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# Technology for Large Digital Mosaics of Landsat Data

## Large area applications are aided by creating a map-projected Landsat data base.

ABSTRACT: *Advances in algorithms and system executive procedures for digital image processing have made ditigal mosaicking of Landsat images (both MSS and RBV) an attractive possibility. The technology developed includes simultaneous map projection and adjustment of frame edges to eliminate both geometric and radiometric seams. The incorporation of ground control points, either by manual or automatic ground control point file identification, has resulted in root-mean-square (RMS) positional accuracies that exceed 1:100,000 scale National Map Accuracy Standards. Rotation to north vertical is accomplished at low computational cost. Input data frames can be cut in any arbitrary shape to remove cloud cover and accommodate terrain offset effects. Similarly, the final digital mosaic can be arbitrarily segmented to suit user requirements. Two large applications in Pennsylvania and Bolivia are reported. A test case utilizing RBV data is described.*

### INTRODUCTION

LANDSAT DIGITAL DATA are presently available by frames whose coverage and location are determined by satellite orbit. For a variety of applications, the utility of Landsat data is increased if arbitrary areas can be reconstructed from multiple frames to a user-selected map projection with no visible seams. In particular, the ability to access data according to latitude/longitude and to incorporate remote sensing data into a geographic information system is desired by a major segment of the user community. This report will focus on a set of software and procedures for digital mosaicking of Landsat data.

The Jet Propulsion Laboratory Image Processing Laboratory (IPL) has had considerable experience in developing geometric rectification and registration algorithms, and has more recently developed software for digital image map reprojection and image mosaicking. Image processing in support of JPL's planetary program provided the basic software and procedures necessary to achieve digital image mosaicking of vidicon imagery using rigid projective geometry (Elliott, 1976; Johnson, 1977). In 1977, specialized techniques were developed for mosaicking Landsat MSS imagery (Zobrist, 1978; Zobrist and Bryant, 1979). Included in these techniques were use of ground control information from maps, integration of edge geometric control information, use of edge brightness control information, and use of the Image Based Information System (IBIS) (Zobrist and Bryant, 1978) to manage the control point data base throughout the complex process. These techniques will be covered later in this report.

A fair degree of success was obtained with the early technology on several applications (see top part of Table 1). A mosaic of the California desert was classified and provided soils, biomass, and forage estimates in support of a comprehensive multiple-use management plan for the California Desert Conservation Area (McLeod and Johnson, 1980; U.S. Dept. of Interior, 1980). A statewide California mosaic was provided to NASA Ames Research Center and California Department of Forestry for use in an inventory of forests using automated classification (Peterson *et al.*, 1980). A

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TABLE 1. SUMMARY OF DIGITAL MOSAIC APPLICATIONS PERFORMED AT THE JPL IMAGE PROCESSING LABORATORY.

| | Sensor | Frames | Pixel Size | Map Proj.* | Total Size |
|---|---|---|---|---|---|
| [Early Technology] | | | | | |
| California Desert | MSS | 12 | 80 m | LCC | 7,500 × 7,400 |
| Arizona | MSS | 21 | 80 m | LCC | 11,000 × 11,000 |
| California State | MSS | 36 | 80 m | LCC | 12,000 × 14,000 |
| [Current Technology] | | | | | |
| Pennsylvania West | MSS | 6 | 57 m | UTM | 6,600 × 8,700 |
| Pennsylvania East | MSS | 6 | 57 m | UTM | 6,600 × 8,700 |
| Oruro Department, Bolivia | MSS | 7 | 50 m | ALB | 9,900 × 9,900 |
| Los Angeles | RBV | 4 | 19 m | UTM | 11,000 × 11,500 |

* LCC = Lambert Conformal Conic Rotated 11°
UTM = Universal Transverse Mercator
ALB = Albers Equal Area Conic

large scale mosaic of the state of Arizona was prepared for the Arizona Resources Information System to assist in natural resource planning and allocation. In these cases, geographic ground control was obtained from 1:250,000 scale topographic maps. The resulting accuracy in these mosaics was consistent with this scale over Arizona and most of the California desert. Procedural difficulties and project deadlines caused planimetric errors in the middle and north of California, but despite these, the thematic mapping applications successfully demonstrated multispectral classification over broad areas.

