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SAR-Landsat Image
Registration Study

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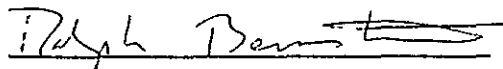
SAR—Landsat Image Registration Study

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September 1978
Final Report

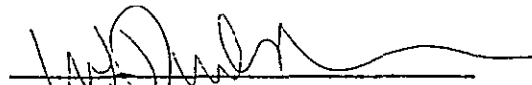
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PREFACE

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.

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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.

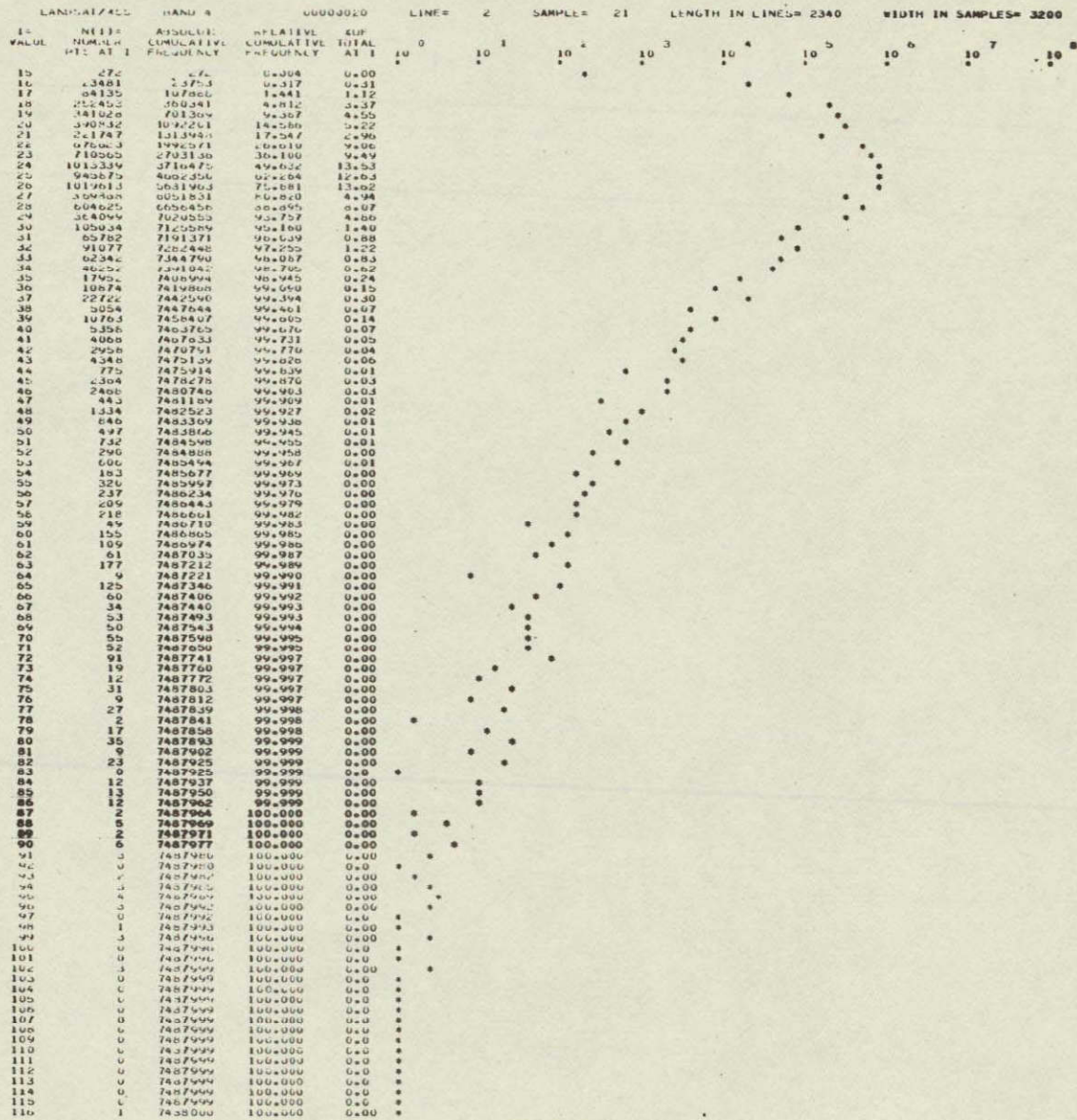
Using the mean and standard deviation of the pixel intensity distribution of the image data and knowledge of the radiometric characteristics of the IBM Drum Scanner/Plotter,¹ gain and bias coefficients were computed for each spectral band of each scene. The data from spectral band 3 (0.7 to 0.8 micron 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 algorithm² was used on all four spectral bands of the Delaware 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 coordinates and input-image pixel coordinates of several control points were needed. Twenty-five control points were found.



ALL LEADING AND TRAILING VALUES OF 1 WITH N(1) = 0 ARE OMITTED FROM THE GRAPH

MEAN = 24.58279 RMS = 24.87309 STANDARD DEVIATION = 3.78905

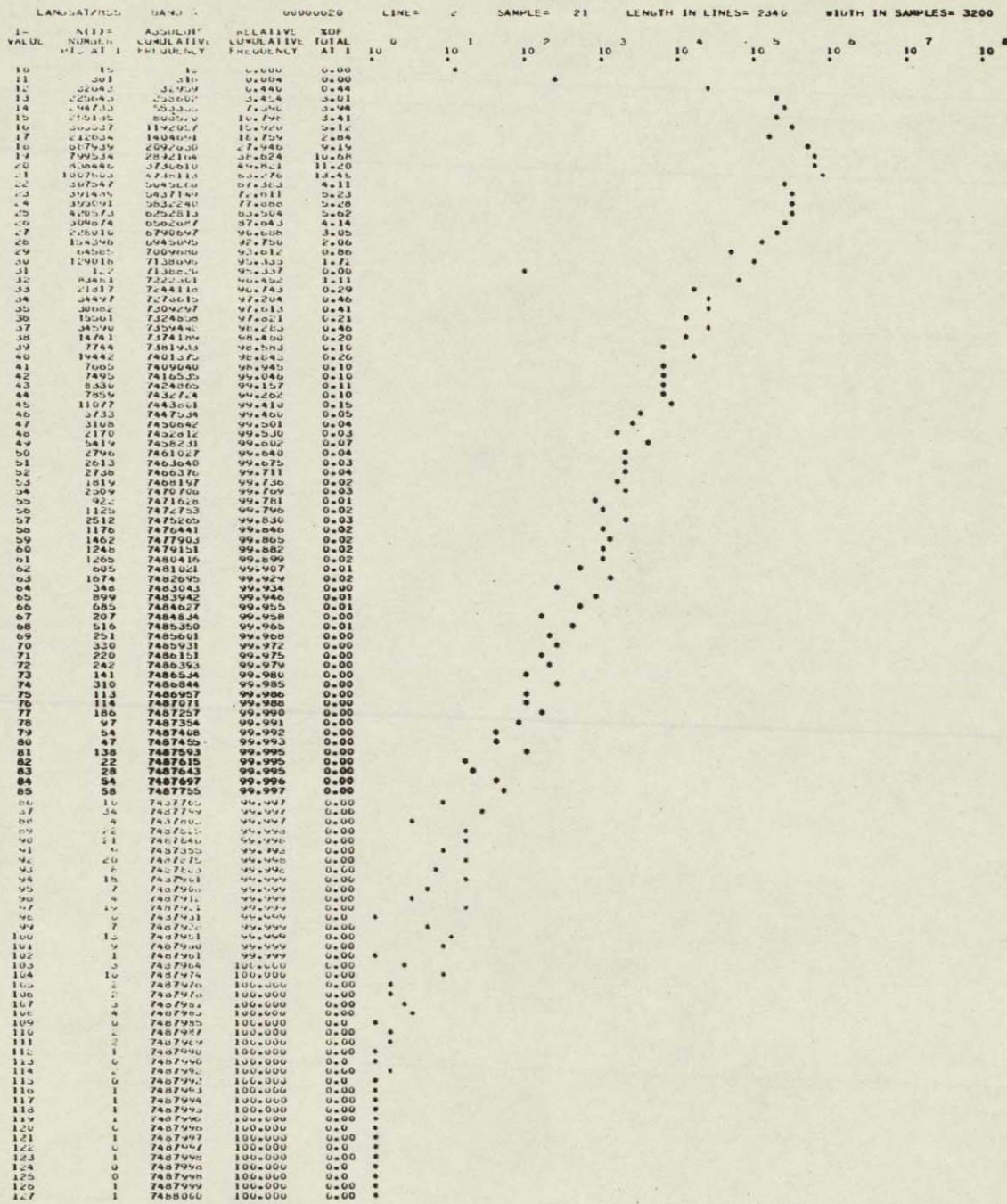
RADIOMETRIC CONSTANTS TO GIVE MEAN = 140.0; STANDARD DEVIATION = 21.0000

GAIN = 5.54228

BIAS = 3.75533

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

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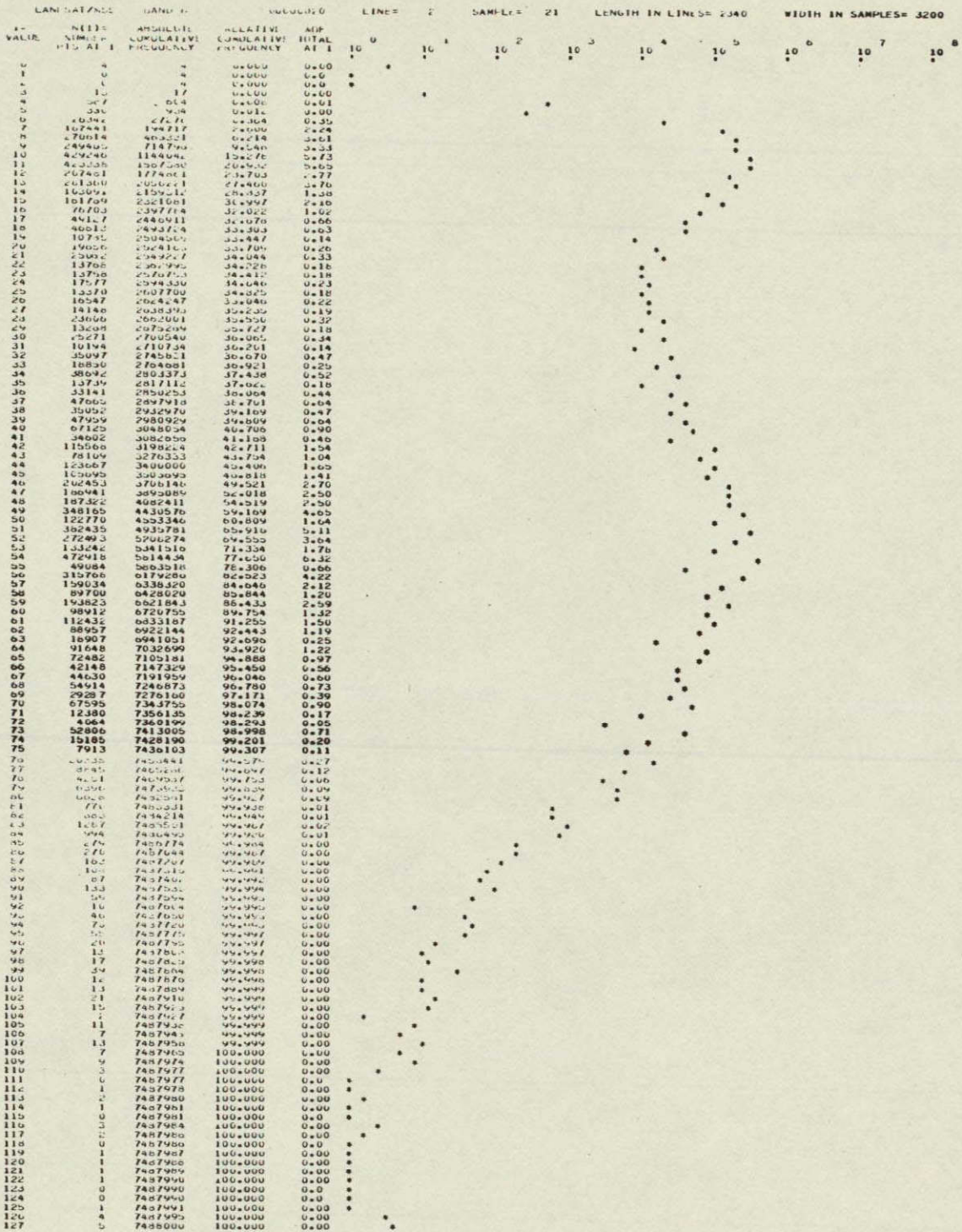


