO WHILE PROCESS CHANGES AT THIS LINE
        IF   A SUBIMAGE BEGINS   THEN
            NLIVE = NLIVE + 1
            COPY ELEMENT FROM CHGFLG ARRAY TO BOTTOM OF SEQLST ARRAY
        ELSE
            FIND ELEMENT OF SEQLST ARRAY THAT IS NO LONGER NEEDED.
            COPY BOTTOM SEQLST ELEMENT INTO VACANT SPOT.
            NLIVE = NLIVE - 1
        ENDIF
        INCREMENT RELATIVE POINTER TO NEXT ELEMENT OF CHANGE ARRAYS.
        K = NLIVE
        DO WHILE  K > 0
            MOVE LINE NUMBER INTO SUBIMAGE BUFFER ( 2 BYTES ).
            MOVE 2 BYTES OF ZERO FILL INTO SUBIMAGE BUFFER.
            DO FOR EACH SPECTRAL BAND
                MOVE IMAGE DATA INTO SUBIMAGE BUFFER.
                MOVE 6 BYTES OF ZERO FILL INTO SUBIMAGE BUFFER.
            ENDDO
    MOVE INPUT IMAGE DATA INTO BUFFER UNDER CONTROL OF ARRAYS
ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLRD

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... READS USER'S REQUESTS AND INITIALIZES CONSTANTS AND ARRAYS

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

CALLING SEQ. ... CALL MCPLRD (CHGFLG,CHGLIN,BANDS,LFTSAM,LINPTR,LENGTH,WIDTH,
RECLEN,SUBPTR,TOPLIN,$TITLE,DEFALT,$FLAGS)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
CHGFLG	I*2	O	2X200	SUBIMAGE INDEX / CHANGE TYPE	-------
CHGLIN	I*4	O	200	LINE NUMBER OF CORRESP. CHANGE	PIXELS
BANDS	I*4	O	100	EACH BIT IS FLAG FOR THAT BAND	-------
LFTSAM	I*4	O	100	COORDINATE OF LEFT SAMPLE	PIXELS
LINPTR	I*4	O	100	ADDRESS OF NEXT LINE IN BUFFER	-------
LENGTH	I*4	O	100	VERTICAL SIZE OF SUBIMAGE	PIXELS
WIDTH	I*4	O	100	HORIZONTAL SIZE OF SUBIMAGE	PIXELS
RECLEN	I*4	O	100	LENGTH OF ONE SUBIMAGE RECORD	BYTES
SUBPTR	I*4	O	100	ADDRESS OF SUBIMAGE IN BUFFER	-------
TOPLIN	I*4	O	100	COORDINATE OF TOP LINE	PIXELS
$TITLE	L*1	O	47X100	TITLE OF SUBIMAGE	-------
DEFALT	I*4	O	10	VARIOUS DEFAULT VALUES	-------
$FLAGS	L*4	O	7	VARIOUS PROCESSING FLAGS	-------

PDL (PROGRAM OUTLINE)

```
SET DEFAULT VALUES FOR USER'S OPTIONS.
READ USER'S OPTIONS
IF   SHADEPRINTS WERE REQUESTED   THEN
     COUNT THE (DEFAULT) NUMBER OF SPECTRAL BANDS TO BE SHADEPRINTED
     IF   SHADEPRINT CHARACTER SET IS SUPPLIED BY THE USER   THEN
          READ THE CHARACTER SET.
          PRINT THE CHARACTER SET.
     ENDIF
ENDIF
INITIALIZE N, MAXLIN, SUBPTR(1), LINPTR(1) TO 0
DO UNTIL END-OF-DATA IS REACHED ON CARD-IMAGE INPUT DATA SET
     N = N + 1
     READ ONE SUBIMAGE-DESCRIPTOR CARD.
     IF   END-OF-DATA WAS NOT REACHED   THEN
          IF   WIDTH(N), LENGTH(N), OR BANDS(N) WERE NOT GIVEN THEN
               USE THE APPROPRIATE DEFAULT VALUE(S) FOR THOSE NOT GIVEN
          ENDIF
          SET SPECTRAL-BAND FLAGS (IN ARRAY ELEMENT) ACCORDING TO BAND LIST.
          TOPLIN (N) = MAXIMUM( 1 , CENLIN - LENGTH(N)/2 )
          LFTSAM (N) = MAXIMUM( 1 , CENLIN - WIDTH(N)/2 )
          SET BOTH INDICES IN CHGFLG ARRAY TO  4 * N - 4
          CHGLIN (1,N)  = TOPLIN(N)
          CHGLIN (1,N)  = TOPLIN(N)  + LENGTH(N)
          RECLEN (N)    = 4 + ( WIDTH(N) + 6 ) * NBANDS
          SUBPTR (N+1)  = SUBPTR(N)  + RECLEN(N)  * LENGTH(N)
          LINPTR (N+1)  = SUBPTR(N+1)
          MAXLIN        = MAXIMUM( MAXLIN , TOPLIN(N) + LENGTH(N) - 1 )
     ENDIF
     N = N - 1
ENDDO
TOTAL BYTES IN BUFFER = SUBPTR(N+1)
SORT BOTH CHANGE ARRAYS SO THAT THEY ARE IN ASCENDING ORDER OF CHGLIN ARRAY.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLWI

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... WRITES ALL EXTRACTED SUBIMAGES TO A SINGLE COMPUTER TAPE

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

CALLING SEQ. ... CALL MCPLWI (BANDS,LENGTH,RECLEN,SUBPTR,IDREC)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
BANDS	I*4	I	100	EACH BIT IS FLAG FOR THAT BAND	-------
LENGTH	I*4	I	100	VERTICAL SIZE OF SUBIMAGE	PIXELS
RECLEN	I*4	I	100	LENGTH OF ONE SUBIMAGE RECORD	BYTES
SUBPTR	I*4	I	100	ADDRESS OF SUBIMAGE IN BUFFER	-------
IDREC	I*4	I	200	ID RECORD FROM INPUT DATA SET	-------

PDL (PROGRAM OUTLINE)

```
INITIALIZE FIELDS IN ID-RECORD BUFFER:
    RUN NUMBER
    CONTINUATION CODE
    FLIGHT-LINE ID
    MONTH, DAY, YEAR, & TIME DATA WAS TAKEN
    ALTITUDE OF PLATFORM
    HEADING OF VEHICLE
    DATE OF THIS TAPE
DO FOR EACH EXTRACTED SUBIMAGE ( I = 1,NUMSUB ).
    OPEN OUTPUT TAPE DATA SET FOR FILE I.
    FILL IN REMAINING FIELDS IN ID-RECORD BUFFER:
        LARS TAPE NUMBER
        FILE NUMBER
        NUMBER OF DATA CHANNELS
        NUMBER OF SAMPLES PER CHANNEL
        NUMBER OF LINES IN THE IMAGE
        WAVELENGTH RANGE OF EACH SPECTRAL BAND
    WRITE THE ID RECORD ONTO THE TAPE.
    OBTAIN THE ADDRESS OF THE SUBIMAGE DATA FROM THE SUBPTR ARRAY.
    OBTAIN THE WIDTH OF ONE RECORD FROM THE RECLEN ARRAY.
    DO FOR EACH LINE IN THE SUBIMAGE.
        WRITE THE CURRENT IMAGE RECORD ONTO THE TAPE.
        INCREMENT ADDRESS OF SUBIMAGE DATA BY THE WIDTH OF ONE RECORD.
    ENDDO.
    CLOSE THE OUTPUT TAPE DATA SET.
ENDDO.
OPEN THE OUTPUT TAPE DATA SET FOR FILE  NUMSUB + 1.
SET FIELDS IN THE END-OF-TAPE-RECORD BUFFER:
    LARS TAPE NUMBER
    FILE NUMBER
    CONTINUATION CODE
WRITE THE END-OF-TAPE RECORD ONTO THE TAPE.
CLOSE THE OUTPUT TAPE DATA SET.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLAH

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... ACCUMULATES HISTOGRAM DATA FOR A SINGLE EXTRACTED SUBIMAGE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

CALLING SEQ. ... CALL MCPLAH (BANDS,LENGTH,RECLEN,SUBPTR,HIST)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
BANDS	I*4	I	100	EACH BIT IS FLAG FOR THAT BAND	-------
LENGTH	I*4	I	100	VERTICAL SIZE OF SUBIMAGE	PIXELS
RECLEN	I*4	I	100	LENGTH OF ONE SUBIMAGE RECORD	BYTES
SUBPTR	I*4	I	100	ADDRESS OF SUBIMAGE IN BUFFER	-------
HIST	I*4	O	256X5	HISTOGRAM ARRAY	-------

PDL (PROGRAM OUTLINE)

```
ZERO THE HISTOGRAM ARRAY.
INITIALIZE THE DATA POINTER.
DO FOR EACH LINE IN THE SUBIMAGE.
    INITIALIZE POINTER TO THE BAND-1 HISTOGRAM ARRAY.
    INITIALIZE POINTER TO THE BAND-1 DATA ARRAY.
    DO FOR EACH SPECTRAL BAND.
        DO FOR EACH PIXEL IN THE LINE.
            OBTAIN THE PIXEL VALUE  V.
            INCREMENT HISTOGRAM-ARRAY-ELEMENT V BY 1.
        ENDDO.
        INCREMENT HISTOGRAM POINTER TO THE NEXT BAND
        INCREMENT DATA POINTER TO THE NEXT BAND
    ENDDO.
    INCREMENT DATA POINTER TO THE NEXT LINE.
ENDDO.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLPH

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... PRINTS HISTOGRAMS AND THE RESULTING STATISTICAL PARAMETERS FOR ALL BANDS OF A SINGLE EXTRACTED SUBIMAGE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

CALLING SEQ. ... CALL MCPLPH (BANDS,HIST,CUMPCT)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
BANDS	I*4	I	100	EACH BIT IS FLAG FOR THAT BAND	-------
HIST	I*4	I	256X5	HISTOGRAM	-------
CUMPCT	R*4	O	256X5	CUMULATIVE HISTOGRAM	PERCENT

PDL (PROGRAM OUTLINE)

```
  DO FOR EACH SPECTRAL BAND.
      FIND SMALLEST PIXEL VALUE THAT OCCURS IN THIS BAND.
      FIND LARGEST PIXEL VALUE THAT OCCURS IN THIS BAND.
      COMPUTE THE TOTAL NUMBER OF PIXELS IN THIS BAND.
      INITIALIZE THE CUMPCT ARRAY TO ZEROS.
      INITIALIZE MENTOT, RMSTOT, & C ARRAYS TO ZEROS.
  ENDDO
  DO FOR EACH SPECTRAL BAND ( B ).
      DO FROM K = 1 TO 256 BY 1
          HISPCT(K,B)   =  HIST(K,B) * 100. / TOTAL(B)
          C(B)          =  C(B) + HIST(K,B)
          CUM(K,B)      =  C(B)
          CUMPCT(K,B)   =  CUM(K,B) * 100. / TOTAL(B)
          IF   HISPCT(K,B) > HISPCT(MODE(B),B)   THEN
              MODE(B)   =  K
          ENDIF
          IF   CUMPCT(K,B) < 50.   THEN
              MEDIAN(B) = K
          ENDIF
          MENTOT(B)     =  MENTOT(B) + (K-1) * HIST(K,B)
          RMSTOT(B)     =  RMSTOT(B) + (K-1)**2 * HIST(K,B)**2
      ENDDO
      MEAN(B)    =  MENTOT(B) / TOTAL(B)
      RMS(B)     =  SQRT( RMSTOT(B) / TOTAL(B) )
      STDEV(B)   =  SQRT( RMS(B)**2 - MEAN(B)**2 )
      MEDIAN(B)  =  MEDIAN(B) - 1
      MODE(B)    =  MODE(B) - 1
      SUM = 0
      DO FROM K = MINIMUM VALUE TO MAXIMUM VALUE BY 1
          SUM    = SUM + HIST(K,B)
          COUNT  = MAXIMUM( 1 , HIST(K,B) )
          L      = MAXIMUM( 1 , 10. * LOG10(COUNT) + .5 )
          PRINT  K-1 , HIST(K,B) , SUM , HISPCT(K,B) , CUMPCT(K,B) ,
                 LINES(1,L) , LINES(2,L) , ... , LINES(10,L)
      ENDDO.
      PRINT  B , NUMBANDS , MEAN(B) , STDEV(B) , RMS(B) , MEDIAN(B) , MODE(B)
  ENDDO.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLCS

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... CREATES CHARACTER SETS (BASED ON HISTOGRAMS) FOR ALL BANDS OF A SINGLE EXTRACTED SUBIMAGE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

CALLING SEQ. ... CALL MCPLCS (BANDS,$CHAR,CUMPCT)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
BANDS	I*4	I	100	EACH BIT IS FLAG FOR THAT BAND	-------
$CHAR	L*1	O	256X5	SHADEPRINT CHARACTER SETS	-------
CUMPCT	R*4	I	256X5	CUMULATIVE HISTOGRAM	PERCENT

PDL (PROGRAM OUTLINE)

```
DO FOR EACH SPECTRAL BAND.
    DO FROM I=1 TO 256 BY 1
        INDEX = MINIMUM(  16   ,   1 + 16. * CUMPCT(I) / 100.   )
        DO FOR EACH STRIKE ( S ).
            $CHAR(I,S) = PRINT(INDEX,S)
        ENDDO.
        IF   INDEX DOES NOT EQUAL I   THEN
            PRINT  K-1 , PRINT(INDEX,1) , PRINT(INDEX,2) , ...
        ENDIF.
    ENDDO.
ENDDO.
```

****** END OF SPECIFICATION ******

****** SAP/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLGP

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS MODULE COMPUTES THE GRID-POINT LOCATIONS AND OTHER CONSTANTS FOR THE RESAMPLING PORTION OF THE MANUAL CONTROL-POINT LOCATION PROGRAM. CORRECTIONS FOR HIGH-FREQUENCY, HORIZONTAL MSS GEOMETRIC ERRORS ARE INCORPORATED INTO THE GRID-POINT LOCATIONS.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... MCPLGP( )