In 1978, an evaluation of this early technology was performed, along with an assessment of mosaicking efforts at other laboratories. Large digital Landsat mosaics had been prepared at IBM Gaithersburg (Bernstein, 1974) and at USGS Flagstaff (Chavez, 1977). Since then, several other organizations have prepared digital mosaics. Most of these efforts used a two-step rectification process. The Landsat frames are first map projected, to yield an approximate fit. A second "rubber sheet" rectification obtains a better fit along the seams (Moik, 1980). Further techniques for improving the seam include selection of seam location to minimize edge effects (Milgram, 1975) and low pass filtering. Many have expressed the hope that precise control (from the spacecraft or elsewhere) will enable the first step of map projection to produce a perfect fit with neighbor frames for mosaicking. At JPL, a decision was made to pursue a "robust" digital mosaic technology which can map project and eliminate seams regardless of the quality or quantity of ground control.

In the latter part of 1978, a three-year effort was undertaken to upgrade the mosaic technology in four areas (Bryant, 1978). First, improved algorithms were developed to lower processing costs and allow rotation to North-vertical map projections. Second, automation and verification techniques eliminated most manual labor and greatly reduced the possibility of error. Third, incorporation of the Ground Control Point File from the Master Data Processor at NASA Goddard Space Flight Center (Bernstein, 1975; Niblack, 1981) enabled the use of 1:24,000-scale accuracy control using automatic correlation. This file contains 32 by 32 sub-images of a Landsat image together with a geographic coordinate obtained from a map. Twenty-five of these are provided for each Landsat frame area. Fourth, a sophisticated technique of cutting each frame exactly along the edge matching points was developed to provide the means for stitching together a seam so that discrepancies in geometry or systematic brightness are minimized. Mosaics prepared with the newer technology are listed in the lower part of Table 1.

## BASIC CONCEPTS FOR LANDSAT DIGITAL MOSAICS

Two characteristics of Landsat data make the proper application of sound photogrammetric principles difficult. First, the MSS is a scanner which forms an image as the satellite moves. This results in a lack of rigid projective geometry inherent in a photographic situation. Second, the quantity of data and the cost of digital processing limits the kinds of processing one can afford to perform. The mosaicking method at JPL was designed to perform mapping of Landsat at available map accuracies with correction of local areas near seams to a higher degree of precision despite the inherent photogrammetric problems.

Four basic concepts are involved in the Landsat data mosaicking process. The first involves adjustment of seam control according to geographic control, developed in 1977 (see Figure 1). Seam control consists of points for which Landsat line-sample coordinates are known in two adjacent frames (i.e., an identical location). Because the usual method of finding seam control points is digital cross correlation, the geographic location of

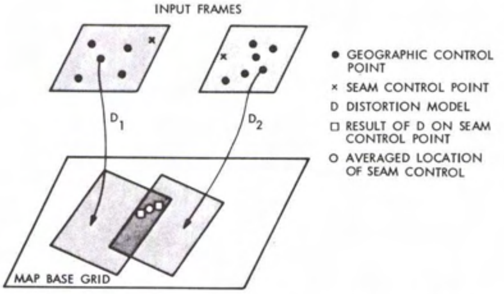

Fig. 1. Adjustment of seam control according to geographic control.

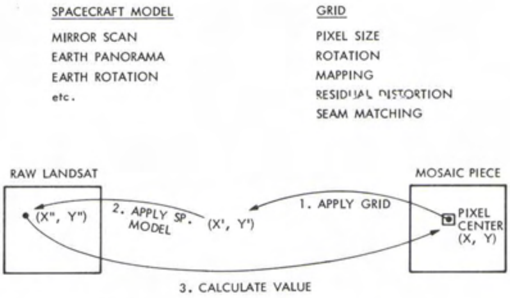

Fig. 2. Compound model for efficient and effective calculation of image processing rubber sheet operation.

these points is not known. Geographic control consists of points for which both the Landsat line-sample coordinates and geographic coordinates are known. The adjustment process involves generation of a distortion model for each frame based upon the geographic control points (the function D in Figure 1), evaluation of the models at seam control points for each frame (the locations marked by a square in Figure 1), and then reconcilement by averaging of the mapped locations of the seam points (the circle in Figure 1). One seam control point is converted into two control point pairs (one for each frame) which specify seam mapping to an accuracy consistent with the original geographic control points but with seam matching precision to a high degree. An additional advantage is that these operations are performed at low cost on point data sets prior to the expensive processing of Landsat digital data.