ALL LEADING AND TRAILING VALUES OF 1 WITH N(1) = 0 ARE OMITTED FROM THE GRAPH

MEAN = 21.36102 RMS = 22.09407 STANDARD DEVIATION = 5.64398

RADIOMETRIC CONSTANTS TO GIVE MEAN = 140.0; STANDARD DEVIATION = 21.0000
GAIN = 3.12075
BIAS = 60.52036

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



ALL LEADING AND TRAILING VALUES OF 1 WITH N(1)= 0 ARE OMITTED FROM THE GRAPH

MEAN= 38.00570 RMS= 43.39944 STANDARD DEVIATION= 20.84500
 RADIOMETRIC CONSTANTS TO GIVE MEAN = 140.01 STANDARD DEVIATION = 21.0000
 GAIN= 1.00743
 BIAS= 101.65129

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

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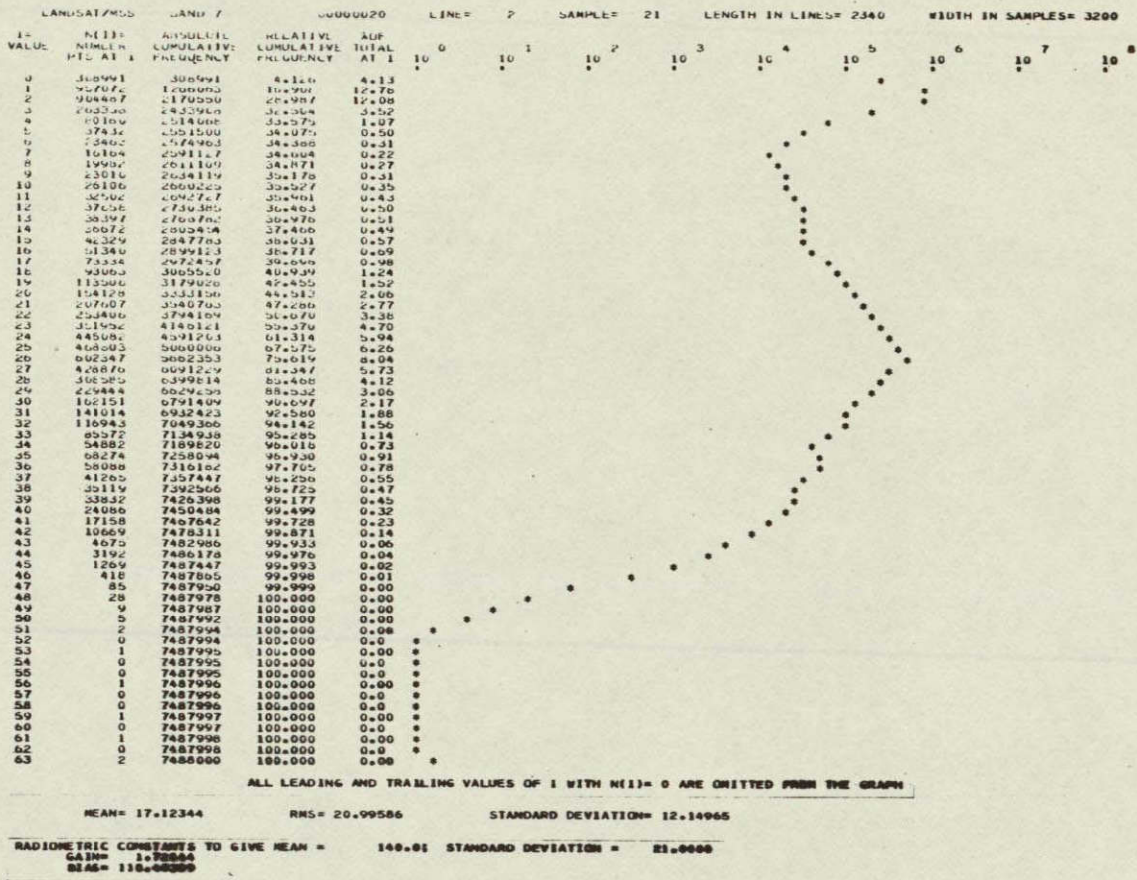


Figure 2-1. Landsat-MSS Histograms (sheet 4 of 4)

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 techniques¹⁰ 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.

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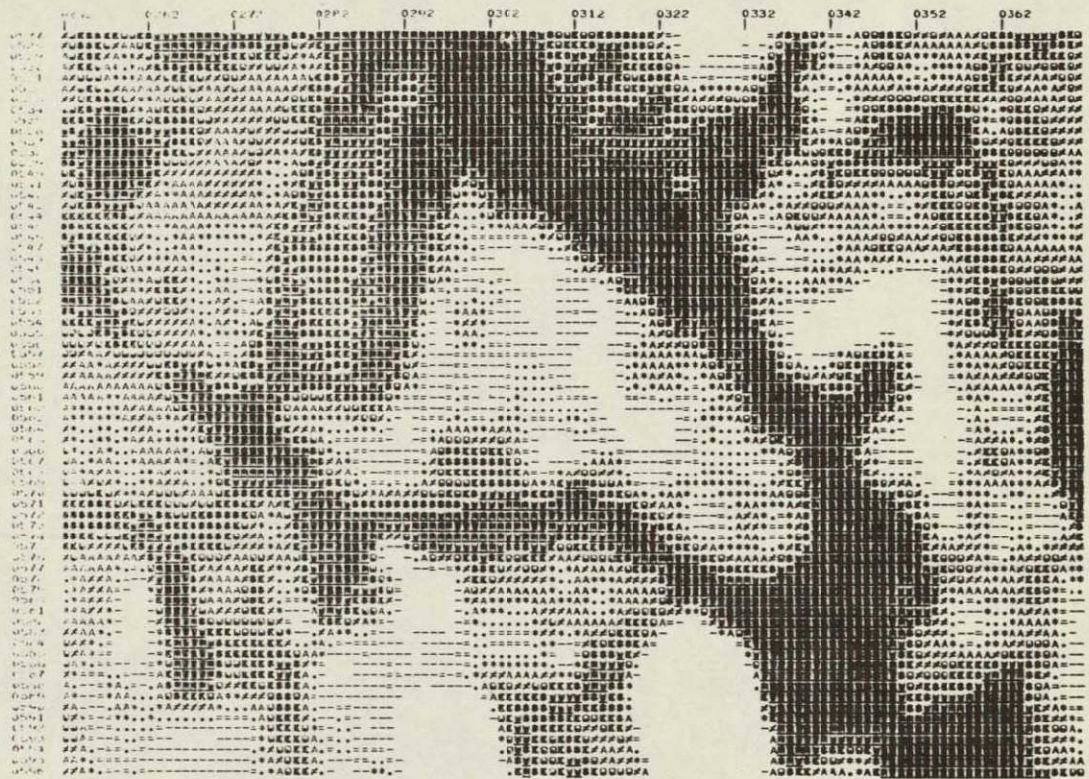


Figure 2-2. Example of Shadeprint

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.

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

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

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

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

$$\begin{aligned}
 H(y,x) = & H_1 + H_2x + H_3x^2 + H_4x^3 + H_5x^4 + H_6x^5 + \\
 & H_7y + H_8yx + H_9yx^2 + H_{10}yx^3 + H_{11}yx^4 + \\
 & H_{12}y^2 + H_{13}y^2x + H_{14}y^2x^2 + H_{15}y^2x^3 + \\
 & H_{16}y^3 + H_{17}y^3x + H_{18}y^3x^2 + \\
 & H_{19}y^4 + H_{20}y^4x + \\
 & H_{21}y^5
 \end{aligned}$$

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

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

The polynomials H and V approximate the mapping

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

in the least square sense. That is,

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

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:

$$g = \frac{S}{s}$$

$$b = M - g m$$

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 $0,1,\dots,255$ and that plots the same gray level for all values in the range $0,1,\dots,55$. In the range $56,57,\dots,255$ assume that the response (gray level versus pixel value) is approximately linear. The effective dynamic range of this hypothetical plotter is $56,57,\dots,255$. 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:

$$F_1 = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

$$F_2 = \begin{bmatrix} -1 & -2 & -1 \\ -2 & 13 & -2 \\ -1 & -2 & -1 \end{bmatrix}$$

$$F_3 = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

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

Each of these examples has the property that the sum of the weights is one. This results in an image that is the sum of 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/Plotter¹. 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 original 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.

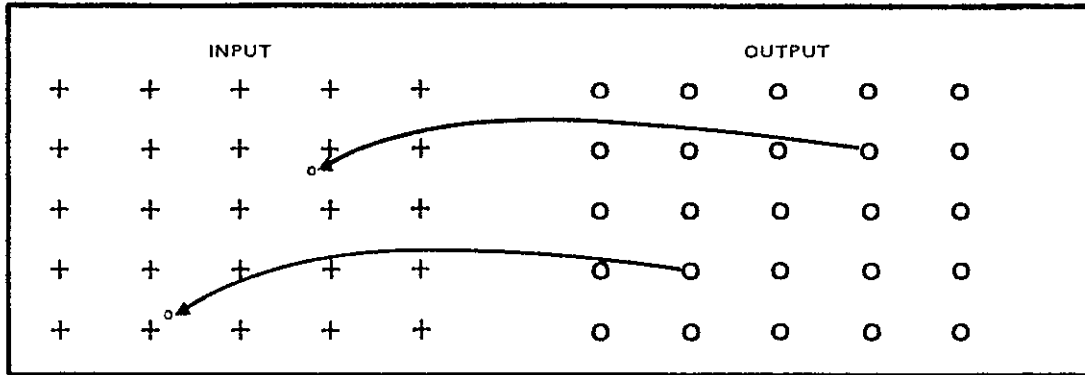


Figure 4-1. Locating Output Points in Input Space

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.