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
LENGTH	I*4	I	-	LENGTH OF INPUT-SPACE SUBIMAGE	PIXELS
WIDTH	I*4	I	-	WIDTH OF INPUT-SPACE SUBIMAGE	PIXELS
LFTSAM	I*4	I	-	COORDINATE OF LEFT SAMPLE	PIXELS
HSFAC	I*4	I	-	HORIZONTAL SCALE FACTOR	PIXELS
VSFAC	I*4	I	-	VERTICAL SCALE FACTOR	PIXELS
OLEN	I*4	O	-	LENGTH OF OUTPUT SPACE	PIXELS
OWID	I*4	O	-	WIDTH OF OUTPUT SPACE	PIXELS
I	I*4	O	-	NUMBER OF GRID-POINT SEGMENTS	PIXELS
N	I*4	O	I	# HYB.-SP. POINTS IN A SEGMENT	PIXELS
DH	R*4	O	I	INPUT-SPACE DISTANCE BETWEEN ADJACENT PIXELS IN A SEGMENT	PIXELS
H	R*4	O	IX26	GRID-POINT COORDINATES	PIXELS
D	I*4	O	VSFAC	VERTICAL RESAMPLING DISPLACEMENTS	PIXELS

PDL (PROGRAM OUTLINE)

```
DO FROM M = 1 TO VSFAC BY 1
    D(M) = ( M - 1 ) / VSFAC
ENDDO
OLEN = VSFAC * ( LENGTH - 3 )
OWID = HSFAC * ( WIDTH - 3 )
ISWID = G( 50 / HSFAC )
OSWID = ISWID * HSFAC
I = 1
C = 1.0
DO WHILE C LESS THAN OR EQUAL TO  WIDTH - 2
    DO FOR EACH DETECTOR ( J = 1 TO 26 BY 1 )
        IF   HIGH-FREQUENCY CORRECTION WAS REQUESTED   THEN
            COMPUTE F( J , C + LFTSAM ) = HIGH-FREQUENCY CORRECTED COORD.
            H(I,J) = F( J , C+LFTSAM ) - LFTSAM
        ELSE
            H(I,J) = C
        ENDIF
    ENDDO
    NIPIX = MINIMUM( ISWID , WIDTH - 3 - C )
    N(I) = NIPIX * HSFAC
    DH(I) = NIPIX / N(I)
    I = I + 1
    C = DH(M) + NIPIX
ENDDO
I = I - 1
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLHF

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS MODULE CORRECTS HORIZONTAL COORDINATES FOR HIGH-FREQUENCY GEOMETRIC ERRORS. IT CONVERTS A HIGH-FREQUENCY-CORRECTED COORDINATE TO AN UNCORRECTED-INPUT-SPACE COORDINATE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... MCPLHF(HFC,LLF,DET,UIS)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
HFC	R*4	I	-	HIGH-FREQUENCY-CORRECTED COORD.	PIXELS
LLF	R*4	I	-	LINE-LENGTH FACTOR	-------
DET	I*4	I	-	DETECTOR NUMBER	-------
UIS	R*4	O	-	UNCORRECTED-INPUT-SPACE COORD.	PIXELS

PDL (PROGRAM OUTLINE)

```
IF   THIS IS FIRST EXECUTION OF THIS MODULE   THEN
    COMPUTE COEFFICIENTS OF CORRECTION POLYNOMIALS.
ENDIF
EVALUATE CORRECTION POLYNOMIAL FOR THIS DETECTOR.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLVR

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS MODULE PERFORMS VERTICAL RESAMPLING AS PART OF THE MANUAL CONTROL-POINT LOCATION PROGRAM.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... MCPLVR( )

PDL (PROGRAM OUTLINE)

```
  ADD FIRST FOUR LINES TO THE HYBRID-SPACE BUFFER.
  INITIALIZE THE FOUR POINTERS TO THE HYBRID-SPACE BUFFER.
  DO FOR EACH HYBRID-SPACE LINE.
      DO FROM I = 1 TO K BY 1  ( K = VERTICAL-SCALE-INCREASE FACTOR )
          DO FOR EACH SPECTRAL BAND.
              DO FOR EACH OUTPUT SPACE PIXEL ( IN ONE LINE )
                  PERFORM CUBIC CONVOLUTION USING D(I)
                  INCREMENT HYBRID-SPACE POINTERS BY 1
              ENDDO
              INCREMENT HYBRID-SPACE POINTERS TO NEXT SPECTRAL BAND.
          ENDDO
          WRITE ONE LINE OF OUTPUT DATA.
      ENDDO
      ADD NEXT HYBRID-SPACE LINE TO HYBRID-SPACE BUFFER.
      RESET THE FOUR POINTERS TO THE HYBRID-SPACE BUFFER.
  ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLHR

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS MODULE PERFORMS HORIZONTAL RESAMPLING AS PART OF THE MANUAL CONTROL-POINT LOCATION PROGRAM. GRID POINTS HAVE BEEN CORRECTED FOR HIGH-FREQUENCY, HORIZONTAL GEOMETRIC ERRORS.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... MCPLHR( )

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
I	I*4	I	-	NUMBER OF GRID-POINT SEGMENTS	-------
N	I*4	I	I	# HYB.-SP. POINTS IN A SEGMENT	-------
DH	R*4	I	I	INPUT-SPACE DISTANCE BETWEEN ADJACENT PIXELS IN A SEGMENT	-------
H	R*4	I	IX26	GRID-POINT COORDINATES	-------

PDL (PROGRAM OUTLINE)

```
DO FOR EACH SPECTRAL BAND.
    INITIALIZE POINTER TO JTH SET OF GRID-POINT COORDINATES.
    DO FOR EACH GRID-POINT SEGMENT ( M = 1 TO I BY 1 ).
        G( * ) = GREATEST INTEGER NOT LARGER THAN *
        D = H(M,J) - G( H(M,J) )
        H = H(M,J)
        P = POINTER TO INPUT-SPACE-BUFFER PIXEL G( H(M,J) ) - 1
        DO FOR EACH HYBRID-SPACE PIXEL IN CURRENT GRID-POINT SEGMENT.
            PERFORM CUBIC CONVOLUTION USING D.
            D = D + DH(M)
            DO WHILE D >= 1.0
                D = D - 1.0
                P = P + 1
            ENDDO
        ENDDO
    ENDDO
ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MCPLPS

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... PRINTS A SHADEPRINT OF A SINGLE SUBIMAGE THAT RESIDES IN THE (VIRTUAL) MEMORY OF THE COMPUTER.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. A PRINTER LISTING DATA SET.

CALLING SEQ. ... CALL MCPLPS (BAND,NSTRKS,OFFSET,SUBINFAD,CHARSAD)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
BAND	I*4	I	-	SPECTRAL BAND NUMBER	-------
NSTRKS	I*4	I	-	NUMBER OF STRIKES TO BE PRINTED	-------
OFFSET	I*4	I	-	OFFSET INTO SUBIMAGE ARRAYS	BYTES
SUBINFAD	I*4	I	-	POINTER TO SUBIMAGE ARRAYS	-------
CHARSAD	I*4	I	-	POINTER TO CHARACTER-SET	-------

PDL (PROGRAM OUTLINE)

```
  INITIALIZE AND SAVE POINTER TO THE SHADEPRINT CHARACTER SET.
  INITIALIZE AND SAVE POINTER TO THE IMAGE DATA.
  INITIALIZE AND SAVE POINTER TO THE TITLE.
  INITIALIZE LEFTSAMPLE AND RIGHTSAMPLE-1 POINTERS
  DO FROM LEFTSAMPLE TO RIGHTSAMPLE-1 BY 120
      PRINT HEADINGS AND SAMPLE NUMBERS ACROSS TOP OF LISTING.
      INITIALIZE LINE COUNTER
      INITIALIZE "FRCM" PCINTER
      INITIALIZE THE POINTER TO THE SHADEPRINT CHARACTER SET.
      BLANK OUT THE PRINT BUFFER
      DO FOR EACH LINE IN THE SUBIMAGE.
          PLACE THE LINE NUMBER IN THE LEFT AND RIGHT EDGES OF THE PRINT BUFFER.
          SET THE CARRIAGE-CONTROL CHARACTER TO A BLANK.
          DO FOR EACH STRIKE.
              MOVE AND TRANSLATE THE IMAGE DATA INTO THE PRINT BUFFER.
              PRINT THE DATA IN THE PRINT BUFFER.
              SET THE CARRIAGE-CONTROL CHARACTER TO A +.
              INCREMENT THE POINTER TO THE SHADEPRINT CHARACTER SET.
          ENDDO
          PRINT SAMPLE NUMBERS ACROSS THE BOTTOM OF THE LISTING.
  ENDDO.
```

****** END OF SPECIFICATION ******

B.6 GEOMETRIC TRANSFORMATION PROGRAM

B.6.1 Statement of Problem

The objective of this program is to determine the mathematical transformation between two MSS image spaces. In particular, this program must produce data that controls the operation of the Resampling Program.

The transformation is always between an input-image space and a resampled-image space. The input space can represent either an uncorrected or a previously resampled, image data set. There are four cases to be considered:

a. Scene processing (with GCPs) of uncorrected or partially processed MSS data.

b. Systematic processing (no GCPs) of uncorrected or partially processed MSS data.

c. Completion processing of partially processed MSS data.

d. Scale/orientation change of fully processed data.

In the case of scene processing, a geometric error assessment from the geometric error models is also computed. In each case, the geometric transformation is specified in tabular form. It consists of input-space grid points (used for horizontal resampling) and hybrid-space grid points used for vertical resampling.

If the input data is uncorrected or partially processed MSS data, there are three image spaces involved in determining the geometric transformation:

a. Input space -- MSS data that has not been geometrically corrected or resampled in any way.

b. High-frequency-corrected input space -- MSS data that has been horizontally resampled to remove all known high-frequency horizontal geometric errors.

c. Corrected output space -- MSS data (at a user-specified scale and orientation) that has been resampled to remove all known geometric errors.

The transformations between these image spaces are illustrated in Figure B-6. The geometric transformation to be determined by this program is a tabular representation of the function H of Figure B-6.

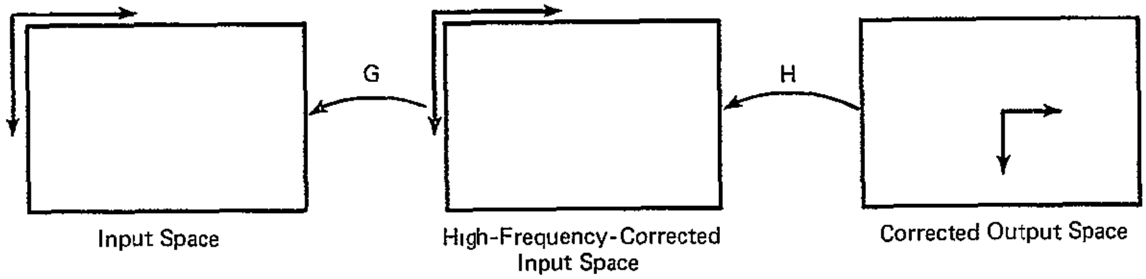

Figure B-6. Image Spaces

If the input data is fully processed MSS data, there are only two image spaces involved in determining the geometric transformation:

a. Fully processed input space -- MSS data that has been resampled to remove all known geometric errors.

b. Corrected output space -- MSS data at a user-specified scale and orientation.

The transformation between these image spaces is a tabular representation of a straightforward rotation and scale change.

B.6.2 Data Flow

The only data used by the Geometric Transformation program is ancillary in nature. This data comes from either the Ancillary data set or the User-Request Data Set. The resulting transformation is written into the Ancillary Data Set for use by the Reformatting program.

B.6.3 Program Description

The design of the Geometric Transformation Program is described in Figure B-7 and the program specifications that follow.

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OF POOR QUALITY

```
                  |---- GTRANC
                  |---- GTRURQ
                  |                  |---- IIUTP
                  |                  |---- MAPLL
                  |                  |---- LLEC
                  |---- GTERMD ------|---- ECCTP
                  |                  |---- DELTAS
                  |                  |---- AAFIT
                  |                  |---- AAFIT2 ---------- ADTAA
                  |
                  |                  |---- CTPEC
                  |                  |---- ECLL
                  |---- GTOSDF ------|---- ILMAP
GTRN -----|                          |---- MAPOI
                  |
                  |                  |---- INITOS
                  |                  |---- OIMAP
                  |                  |---- MAPLL
                  |                  |---- LLEC
                  |---- GTGDPT ------|---- ECCTP
                  |                  |---- CTPUTP
                  |                  |---- UTPII
                  |                  |---- IIUTP
                  |                  |---- UTPCTP
                  |---- GTERAS
                  |---- GTWANC
```

FIGURE B-7. MODULE HIERARCHY FOR GEOMETRIC TRANSFORMATION PROGRAM.

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... GTRN

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS IS THE TOP LEVEL DRIVER FOR THE LANDSAT MSS GEOMETRIC TRANSFORMATION PROGRAM.

INPUTS .... 1. AN SLDMS ANCILLARY DATA SET FOR THE SCENE TO BE PROCESSED.
2. A DATA SET CONTAINING USER'S REQUESTS (ON CARD IMAGES).

OUTPUTS .... 1. THE UPDATED SLDMS ANCILLARY DATA SET.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... NOT APPLICABLE.