The second basic concept is use of a compound geometric distortion model which performs all systematic corrections with a single use of the image processing resampling algorithm. Because this model is applied to a Landsat image, not just a point set as in the previous paragraph, it is necessarily more complex. The compound model integrates compensating functions for nominal spacecraft distortions, rotating to North, map projecting, eliminating residual geographic location error, and obtaining a high degree of conformance to the seam control points. If these corrections are not compounded in a single computation, the multiple applications of image resampling are both expensive and degrade the data. In essence, the value of an output pixel is obtained by transforming its location backwards through the distortion model to a location in the raw Landsat frame, and interpolating a value from the neighboring pixels there. No single computational method is efficient for all of these transformations, so a compound method is used (Figure 2). The grid calculations are efficient in computer time but cannot represent some spacecraft model terms with sufficient accuracy. The spacecraft model is efficient because the main calculations to obtain a Mercator or an orthographic projection can be represented as one-dimensional corrections. For example, mirror scan distortion is an along-scan function of along-scan position while the Earth rotation skew is an along-scan function of along-track position. An important aspect of the grid method involves the conversion of the irregularly spaced seam control points to a regular grid. A popular method is to best fit a polynomial surface through the control points and evaluate the polynomial at the grid. However, the polynomial will usually not pass through the edge points, and visible tears at the seams will develop. The proper method to use is the finite element surface fit (Lawson, 1977) which passes through all of the input data points and interpolates continuously elsewhere.

The third basic concept developed involves the use of carefully defined polygonal seams inside the border of each Landsat frame to coordinate a number of steps in the mosaic process. These polygons can be punched onto data cards, or keyed in if they are simple quadrilaterals, or digitized if they are more complex polygons associated with cloud cover or topography. They define where the automatic correlation routine is applied to produce seam control points (Figure 3). Processing is limited to the data necessary to cover the area enclosed by the seam. Finally, the processed Landsat data are cut precisely and cleanly at the mapped seam boundary to produce the mosaic piece. Aside from the elegance and flexibility lent to the entire mosaic process by seam boundaries, their greatest contribution is that they guarantee that seam control points will be precisely on the seam boundary.

The fourth concept developed is that of obtaining brightness information from the seam control points for use in a general scheme for correcting brightness. At present, the brightness differences are input to a surface fitting routine to generate a brightness correction surface that is added to the Landsat brightness values. In the future, changes for latitude, sensor calibration, and variance difference will be incorporated.

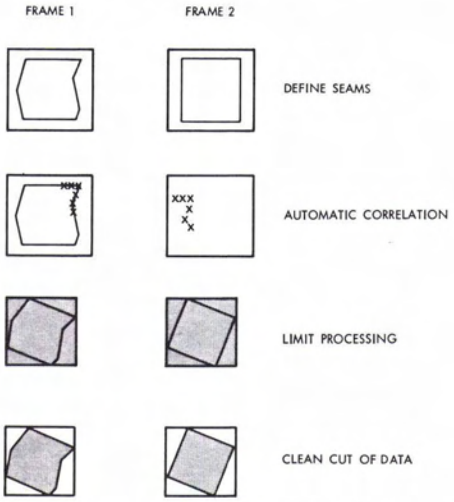

FIG. 3. Use of polygonal seams in the mosaic process.

## TECHNOLOGY FOR LANDSAT DIGITAL MOSAICS

The JPL Image Processing laboratory has a full complement of hardware resources for image processing as well as general computing. The host computer is an IBM 370/158 with 3 megabytes of memory and 3700 megabytes of CDC 3350 online disk storage. The operating system is MVS with TSO to support an interactive environment. Actual image processing is accomplished with the Video Image Communication And Retrieval (VICAR) system which consists of over 350 application programs and an executive user interface. Additions to this basic system for digital mosaicking will now be described.

The first technical requirement is for the coordinated handling of image, tabular, and graphics files. Control points are in tabular format and are subjected to numerous operations such as collation, sorting, arithmetic, plotting, editing, and reporting. Seam boundaries and the Goddard Ground Control Point File are converted to a graphics type format and are also used in diverse operations. An example of such an operation is the mapping of seam boundaries according to control points. Landsat image processing is performed in conjunction with both of these data types. Examples of this are rectification according to control points and cutting according to a contour. The coordinated handling of these three data types is handled by the Image Based Information System (IBIS), a collection of over 70 VICAR routines (Zobrist and Bryant, 1978).

The second technical element is the incorporation of the Goddard Master Data Processor Ground Control Point File. This file contains approximately 25 control points for each Landsat path/row in the United States and a number of foreign countries. Each Ground Control Point (GCP) consists of a 32 by 32 image chip cut from a Landsat scene and a latitude-longitude coordinate obtained from 1:24,000 topographic maps (or the best available). Figure 4 shows a set of 25 GCP chips for a Landsat frame in Pennsylvania. Automatic correlation of this file with a new Landsat frame can provide a set of geographic control points for the new frame. The second part of Figure 4 is obtained after a correlation computation where a read-out of the matching areas has been requested.