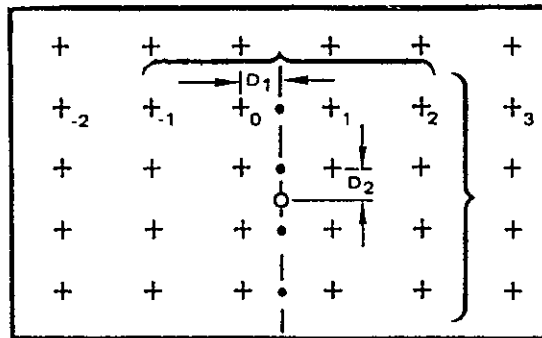


Figure 4-2. Two-Way Cubic Convolution Resampling

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

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

An experimental program that evaluates this equation five times for each output pixel and that uses 32-bit floating point arithmetic 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

GCP	Measured UTM Map Coordinates			Observed Input-Space Coordinates		Nominal Input-Space Coordinates		Input-Space Differences In Pixels		Radial Error In Meters
	NORTHING	EASTING	ZONE	YOBS	XOBS	YNOM	XNOM	DELY	DELX	RSSM
1	4368380	399200	18	351.00	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	1754.00	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	4340075	399120	18	261.00	465.00	260.61	465.84	0.3899	-0.8435	70.425
13	4302940	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	453565	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	2026.06	626.00	2025.99	626.98	0.0140	-6.9799	77.609
23	4319340	516745	18	2589.00	1031.00	2588.68	1031.95	0.3244	-0.9549	77.866
24	4317520	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

5-2

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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
1737.0000	1757.0000	393.0000	259.0000	393.0143	259.7749	-0.0143	-0.7749	0.0377
1163.0000	1847.0000	663.0000	2488.0000	662.3730	2486.4555	0.6270	1.5445	1.6045
870.0000	1843.0000	367.0000	2570.0000	366.6870	2560.6435	0.3130	1.3565	0.4785
775.0000	2058.0000	326.0000	2304.0000	327.7827	2304.3825	-1.3827	-0.3825	1.1476
1175.0000	2173.0000	685.0000	2812.0000	685.0722	2811.7775	0.9278	-0.0225	0.9254
669.0000	2223.0000	244.0000	2976.0000	243.7904	2975.2975	0.6096	-0.2975	0.6752
583.0000	2246.0000	245.0000	3265.0000	247.1559	3264.0272	-0.1559	-0.0272	0.1500
623.0000	2267.0000	350.0000	3402.0000	357.9502	3402.7032	-0.9502	-0.0032	0.1757
1153.0000	1851.0000	655.0000	2502.0000	655.8181	2503.6969	-0.8181	1.6969	1.8748
1151.0000	2197.0000	689.0000	2925.0000	684.6824	2925.9388	0.3176	-0.9388	1.0385
949.0000	2150.0000	562.0000	2830.0000	562.1898	2830.0688	0.1998	-0.0688	0.2019
917.0000	2182.0000	571.0000	2879.0000	494.9147	2870.7236	0.0853	0.7236	2.2312
654.0000	2213.0000	542.0000	2899.0000	547.6766	2895.0484	-0.6766	0.9516	1.0673
687.0000	2246.0000	286.0000	3011.0000	286.1294	3010.5073	0.4927	0.4927	0.5094
				MEAN_OF_EACH_COLUMN		-0.0000	0.0000	0.9263

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

LEAST-SQUARES FIT EVALUATION BY SUBROUTINE LS22EV:

RESULTS OF LEAST SQUARES FIT:				Radial		
Observed		Mapped		Errors		
Output-Space Coordinates	Input-Space Coordinates	Input-Space Coordinates	Input-Space Coordinates	in Pixels	in Pixels	
300.0000	246.0000	132.0000	257.4587	131.2214	0.7786	3.6722
339.0000	261.0000	146.0000	760.8242	147.9109	-2.8242	3.4100
235.0000	290.0000	114.0000	293.0000	119.2300	-6.2300	5.2702
856.0000	369.0000	1696.0000	150.0000	1690.9051	5.0949	5.2392
871.0000	509.0000	1795.0000	523.0000	1796.5433	-0.5433	6.2533
698.0000	654.0000	1229.0000	1083.0000	1229.9474	-0.9474	2.3368
284.0000	809.0000	534.0000	1713.0000	533.8438	0.1562	2.6052
560.0000	901.0000	1254.0000	1796.0000	1251.0308	2.9692	7.6598
483.0000	899.0000	1062.0000	1846.0000	1061.5174	0.4826	2.8189
734.0000	1110.0000	1797.0000	2240.0000	1796.1665	0.8335	0.9720
759.0000	975.0000	1779.0000	1892.0000	1780.1392	-1.1392	1.3213
259.0000	236.0000	408.0000	60.0000	397.4642	10.5358	10.5357
486.0000	263.0000	717.0000	70.0000	719.0023	-2.0023	6.5308
531.0000	270.0000	830.0000	54.0000	830.5994	-0.5994	1.9595
575.0000	316.0000	957.0000	154.0000	961.8319	-5.8319	5.6914
633.0000	345.0000	1120.0000	203.0000	1118.3321	1.6679	3.1247
701.0000	319.0000	1271.0000	97.0000	1269.6223	1.3777	5.4476
293.0000	364.0000	502.0000	460.0000	502.3310	-0.3310	0.7070
339.0000	375.0000	420.0000	461.0000	422.6584	-2.6584	3.9208
387.0000	445.0000	579.0000	632.0000	580.5310	1.4690	1.5341
832.0000	424.0000	1659.0000	309.0000	1657.3208	1.6792	1.0388
853.0000	481.0000	1731.0000	448.0000	1738.2924	-7.2924	8.4105
653.0000	434.0000	1222.0000	444.0000	1217.9625	4.0375	4.2008
538.0000	580.0000	981.0000	562.0000	985.8324	-4.8324	5.7329
609.0000	549.0000	1164.0000	779.0000	1165.4026	-1.4026	1.3084
384.0000	527.0000	621.0000	866.0000	619.2737	1.7263	2.4640
177.0000	102.0000	102.0000	1051.0000	97.2765	4.9235	7.9276
162.0000	547.0000	80.0000	1051.0000	1056.2534	-2.2534	5.7695
352.0000	614.0000	693.0000	1128.0000	589.6485	1128.4670	3.3632
457.0000	618.0000	647.0000	1073.0000	845.5150	1.4850	3.2008
623.0000	685.0000	1281.0000	1165.0000	1283.5201	-1162.0799	3.2933
138.0000	625.0000	61.0000	1283.0000	68.7962	-7.7962	10.8489
153.0000	717.0000	154.0000	1541.0000	160.0308	1539.9692	5.2937
363.0000	750.0000	691.0000	1513.0000	693.6051	-2.6051	4.1250
346.0000	854.0000	714.0000	1809.0000	707.6400	1.3600	9.0090
250.0000	791.0000	421.0000	1660.0000	435.6764	1.3236	4.4332
115.0000	828.0000	131.0000	1861.0000	130.3736	0.6264	5.9144
782.0000	991.0000	1042.0000	1920.0000	1840.8372	1919.2020	1.4103
716.0000	1011.0000	1701.0000	2016.0000	1703.3201	2020.3301	4.4332
538.0000	987.0000	1291.0000	2050.0000	1246.6647	2056.3353	6.0610
93.0000	1039.0000	185.0000	2480.0000	190.8386	2472.9708	5.8386
337.0000	1015.0000	777.0000	2250.0000	775.4284	2256.2984	1.5716
541.0000	1095.0000	1410.0000	2334.0000	1415.0974	2335.2342	-1.2392
645.0000	1112.0000	1311.0000	2341.0000	1313.4768	2344.4251	-2.4768
644.0000	1147.0000	1601.0000	2439.0000	1598.2350	2439.4672	2.7650
742.0000	1116.0000	1817.0000	2292.0000	1817.2169	2291.1601	0.8339
181.0000	459.0000	42.0000	800.0000	78.1625	795.8774	3.8375
423.0000	599.0000	588.0000	500.0000	596.4240	202.2526	-2.2526
450.0000	561.0000	683.0000	359.0000	686.5083	359.7078	-3.5083
224.0000	543.0000	232.0000	1010.0000	233.9790	1006.7908	-1.4790
793.0000	737.0000	1501.0000	86.0000	1511.8117	91.1485	-10.8117
758.0000	454.0000	1493.0000	444.0000	1490.0465	445.5474	-2.9535
878.0000	636.0000	1464.0000	845.0000	1868.9024	857.7769	-4.9024
271.0000	968.0000	563.0000	2171.0000	592.3211	2166.5158	-9.3213
170.0000	837.0000	274.0000	1862.0000	272.3522	1866.5066	-4.6066
170.0000	841.0000	262.0000	1870.0000	274.6302	1873.5934	-3.5934
117.0000	919.0000	143.0000	1851.0000	130.1549	1841.0735	2.8451
255.0000	763.0000	451.0000	1660.0000	448.9608	1661.5024	-2.0392
125.0000	626.0000	-8.0000	1290.0000	37.2706	1300.6084	0.7294
694.0000	312.0000	1253.0000	76.0000	1248.3004	76.9457	4.6996
220.0000	293.0000	30.0000	308.0000	310.0807	310.0807	-1.9768
379.0000	443.0000	560.0000	624.0000	559.8094	631.0028	0.1906
879.0000	514.0000	174.0000	53.0000	1817.1143	525.3856	6.0057
156.0000	278.0000	94.0000	1030.0000	97.0087	1028.3599	6.9913
143.0000	708.0000	127.0000	1523.0000	129.9369	1519.8341	-2.4369
618.0000	743.0000	1299.0000	1379.0000	1303.4091	1326.8971	-4.4091
745.0000	633.0000	1670.0000	1506.0000	1664.7513	1501.6069	5.4885
768.0000	912.0000	1764.0000	1713.0000	1764.4490	1708.3789	4.5510
726.0000	1020.0000	1724.0000	2036.0000	1729.2484	2038.8225	-6.2489
572.0000	889.0000	1270.0000	1760.0000	1270.6397	1764.5170	-3.6397
487.0000	847.0000	1069.0000	1840.0000	1070.0679	1835.6632	-1.0979
105.0000	1037.0000	227.0000	2485.0000	220.8415	2461.8611	6.1586
542.0000	1128.0000	1737.0000	2452.0000	1733.0981	2446.6171	5.3829

MEAN OF EACH COLUMN 0.0000 0.0000 5.0113

RMS OF RESIDUALS 5.7230

ID NUMBER OF POINT WITH LARGEST RESIDUAL ERROR 51

RETURNING NORMALLY FROM SUBROUTINE LS22EV

ORIGINAL PAGE IS
OF POOR QUALITY

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.

1

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

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APPENDIX A,

FUNCTIONAL DESCRIPTION
OF THE
SAR/LANDSAT DATA MERGING SYSTEM

September 1978

By
Stephen W. Murphrey

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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.