PDL (PROGRAM OUTLINE)

```
PRINT SEPARATOR PAGE TO INDICATE START OF RUN.
READ USER'S REQUESTS.
READ ANCILLARY DATA SET TO INITIALIZE DATA AREAS.
CASENTRY
    CASE 1: SCENE PROCESSING OR SYSTEM PROCESSING.
        PERFORM ERROR MODELING (ATTITUDE/ALTITUDE FIT).
        DEFINE THE OUTPUT SPACE.
        CREATE INTERPOLATION GRID POINTS ( FROM ERROR MODELS ).
        PERFORM ERROR ASSESSMENT ( FROM ERROR MODELS ).
        WRITE GRID POINT CORRESPONDENCE TO ANCILLARY DATA SET.
    CASE 2: COMPLETION PROCESSING.
        DEFINE THE OUTPUT SPACE.
        CREATE INTERPOLATION GRID POINTS ( FROM INPUT HRS/VRS COORDINATES ).
        PERFORM ERROR ASSESSMENT ( FROM INPUT ANCILLARY DATA ).
        WRITE GRID POINT CORRESPONDENCE TO ANCILLARY DATA SET.
    CASE 3: SCALE/ORIENTATION CHANGE.
        DEFINE THE OUTPUT SPACE.
        CREATE INTERPOLATION GRID POINTS ( BASED ON SCALE AND ORIENTATION ).
        PERFORM ERROR ASSESSMENT ( FROM INPUT ANCILLARY DATA ).
        WRITE GRID POINT CORRESPONDENCE TO ANCILLARY DATA SET.
ENDCASE
PRINT SEPARATOR PAGE TO INDICATE END OF RUN.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... GTRANC

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... READS THE SLDMS ANCILLARY DATA SET

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS .. MSSCONS

RESTRICTIONS ...

CALLING SEQ. ... CALL GTRANC ()

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS

PDL (PROGRAM OUTLINE)

```
  PRINT PROGRAM-ENTRY MESSAGE.
  DO UNTIL END-OF-DATA ON ANCILLARY DATA SET.
    READ NEXT RECORD (ID RECORD).
    IF IT IS "CCT-HEADER DATA", THEN
      READ NEXT TWO RECORDS (DATA RECORDS).
      PRINT CCT-HEADER DATA.
    ENDIF
    IF IT IS "SIAT DATA", THEN
      READ NEXT TWENTY-ONE RECORDS (DATA RECORDS).
      PRINT SIAT DATA.
    ENDIF
  ENDDO
  PRINT PROGRAM-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

```
******         SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION           ******

NAME ........... GTRURQ

DESIGNER ....... STEPHEN W. MURPHREY

FUNCTION ....... READS USER'S REQUESTS FOR "LMSSGT" PROGRAM.

INPUTS ......... 1. SEE CALLING SEQUENCE.

OUTPUTS ........ 1. SEE CALLING SEQUENCE.
                 2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL GTRURQ ()

  VARIABLE  TYPE  I/O  DIM    DESCRIPTION                           UNITS

PDL (PROGRAM OUTLINE)

  PRINT PROGRAM-ENTRY MESSAGE.
  INITIALIZE NAMELIST PARAMETERS.
  READ NAMELIST OF USER'S REQUESTS AND PARAMETERS.
  STORE RESULTS.
  PRINT USER'S REQUESTS AND DEFINING PARAMETERS.
  PRINT PROGRAM-EXIT MESSAGE.
******                     END OF SPECIFICATION                                ******
```

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****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... GTERMD

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... IT COMPUTES THE 14 COEFFICIENTS WHICH MODEL THE ATTITUDE AND ALTITUDE OVER A SCENE. THE COMPUTATION IS DONE BY A WEIGHTED LEAST-SQUARES FIT TO CONTROL-POINT AND AMS/EPHEMERIS DATA. AS A BY-PRODUCT OF THE FIT, COVARIANCE MATRICES WHICH ARE LATER USED TO ESTIMATE THE ACCURACY OF THE COMPUTED COEFFICIENTS, ARE COMPUTED.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL GTERMD (NMCP, NATEST, NALEST, KWALTY, AMSROL, AMSPIT, AMSYAW, AMSALT, ATTTIM, ALTTIM, TIMECP, CTPH, DELTAV, DELTAH, ALTNOM, AAMOD, PINV, QINV)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
NMCP	I*2	I	-	# OF CONTROL POINTS	-
NATEST	I*2	I	-	# OF ATTITUDE ESTIMATES	-
NALEST	I*2	I	-	# OF ALTITUDE ESTIMATES	-
KWALTY	I*2	I	NMCP	STATUS OF CONTROL POINTS	-
AMSROLL	R*8	I	NATEST	AMS ROLL VALUES	RADIANS
AMSPIT	R*8	I	NATEST	AMS PITCH VALUES	RADIANS
AMSYAW	R*8	I	NATEST	AMS YAW VALUES	RADIANS
AMSALT	R*8	I	NALEST	AMS ALTITUDE VALUES	METERS
ATTTIM	R*8	I	NATEST	TIME ASSOCIATED WITH ROLL, PITCH AND YAW VALUES	SECONDS
ALTTIM	R*8	I	NALEST	TIME ASSOCIATED WITH ALTITUDE	SECONDS
TIMECP	R*8	I	NMCP	TIME ASSOCIATED WITH CONTROL POINTS	SECONDS
CTPH	R*8	I	NMCP	HORIZONTAL COORDINATES OF CONTROL POINTS IN CTP	METERS
DELTAV	R*8	I	NMCP	VERTICAL RESIDUAL OF CONTROL POINTS IN CTP	METERS
DELTAH	R*8	I	NMCP	HORIZONTAL RESIDUALS OF CONTROL POINTS	METERS
ALTNOM	R*8	I	-	NOMINAL ALTITUDE OF SPACECRAFT	METERS
AAMOD	R*8	O	14	COEFFICIENTS OF ROLL, PITCH, YAW, AND ALTITUDE	-
PINV	R*8	O	6X6	COVARIANCE MATRIX (ROLL AND ALTITUDE)	-
QINV	R*8	O	8X8	COVARIANCE MATRIX (PITCH AND YAW)	-

PDL (PROGRAM OUTLINE)

```
MAP OBSERVED INPUT-SPACE CP COORDINATES TO UNCORRECTED TANGENT-SPACE.
MAP NOMINAL MAP CP COORDINATES TO CORRECTED TANGENT SPACE.
COMPUTE DIFFERENCES OF UNCORRECTED AND CORRECTED TANGENT-SPACE COORDINATES.
IF THERE ARE TWO OR MORE CONTROL POINTS THEN
  INITIALIZE ISING FLAG TO BE NONZERO.
  ATTEMPT TO PERFORM ATTITUDE/ALTITUDE FIT WITH "AAFIT" ALGORITHM.
  IF "AAFIT" IS UNSUCCESSFUL THEN
    SET ISING FLAG TO ZERO.
  ENDIF
ELSE
  INITIALIZE ISING FLAG TO BE ZERO.
ENDIF
IF ISING FLAG IS ZERO THEN
  PERFORM ATTITUDE/ALTITUDE FIT WITH "AAFIT2" ALGORITHM.
ENDIF
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... IIUTP

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... CONVERTS AN ARRAY OF INPUT-SPACE COORDINATES (LINE AND SAMPLE) TO UNCORRECTED-TANGENT-SPACE COORDINATES.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS .. MSSCONS

RESTRICTIONS ...

CALLING SEQ. ... CALL IIUTP (NMCP, VRA, VRC, VRAN, VRCN, DELVV, CLINE, CSAMP, KWALTY, UTPV, UTPH, DTIME, CTIME)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NMCP	I*2	I	-	# OF POINTS	-
VRA	R*8	I	NMCP	EARTH ROTATION VELOCITY (ALONG-TRACK) AT INPUT POINT	METERS/ SEC
VRC	R*8	I	NMCP	EARTH ROTATION VELOCITY (ACROSS-TRACK) AT INPUT POINT	"
VRAN	R*8	I	-	EARTH ROTATION VELOCITY (ALONG-TRACK) AT NADIR	"
VRCN	R*8	I	-	EARTH ROTATION VELOCITY (ACROSS-TRACK) AT NADIR	"
DELVV	R*8	I	-	SPACECRAFT VELOCITY ERROR	"
CLINE	R*8	I	NMCP	LINE OF CONTROL POINT	PIXELS
CSAMP	R*8	I	NMCP	SAMPLE OF CONTROL POINT	PIXELS
KWALTY	I*2	I	NMCP	STATUS OF POINTS	PIXELS
UTPV	.R*8	O	NMCP	VERTICAL COORDINATE OF POINT IN UTP	METERS
UTPH	R*8	O	NMCP	HORIZONTAL COORDINATE OF POINT IN UTP	METERS
CTIME	R*8	O	NMCP	TIME (CONTINUOUS) ASSOCIATED WITH POINT	SECONDS
DTIME	R*8	O	NMCP	TIME (DISCRETE) ASSOCIATED WITH POINT	SECONDS

PDL (PROGRAM OUTLINE)

```
PRINT SUBROUTINE-ENTRY MESSAGE.
PRINT HEADINGS.
DO FOR EACH CONTROL POINT:
   CONVERT TO IMAGE-CENTER-ORIGIN COORDINATES.
   CORRECT HORIZONTAL COORDINATE FOR MIRROR-VELOCITY ERRORS.
   CORRECT FOR DIFFERENTIAL INPUT SCALES.
   CORRECT VERTICAL COORDINATE FOR SCAN-SKEW ERRORS.
   CORRECT VERTICAL COORDINATE FOR SPACECRAFT-VELOCITY ERRORS.
   CORRECT FOR DISTORTIONS DUE TO EARTH ROTATION.
   CORRECT HORIZ. COORDINATE FOR EARTH-CURVATURE / PANORAMIC-PROJECTION ERRORS.
   PRINT RESULTS OF ABOVE ERROR CORRECTIONS.
ENDDO
PRINT SUBROUTINE-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... DELTAS

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... COMPUTE THE DIFFERENCES OF THE UNCORRECTED-TANGENT-SPACE COORDINATES AND THE CORRECTED-TANGENT-SPACE COORDINATES OF THE CONTROL POINTS.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL DELTAS (NMCP, KWALTY, CTPV, CTPH, UTPV, UTPH, DELTAV, DELTAH)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NMCP	I*2	I	-	# OF CONTROL POINTS EQUAL	-
KWALTY	I*8	I	NMCP	STATUS OF CONTROL POINTS	
CTPV	R*8	I	NMCP	CTP VERTICAL COORDINATES	METERS
CTPH	R*8	I	NMCP	CTP HORIZONTAL COORDINATES	METERS
UTPV	R*8	I	NMCP	UTP VERTICAL COORDINATES	METERS
UTPH	R*8	I	NMCP	UTP HORIZONTAL COORDINATES	METERS
DELTAV	R*8	O	NMCP	DIFFERENCES BETWEEN VERTICAL UTP AND CTP COORDINATES	METERS
DELTAH	R*8	O	NMCP	DIFFERENCES BETWEEN HORIZONTAL UTP AND CTP COORDINATES	METERS

PDL (PROGRAM OUTLINE)

```
PRINT PROGRAM-ENTRY MESSAGE.
PRINT HEADINGS.
DO FOR EACH CONTROL POINT
  IF THIS IS A GOOD CONTROL POINT (AS DETERMINED BY THE KWALTY ARRAY)
    SET DELTAV = UTPV-CTPV FOR THIS POINT
    SET DELTAH = UTPH-CTPH FOR THIS POINT
  ENDIF
  PRINT RESULTS.
ENDDO
PRINT PROGRAM-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... AAFIT

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... COMPUTE THE 14 COEFFICIENTS WHICH MODEL THE ATTITUDE AND ALTITUDE OVER A SCENE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL AAFIT (NMCP, NATEST, NALEST, KWALTY, AMSROL, AMSPIT, AMSYAW, AMSALT, ATTTIM, ALTTIM, TIMECP, CTPH, DELTAV, DELTAH, ALTNOM, AAMOD, PINV, QINV)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NMCP	I*2	I	-	# OF CONTROL POINTS	-
NATEST	I*2	I	-	# OF ATTITUDE ESTIMATES	-
NALEST	I*2	I	-	# OF ALTITUDE ESTIMATES	-
KWALTY	I*2	I	NMCP	STATUS OF CONTROL POINTS	-
AMSROLL	R*8	I	NATEST	AMS ROLL VALUES	RADIANS
AMSPIT	R*8	I	NATEST	AMS PITCH VALUES	RADIANS
AMSYAW	R*8	I	NATEST	AMS YAW VALUES	RADIANS
AMSALT	R*8	I	NALEST	AMS ALTITUDE VALUES	METERS
ATTTIM	R*8	I	NATEST	TIME ASSOCIATED WITH ROLL, PITCH AND YAW VALUES	SECONDS
ALTTIM	R*8	I	NALEST	TIME ASSOCIATED WITH ALTITUDE	SECONDS
TIMECP	R*8	I	NMCP	TIME ASSOCIATED WITH CONTROL POINTS	SECONDS
CTPH	R*8	I	NMCP	HORIZONTAL COORDINATES OF CONTROL POINTS IN CTP	METERS
DELTAV	R*8	I	NMCP	VERTICAL RESIDUAL OF CONTROL POINTS IN CTP	METERS
DELTAH	R*8	I	NMCP	HORIZONTAL RESIDUALS OF CONTROL POINTS	METERS
ALTNOM	R*8	I	-	NOMINAL ALTITUDE OF SPACECRAFT	METERS
AAMOD	R*8	O	14	COEFFICIENTS OF ROLL, PITCH, YAW, AND ALTITUDE	-
PINV	R*8	O	6X6	COVARIANCE MATRIX (ROLL AND ALTITUDE)	-
QINV	R*8	O	8X8	COVARIANCE MATRIX (PITCH AND YAW)	-

PDL (PROGRAM OUTLINE)

```
PRINT PROGRAM-ENTRY MESSAGE.
PRINT HEADINGS.
INITIALIZE "P", "Q", "R", AND "S" MATRICES TO ZEROS.
CALCULATE ATTITUDE DIFFERENCES.
CALCULATE ALTITUDE DIFFERENCES.
CALCULATE TIME CONSTANTS.
COMPUTE ELEMENTS OF THE "R" MATRIX.
COMPUTE ELEMENTS OF THE "S" MATRIX.
COMPUTE ELEMENTS OF THE "P" MATRIX.
COMPUTE ELEMENTS OF THE "Q" MATRIX.
PRINT THE "P", "Q", "R", AND "S" MATRICES.
SOLVE THE TWO SYSTEMS OF EQUATIONS.
PRINT PROGRAM-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME AAFIT2