The third technical element is automated processing, verification, and editing. The VICAR language has a command mode in which users can execute individual program steps on data sets, but mosaicking requires thousands of steps per frame with frequent chances for error. To manage this problem, all mosaic processes have been organized into macro sequences invoked by the user who specifies parameters only. Verification consists of the following steps: (1) initial data sets are self-identified, (2) input data sets to macro procedures must have the proper identification or the procedure will halt, and (3) output data sets are automatically self-identified by the macro procedures. Editing procedures are computer assisted to the degree that is possible. For example, editing of control point files is assisted by computer generated plots, reports, and photo products.

The fourth technical element is software and algorithms. More than 30 VICAR routines are needed to perform a mosaic. The principal routines are listed in Table 2 with their VICAR names. The steps necessary to perform a mosaic are listed below with specific references to the algorithms in Table 2.

(1) Select Landsat frames to cover area. Use photographic prints to examine a mock mosaic for coverage and overlap.
(2) Create seam boundary file by digitizing on photographic prints or by giving line-sample corner points.
(3) Create verification file by copying tape label information into a disk data set.
(4) Create geographic control point files by running PICMATCH on the Landsat frames and their corresponding Goddard chips. Edit bad matches.
(5) Use geographic control to estimate where overlap areas will register. Use program PICMATCH to automatically match the overlap areas along the seams, storing the results in disk data sets.
(6) Combine all control point data sets into one large data set and start editing out the obviously bad matches.
(7) Use the geographic control points for each frame to position the seam control points for that frame.
(8) Average each seam control point location with

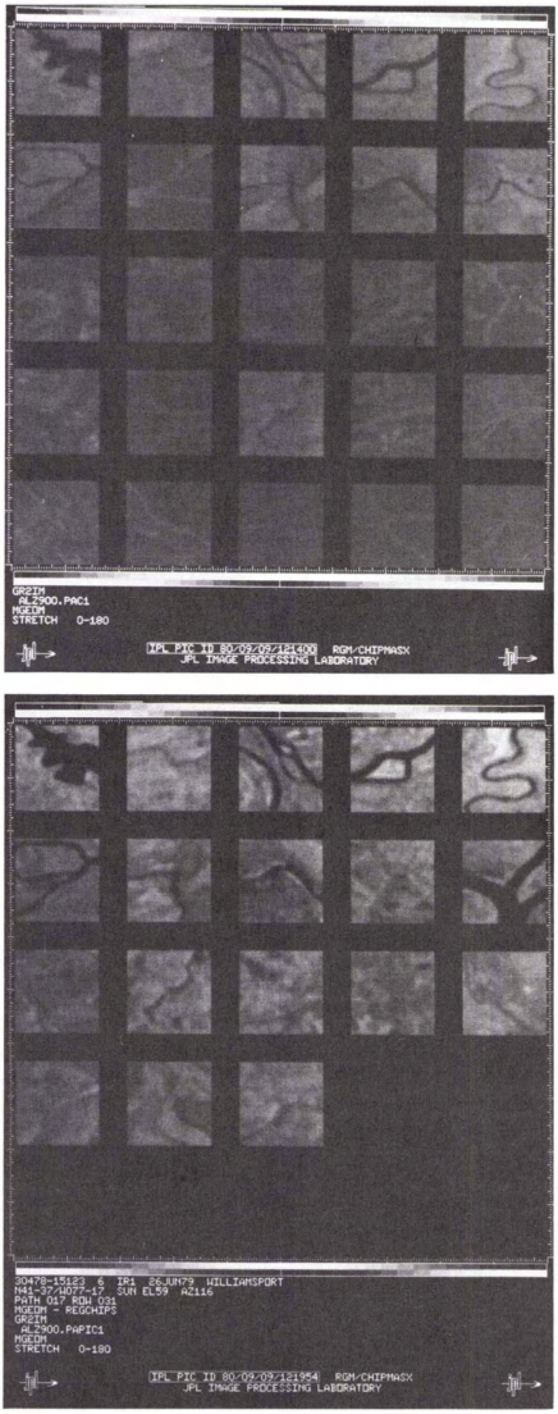

FIG. 4. Ground control point chips from Goddard Master Data Processor and matching areas from a Landsat MSS image.