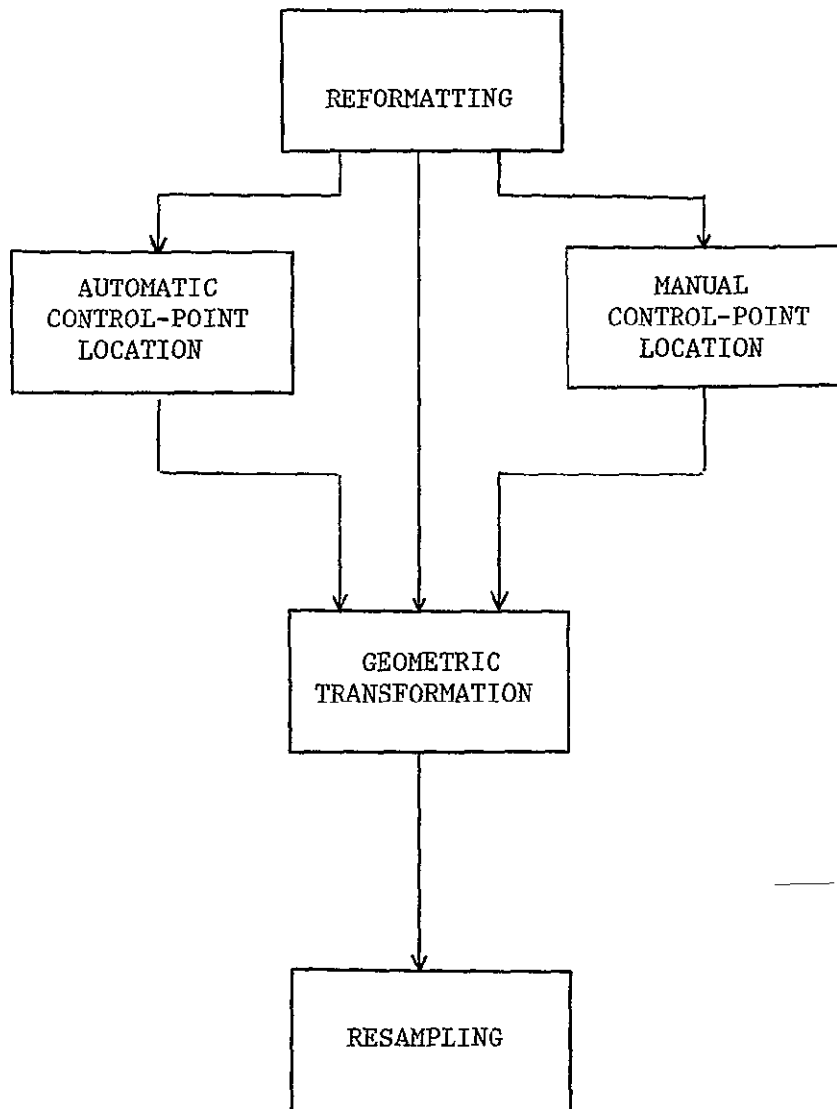


Figure A-1. Software Paths

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. Convert fully corrected MSS data from BSQ format to MIST format.	3. Printer listing.
c. Fully corrected	4. Remove line-length correction (LLC) pixels from uncorrected data.	
2. User's requests.	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:	1. Enlarged ancillary data set containing control point locations.
2. Ancillary data set (from Reformatting).	a. Control Point Library Copy Tape	2. Printer listing.
3. MIST format tape (from Reformatting).	b. MIST format image tape	
4. User's requests.	2. Extract search areas from image tape.	
	3. Horizontally resample search areas (and control points, if from image tape) to correct high-frequency errors.	
	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:	2. Shadeprints on listing data set.
	a. Scale change	3. Printer listing.
	b. High-frequency error correction	
	3. Histogram small subimages.	
	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 grid-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

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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	IO		IO
CPL Copy Tape		I			
Checkpoint Tape					IO
Ancillary Data Set	O	IO		IO	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

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TABLE B-3. LIBRARY CONTROL RECORD

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
DMCFNAM	ALPHANUMERIC SYSTEM NAME OF FILE	1 - 8	C8
DMCFPROG	NAME OF PROGRAM THAT WROTE THIS RECCRD	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
DMCFYSI	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
DMCFLENM	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
-	SPACE	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
DMCFPCSV	CONTROL POINT FILE SNT VALUE	69 - 70	I2
DMCFPCNM	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 RECCRDS	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
DMCFAPC	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
DMDFPROG	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
DMDFROWN	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: IDDDHHMMSS	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
DMDFNGLA	GEODETTIC 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
DMDUCDAT	DATE OF UPDATE FOR LATEST UPDATE LEVEL	313 - 316	I4
DMDUCUID	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 RECCRD	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
DMCPPTH	WRS PATH NUMBER	29 - 30	I2
DMCPRCWN	WRS RCW NUMBER	31 - 32	I2
DMCPQUAD	FBV IMAGE QUADRANT	33 - 34	I2
DMCPREGT	REGISTRATION TYPE	35 - 36	I2
DMCPMISN	LANDSAT MISSION	37 - 38	C2
DMCPOBSV	IMAGE OBSERVATION TIME: DDDDDHHMMS	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
DMCPWITY	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
DMCPXMXN	MEAN OF WINDOW PIXEL VALUES (DECIMAL AFTER BIT 8)	65 - 66	I2
DMCPSHFT	SHIFT FACTOR (P0)	67 - 68	I2
DMCPXVVR	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	
DMCFCOFS	ORDER OF SELECTION BY EDIT; 1 - N	1105 - 1106	I2
DMCSPBDB	SPECTRAL BAND NUMBER	1107 - 1108	I2
DMCPLXFC	GEOCENTRIC RECTANGULAR X COORD OF CONTROL POINT	1109 - 1116	D8
DMCPLYFC	GEOCENTRIC RECTANGULAR Y COORD OF CONTROL POINT	1117 - 1124	D8
DMCPLZFC	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
DMCSOBS	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 LCC. 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.

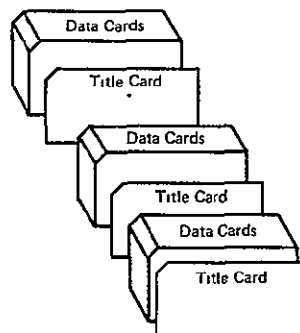


Figure B-1. Organization of Ancillary Data Set

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. ANCIILLARY 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).	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. ANCIILLARY DATA SET: DATA CARD FORMAT

PARAMETER	DESCRIPTION	COLUMNS	FORMAT
-	BLANK CHARACTER (X'40').		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	ACODATE	ACOSITE	DIRECT/RECORDED			
NADLAT	NADLON	FCLAT	FCLON			
CCT SIAT DATA:						13
NATEST	NALEST	ALFER	DELVV	AMSNLT	AMSNLN	
ATTTIM1	AMSR0L1	AMSPIT1	AMSYAW1	AITTIM1	AMSALT1	
ATTTIM2	AMSR0L2	AMSPIT2	AMSYAW2	ALTTIM2	AMSALT2	
ATTTIM3	AMSR0L3	AMSPIT3	AMSYAW3	AITTIM3	AMSALT3	
ATTTIM4	AMSR0L4	AMSPIT4	AMSYAW4	ALTTIM4	AMSALT4	
ATTTIM5	AMSR0L5	AMSPIT5	AMSYAW5	AITTIM5	AMSALT5	
ATTTIM6	AMSR0L6	AMSPIT6	AMSYAW6	ALTTIM6	AMSALT6	
ATTTIM7	AMSR0L7	AMSPIT7	AMSYAW7	AITTIM7	AMSALT7	
ATTTIM8	AMSR0L8	AMSPIT8	AMSYAW8	ALTTIM8	AMSALT8	
ATTTIM9	AMSR0L9	AMSPIT9	AMSYAW9	AITTIM9	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	FMAP1	FMAP2	FMAP3

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		
SCENE	NASA SCENE IDENTIFIER	2 - 11	C10
ACODATE	DATE OF ACQUISITION OF SCENE	12 - 21	C10
ACOSITE	SITE OF ACQUISITION OF SCENE	22 - 31	C10
DIRPEC	DIRECT OR RECORDED DATA INDICATOR	32 - 41	C10
-	BLANK CHARACTER		
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		
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
AMSNI1	LATITUDE OF SPACECRAFT NADIR (RADIANS)	42 - 51	F10
AMSNI1N	LONGITUDE OF SPACECRAFT NADIR (RADIANS)	52 - 61	F10
-	BLANK CHARACTER		
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
AITTIM1	TIME OF ALTITUDE MEASUREMENT 1	42 - 51	F10
AMSALT1	AMS ALTITUDE MEASUREMENT 1	52 - 61	F10
:	:	:	:
-	BLANK CHARACTER		
ATTTIM9	TIME OF ATTITUDE MEASUREMENT 9	2 - 11	F10
AMSRCL9	AMS ROLL MEASUREMENT 9	12 - 21	F10
AMSPIT9	AMS PITCH MEASUREMENT 9	22 - 31	F10
AMSYAW9	AMS YAW MEASUREMENT 9	32 - 41	F10
AITTIM9	TIME OF ALTITUDE MEASUREMENT 9	42 - 51	F10
AMSALT9	AMS ALTITUDE MEASUREMENT 9	52 - 61	F10
-	BLANK CHARACTER		
-	SPARE		
AITTIM10	TIME OF ALTITUDE MEASUREMENT 10	42 - 51	F10
AMSALT10	AMS ALTITUDE MEASUREMENT 10	52 - 61	F10
-	BLANK CHARACTER		
-	SPARE		
AITTIM11	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
NPEC	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-SPACE DEFINITION:	1 - 60	C60
NREC	NUMBER OF DATA RECORDS IN THIS "SECTION" (= 3)	61 - 70	I10
-	BLANK CHARACTER		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		C1
FCV	FORMAT CENTER COORDINATE (HORIZONTAL)	2 - 11	F10
FCV	FORMAT CENTER COORDINATE (VERTICAL)	12 - 21	F10
FCLAT	FORMAT CENTER LATITUDE (RADIAN)	22 - 31	F10
FCLON	FORMAT CENTER LONGITUDE (RADIAN)	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		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		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		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		C1
DELHC	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		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		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

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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		
SCENE	NASA SCENE IDENTIFIER	2 - 11	C10
ASCDSC	ASCENDING OR DESCENDING NODE	12 - 21	C10
WRSPTH	WRS PATH NUMBER	22 - 31	I10
WRSROW	WRS POW NUMBER	32 - 41	I10
-	BLANK CHARACTER		
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		
WRSLIN	LINE NUMBER OF WRS FORMAT CENTER	2 - 11	I10
WRSPIX	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		
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		
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		
WRSOFF	WRS OFFSET FROM FULLY PROCESSED IMAGE CENTER	2 - 11	I10
IDJUST	IMAGE DATA JUSTIFICATION	12 - 21	C10
UBANDS	NUMBER OF USABLE SPECTRAL BANDS	22 - 31	I10
MBNDNC	MSS SPECTRAL BAND NUMBER	32 - 41	I10
-	BLANK CHARACTER		
PASSTYPE	TYPE OF PASS (DAY / NIGHT)	2 - 11	C10
CALTYPE	MODE OF CALIBRATION WEDGE	12 - 21	C10

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		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		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		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		C1
MIRR3	DEGREE-3 COEFFICIENT OF MIRROR-VELOCITY MODEL	2 - 21	D20
MAXMIR	MAXIMUM SCAN-MIRROR ANGLE (RADIAN)	22 - 41	D20
-	BLANK CHARACTER		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		C1
A	SEMI-MAJOR AXIS OF EARTH-SPHEROID MODEL (METERS)	2 - 21	D20
B	SEMI-MINOR AXIS OF EARTH-SPHEROID MODEL (METERS)	22 - 41	D20
ECCON	EARTH-CURVATURE CONSTANT	42 - 61	D20
-	BLANK CHARACTER		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		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		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		
WRSFPM	WRS FRAME	2 - 11	F10
WRSORB	WRS ORBIT	12 - 21	F10
WRSLAT	GEODETTIC LATITUDE OF WRS FORMAT CENTER (RADIANS)	22 - 31	F10
WRSLOX	LONGITUDE OF WRS FORMAT CENTER (RADIANS)	32 - 41	F10
FCXCTIM	SPACECRAFT TIME OF FRAME CENTER	42 - 61	C20
-	BLANK CHARACTER		
NADLAT	GEODETTIC LATITUDE OF SPACECRAFT NADIR (RADIANS)	2 - 21	D20
NADLON	LONGITUDE OF SPACECRAFT NADIR (RADIANS)	22 - 41	D20
-	BLANK CHARACTER		
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		
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		
DELVV	NORMALIZED VELOCITY CHANGE OF SPACECRAFT	2 - 21	D20
EFVEL		22 - 41	D20
ERPARM	EARTH-ROTATION PARAMETER	42 - 61	D20
-	BLANK CHARACTER		
ROLLC	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		
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		
YAWC	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		
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		
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	I 10
-	BLANK CHARACTER	1	C1
H1	HRS PCINT 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	I 10
-	BLANK CHARACTER	1	C1
V1	VRS PCINT 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 PCINT NUMBER 17	2 - 5	R4
V18	VRS POINT NUMBER 18	6 - 9	R4
:	:	:	:
:	:	:	:
V32	VRS PCINT NUMBER 32	62 - 65	R4
:	:	:	:
:	:	:	:

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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.