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... COMPUTE THE 14 COEFFICIENTS WHICH MODEL THE ATTITUDE AND ALTITUDE OVER A SCENE WHEN "AAFIT" IS NOT APPLICABLE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL AAFIT2(NMCP, NATEST, NALEST, KWALTY, AMSROL, AMSPIT, AMSYAW, AMSALT, ATTTIM, ALTTIM, TIMECP, CTPH, DELTAV, DELTAH, ALTNOM, AAMOD, PINV, QINV)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NMCP	I*2	I	-	# OF CONTROL POINTS	-
NATEST	I*2	I	-	# OF ATTITUDE ESTIMATES	-
NALEST	I*2	I	-	# OF ALTITUDE ESTIMATES	-
KWALTY	I*2	I	NMCP	STATUS OF CONTROL POINTS	-
AMSROLL	R*8	I	NATEST	AMS ROLL VALUES	RADIANS
AMSPIT	R*8	I	NATEST	AMS PITCH VALUES	RADIANS
AMSYAW	R*8	I	NATEST	AMS YAW VALUES	RADIANS
AMSALT	R*8	I	NALEST	AMS ALTITUDE VALUES	METERS
ATTTIM	R*8	I	NATEST	TIME ASSOCIATED WITH ROLL, PITCH AND YAW VALUES	SECONDS
ALTTIM	R*8	I	NALEST	TIME ASSOCIATED WITH ALTITUDE	SECONDS
TIMECP	R*8	I	NMCP	TIME ASSOCIATED WITH CONTROL POINTS	SECONDS
CTPH	R*8	I	NMCP	HORIZONTAL COORDINATES OF CONTROL POINTS IN CTP	METERS
DELTAV	R*8	I	NMCP	VERTICAL RESIDUAL OF CONTROL POINTS IN CTP	METERS
DELTAH	R*8	I	NMCP	HORIZONTAL RESIDUALS OF CONTROL POINTS	METERS
ALTNOM	R*8	I	-	NOMINAL ALTITUDE OF SPACECRAFT	METERS
AAMOD	R*8	O	14	COEFFICIENTS OF ROLL, PITCH, YAW, AND ALTITUDE	-
PINV	R*8	O	6X6	COVARIANCE MATRIX (ROLL AND ALTITUDE)	-
QINV	R*8	O	8X8	COVARIANCE MATRIX (PITCH AND YAW)	-

PDL (PROGRAM OUTLINE)

```
PRINT PROGRAM-ENTRY MESSAGE.
PRINT HEADINGS.
COMPUTE AMS ATTITUDE AND ALTITUDE MODEL COEFFICIENTS.
ADJUST GCP DATA FOR AMS RATE AND ALTITUDE.
COMPUTE ROLL BIAS TERM.
COMPUTE PITCH AND YAW BIAS TERMS.
COMPUTE NEW PREVIOUS BIASES AND VARIANCES.
WRITE QUALITY DATA.
PRINT PROGRAM-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ADTAA

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... TO COMPUTE THE 14 ATTITUDE / ALTITUDE COEFFICIENTS BASED ON AMS ESTIMATES OF ROLL, PITCH, YAW, AND ALTITUDE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ... THE NUMBER OF AMS ATTITUDE VALUES AND THE NUMBER OF EPHEMERIS ALTITUDE VALUES MUST BOTH BE GREATER THAN 1.

CALLING SEQ. ... CALL ADTAA (NATEST, NALEST, AMSROL, AMSPIT, AMSYAW, AMSALT, ATTTIM, ALTTIM, ALTNOM, AAAMOD)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NATEST	I*2	I	-	# OF ATTITUDE ESTIMATES	-
NALEST	I*2	I	-	# OF ALTITUDE ESTIMATES	-
AMSROL	R*8	I	NATEST	AMS ROLL VALUES	RADIANS
AMSPIT	R*8	I	NATEST	AMS PITCH VALUES	RADIANS
AMSYAW	R*8	I	NATEST	AMS YAW VALUES	RADIANS
AMSALT	R*8	I	NALEST	AMS ALTITUDE VALUES	METERS
ATTTIM	R*8	I	NATEST	TIME ASSOCIATED WITH ROLL, PITCH, YAW VALUES	SECONDS FROM IC
ALTTIM	R*8	I	NALEST	TIME ASSOCIATED WITH ALTITUDE VALUES	SECONDS FROM IC
ALTNOM	R*8	I	-	NOMINAL ALTITUDE	METERS
AAAMOD	R*8	O	14	COEFFICIENTS OF ROLL, PITCH YAW AND ALTITUDE DEVIATION	-

PDL (PROGRAM OUTLINE)

```
PRINT PROGRAM-ENTRY MESSAGE.
INITIALIZE AP, AQ, RM, PM, YM, AND HM MATRICES TO ZEROS.
CALCULATE AP, AQ, RM, PM, YM, AND HM ELEMENTS.
PRECONDITION AP MATRIX.
INVERT AND TEST AP MATRIX.
COMPUTE ROLL, PITCH, AND YAW MODEL COEFFICIENTS.
PRECONDITION AQ MATRIX.
INVERT AND TEST AQ MATRIX.
COMPUTE ALTITUDE MODEL COEFFICIENTS.
PRINT RESULTS.
PRINT PROGRAM-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... GTOSDF

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS SUBROUTINE DEFINES THE OUTPUT SPACE. IT COMPUTES THE OUTPUT-SPACE PIXEL COORDINATES OF THE NOMINAL FORMAT CENTER.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL GTOSDF ( )

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS

PDL (PROGRAM OUTLINE)

```
  PRINT PROGRAM-ENTRY MESSAGE.
  COMPUTE TANGENT-SPACE COORDINATES OF FORMAT CENTER.
  TRANSFORM FORMAT-CENTER COORDINATES TO GEODETIC LATITUDE AND LONGITUDE
  TRANSFORM FORMAT-CENTER COORDINATES TO MAP COORDINATES.
  INPUT NOMINAL-FORMAT-CENTER MAP COORDINATES.
  COMPUTE OUTPUT-SPACE COORDINATES OF NOMINAL FORMAT CENTER.
  SCALE AND ROUND THE NOMINAL-FORMAT-CENTER COORDINATES.
  PRINT RESULTS.
  PRINT PROGRAM-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... CTPEC

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... TO MAP POINTS FROM THE CORRECTED TANGENT SPACE TO THE EARTH-CENTERED CARTESIAN COORDINATE SYSTEM. THE MAPPING IS, IN ORDER, A ROTATION (FROM THE TANGENT-SPACE ORIENTATION TO THE EARTH-CENTERED ORIENTATION), A TRANSLATION (FROM THE TANGENT-SPACE ORIGIN TO THE EARTH-CENTERED ORIGIN), AND A PROJECTION (FROM THE TANGENT SPACE ONTO THE EARTH SURFACE).

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL CTPEC(XEX, XEY, XECNAD, YEX, YEY, YECNAD, ZEX, ZEY, ZECNAD, ASQR, BSQR, A4TH, B4TH, V, NUM, CTPV, CTPH, XEC, YEC, ZEC)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
XEX	R*8	I	-	ROTATION MATRIX ELEMENT	-
XEY	R*8	I	-	ROTATION MATRIX ELEMENT	-
XECNAD	R*8	I	-	NADIR EARTH CENTERED X COORDINATE	METERS
YEX	R*8	I	-	ROTATION MATRIX ELEMENT	-
YEX	R*8	I	-	ROTATION MATRIX ELEMENT	-
YECNAD	R*8	I	-	NADIR EARTH CENTERED Y COORDINATE	METERS
ZEX	R*8	I	-	ROTATION MATRIX ELEMENT	-
ZEY	R*8	I	-	ROTATION MATRIX ELEMENT	-
ZECNAD	R*8	I	-	NADIR EARTH CENTERED Z COORDIANTE	METERS
ASQR	R*8	I	-	PRECOMPUTED EARTH A**2	-
BSQR	R*8	I	-	PRECOMPUTED EARTH B**2	-
A4TH	R*8	I	-	PRECOMPUTED EARTH A**4	-
B4TH	R*8	I	-	PRECOMPUTED EARTH B**4	-
V	R*8	I	-	PROJECTION PARAMETERS	-
NUM	R*8	I	-	NUMBER OF POINTS TO MAP	-
CTPV	R*8	I	NUM	CTP VERTICAL COORDINATES	METERS
CTPH	R*8	I	NUM	CTP HORIZONTAL CCORDIANTES	METERS
XEC	R*8	I	NUM	EARTH CENTERED X OF THE POINTS	METERS
XEC	R*8	I	NUM	EARTH CENTERED Y OF THE POINTS	METERS
XEC	R*8	I	NUM	EARTH CENTERED Z OF THE POINTS	METERS

PDL (PROGRAM OUTLINE)

```
 DO FOR EACH POINT
   ROTATE AND TRANSLATE THE TANGENT SPACE COORDINATES OF THE POINT
   INTO EARTH CENTERED COORDINATES
        XECT = CV*XEX+CH*XEY+XECNAD
        YECT = CV*YEX+CH*YEY+YECNAD
        ZECT = CV*ZEX+CH*ZEY+ZECNAD
   COMPUTE PARAMETERS USED TO PROJECT THE POINT FROM THE TANGENT
   SPACE TO THE EARTH SURFACE
        P1   = BSQR*(V(1)*XECT+V(2)*YECT)+A4TH/BSQR*V(3)*ZECT
        P2   = ASQR*BSQR+V(3)*V(3)*(A4TH/B4TH-1.0D0)
        P3   = BSQR*(XECT*XECT+YECT*YECT)+ASQR*(ZECT*ZECT-BSQR)
        S    = (P1-DSQRT(P1*P1-P2*P3))/P2
   PROJECT THE POINT FROM THE TANGENT SPACE TO THE EARTH SURFACE
        XEC  = XECT-V(1)*S
        YEC  = YECT-V(2)*S
        ZEC  = ZECT-V(3)*S*ASQR/BSQR
 ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ECLL

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... MAP POINTS FROM EARTH-CENTERED COORDINATES TO GEODETIC LATITUDE AND LONGITUDE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL ECLL (AELLPS, BELLPS, NUM, XEC, YEC, ZEC, RDLATR, RLONGR)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
AELLPS	R*8	I	-	MAJOR AXIS OF EARTH ELLIPSOID	METERS
BELLPS	R*8	I	-	MINOR AXIS OF EARTH ELLIPSOID	METERS
NUM	I*2	I	-	NUMBER OF POINTS TO TRANSFORM	-
XEC	R*8	I	NUM	EARTH CENTERED X COORDINATE	METERS
YEC	R*8	I	NUM	EARTH CENTERED Y COORDINATE	METERS
ZEC	R*8	I	NUM	EARTH CENTERED Z COORDINATE	METERS
RDLATR	R*8	O	NUM	GEODETIC LATITUDE OF INPUT POINTS	RADIANS
RDLONR	R*8	O	NUM	LONGITUDE OF INPUT POINTS	RADIANS

PDL (PROGRAM OUTLINE)

```
DO FOR EACH POINT
   LATTITUDE=ARCTAN((ASQR/BSQR)*ZEC/SQRT(XEC*XEC+YEC*YEC))
   LONGITUDE=ARCSIN(DABS(YEC)/SQRT(XEC*XEC+YEC*YEC))
   IF (XEC > OR = 0)
      IF (YEC < 0)
         LONGITUDE=-LONGITUDE
      ENDIF
   ELSE
      IF (YEC < 0)
         LONGITUDE=LONGITUDE-PI
      ELSE
         LONGITUDE=PI-LONGITUDE
      ENDIF
   ENDIF
   PRINT RESULTS FOR THIS POINT
ENDDO
```

****** END OF SPECIFICATION ******

ORIGINAL PAGE IS
OF POOR QUALITY

```
******        SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION        ******
NAME ........... LLMAP

DESIGNER ....... STEPHEN W. MURPHREY

FUNCTION ....... MAP GEODETIC LATITUDE AND LONGITUDE COORDINATES TO (UTM) MAP
                 COORDINATES.

INPUTS ......... 1. SEE CALLING SEQUENCE.

OUTPUTS ........ 1. SEE CALLING SEQUENCE.
                 2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL LLMAP ( AELLPS , BELLPS , NUM , IZONED , RDLATR , RLONGR ,
                              DNORTH , DEAST  , IZONE )

  VARIABLE  TYPE  I/O  DIM    DESCRIPTIION                       UNITS

  AELLPS    R*8    I    -     MAJOR AXIS OF EARTH ELLIPSOID      METERS
  BELLPS    R*8    I    -     MINOR AXIS OF EARTH ELLIPSOID      METERS
  NUM       I*4    I    -     NUMBER OF POINTS TO TRANSFORM        -
  IZONED    I*4    I          UTM ZONE DESIRED                     -
  RDLATR    R*8    I   NUM    GEODETIC LATITUDE OF INPUT POINTS  RADIANS
  RDLONR    R*8    I   NUM    LONGITUDE OF INPUT POINTS          RADIANS
  DNORTH    R*8    O   NUM    UTM NORTHING COORDINATE            METERS
  DEAST     R*8    O   NUM    UTM EASTING COORDINATE             METERS
  IZONE     I*4    O   NUM    UTM ZONE                             -

COMMENTS ....... THIS MODULE IS A MODIFICATION OF A FORTRAN PROGRAM
                 OBTAINED FROM THE UNITED STATES GEOLOGICAL SURVEY.
******                        END OF SPECIFICATION                          ******
```

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MAPOI

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... CONVERT (UTM) MAP COORDINATES TO OUTPUT-SPACE PIXEL COORDINATES.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

```
CALLING SEQ. ... CALL MAPOI ( NUM    , IZONED , CNORTH , CEAST  , BETA ,
                              DNORTH , DEAST  , IZONE  , HO     , VO   )
```

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
NUM	I*4	I	-	NUMBER OF POINTS TO TRANSFORM	-
BETA	R*8	I	-	HEADING ANGLE	RADIANS
IZONED	I*4	I		UTM ZONE DESIRED	-
CNORTH	R*8	I	NUM	UTM NORTHING OF FORMAT CENTER	METERS
CEAST	R*8	I	NUM	UTM EASTING OF FORMAT CENTER	METERS
DNORTH	R*8	I	NUM	UTM NORTHING COORDINATE	METERS
DEAST	R*8	I	NUM	UTM EASTING COORDINATE	METERS
IZONE	I*4	I	NUM	UTM ZONE	-
HO	R*8	I	NUM	OUTPUT SPACE COORDINATE	PIXELS
VO	R*8	I	NUM	OUTPUT SPACE COORDINATE	PIXELS