TABLE 2. PRINCIPAL VICAR ROUTINES USED FOR MOSAICKING

PICMATCH—can register (a) Goddard chips to a Landsat MSS or (b) two adjacent Landsat scenes along a seam boundary. It uses the fast Fourier transform implementation of a complex discrete Fourier transform, normalizing all components in the Fourier domain to perform phase correlation (Kuglin and Hines, 1975). It uses a projective model between the two inputs to predict where a point from one will match in the other, and also to resample from one input to match the pixel size and rotation of the other.

MGEOM—performs a rubber sheet correction of an image according to a uniform grid of control points. In one application, this routine rotated a 7000 × 7400 image through 45° into a 4800 × 9600 image in 40 minutes real time on an IBM 370/158 using 250 kilobytes of main memory.

ERTMGEOM—performs a compound correction of Landsat MSS data using a spacecraft model correction followed by a grid correction. This is accomplished with a single resample of the input data.

TIECONM—converts arbitrarily spaced control point data sets to gridded format. It uses the finite element method of triangulating the input points, interpolating linearly on the triangular patches, and evaluating this surface on the grid (Manacher and Zobrist, 1978). A special method has been developed to extend the affine trend outside the convex hull of input points. This is because the routine is usually used to extend control point information inside a Landsat frame to the edges and corners of the frame.

POLYMASK—cuts an image at a graphics contour, leaving data inside the contour and zeros elsewhere. A Landsat frame can be cut in about twenty seconds CPU time.

RAPIDMOS—mosaics image pieces together. The Los Angeles RBV mosaic described in the next section was put together from its four constituent parts in 20 minutes CPU time.

LABVFY—verifies that the label of a tape or disk file contains character strings from a verification file to ensure that the proper data sets are used in a mosaic step.

the location obtained for its mate in the neighboring frame.

(9) Perform a surface model fit to each set of points in a frame and begin editing bad correlation matches (usually outliers in the model fit). If any geographic control points are deleted, return to step 7.

(10) Use the surface model fit to map the seam control points to a polygon in the map coordinate system and use the extrema to determine a bounding rectangle for the seam area.

(11) For each seam point in the control point data set, look up its brightness (grey scale) value in each of the Landsat spectral bands for both frames in the overlapping areas.

(12) Choose one spectral band. For each frame in that band, perform the geometric correction (program MGEOM or ERTMGEOM as needed) and the brightness correction. Limit processing to the bounding rectangle determined in step 10. Perform the same geometric correction on the seam data set. Use the corrected seam to cut the corrected image using program POLYMASK. Save the result on tape.

(13) Use program RAPIDMOS to mosaic the corrected pieces together in the relative location given by the limits of the bounding rectangle determined in step 10.

(14) Perform a complete quality control check on the first band mosaic.

(15) Perform steps 12 and 13 on the other spectral bands.

(16) Perform a quick check on the full mosaic. It can be assumed that the geometric character of all spectral bands is the same.

(17) Cut the mosaic image into quadrangles or segments as needed.

## MOSAICKING APPLICATIONS

### PENNSYLVANIA

A Landsat digital mosaic for the state of Pennsylvania was prepared for use in the development of an automated system to annually estimate the extent and severity of Gypsy Moth defoliation of Pennsylvania's hardwood forests. Present methods of ground and aerial inspections and surveys are expensive and frequently fail to provide adequate information soon enough for countermeasures to limit the local infestations. The techniques for detecting the defoliated hardwoods and development of a Geographic Information System (GIS) to assess the extent of damage are being developed jointly by NASA Goddard Space Flight Center and Pennsylvania State University. JPL mosaic technology was used to prepare Landsat data for direct input to this GIS. Additional efforts have yielded automatic techniques to register additional Landsat data, whether they be from Landsats 1, 2, 3, or 4, to the existing data sets to assist in future defoliation assessment or detection.

The Landsat data base was designed to conform to the architecture used by the Pennsylvania Power and Light Company. That data base design conforms to the USGS map series, incorporating nested mapping units of 15 minute quadrangles, 7½ minute quadrangles, 2½ minute cells, 15 second cells, and a minimum aggregation unit of ten acre blocks. The JPL processing involved the use of ground control points from the Master Data Processor (MDP) file for precision rectification, resampling of Landsat to 57 by 57 metre pixels, and reprojection to the Universal Transverse Mercator (UTM) projection with North-vertical orientation. Because the state is bisected by a UTM zone boundary, two separate UTM mosaics were prepared. The western portion of the state is UTM Zone 17 and the eastern portion is UTM Zone 18. Ten Landsat frames are needed to provide coverage for the entire state, but due to UTM zone conventions, each zone mosaic was compiled from six frames. The two frames along the UTM Zone boundary were used twice, once for each zone. Figure 5 shows part of the Western Pennsylvania mosaic. The completed mosaics for each UTM zone were subdivided into 1 degree latitude by 2 degree longitude quadrangles for easy handling of the data and for further segmenting into smaller units. Figure 6 is a 1° by 2° quadrangle photo product extracted from the Pennsylvania state mosaic.