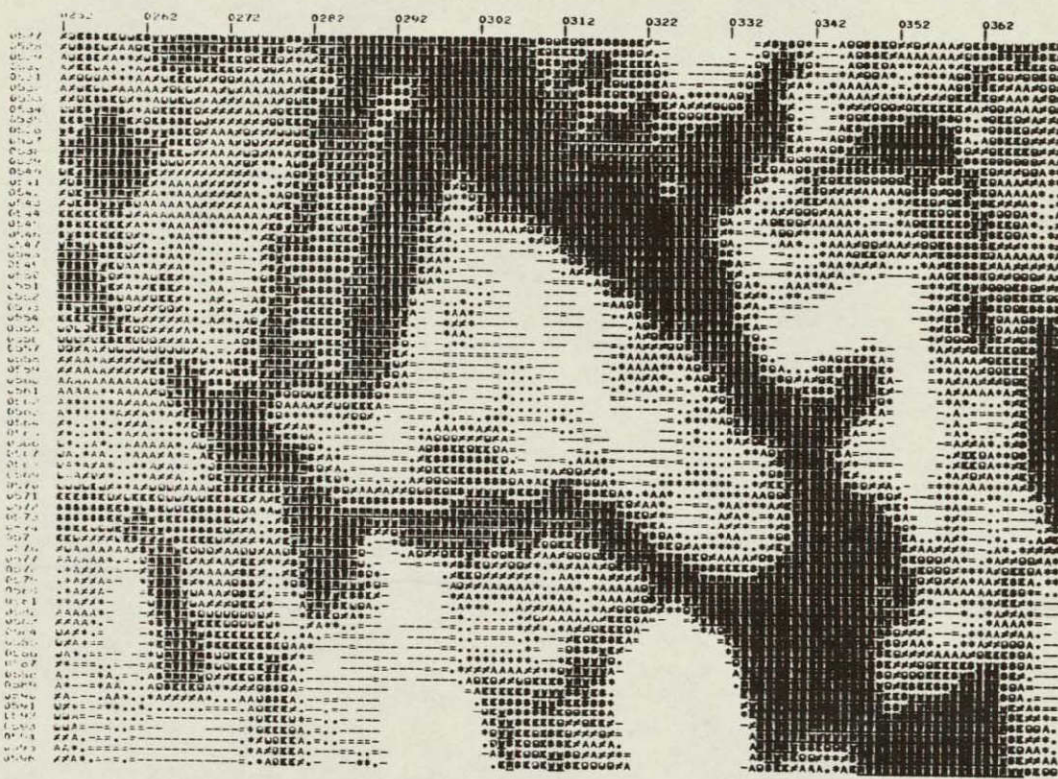


Figure B-2. Example of a Shadeprint

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.

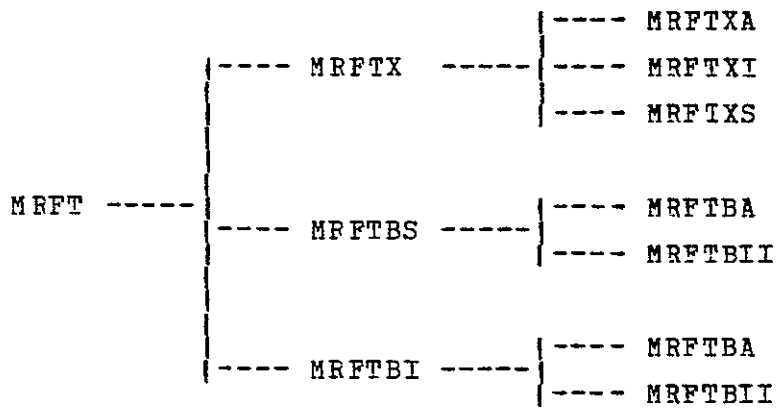


FIGURE B-3. MODULE HIERARCHY FOR LANDSAT MSS REFORMATTING PROGRAM.

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***** 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 PPRINTER 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-FCRMT 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 RECCRD
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 RECCRD (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
----------	------	-----	-----	-------------	-------

PDI (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 FOW
    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
    NDPE 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
    
```

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END OF SPECIFICATION

***** 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 ..
 PRESENTATIONS ...
 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)
    ENDDC
    WRITE END-OF-TAPE RECORD
    CLOSE DATA SETS (I,N) AND (O,N-1) AND (O,N)
ENDDO
READ AND PROCESS SIAT FILE
    
```

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

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

NAME MRFTBA
DESIGNER STEPHEN W. MURPHREY
FUNCTION READS AND PROCESSES NCN-IMAGE RECORDS FROM BSQ-FORMAT OR
BIL-FCRMT 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 NCN-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 *****

***** SAP/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
----------	------	-----	-----	-------------	-------

PDI (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
-----	---	-	-----	-----	-----

PDI (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.

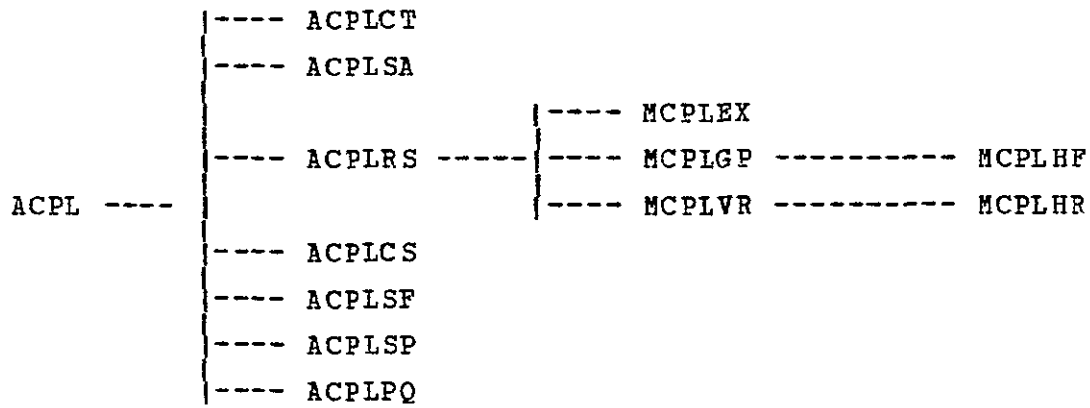
This program is required to determine control-point locations in an automatic process that requires no manual effort by the user.

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.



FIGUPE B-4. MODULE HIERARCHY FOR AUTOMATIC CCNTROL-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.
PDI (PROGRAM CUTLINE)
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 CF 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
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 ESTIMATE THE LOCATIONS IN THE INPUT SPACE OF THE INPUT MAP
 CCNTRCL PCINTS.
 INPUTS 1. SEE CALLING SEQUENCE.
 OUTPUTS 1. SEE CALLING SEQUENCE.
 COMMON BLOCKS .. ERTHCONS, MSSCONS
 RESTRICTIONS ...

CALLING SEQ. ... CALL ACPLSA (NATEST, ATTTIM, AMSROL, AMSPTI,
 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	P*8	I	NATEST	TIME OF ATTITUDE VALUES	SECONDS
ATTPOL	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	EPOCHERIS 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
RNCMLL	R*8	I	-	NOMINAL LINE LENGTH IN INPUT	SAMPLES
NMCP	I*2	I	-	NUMBER OF INPUT MAP CONTROL POINTS	-
RLDR	R*8	I	NMCP	GEODETTIC LATITUDE OF CP'S	RADIANS
RLNR	R*8	I	NMCP	LONGITUDE OF CP'S	RADIANS
ELEV	P*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	P*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	P*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 LAI/LON TO EARTH CENTERED (LLEC)
 MAP THE INPUT CONTROL POINTS FROM EARTH CENTERED TO CTP <ECCTP>
 COMPUTE EARTH-ROTATIONAL VELOCITY 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 (MCFLEX).
DO FOR EACH EXTRACTED SUBIMAGE.
 COMPUTE GPID-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 PCINT.
 INPUTS 1. SEE CALLING SEQUENCE.
 OUTPUTS 1. SEE CALLING SEQUENCE.
 COMMON BLOCKS ..
 RESTPCTIONS ...
 CALLING SEQ. ... CALL ACPLCS(C,A)

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

PDL (PROGRAM OUTLINE)

```

DO FOR EACH CONTROL PCINT.
  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 ARPAY 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 TRANSFOPM OF CURRENT ROW.
  ENDDO
  DO FOR EACH COLUMN OF 128-BY-128 TRANSFORMED SEARCH-AREA ARRAY.
    CALCULATE COCLEY-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 PRCDUCT ARRAY.
    CALC. COOLEY-TUKEY INVERSE FAST FOURIER TRANSFORM OF CURENT COLUMN.
  ENDDO
  DO FOR EACH ROW OF 128-BY-128 TRANSFORMED PRODUCT ARRAY.
    CALCULATE COCLEY-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.
ENDDC

```

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

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

NAME ACPLSF
 DESIGNER STEPHEN W. MUPPHREY
 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	-