PDL (PROGRAM OUTLINE)

```
ALPHA = 3 * PI / 2 - BETA
SA    = SINE( ALPHA )
CA    = COSINE( ALPHA )
DO FOR EACH POINT
    HO(I) = (SA * ( DNORTH(I) - CNORTH ) - CA * ( DEAST(I) - CEAST )) / HSCALE
    VO(I) = (CA * ( DNORTH(I) - CNORTH ) + SA * ( DEAST(I) - CEAST )) / VSCALE
ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... GTGDPT

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS SUBROUTINE CALCULATES THE GRID-POINT CORRESPONDENCE THAT IS THE GEOMETRIC TRANSFORMATION BETWEEN THE OUTPUT SPACE AND THE INPUT SPACE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. PRINTER LISTING.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL GTGDPT ( )

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS

PDL (PROGRAM OUTLINE)

```
  PRINT PROGRAM-ENTRY MESSAGE.
  INITIALIZE OUTPUT-SPACE ARRAY OF GRID POINTS.
  CONVERT OUTPUT-SPACE COORDINATES TO MAP COORDINATES.
  CONVERT MAP COORDINATES TO GEODETIC COORDINATES.
  CONVERT GEODETIC COORDINATES TO EARTH-CENTERED COORDINATES.
  CONVERT EARTH-CENTERED COORDINATES TO CORRECTED-TANGENT-SPACE COORDINATES.
  DO WHILE (# ITERATIONS < MAXIMUM) AND (|NOMINAL-COMPUTED| > MAXIMUM).
    CONVERT CORRECTED-TANGENT-SPACE COORDINATES TO UNCORRECTED-TANGENT SPACE.
    CONVERT UNCORRECTED-TANGENT-SPACE COORDINATES TO INPUT SPACE.
    CONVERT INPUT-SPACE COORDINATES TO UNCORRECTED-TANGENT SPACE.
    CONVERT UNCORRECTED-TANGENT-SPACE COORDINATES TO CORRECTED-TANGENT SPACE.
    COMPUTE DIFFERENCES OF NOMINAL AND COMPUTED TANGENT-SPACE COORDINATES.
  ENDDO.
  PRINT RESULTS.
  PRINT PROGRAM-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... INITOS

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... INITIALIZE A RECTANGULAR LATTICE OF OUTPUT-SPACE GRID-POINT COORDINATES.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL INITOS (NUM , HO , VO)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NUM	I*4	I	-	NUMBER OF POINTS TO TRANSFORM	-
HO	R*8	I	NUM	OUTPUT SPACE COORDINATE	PIXELS
VO	R*8	I	NUM	OUTPUT SPACE COORDINATE	PIXELS

PDL (PROGRAM OUTLINE)

TO BE DETERMINED

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... OIMAP

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... CONVERT OUTPUT-SPACE PIXEL COORDINATES TO (UTM) MAP COORDINATES.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL OIMAP (NUM , CNORTH , CEAST , BETA , DNORTH , DEAST , HO , VO)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NUM	I*4	I	-	NUMBER OF POINTS TO TRANSFORM	-
BETA	R*8	I	-	HEADING ANGLE	RADIANS
CNORTH	R*8	I	NUM	UTM NORTHING OF FORMAT CENTER	METERS
CEAST	R*8	I	NUM	UTM EASTING OF FORMAT CENTER	METERS
DNORTH	R*8	I	NUM	UTM NORTHING COORDINATE	METERS
DEAST	R*8	I	NUM	UTM EASTING COORDINATE	METERS
HO	R*8	I	NUM	OUTPUT SPACE COORDINATE	PIXELS
VO	R*8	I	NUM	OUTPUT SPACE COORDINATE	PIXELS

PDL (PROGRAM OUTLINE)

```
SB     = SINE( BETA )
CB     = COSINE( BETA )
DO FOR EACH POINT
   HOC        = HO(I) - HSZO / 2
   VOC        = VO(I) - VSZO / 2
   DNORTH(I)  = CNORTH  -  HOC * HSPACI * CB  -  VOC * VSPACI * SB
   DEAST(I)   = CEAST   +  HOC * HSPACI * SB  -  VOC * VSPACI * CB
ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... MAPLL

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... CONVERTS (UTM) MAP COORDINATES TO GEODETIC LATITUDE AND LOGNITUDE COORDINATES.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL MAPLL (AELLPS , BELLPS , NUM , IZONED , RDLATR , RLONGR , DNORTH , DEAST , IZONE)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
AELLPS	R*8	I	-	MAJOR AXIS OF EARTH ELLIPSOID	METERS
BELLPS	R*8	I	-	MINOR AXIS OF EARTH ELLIPSOID	METERS
NUM	I*4	I	-	NUMBER OF POINTS TO TRANSFORM	-
IZCNED	I*4	I		UTM ZONE DESIRED	-
RDLATR	R*8	O	NUM	GEODETIC LATITUDE OF INPUT POINTS	RADIANS
RDLONR	R*8	O	NUM	LONGITUDE OF INPUT POINTS	RADIANS
DNORTH	R*8	I	NUM	UTM NORTHING COORDINATE	METERS
DEAST	R*8	I	NUM	UTM EASTING COORDINATE	METERS
IZONE	I*4	I	NUM	UTM ZONE	-

COMMENTS .... THIS MODULE IS A MODIFICATION OF A FORTRAN PROGRAM OBTAINED FROM THE UNITED STATES GEOLOGICAL SURVEY.

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... LLEC

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... MAP POINTS EXPRESSED IN LATITUDE AND LONGITUDE TO EARTH-CENTERED CARTESIAN COORDINATES (X, Y, Z).

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL LLEC (N, RLDR, RLNR, ELEV, FISHA, FISHB, XEC, YEC, ZEC)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
N	I*2	I	-	# OF POINTS	-
RLNR	R*8	I	N	LONGITUDE OF POINTS	RADIANS
RLDR	R*8	I	N	LATITUDE OF POINTS	RADIANS
ELEV	R*8	I	N	TERRAIN ELEVATION OF POINTS	METERS
FISHA	R*8	I	-	AXIS OF EARTH MODEL (FISHER ELLIPSOID)	METERS
FISHB	R*8	I	-	"	METERS
XEC	R*8	O	N	EARTH-CENTERED X-COORDINATE OF POINT	METERS
YEC	R*8	O	N	EARTH-CENTERED Y-COORDINATE	METERS
ZEC	R*8	O	N	EARTH-CENTERED Z-COORDINATE	METERS

PDL (PROGRAM OUTLINE)

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... ECCTP

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... MAPS CONTROL POINTS EXPRESSED IN EARTH-CENTERED COORDINATES TO CORRECTED-TANGENT-SPACE COORDINATES.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL ECCTP (NMCP, XEC, YEC, ZEC, XECNAD, YECNAD, ZECNAD, BETAN, RNADLD, RNADLN, CTPV, CTPH)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NMCP	I*2	I	-	# OF CONTROL POINTS	-
XEC	R*8	I	NMCP	X-COORDINATE (EARTH-CENTERED)	METERS
YEC	R*8	I	NMCP	Y-COORDINATE " "	METERS
ZEC	R*8	I	NMCP	Z-COORDINATE " "	METERS
XECNAD	R*8	I	-	X-COORDINATE-NADIR " "	METERS
YEXNAD	R*8	I	-	Y-COORDINATE-NADIR " "	METERS
ZECNAD	R*8	I	-	Z-COORDINATE-NADIR " "	METERS
BETAN	R*8	I	-	SPACECRAFT HEADING ANGLE	RADIANS
RNADLD	R*8	I	-	GEODETIC LATITUDE OF NADIR	RADIANS
RNADLN	R*8	I	-	LONGITUDE OF NADIR	RADIANS
CTPV	R*8	O	NMCP	CTP VERTICAL COORDINATE	METERS
CTPH	R*8	O	NMCP	CTP HORIZONTAL COORDINATE	METERS

PDL (PROGRAM OUTLINE)

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... CTPUTP

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... MAP POINTS FROM THE CORRECTED-TANGENT-SPACE TO THE UNCORRECTED-TANGENT-SPACE. THIS MAPPING CONSISTS OF APPLYING THE ATTITUDE AND ALTITUDE CORRECTIONS.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL CTPUTP (NUM, TIMEPT, UTPV, UTPH, AAMOD, ALTNOM, APRXCH, CTPV, CTPH)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
NUM	I*2	I	-	NUMBER OF POINTS TO TRANSFORM	-
TIMEPT	R*8	I	NUM	TIME OF EACH POINT	SECONDS
UTPV	R*8	I	NUM	UTP VERTICAL COORDINATES	METERS
UTPH	R*8	I	NUM	UTP HORIZONTAL CCORDINATES	METERS
AAMOD	R*8	I	14	A/A MODEL COEFFICIENTS	-
ALTNCM	R*8	I	-	NOMINAL S/C ALTITUDE	METERS
CTPV	R*8	I	NUM	CTP VERTICAL COORDINATE	METERS
CTPH	R*8	I	NUM	CTP HORIZONTAL COORDINATE	METERS

PDL (PROGRAM OUTLINE)

```
DO FOR EACH POINT
    EVALUATE ROLL, PITCH, YAW, AND DELTA ALT POLYNOMIALS AT TIMEPT(I)
    UTPV(I) = CTPV(I)  +  YAW * CTPH(I)  +  PITCH * ALTNOM
    UTPH(I) = CTPH(I)  +  DH * CTPH(I) / ALTNOM
                       -  ROLL * ( ALTNOM + CTPH(I)**2 / ALTNOM )
ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... UTPII

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... CONVERTS AN ARRAY OF UNCORRECTED-TANGENT-SPACE COORDINATES TO INPUT-SPACE COORDINATES.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS .. MSSCONS

RESTRICTIONS ...

CALLING SEQ. ... CALL UTPII (NMCP, VRA, VRC, VRAN, VRCN, DELVV, CLINE, CSAMP, KWALTY, UTPV, UTPH, DTIME, CTIME)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NMCP	I*2	I	-	# OF POINTS	-
VRA	R*8	I	NMCP	EARTH ROTATION VELOCITY (ALONG-TRACK) AT INPUT POINT	METERS/ SEC
VRC	R*8	I	NMCP	EARTH ROTATION VELOCITY (ACROSS-TRACK) AT INPUT POINT	"
VRAN	R*8	I	-	EARTH ROTATION VELOCITY (ALONG-TRACK) AT NADIR	"
VRCN	R*8	I	-	EARTH ROTATION VELOCITY (ACROSS-TRACK) AT NADIR	"
DELVV	R*8	I	-	SPACECRAFT VELOCITY ERROR	"
CLINE	R*8	I	NMCP	LINE OF CONTROL POINT	PIXELS
CSAMP	R*8	I	NMCP	SAMPLE OF CONTROL POINT	PIXELS
KWALTY	I*2	I	NMCP	STATUS OF POINTS	PIXELS
UTPV	R*8	O	NMCP	VERTICAL COORDINATE OF POINT IN UTP	METERS
UTPH	R*8	O	NMCP	HORIZONTAL COORDINATE OF POINT IN UTP	METERS
CTIME	R*8	O	NMCP	TIME (CONTINUOUS) ASSOCIATED WITH POINT	SECONDS
DTIME	R*8	O	NMCP	TIME (DISCRETE) ASSOCIATED WITH POINT	SECONDS

PDL (PROGRAM OUTLINE)

```
PRINT SUBROUTINE-ENTRY MESSAGE.
PRINT HEADINGS.
DO FOR EACH CONTROL POINT:
   CORRECT HORIZ. COORDINATE FOR EARTH-CURVATURE / PANORAMIC-PROJECTION ERRORS.
   CORRECT FOR DISTORTIONS DUE TO EARTH ROTATION.
   CORRECT VERTICAL COORDINATE FOR SPACECRAFT-VELOCITY ERRORS.
   CORRECT VERTICAL COORDINATE FOR SCAN-SKEW ERRORS.
   CORRECT FOR DIFFERENTIAL INPUT SCALES.
   CORRECT HORIZONTAL COORDINATE FOR MIRROR-VELOCITY ERRORS.
   CONVERT TO IMAGE-CENTER-ORIGIN COORDINATES.
   PRINT RESULTS OF ABOVE ERROR CORRECTIONS.
ENDDO
PRINT SUBROUTINE-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... IIUTP

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... CONVERTS AN ARRAY OF INPUT-SPACE COORDINATES (LINE AND SAMPLE) TO UNCORRECTED-TANGENT-SPACE COORDINATES.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS .. MSSCONS

RESTRICTIONS ...

CALLING SEQ. ... CALL IIUTP (NMCP, VRA, VRC, VRAN, VRCN, DELVV, CLINE, CSAMP, KWALTY, UTPV, UTPH, DTIME, CTIME)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NMCP	I*2	I	-	# OF POINTS	-
VRA	R*8	I	NMCP	EARTH ROTATION VELOCITY (ALONG-TRACK) AT INPUT POINT	METERS/ SEC
VRC	R*8	I	NMCP	EARTH ROTATION VELOCITY (ACROSS-TRACK) AT INPUT POINT	"
VRAN	R*8	I	-	EARTH ROTATION VELOCITY (ALONG-TRACK) AT NADIR	"
VRCN	R*8	I	-	EARTH ROTATION VELOCITY (ACROSS-TRACK) AT NADIR	"
DELVV	R*8	I	-	SPACECRAFT VELOCITY ERROR	"
CLINE	R*8	I	NMCP	LINE OF CONTROL POINT	PIXELS
CSAMP	R*8	I	NMCP	SAMPLE OF CONTROL POINT	PIXELS
KWALTY	I*2	I	NMCP	STATUS OF POINTS	PIXELS
UTPV	R*8	O	NMCP	VERTICAL COORDINATE OF POINT IN UTP	METERS
UTPH	R*8	O	NMCP	HORIZONTAL COORDINATE OF POINT IN UTP	METERS
CTIME	R*8	O	NMCP	TIME (CONTINUOUS) ASSOCIATED WITH POINT	SECONDS
DTIME	R*8	O	NMCP	TIME (DISCRETE) ASSOCIATED WITH POINT	SECONDS

PDL (PROGRAM OUTLINE)