In its operational use, the system currently being installed at Pennsylvania State University will experience the following scenario. Early Spring Landsat acquisitions will be automatically registered to the master mosaic imagery. Band-by-band difference images will be generated between the new acquisition and the master mosaic imagery which had been chosen specifically because it represented a non-defoliation condition. Areas of defoliation will be evident as stressed vegetative cover in the new acquisition and be highlighted in the difference images. A forest-nonforest binary mask, previously prepared from the master imagery at Goddard Space Flight Center (Nelson *et al.*, 1980), will be applied to highlight forest damage visually. Areas of concern can then be located by UTM coordinates, transferred to large scale maps, and the damage assessed by ground crews or aerial reconnaissance.

### ORURO DEPARTMENT, BOLIVIA

A digital mosaic of seven Landsat images of the Oruro Department region of Bolivia was produced to serve as the map base for a digital information system for the Department. The project, funded by the Inter-American Development Bank and sponsored by Programa ERTS/Bolivia (ERTS/GEOBOL) in Bolivia, was carried out jointly by the Laboratory for Applications of Remote Sensing (LARS) at Purdue University and JPL. The project was designed as a prototype study for the development of a nationwide digital data base that uses Landsat MSS for planimetric control and future updating.

The digital mosaic was designed to conform to the Bolivian government's current needs and mapping conventions. In particular, the Landsat imagery was rotated to North, resampled to 50 metre pixels, and map projected to the Albers equal area conic projection (Figure 7). The final mosaic was segmented into 100-km quadrangles of 2000 elements by 2000 elements per quadrangle.

Landsat data imaged in 1977 were obtained from the Brazilian receiving station. The Purdue LARS programming staff reformatted and edited the data, yielding a series of computer tapes compatible with the VICAR system. Editing operations

FIG. 5. The western portion of the State of Pennsylvania, UTM zone 17. Portions of six Landsat scenes of Band 6 (IR1) are shown here. The pixel resolution selected is 57 metres and is rotated so that north is vertical.

FIG. 6. The Harrisburg NK18-10 1° × 2° Quadrangle in Band 6 (IR1) is shown here. Segmenting the mosaic into manageable and conventional quadrangles eases data handling problems. A southerly extending start of data to 39.5°N latitude is provided to include the entire state area.

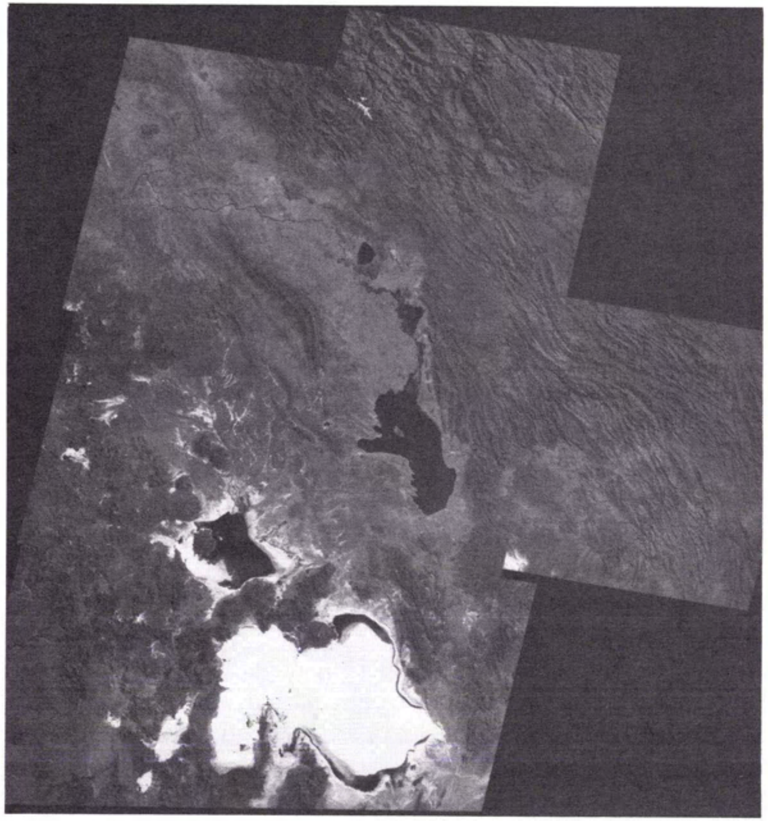

FIG. 7. The Oruro Department mosaic of Bolivia Band 7 (IR2) is shown here The final image is dimensioned 9900 lines by 9900 samples (columns). The mosaic digital data base is in the Albers equal area conic projection with 50 metre pixels. To display the data base here the pixels were subsampled to 100 metres.