PDI (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 = ( MT M )-1 MT      ( MATRIX EQUATION; P IS 15-BY-25 MATRIX )
DO FOR EACH CONTROL POINT.
  A = P C      ( MATRIX EQUATION )
ENDDO

```

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

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

NAME ACPLSP

DESIGNER STEPHEN W. MURPHREY

FUNCTION COMPUTES LOCATION OF THE CORRELATION-SURFACE PEAK USING
NEWTN'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.

$$F(1) = A_1 + 2A_3 X + A_4 Y + 3A_6 X^2 + 2A_7 XY + A_8 Y^2 + 4A_{10} X^3 + 3A_{11} X^2 Y + 2A_{12} XY^2 + A_{13} Y^3$$

$$F(2) = A_2 + 2A_4 X + A_5 Y + 3A_7 X^2 + 2A_8 XY + A_9 Y^2 + 4A_{11} X^3 + 3A_{12} X^2 Y + 2A_{13} XY^2 + A_{14} Y^3$$

$$N(2,2) = DF1DX = 2A_3 + 6A_6 X + 2A_7 Y + 12A_{10} X^2 + 6A_{11} XY + 12A_{12} Y^2$$

$$N(1,2) = -DF1DY = -A_4 - 2A_7 X - 2A_8 Y - 3A_{11} X^2 - 4A_{12} XY - 3A_{13} Y^2$$

$$N(2,1) = -DF2DX = -DF1DY$$

$$N(1,1) = DF2DY = 2A_5 + 2A_8 X + 6A_9 Y + 2A_{12} X^2 + 6A_{13} XY + 12A_{14} Y^2$$

$$D = 1. / (DF1DX * DF2DY - DF1DY * DF2DX)$$

$$S = S - D N F \quad (\text{MATRIX EQUATION})$$

$$X = S(1)$$

$$Y = S(2)$$

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 = A0 + A1X + A2Y + A3X2 + A4XY + A5Y2 + A6X3 + A7X2Y + A8XY2 +
    A9Y3 + A10X4 + A11X3Y + A12X2Y2 + A13XY3 + A14Y4
  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	-
NSTFK	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.

ORIGINAL PAGE IS
OF POOR QUALITY

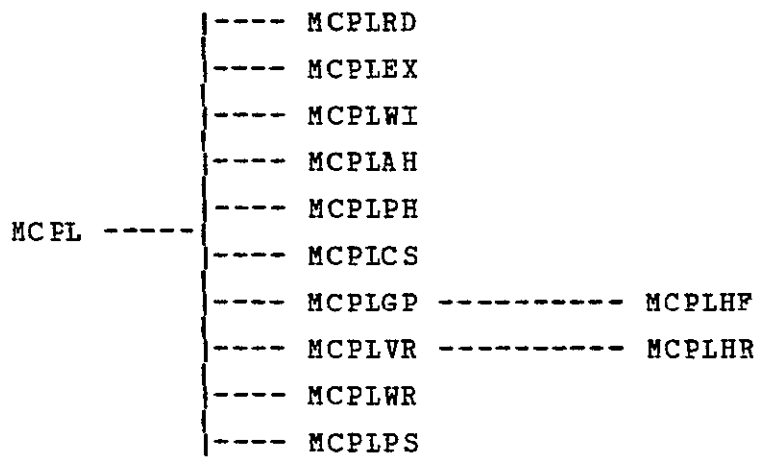


FIGURE B-5. MODULE HIERARCHY FOR MANUAL CONTROL-POINT LOCATION PROGRAM.

***** 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
 LOCATICN 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.
RESAMELE 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	DESCRIPTION	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 SEQLIST ARRAY
    ELSE
      FIND ELEMENT OF SEQLIST ARRAY THAT IS NO LONGER NEEDED.
      COPY BOTTOM SEQLIST 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, RECLN, SUBPTR, TOPLIN, \$TITLE, DEFAULT, \$FLAGS)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
CHGFLG	I*2	O	2X200	SUBIMAGE INDEX / CHANGE TYPE	-----
CHGLIN	I*4	O	200	LINE NUMBER OF CORRSP. 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
RECLN	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	-----
DEFAULT	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.
  ENDDIF
ENDDIF
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
    ENDDIF
    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)
    RECLN(N) = 4 + ( WIDTH(N) + 6 ) * NBANDS
    SUBPTR(N+1) = SUBPTR(N) + RECLN(N) * LENGTH(N)
    LINPTR(N+1) = SUBPTR(N+1)
    MAXLIN = MAXIMUM( MAXLIN, TOPLIN(N) + LENGTH(N) - 1 )
  ENDDIF
  N = N - 1
ENDDO
TOTAL BYTES IN BUFFER = SUBPTR(N+1)
SORT BOTH CHANGE ARRAYS SO THAT THEY ARE IN ASCENDING ORDER OF CHGLIN APRAY.

```

***** 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,RECLN,SUBPTR,IDREC)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
BANDS	I*4	I	100	EACH BIT IS FLAG FOR THAT BAND	-----
LENGTH	I*4	I	100	VERTICAL SIZE OF SUBIMAGE	PIXELS
RECLN	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 RECCRD ONTO THE TAPE.
  OBTAIN THE ADDRESS OF THE SUBIMAGE DATA FROM THE SUBPTR ARRAY.
  OBTAIN THE WIDTH OF ONE RECORD FROM THE RECLN 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	DESCRIPTION	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 RECOFD	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.
ENDDC.
  
```

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	DESCRIPTION	UNITS
BANDS	I*4	I	100	EACH BIT IS FLAG FOR THAT BAND	-----
HIST	I*4	I	256X5	HISTOGRAM	-----
CUMPCT	F*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
    HISTPCT(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 HISTPCT(K,B) > HISTPCT(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, HISTPCT(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	DESCRIPTION	UNITS
BANDS	I*4	I	100	EACH BIT IS FLAG FOR THAT BAND	-----
\$CHAR	L*1	O	256X5	SHADEPRINT CHARACTER SETS	-----
CUMPCT	F*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
T	I*4	O	-	NUMBER OF GRID-PCINT 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
CLEN = VSFAC * ( LENGTH - 3 )
OWID = HSFAC * ( WIDTH - 3 )
ISWID = G( 50 / HSFAC )
CSWID = 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	DESCRIPTION	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                               *****
```


NAME MCPLHR
 DESIGNER STEPHEN W. MURPHEY
 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	DESCRIPTION	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.
      E = D + LH(M)
      DO WHILE D >= 1.0
        D = D - 1.0
        P = P + 1
      ENDDO
    ENDDO
  ENDDO
ENDDO

```

***** 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 PCINTER 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 "FCRM" 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.

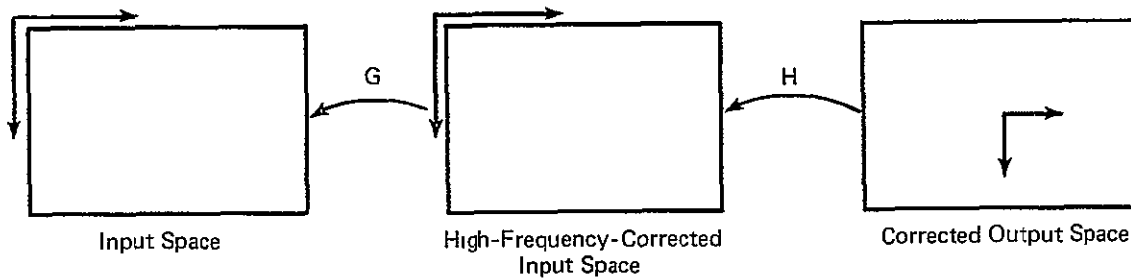


Figure B-6. Image Spaces

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.

ORIGINAL PAGE IS
OF POOR QUALITY

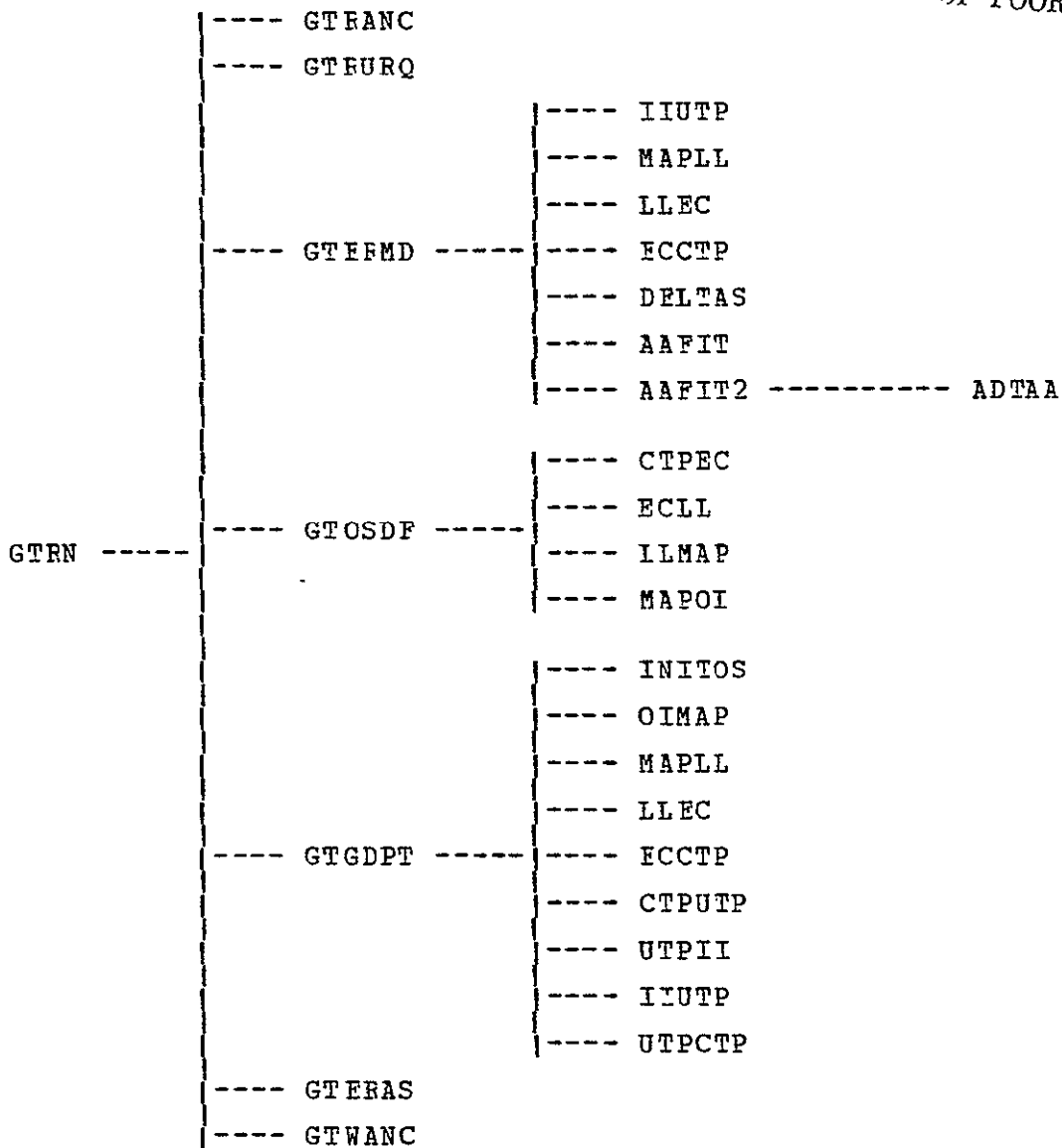


FIGURE B-7. MODULE HIERARCHY FOR GEOMETRIC TRANSFORMATION PROGRAM.

***** 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 (FROGFAM OUTLINE)

PRINT SEPARATOR PAGE TO INDICATE START OF RUN.
READ USER'S REQUESTS.
READ ANCILLARY DATA SET TO INITIALIZE DATA AREAS.
CASEENTRY
CASE 1: SCENE PROCESSING OR SYSTEM PROCESSING.
PERFORM ERROR MODELING (ATTITUDE/ALTITUDE FIT).
DEFINE THE OUTPUT SPACE.
CREATE INTERECLATION GRID POINTS (FROM ERROR MODELS).
PERFORM ERROR ASSESSMENT (FROM ERRCP MODELS).
WRITE GRID POINT CORRESPONDENCE TO ANCILLARY DATA SET.
CASE 2: COMPLETION PROCESSING.
DEFINE THE OUTPUT SPACE.
CREATE INTERECLATION 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 INTERECLATION 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	DESCRIPTION	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)

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

END OF SPECIFICATION

***** 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, AMSPOL, AMSPT, 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	P*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	DESCRIPTION	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 CCNTROL 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	DESCRIPTION	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.
DC FOR EACH CONTROL PCINT
  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
PPINT PPROGRAM-EXIT MESSAGE.