```
PRINT SUBROUTINE-ENTRY MESSAGE.
PRINT HEADINGS.
DO FOR EACH CONTROL POINT:
   CONVERT TO IMAGE-CENTER-ORIGIN COORDINATES.
   CORRECT HORIZONTAL COORDINATE FOR MIRROR-VELOCITY ERRORS.
   CORRECT FOR DIFFERENTIAL INPUT SCALES.
   CORRECT VERTICAL COORDINATE FOR SCAN-SKEW ERRORS.
   CORRECT VERTICAL COORDINATE FOR SPACECRAFT-VELOCITY ERRORS.
   CORRECT FOR DISTORTIONS DUE TO EARTH ROTATION.
   CORRECT HORIZ. COORDINATE FOR EARTH-CURVATURE / PANORAMIC-PROJECTION ERRORS.
   PRINT RESULTS OF ABOVE ERROR CORRECTIONS.
ENDDO
PRINT SUBROUTINE-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... UTPCTP

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... MAP POINTS FROM THE UNCORRECTED-TANGENT-SPACE TO THE CORRECTED-TANGENT-SPACE. THIS MAPPING CONSISTS OF APPLYING THE ATTITUDE AND ALTITUDE CORRECTIONS.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL UTPCTP (NUM, TIMEPT, UTPV, UTPH, AAMOD, ALTNOM, APRXCH, CTPV, CTPH)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
NUM	I*2	I	-	NUMBER OF POINTS TO TRANSFORM	-
TIMEPT	R*8	I	NUM	TIME OF EACH POINT	SECONDS
UTPV	R*8	I	NUM	UTP VERTICAL COORDINATES	METERS
UTPH	R*8	I	NUM	UTP HORIZONTAL COORDINATES	METERS
AAMOD	R*8	I	14	A/A MODEL COEFFICIENTS	-
ALTNOM	R*8	I	-	NOMINAL S/C ALTITUDE	METERS
APRXCH	R*8	I	NUM	APPROXIMATE CTP HORIZONTAL	METERS
CTPV	R*8	I	NUM	CTP VERTICAL COORDINATE	METERS
CTPH	R*8	I	NUM	CTP HORIZONTAL COORDINATE	METERS

PDL (PROGRAM OUTLINE)

```
DO FOR EACH POINT
  COMPUTE THE TIME FOR THE POINT
  COMPUTE ROLL, PITCH, YAW, AND DELTA ALT BY EVALUATING THE A/A
     POLYNOMIALS AT THE TIME OF THE POINT
  COMPUTE THE DELTA CORRECTIONS FOR THE TANGENT PLANE COORDINATES
    BY PUTTING THE ATTITUDE VALUES INTO THE DISTORTION MODELS
  ADD THE DELTA CORRECTIONS TO THE UNCORRECTED VALUES
ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... GTERAS

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... ESTIMATES THE ACCURACY TO WHICH GEODETIC COORDINATES (LAT/LON) CAN BE ASSIGNED TO POINTS IN A SCENE.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS .. MSSCCNS

RESTRICTIONS ...

CALLING SEQ. ... CALL GTERAS (NMCP, RACOV, PYCOV, CTPV, CTPH, SIGM, AESTV,AESTH)

VARIABLE	TYPE	I/O	DIM	DESCRIPTIION	UNITS
NMCP	I*2	I	-	# OF CONTROL POINTS	-
RACOV	R*8	I	6X6	COVARIANCE MATRIX (ROLL AND ALTITUDE DEVIATION)	-
PYCOV	R*8	I	8X8	COVARIANCE MATRIX (PITCH AND YAW)	-
CTPV	R*8	I	NMCP	VERTICAL COORDINATE OF POINT IN CORRECTED TANGENT PLANE	METERS
CTPH	R*8	I	NMCP	HORIZONTAL COORDINATE OF POINT IN CORRECTED TANGENT PLANE	METERS
AESTV	R*8	O	NMCP	ACCURACY ESTIMATE OF VERTICAL COORDINATE	METERS
AESTH	R*8	O	NMCP	ACCURACY ESTIMATE OF HORIZONTAL COORDINATE	METERS

PDL (PROGRAM OUTLINE)

```
DO FOR EACH INPUT POINT
   COMPUTE THE TIME OF THE POINT
   COMPUTE MATRIX M1 WHICH RELATES THE A/A MODEL COVARIANCES TO
      HORIZONTAL GEODETIC COVARIANCES
   COMPUTE MATRIX M2 WHICH RELATES THE A/A MODEL COVARIANCES TO
      VERTICAL GEODETIC COVARIANCES
   FROM THE TIME OF THE POINT, COMPUTE THE MATRIX T1 WHICH ALLOWS M1
      TO BE EVALUATED AT THE TIME OF THE GIVEN POINT
   FROM THE TIME OF THE POINT, COMPUTE THE MATRIX T2 WHICH ALLOWS M2
      TO BE EVALUATED AT THE TIME OF THE GIVEN POINT
   COMPUTE F1 = M1*T1 WHICH RELATES THE A/A MODEL COVARIANCES TO
      HORIZONTAL GEODETIC COVARIANCES AT THE TIME OF THE POINT
   COMPUTE F2 = M2*T2 WHICH RELATES THE A/A MODEL COVARIANCES TO
      VERTICAL GEODETIC COVARIANCES AT THE TIME OF THE POINT
   COMPUTE THE VARIANCE OF THE GEODETIC ACCURACY OF THE HORIZONTAL
      COORDINATE OF THE GIVEN POINT (H VAR = F2*PYCOV*F2T)
   COMPUTE THE VARIANCE OF THE GEODETIC ACCURACY OF THE VERTICAL COOR-
      DINATE OF THE GIVEN POINT (V VAR = F1*RACOV*F1T)
   COMPUTE THE HORIZONTAL "ERROR ELLIPSE RADII"= SIGM*SQRT(H VAR)
   COMPUTE THE VERTICAL "ERROR ELLIPSE RADII"= SIGM*SQRT(H VAR)
ENDDO
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION *****

NAME .... GTWANC

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... WRITES GEOMETRIC-TRANSFORMATION PARAMETERS TO THE SLDMS ANCILLARY DATA SET.

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL GTWANC ()

VARIABLE TYPE I/O DIM DESCRIPTIION UNITS

PDL (PROGRAM OUTLINE)

```
PRINT PROGRAM-ENTRY MESSAGE.
WRITE ERROR MODELS TO THE SLDMS ANCILLARY DATA SET.
WRITE ERROR ASSESSMENT TO THE SLDMS ANCILLARY DATA SET.
WRITE OUTPUT-SPACE DEFINITION TO THE SLDMS ANCILLARY DATA SET.
WRITE GRID-POINT CORRESPONDENCE TO THE SLDMS ANCILLARY DATA SET.
PRINT PROGRAM-EXIT MESSAGE.
```

****** END OF SPECIFICATION ******

B.7 RESAMPLING PROGRAM

B.7.1 Statement of Problem

Resampling, as defined here, is the creation of a two-dimensional array of eight-bit words (called output-space pixels) from another two-dimensional array of eight-bit words (called input-space pixels) by the process indicated in Figure B-8. It involves two main steps: the creation of an intermediate two-dimensional array (called hybrid-space pixels) directly from the input-space array; and the creation of the output-space array from the hybrid-space array. The first of these steps is called horizontal resampling, and the second is called vertical resampling.

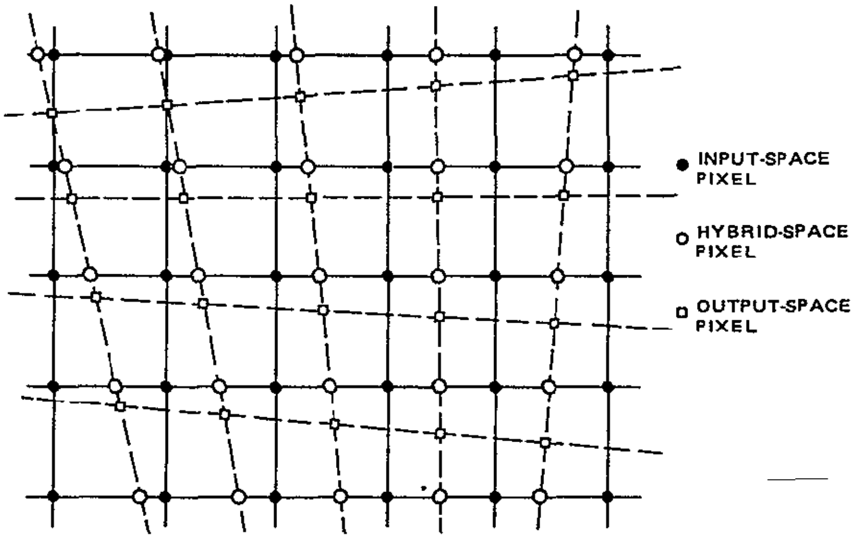

Figure B-8. Horizontal and Vertical Resampling

B.7.2 Data Flow

The three resampling spaces are shown in Figure B-9. Hybrid space is created by a one-dimensional resampling of input space. This is a horizontal resampling. Output space is created by a one-dimensional resampling of hybrid space. This is vertical resampling.

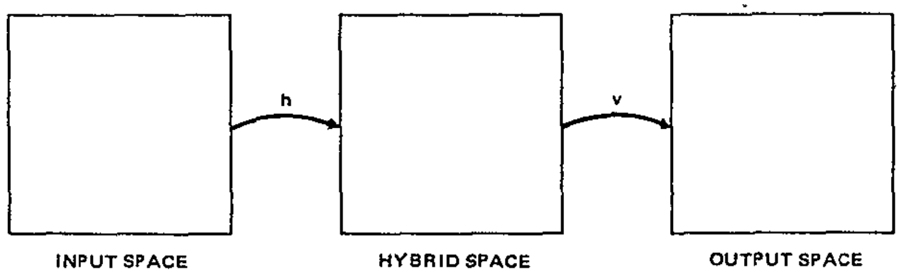

Figure B-9. Resampling Spaces

In each case, the resultant image is created one line at a time. The flow is from the top of the image to the bottom. A resampled line is created in segments, as shown in Figure B-10.

In order to resample one line's worth of data, the location of each point in the input data array must be obtained. This is done, within each segment, by a linear interpolation scheme. Consider Figures B-10 and B-11. A rectangular lattice of grid points (usually, but not necessarily, equally spaced) is set up in the coordinate system of the image being created. These interpolation grid points are then mapped to the corresponding input-data coordinate system. The mapped grid points are the SVO and LHO points shown in Figures B-10 and B-11. In each case, another set of grid points with a finer mesh is created by linear interpolation between the mapped grid points. These are the SV and LH points shown in Figures B-10 and B-11. There is a set of SV grid points for each line in hybrid space, and there is a set of HV grid points for each column in output space. In the case of horizontal resampling, some high-frequency geometric errors that are a function of the line number are corrected by adjusting the SV grid points by the magnitude of the errors. The resulting points are the SV' grid points shown in Figure B-10. Finally, the location of each point in the input data array is calculated by linear interpolation between the SV' or LH grid points.

B.7.3 Inputs to Resampling Process

The following data is required to perform the resampling function:

a. Hybrid-space grid-point locations and corresponding input-space grid-point locations (SVO grid points).