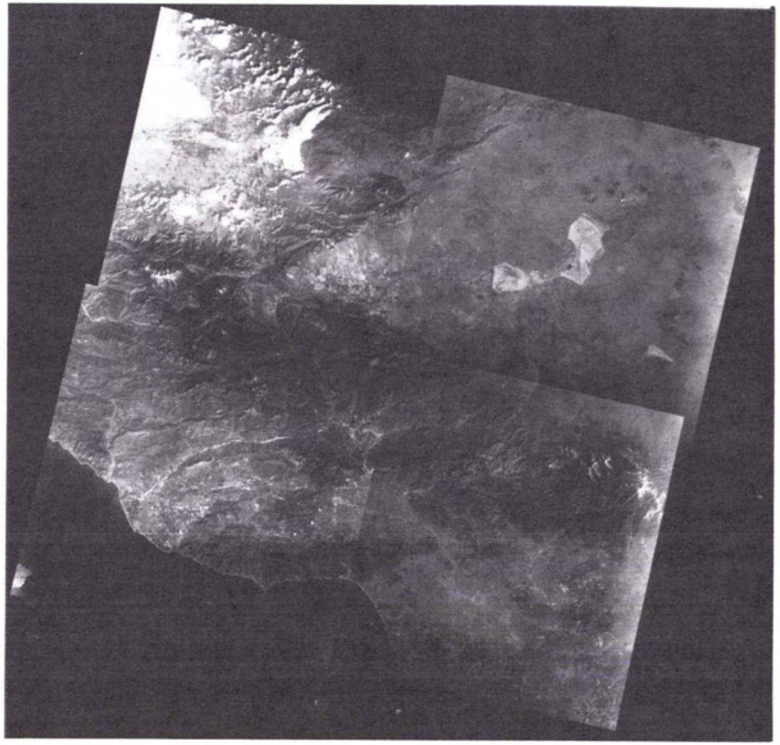

FIG. 8. Four frame RBV mosaic of Los Angeles area.

included repair and replacement of bad image lines. Under development at this time at JPL was the algorithm ERTMGEOM which, in a single pass of the data, corrected for spacecraft and sensor distortion and allowed additional information input for ground control and map projection. In addition, a new process was developed at JPL to edit and select specific ground control points based upon deviation from the predicted location of a ground control point or disagreement with neighboring points. The ground control points were selected by the LARS staff. Personnel from Bolivia were on hand to participate in and supervise the GCP selection process. The ground control points were referenced with respect to the uncorrected (raw) Landsat scenes as received from Brazil. JPL, using the same algorithm formulae used in correcting the image frames that were input to the mosaic, corrected the ground control point locations so that they would correspond to the proper locations in the JPL logged scenes. The logged scenes were then rectified and used as mosaic segments.

### LANDSAT RBV MOSAIC

Four adjacent scenes of digital RBV (return beam vidicon) imagery from Landsat-3 in the Los Angeles region have recently been mosaicked as part of an ongoing applications research task supported by NASA. Interest in the development of mosaics of RBV imagery is stimulated because of its relatively high resolution (18 to 20 metre pixels), and its amenability to reprojection to a photogrammetrically controlled mosaic (Sharma, 1980). Each RBV scene is instantaneously acquired over the full image area, unlike scanner and future multi-linear array systems which have non-systematic along-track and across-track distortions. Preliminary analysis shows that the RBV cameras display systematic, easily corrected, geometric distortions. To test the feasibility of RBV mosaicking, approximate ground control of four points per scene were used in the mosaic. Brightness correction was performed, but better results would be obtained if corrections to some known artifacts are included in the process (EROS Data Center, 1981). Figure 8 shows the completed mosaic. As a result, this technique could provide future NASA spaceborne imaging systems, such as the Landsat-D Thematic Mapper, with an easily and rapidly developable ground control pattern chip file for precision registration and rectification.