```

END OF SPECIFICATION

ORIGINAL PAGE IS OF POOR QUALITY

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

NAME AAFIT
 DESIGNER STEPHEN W. MURPHY
 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, AMSPI, 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	-
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	P*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	P*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, AMSPTI, 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	-
AMSPOLL	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

ORIGINAL PAGE IS
OF POOR QUALITY

***** 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	DESCRIPTION	UNITS
NATEST	I*2	I	-	# OF ATTITUDE ESTIMATES	-
NALEST	I*2	I	-	# OF ALTITUDE ESTIMATES	-
AMSPOL	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
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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 TC MAE 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 PPRINTER 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	-
YEY	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 COORDINATE	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 COORDINATES	METERS
XEC	R*8	I	NUM	EARTH CENTERED X OF THE POINTS	METERS
YEC	R*8	I	NUM	EARTH CENTERED Y OF THE POINTS	METERS
ZEC	R*8	I	NUM	EARTH CENTERED Z OF THE POINTS	METERS

PDI (PROGRAM OUTLINE)

```

DC 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

PDI (PROGRAM OUTLINE)

```

DO FOR EACH POINT
  LATITUDE=ARCTAN ((A SOP /B SOP) *ZEC /SQRT (XEC*XEC+YEC*YEC))
  LONGITUDE=ARCSIN (LABS (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 *****

***** 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 , PDLATR , RLONGR ,
 DNORTH , DEAST , IZONE)

VARIABLE	TYPE	I/O	DIM	DESCRIPTION	UNITS
AELLPS	F*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
RDLONF	R*8	I	NUM	LONGITUDE OF INPUT POINTS	RADIANS
DNOPTH	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	P*8	I	NUM	UTM NORTHING OF FORMAT CENTER	METERS
CEAST	P*8	I	NUM	UTM EASTING OF FORMAT CENTER	METERS
DNORTH	P*8	I	NUM	UTM NORTHING COORDINATE	METERS
DEAST	P*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 PCINT
 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	DESCRIPTION	UNITS
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PDL (PROGRAM OUTLINE)

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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).
  CCNVERT CORRECTED-TANGENT-SPACE COORDINATES TO UNCORRECTED-TANGENT SPACE.
  CCNVERT UNCORRECTED-TANGENT-SPACE COORDINATES TO INPUT SPACE.
  CCNVERT INPUT-SPACE COORDINATES TO UNCORRECTED-TANGENT SPACE.
  CCNVERT 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 *****

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

NAME INITOS
 DESIGNER STEPHEN W. MURPHREY
 FUNCTION INITIALIZE A RECTANGULAR LATTICE OF OUTPUT-SPACE GRID-POINT
 CCORDINATES.
 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	DESCRIPTION	UNITS
NUM	I*4	I	-	NUMBER OF PCINTS 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	DESCRIPTION	UNITS
NUM	I*4	I	-	NUMBER OF PCINTS TO TRANSFORM	-
BETA	R*8	I	-	HEADING ANGLE	RADIANS
CNORTH	R*8	I	NUM	UTM NORTHING OF FORMAT CENTER	METERS
CEAST	P*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 PCINT
  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

ORIGINAL PAGE IS
 OF POOR QUALITY

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

NAME MAPLL
 DESIGNER STEPHEN W. MURPHREY
 FUNCTION CONVERTS (UTM) MAP COORDINATES TO GEODETIC LATITUDE AND
 LONGITUDE 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	P*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	DESCRIPTION	UNITS
N	I*2	I	-	# OF POINTS	-
RLNR	R*8	I	N	LONGITUDE OF POINTS	RADIANS
RLDR	F*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 ELLIPSCID)	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	F*8	O	N	EARTH-CENTERED Z-COORDINATE	METERS

PDL (PROGRAM OUTLINE)

END OF SPECIFICATION

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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	DESCRIPTION	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	-	GEODETC 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

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***** 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 COORDINATES	METERS
AAMOD	R*8	I	14	A/A MODEL COEFFICIENTS	-
ALTNOM	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