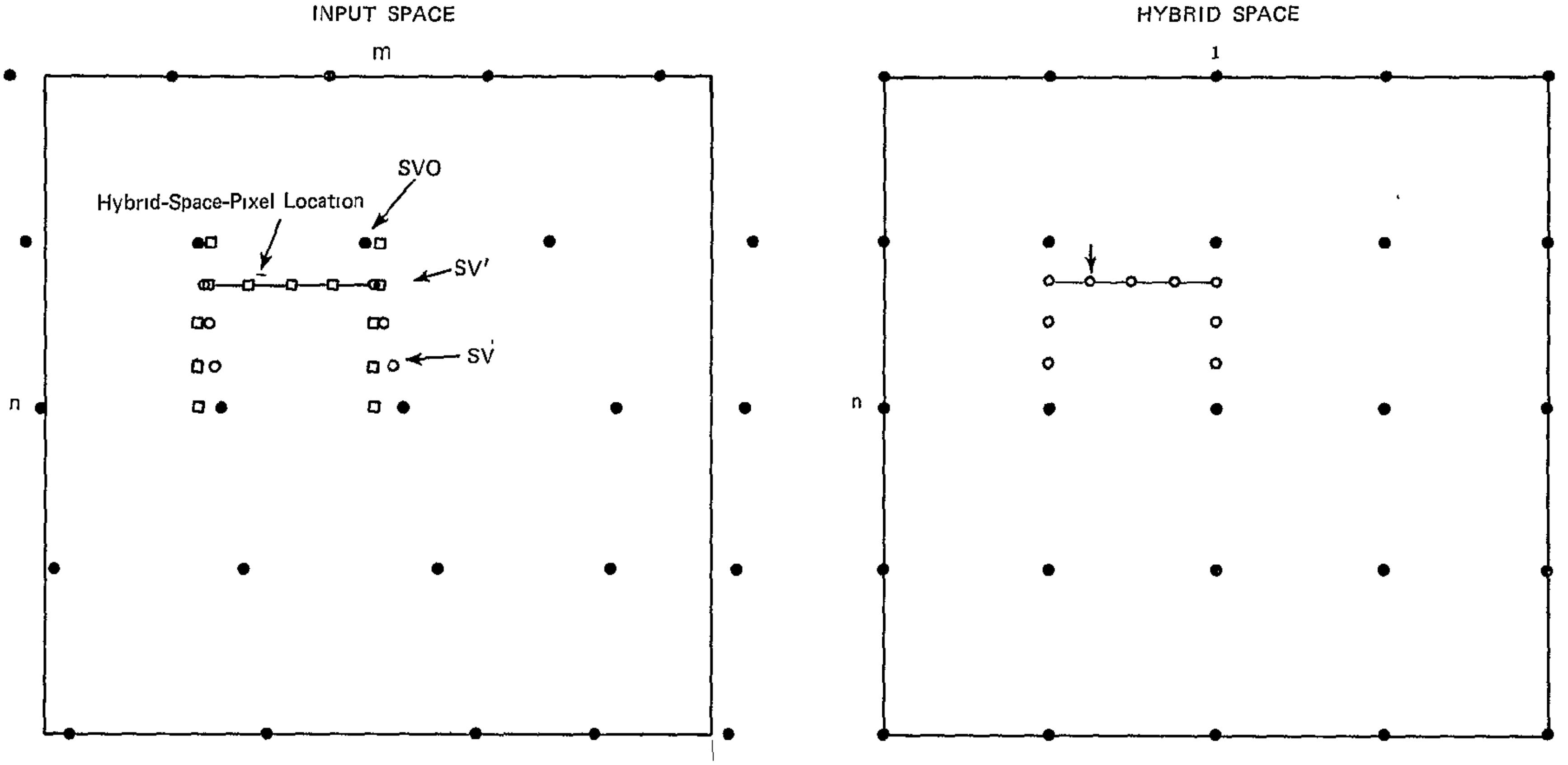

Figure B-10. Construction of Hybrid Space

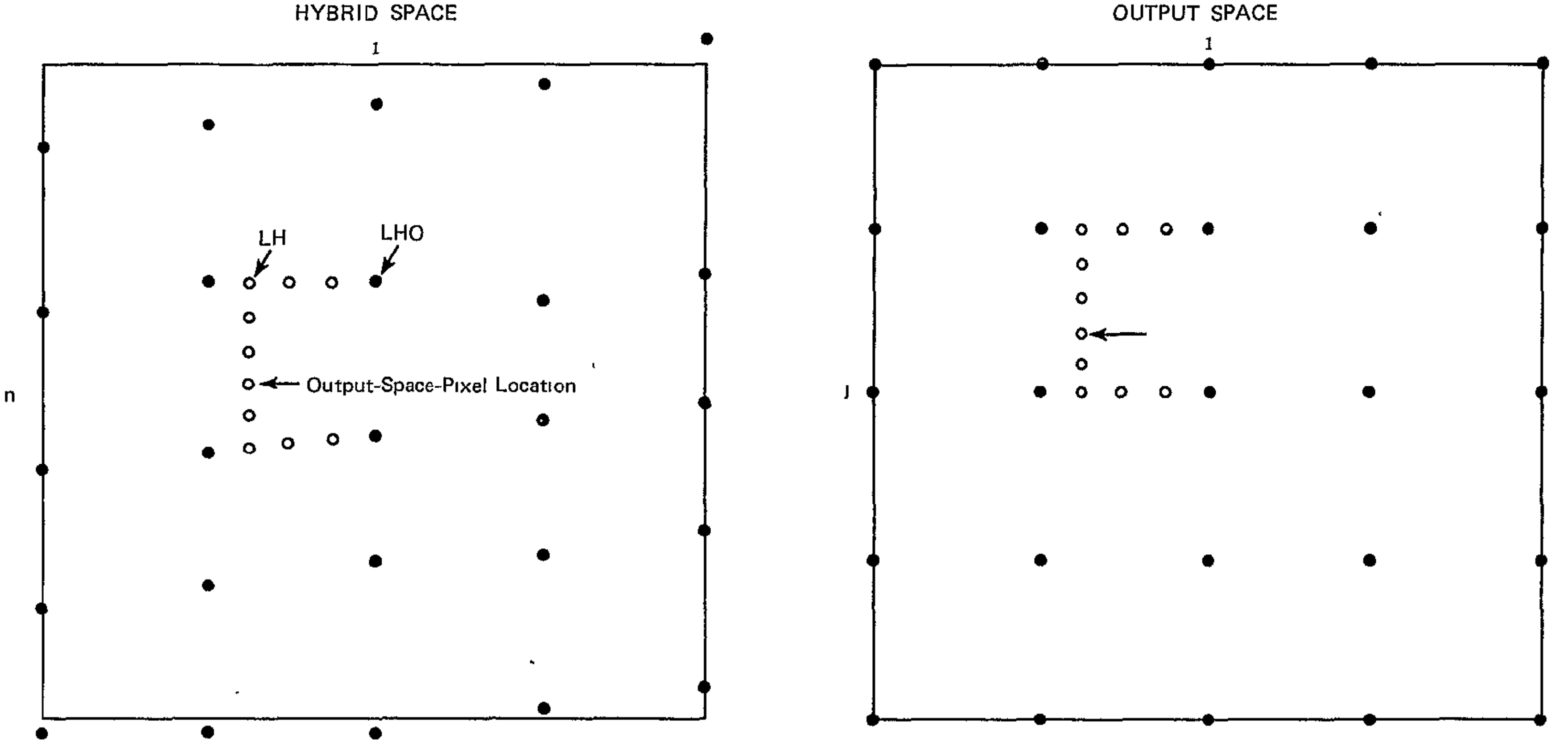

Figure B-11. Construction of Output Space

b. Constants required to compute horizontal, high-frequency correction coefficients.

c. Output-space grid-point locations and corresponding hybrid-space grid-point locations (LHO grid points).

d. Input-space array of data values (assume 8-bit pixels).

e. Constants required to evaluate resampling polynomial.

B.7.4 Algorithm Considerations

The general formula for a six-point, one-dimensional resampling algorithm may be stated as follows:

$$V = \frac{D}{K}\left(\frac{D}{K}\left(\frac{D}{K}\left(\sum_{-2}^{3} W_{3,N} I_N\right) + \sum_{-2}^{3} W_{2,N} I_N\right) + \sum_{-2}^{3} W_{1,N} I_N\right) + I_0 \qquad (1)$$

where

I_N = the intensity of pixel N

$W_{I,N}$ = the weight for pixel N in the term of degree I (a known constant)

K = a known constant

D = the (positive) distance between pixel 0 and the output pixel.

The relationships are illustrated in Figure B-12.

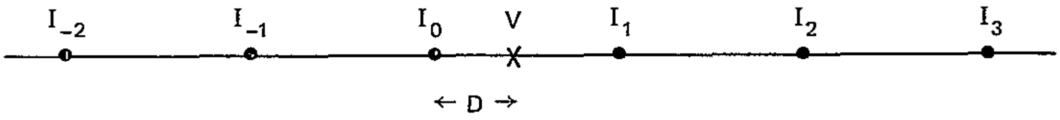

Figure B-12. Six-point Resampling

If equation (1) is implemented in hardware or software in such a way that the weights $W_{I,N}$ and the constant K may be easily changed, then a large class of resampling algorithms are included in the single implementation. In particular, all six-point and four-point cubic-convolution resamplers are included, as is the four-point quadratic-convolution algorithm. Some common resampling-algorithm constants are given in Table B-24.

It is obvious from equation (1) that the single-implementation approach would be a very poor strategy for a software resampler on an IBM 370 computer. Using

Table B-24. Typical Resampling Constants (Weights)

RESAMPLING ALGORITHM	CONSTANTS																		K
I	3	3	3	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	
N	-2	-1	0	1	2	3	-2	-1	0	1	2	3	-2	-1	0	1	2	3	
CLASSIC 4-POINT CUBIC	0	-1	1	-1	1	0	0	2	-2	1	-1	0	0	-1	0	1	0	0	1
OPTIMIZED 4-POINT CUBIC	0	-1	3	-3	1	0	0	2	-3	2	-1	0	0	-1	0	1	0	0	2
CLASSIC 6-POINT CUBIC	1	-1	2	-2	1	-1	-2	3	-4	2	-1	1	1	-1	0	1	0	0	2
OPTIMIZED 6-POINT CUBIC	1	-3	6	-6	3	-1	-2	7	-11	7	-2	1	1	-4	0	4	-1	0	5
4-POINT QUADRATIC	0	0	0	0	0	0	0	1	-1	-1	1	0	0	-1	0	2	-1	0	1

equation (1) for a four-point quadratic convolution would use more than twice as much CPU time as would be required by the equation

$$V = D(D(I_{-1} - I_0 - I_1 + I_2) + (-I_{-1} + 2I_1 - I_2)) + I_0, \tag{2}$$

which would eliminate all of the unnecessary multiplications by zero. A good software approach is to code each resampling algorithm separately to minimize CPU utilization. This approach will be used for the SLDMS Resampling Program. The classic 4-point cubic convolution algorithm will be used.

B.7.5 Handling of Edges in Resampling Via Hybrid Space

The boundary of a digital image that has been resampled is usually not a rectangle that is aligned with the rows and columns of pixels. There is normally some non-image fill data at the edges of a digital image. In order to simplify the handling of edges during resampling, the input-space data will be artificially enlarged by placing fill pixels around the edges. This padding will be sufficiently large to guarantee that input-space data exists for every hybrid-space pixel and that hybrid-space data exists for every output-space pixel.

Figures B-10 and B-11 assume no such enlargement of input space. Figures B-13 and B-14 assume the enlargement described above. In this case, there are no SV' points (or LH points) that are not at least three columns (or rows) interior to the enlarged input space (or enlarged hybrid space). Therefore, no special case will have to be made for output-space pixels that would be mapped outside the input-space image data. All hybrid-space and output-space pixels are created in the same way by the resampling function. A scale drawing of the three resampling spaces is shown in Figure B-15.

B.7.6 Program Description

Although the resampling problem is conceptually straightforward, computer software that performs resampling is somewhat complicated. This program, the largest CPU user in the SLDMS, will be written primarily in assembler language to minimize computer utilization costs.

The design of this program is described in Figure B-16 and the program specifications that follow. These describe the cubic convolution algorithm. The nearest-neighbor resampling algorithm will use the same design.

The design of the resampling program has a few significant features. The resampling is performed via an intermediate hybrid space. This method was chosen to minimize computer utilization. The four point resampling algorithm will be implemented in fixed-point arithmetic to minimize computer use. The alternative, floating-point arithmetic, would use considerably more CPU.

Another significant feature is the large hybrid-space buffer. In order to minimize the I/O processing of the resampling program, the output image will be