## ACCURACY

It is difficult to give a theoretical estimate of error for the mosaic process. Errors could be broken down into the categories of control point error, spacecraft model error, and data processing error; however, the compound distortion model used effectively reduces the error in the spacecraft model by passing the residuals still present in the control points after the spacecraft model has been applied onward to the grid correction model. Even without a thorough analysis, the following components of error can readily be identified:

- Error of control point determination (within 20 metres for most frames using the Goddard GCP file in Continental US, but a function of source maps elsewhere).
- Error in automatic correlation of control points (within 10 metres).
- Error of interpolation on control points (estimated 20 metres, but a function of density of control points).
- Error in data processing due to finite precision arithmetic and calculating schemes (within 1 metre).
- Error inherent in the Landsat MSS scanner (within 10 metres).

Finally, the spacecraft model specific to each Landsat may not completely compensate for mirror scan distortions, and this error is not always eliminated by the rubber sheeting.

Elevation values receive only a primitive treatment in the mosaic process. The maximum look angle from the Landsat satellite is 5.78 degrees and can cause an area to be shifted approximately 1/10 of its height. The treatment of elevation is to map a control point to its geographic coordinate regardless of its elevation. Because areas between the control points are mapped by interpolation, they will also be mapped to the correct geographic location if they happen to be at the proper in-between elevation. Thus, a high, but level, plateau will not be subject to much elevation offset error. Mountainous areas will be subject to greater errors, but not much can be done about this without the incorporation of detailed elevation information and expensive processing.

A quantitative planimetric accuracy assessment of the Oruro Department mosaic was performed by the LARS Purdue technical staff (Purdue LARS, 1981). While the initial ground control points that were used to map project the mosaic were obtained from a map series at the 1:250,000 scale, the actual assessment was completed with verification points that were selected from 1:50,000-scale series maps. The 1:50,000-scale series map became available only after the mosaic was completed; otherwise, ground control points would have been chosen from that series. One frame out of the seven for the mosaic had severe data integrity problems which caused some control problems. The remaining six frames had an average error of 225 metres (238 RMS). The Pennsylvania and Los Angeles cases have not been checked with the rigor of the LARS study.

## DATA BASE CONSIDERATIONS

Even though digital Landsat mosaics are presently constructed to form applications data sets, their potential as a digital cartographic data base is worth discussion. Photographic playback is a product extracted from the data base according to the needs of a particular user. The pixel size, map projection, and radiometric adjustments are set in the digital data base, but picture products can be made with user selected scale and color enhancement. Reprojection to different map projections is possible but requires an image rubber sheet computation with resampling.

Because a mosaic is a large cartographic data base, it should be cut into conventional segments. Latitude-longitude quadrangles will usually have slightly curved boundaries and fractional pixels at the edge. A better method might be to cut rectilinear boundaries in the map projection. Rectilinear pieces are more easily put together to produce an application data set.

Large area digital mosaics will engender a new data format with its own peculiar set of characteristics to be dealt with by users. In order to obtain good imagery over a large area, it is likely that mosaics will be multi-season and multi-year. It is also possible that radiometric integrity will be sacrificed slightly to achieve esthetic quality (lack of seams). These trade-offs will be determined by the primary users, for example, geology or forestry. An assessment of the user needs will be necessary prior to the final setting of all the parameters of the mosaic process and data base format.

## ACKNOWLEDGMENTS

The authors wish to thank a number of individuals for their contributions to this work. Part of the programming was performed by Howard Wilczynski and Boris Gokhman. The Los Angeles RBV mosaic was prepared by Jerry Clark, and construction of the California desert mosaic was aided by Jerry Clark, Tom Logan, Gary Angelici, and Dave Wherry. Work was also performed at the Goddard Space Flight Center and the Pennsylvania State University for the Pennsylvania mosaic and at Purdue University for the Oruro, Bolivia mosaic. The authors would like to thank Lisette Dottavio, Darrel Williams, and Mark Stauffer at Goddard and Luis Bartolucci, Terry Phillips, and Carlos Valenzuela at Purdue LARS. The Goddard GCP file was provided by Gerry Grebowski. This paper presents the result of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract No. NAS 7-100, sponsored by the National Aeronautics and Space Administration.

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(Received 11 May 1982, revised and accepted 19 March 1983)

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# CALL FOR PAPERS

## Commission III International Society for Photogrammetry and Remote Sensing

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- Theory of adjustments of observations, and measures of precision and accuracy of results.
- Theory of digital processing of sensor data for geometric, radiometric, and visual enhancement.

Those wishing to present papers should submit an abstract by *31 December 1983* to both of the following addresses:

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