PDI (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 *****

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	DESCRIPTION	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
PPINT SUBROUTINE-EXIT MESSAGE.
  
```

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***** SAP/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	DESCRIPTION	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-ENTPY MESSAGE.
 PRINT HEADINGS.
 DO FOR EACH CONTROL POINT:
 CCNVERT 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 CCOORDINATE 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 SUBPOUTINE-EXII 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	F*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	F*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	DESCRIPTION	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(V 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	DESCRIPTION	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-

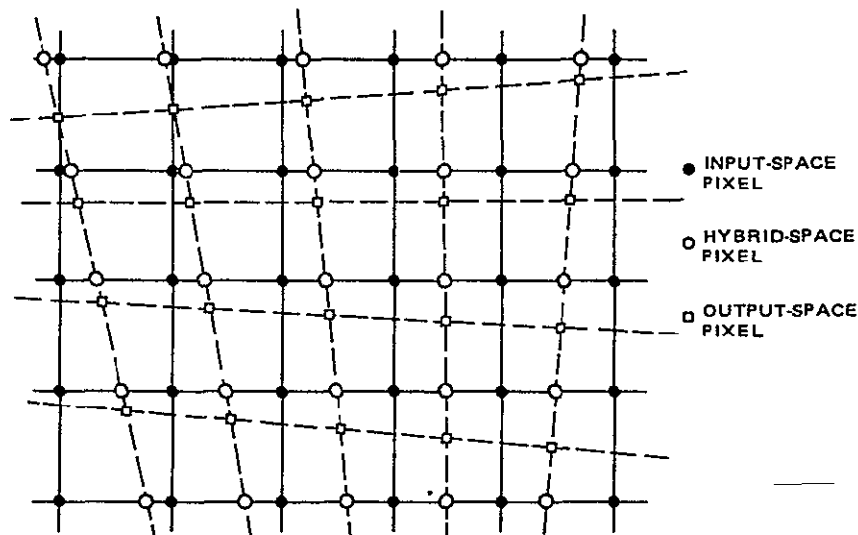


Figure B-8. Horizontal and Vertical Resampling

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.

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.

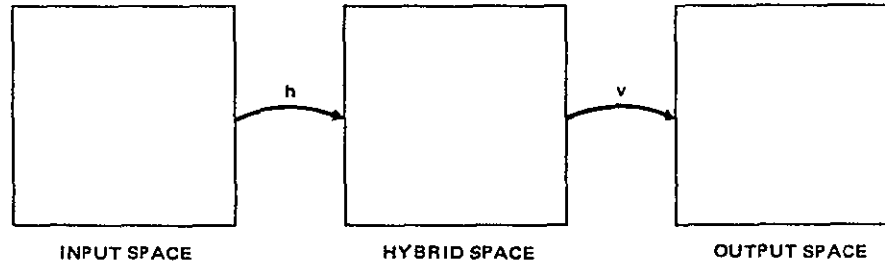


Figure B-9. Resampling Spaces

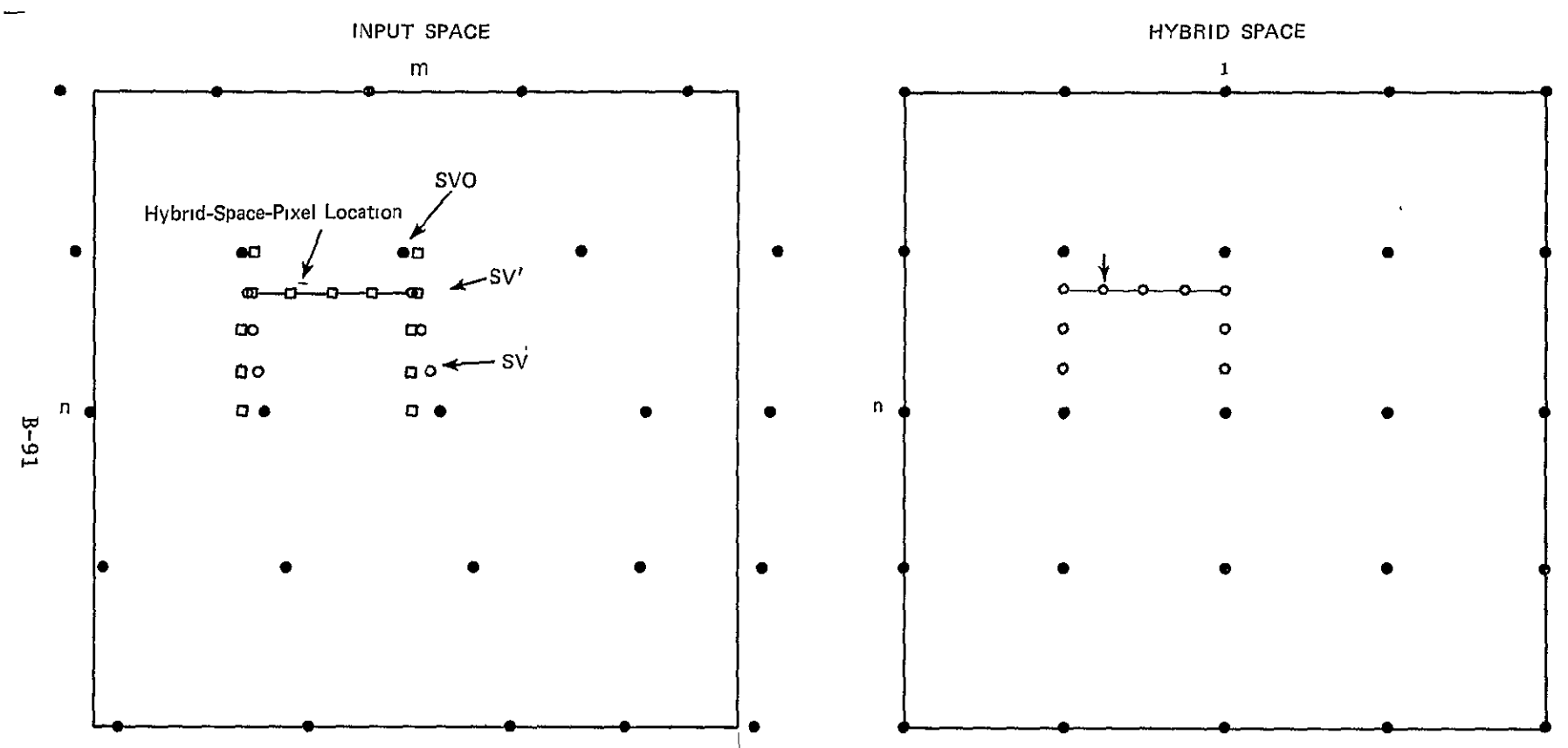
In each case, the resultant image is created one line at a time. The flow is from the top of the image to the bottom. A resampled line is created in segments, as shown in Figure B-10.

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).



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Figure B-10. Construction of Hybrid Space

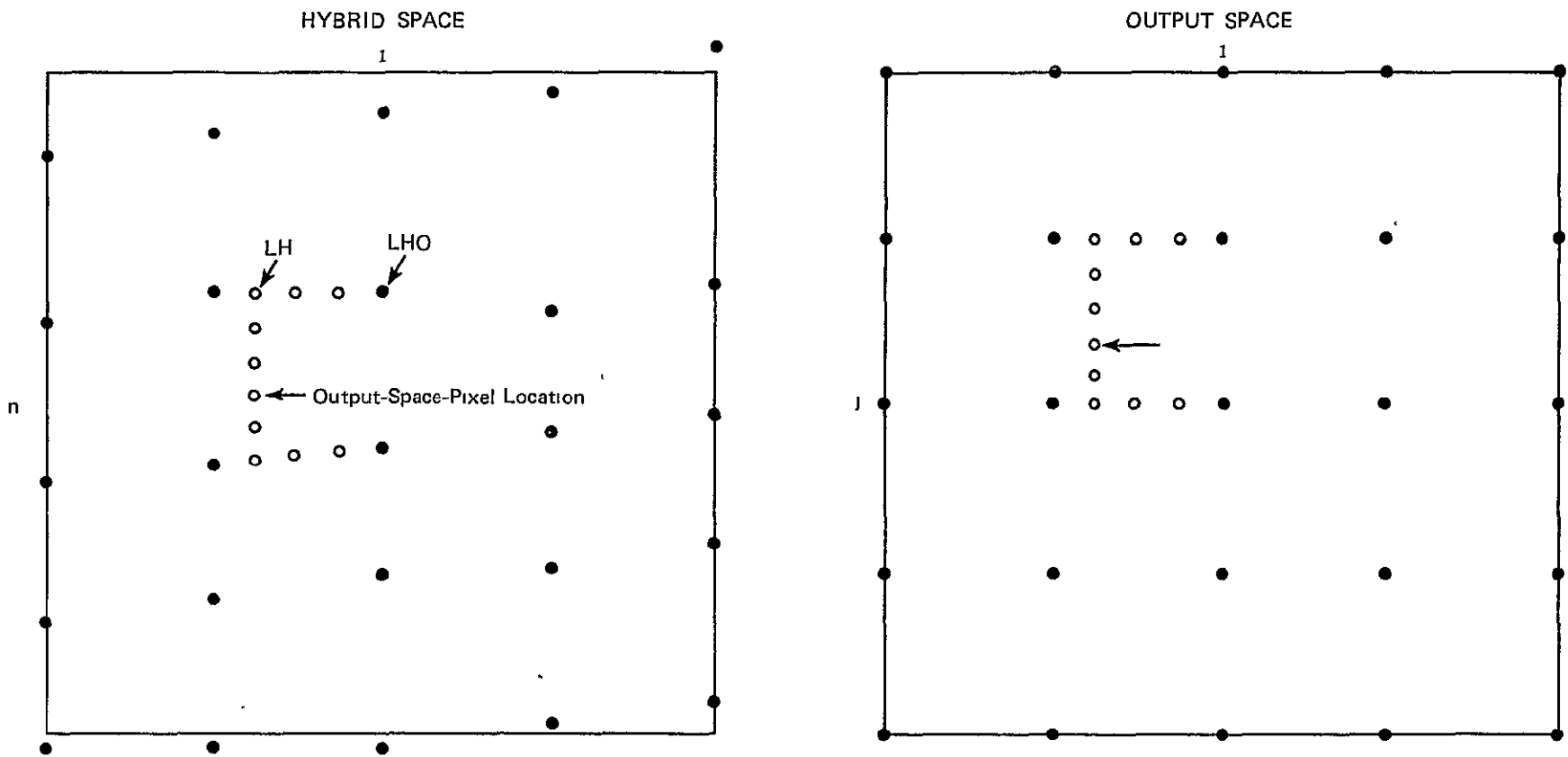


Figure B-11. Construction of Output Space

- 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:

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

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.

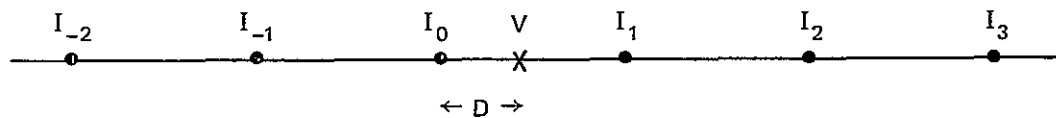


Figure B-12. Six-point Resampling

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

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

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

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

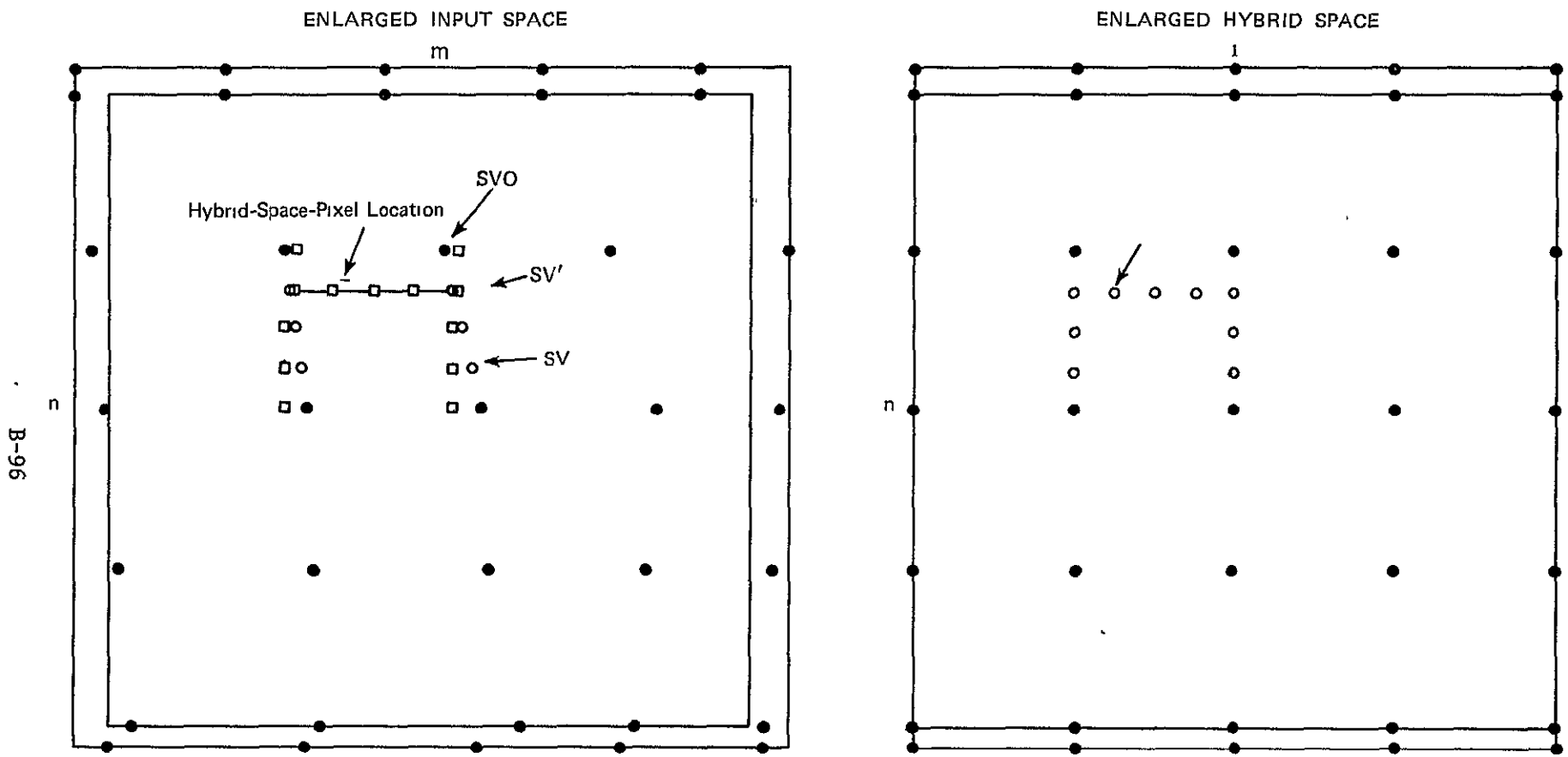


Figure B-13. Construction of Hybrid Space

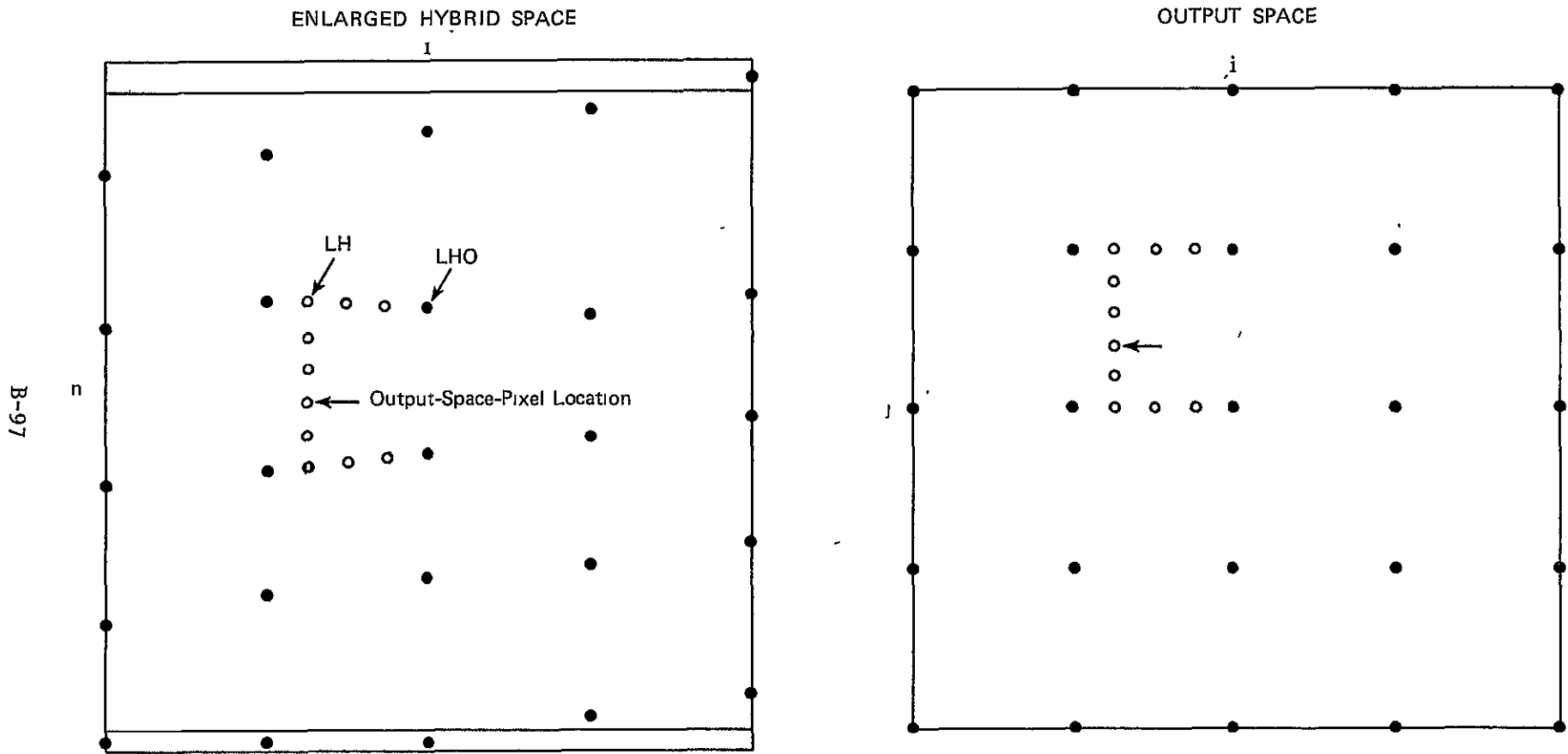


Figure B-14. Construction of Output Space

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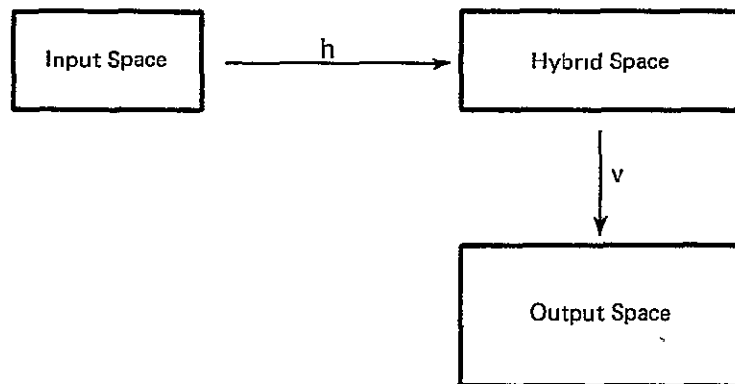


Figure B-15. Resampling Spaces (Drawn to Scale)

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.

RSEL ----- RSELV ----- RSPLH

FIGURE B-16. MODULE HIERARCHY FOR RESAMPLING PROGRAM.

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***** 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)

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```

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
  CPEN 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 RCWS 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. MURPHY
 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 = ILC / ( ILA - 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
  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
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 *****

**U.S. DEPARTMENT OF COMMERCE
National Technical Information Service**

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SAR/LANDSAT IMAGE REGISTRATION STUDY

STEPHEN W. MURPHREY

SEPTEMBER 1978



IBM