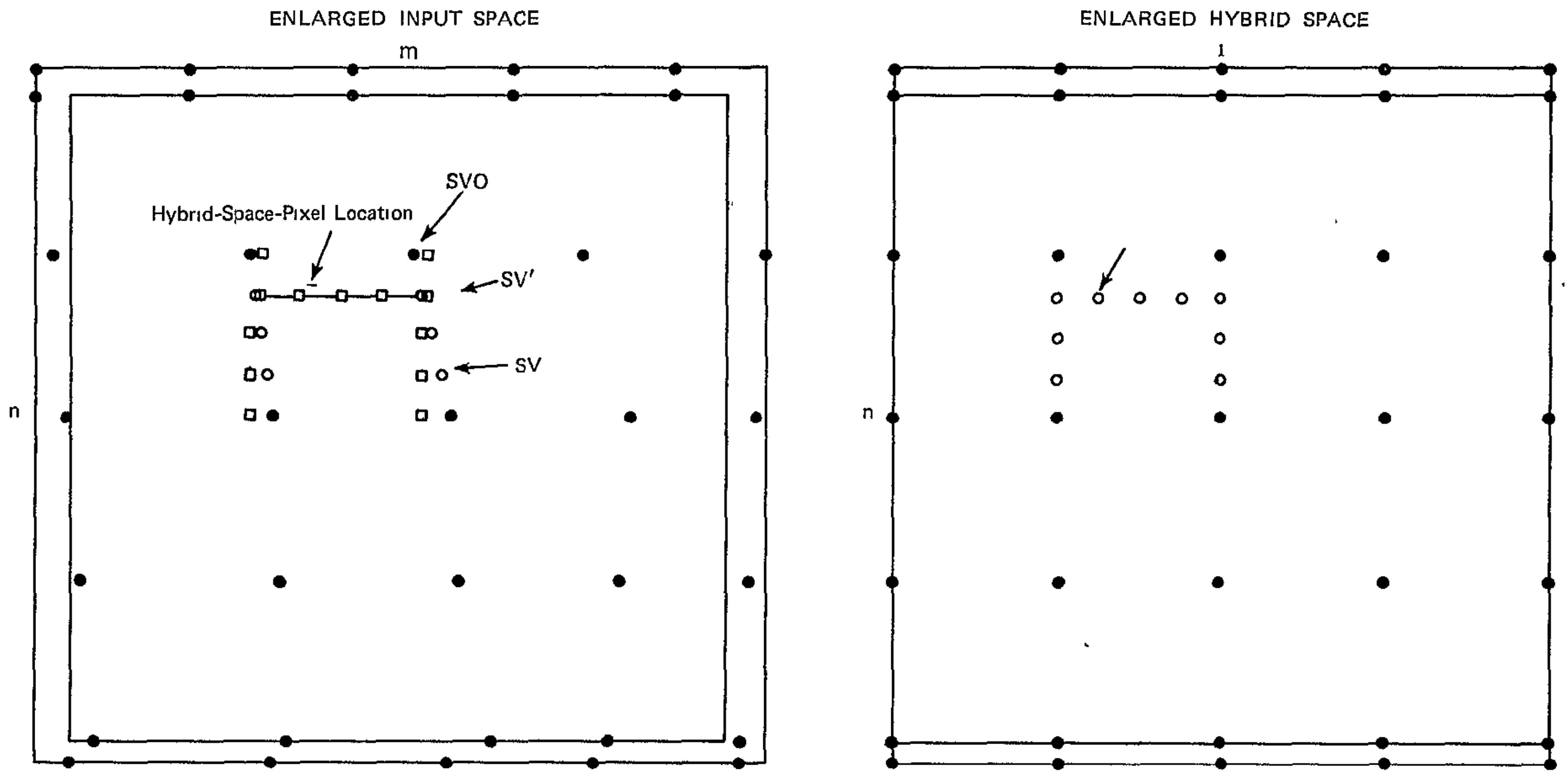

Figure B-13. Construction of Hybrid Space

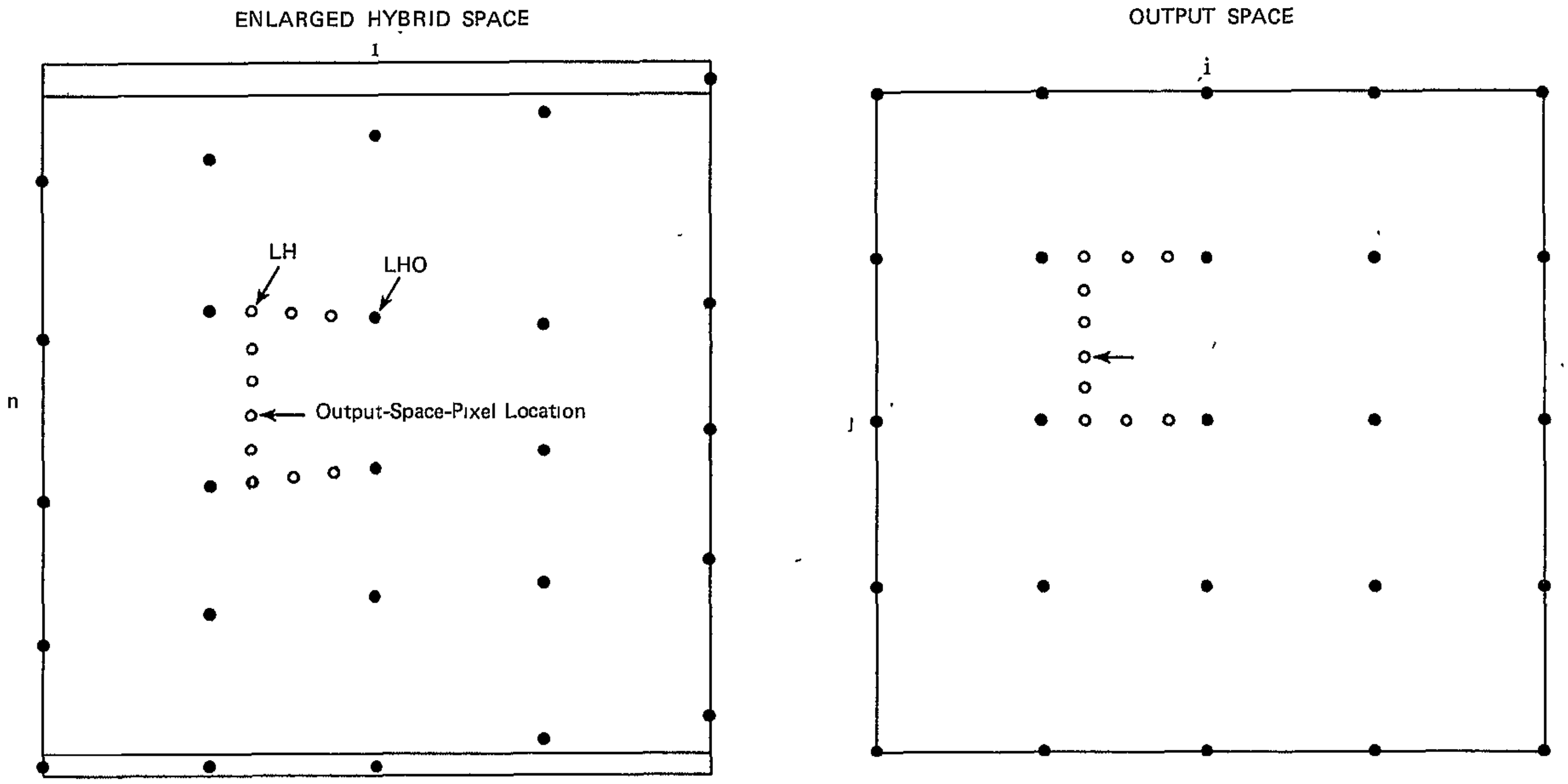

Figure B-14. Construction of Output Space

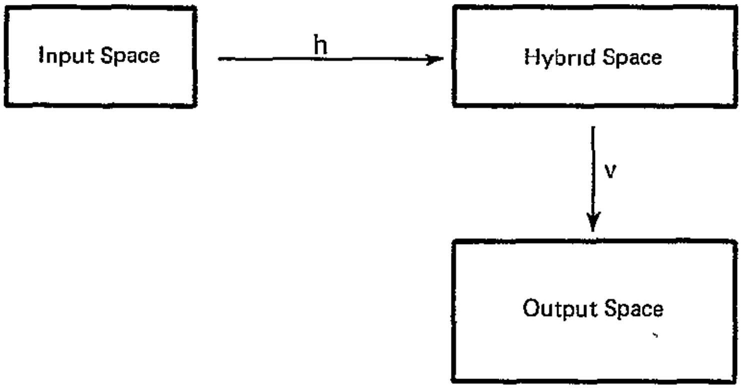

Figure B-15. Resampling Spaces (Drawn to Scale) created in full-line increments. This requires hybrid-space data from several lines to be available at essentially the same time. This availability will be provided by a large buffer in the computer memory. The size of this hybrid-space buffer is dependent on the size of the output space and the particular geometric transformation between the input and output spaces. The buffer will be allocated dynamically during program execution. This will permit the program to be run in small regions where possible.

Due to the generally high running cost of the resampling program, it will have a checkpoint/restart capability. A checkpoint is taken for each row of LHO grid points. In the event of a computer failure during execution of the resampling program, processing can be resumed at the point at which the last checkpoint was taken.

```
RSPL ---------- RSPLV ---------- RSPLH
```

FIGURE B-16. MODULE HIERARCHY FOR RESAMPLING PROGRAM.

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... RSPL

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... THIS IS THE TOP-LEVEL DRIVER FOR THE RESAMPLING PROGRAM.

INPUTS .... 1. AN SLDMS ANCILLARY DATA SET FOR THE SCENE TO BE PROCESSED.
2. AN IMAGE DATA SET IN MIST FORMAT.
3. A DATA SET CONTAINING USER'S REQUESTS (ON CARD IMAGES).

OUTPUTS .... 1. AN IMAGE DATA SET IN MIST FORMAT.
2. A PRINTER LISTING DATA SET.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... NOT APPLICABLE.

PDL (PROGRAM OUTLINE)

```
PRINT PROGRAM-ENTRY MESSAGE
START CPU TIMING
IF   THIS IS A CHECKPOINT/RESTART RUN   THEN
    PERFORM RESTART INITIALIZATION
    POSITION DATA SETS
    PRINT RESULTS
ELSE
    READ GRID-POINT CORRESPONDENCE FROM ANCILLARY DATA SET
    INITIALIZE CONSTANTS AND OTHER DATA AREAS
    PRINT RESULTS
    OBTAIN HYBRID SPACE BUFFER AREA IN (VIRTUAL) MEMORY
    OPEN DATA SETS
    PRINT RESULTS
ENDIF
TAKE CPU-TIMING READING
PERFORM VERTICAL RESAMPLING
TAKE CPU-TIMING READING
CLOSE DATA SETS
PRINT RESULTS OF CPU TIMINGS
PRINT PROGRAM-EXIT MESSAGE
```

****** END OF SPECIFICATION ******

****** SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION ******

NAME .... RSPLV

DESIGNER .... STEPHEN W. MURPHREY

FUNCTION .... PERFORMS VERTICAL RESAMPLING (INCLUDES CONTROL OF HORIZONTAL RESAMPLING).

INPUTS .... 1. SEE CALLING SEQUENCE.

OUTPUTS .... 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ...

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS

PDL (PROGRAM OUTLINE)

```
DO FROM   J = 1 TO N - 1    ( N = NUMBER OF ROWS OF LHO GRID POINTS )
    COMPUTE LHK GRID POINTS FOR EACH COLUMN (K) OF PIXELS
    COMPUTE DUK FOR EACH COLUMN OF PIXELS
    DO FROM   I = 0 TO MJ - 1    ( MJ = # ROWS OF PIXELS IN SEGMENT J )
        DETERMINE LOCATION OF FIRST PIXEL IN OUTPUT-SPACE BUFFER
        DO FROM   K = 1 TO L    ( L = WIDTH OF ONE OUTPUT-SPACE ROW )
            C = LHK + I * DUK
            IC = G(C) + 2        ( G(C) = MAXIMUM INTEGER <= C )
            DO WHILE LINE ID IS NOT IN THE HYBRID-SPACE BUFFER
                HORIZONTALLY RESAMPLE ONE LINE OF INPUT-SPACE DATA
            ENDDO
            OBTAIN THE FOUR PIXEL INTENSITIES STARTING WITH PIXEL IC
            D = C - IC + 2
            PERFORM THE FOUR-POINT RESAMPLING   (EQUATION 2 )
            INSERT RESULT INTO THE OUTPUT-SPACE BUFFER
            DETERMINE LOCATION OF NEXT PIXEL IN OUTPUT-SPACE BUFFER
        ENDDO
        WRITE ONE OUTPUT-SPACE RECORD
    ENDDO
    TAKE A CHECKPOINT
ENDDO
```

****** END OF SPECIFICATION ******

```
******        SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION          ******
NAME ........... RSPLH
DESIGNER ....... STEPHEN W. MURPHREY
FUNCTION ....... HORIZONTAL RESAMPLING OF ONE LINE OF INPUT-SPACE DATA.
INPUTS ......... 1. SEE CALLING SEQUENCE.
OUTPUTS ........ 1. SEE CALLING SEQUENCE.
COMMON BLOCKS ..
RESTRICTIONS ...
CALLING SEQ. ...
  VARIABLE  TYPE  I/O  DIM    DESCRIPTION                          UNITS
  ------    ---    -  ------ -------------------------------      -------
PDL (PROGRAM OUTLINE)
  READ NEXT RECORD INTO INPUT-SPACE BUFFER
  READ NEXT SET OF SV' GRID-POINT COORDINATES
  DETERMINE LOCATION OF NEXT LINE IN HYBRID-SPACE BUFFER
  DO FROM   J = 1 TO N - 1         ( N = NUMBER OF SV' GRID POINTS IN ONE ROW )
      DETERMINE DVJ
      DO FROM   I = 0 TO MJ - 1    ( MJ = NUMBER OF PIXELS IN SEGMENT J )
          C = SV'J + I * DVJ
          IC = G(C) - 1            ( G(C) = MAXIMUM INTEGER <= C )
          OBTAIN THE FOUR PIXEL INTENSITIES STARTING WITH PIXEL IC
          D = C - IC - 1
          PERFORM THE FOUR-POINT RESAMPLING (EQUATION 2)
          INSERT THE RESULT INTO THE HYBRID-SPACE BUFFER
          DETERMINE THE LOCATION OF THE NEXT PIXEL IN HYBRID-SPACE BUFFER
      ENDDO
  ENDDO
******                       END OF SPECIFICATION                            ******
```

```
******        SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION          ******

NAME ........... MRFTXI

DESIGNER ....... STEPHEN W. MURPHREY

FUNCTION ....... PROCESSES X-FORMAT IMAGE DATA.

INPUTS ......... 1. SEE CALLING SEQUENCE.

OUTPUTS ........ 1. SEE CALLING SEQUENCE.

COMMON BLOCKS ..

RESTRICTIONS ...

CALLING SEQ. ... CALL MRFTXI (     )

  VARIABLE  TYPE  I/O  DIM    DESCRIPTION                              UNITS

  ------    ---    -  ------  -------------------------------          -------

PDL (PROGRAM OUTLINE)

  IF   THIS IS NOT A THERMAL-BAND RECORD   THEN
      DO FOR EACH 8-BYTE GROUP OF INPUT DATA
          MOVE BYTES 1 AND 2 TO BAND-1 AREA OF OUTPUT BUFFER
          MOVE BYTES 3 AND 4 TO BAND-2 AREA OF OUTPUT BUFFER
          MOVE BYTES 5 AND 6 TO BAND-3 AREA OF OUTPUT BUFFER
          MOVE BYTES 7 AND 8 TO BAND-4 AREA OF OUTPUT BUFFER
      ENDDO
      IF   THIS IS INPUT DATA FOR STRIP 4   THEN
          D = LLC / ( LLA - LLC - 6 ) = LENGTH OF SEGMENT W/O DUPLICATED PIXEL
          LLF = ( LLC + 6 ) / LLA = LINE-LENGTH FACTOR (SAVED IN OUTPUT BUFFER)
          INITIALIZE "FROM" AND "TO" ADDRESSES
          DO  FOR BANDS 1 TO 4
              R = LLA
              DO WHILE   R > D
                  MOVE D PIXELS
                  INCREMENT "FROM" BY  D + 1
                  INCREMENT "TO" BY  D
                  R = R - ( D + 1 )
              ENDDO
              IF   R > 0
                  MOVE R PIXELS
              ENDIF
              FILL REMAINDER OF BUFFER AREA WITH FILL CHARACTERS
              DO FOR EACH IMAGE PIXEL
                  OBTAIN  V = PIXEL VALUE
                  INCREMENT V COUNTER FOR CURRENT DETECTOR BY 1
              ENDDO
          ENDDO
      ENDIF
  ELSE
      MOVE ALL IMAGE DATA TO BAND-5 AREA OF OUTPUT BUFFER
      IF   THIS IS INPUT DATA SET FOR STRIP 4
          REMOVE LINE-LENGTH CORRECTION PIXELS
          FILL REMAINDER OF BUFFER AREA WITH FILL CHARACTERS
          DO FOR EACH IMAGE PIXEL
              OBTAIN  V = PIXEL VALUE
              INCREMENT V COUNTER FOR CURRENT DETECTOR BY 1
          ENDDO
      ENDIF
  ENDIF

******                        END OF SPECIFICATION                          ******
```

```
******        SAR/LANDSAT DATA MERGING SYSTEM PROGRAM SPECIFICATION        ******
NAME ........... MRFTXS
DESIGNER ....... STEPHEN W. MURPHREY
FUNCTION ....... READS AND PROCESSES SIAT FILE FROM X-FORMAT MSS TAPE.
INPUTS ......... 1. SEE CALLING SEQUENCE.
OUTPUTS ........ 1. SEE CALLING SEQUENCE.
COMMON BLOCKS ..
RESTRICTIONS ...
CALLING SEQ. ... CALL MRFTXS (     )
  VARIABLE  TYPE  I/O  DIM    DESCRIPTION                       UNITS
  ------    ---    -  ------ --------------------------------  -------
PDL (PROGRAM OUTLINE)
  DETERMINE FORMAT LEVEL
  READ ALL 7 OR 8 SIAT RECORDS
  IF   FORMAT LEVEL 2 OR 3   THEN
      PRINT CALIBRATION MODIFIERS
  ENDIF
  PRINT SPACECRAFT PERFORMANCE DATA
  PRINT ANNOTATION BLOCK DATA
  PRINT MSS COMPUTATIONAL DATA
  PRINT IMAGE LOCATION DATA
  WRITE SIAT DATA TO ANCILLARY DATA SET
******                       END OF SPECIFICATION                          ******
```

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STEPHEN W. MURPHREY

SEPTEMBER 1978

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