S&T

NASA

National Aeronautics and Space Administration

EARTH RESOURCES LABORATORY

DIGITAL OVERLAYING OF THE UNIVERSAL TRANSVERSE MERCATOR GRID WITH LANDSAT-DATA-DERIVED PRODUCTS

REPORT NO. 160 **JUNE 1976**

(NASA-TM-74761) DIGITAL OVERLAYING OF THE UNIVERSAL TRANSVERSE MERCATOR GRID WITH LANDSAT-DATA DERIVED PRODUCTS (NASA) 45 p HC A03/MF A01 CSCL 08B

N77-27479

Unclas
G3/43 36824

LYNDON B. JOHNSON SPACE CENTER

DIGITAL OVERLAYING OF THE UNIVERSAL TRANSVERSE MERCATOR GRID WITH LANDSAT-DATA-DERIVED PRODUCTS

by

Thomas W. Pendleton

Report No. 160

June 1976

TABLE OF CONTENTS

ABSTRACT

Surface classifications and pictorial (map) representations of the earth are of more utility if such data can be related to standard geographic referencing systems. The Universal Transverse Mercator Grid is such a geographic referencing system. The LANDSAT multispectral scanner system acquires data which can be used to generate surface classifications and pictorial representations of the earth's surface. The mapping equations which relate LANDSAT data to the Universal Transverse Mercator Grid are in general quite complicated. However, almost linear approximations are reasonably accurate in local areas. Software has been written in FORTRAN IV for a Varian 73 computer which reformats LANDSAT-data-derived surface classifications and pictorial representations into a digital array which corresponds to the Universal Transverse Mercator Grid.

I. INTRODUCTION

The Earth Resources Laboratory (ERL), since its inception early in 1971, has been engaged in automatic processing of digital multispectral data such as that acquired by the multispectral scanners aboard the LANDSAT satellites. The processing has been performed with emphasis on automatic recognition of surface cover and on development of automatic recognition techniques. Pattern recognition techniques used at ERL are characterized as supervised maximum likelihood techniques based on the assumption of normally distributed multispectral data. The result of applying these pattern recognition techniques to LANDSAT scanner data is a classification of each pixel of multispectral data as a particular type of surface cover or as an unknown type of surface cover.

It was recognized at ERL that the full usefulness of the pixel by pixel classification would not be realized unless the classification could be related to a geographic coordinate system, such as latitude and longitude or northings and eastings. Further, it was recognized that the ability to update files of geographically referenced surface classifications would also be desirable, particularly in consideration of the repetitious nature of the LANDSAT coverage and the potential for gaps in the coverage due to concealing cloud cover.

The immediate circumstance that led to the development of the current set of software, which is used to create files of LANDSAT-data-derived geographically referenced surface classifications, was a request from the Department of the Army, Corps of Engineers, relative to the utility of remotely acquired, in particular LANDSAT MSS, data in updating environmental information.

The following is written as a guide to the techniques used in keying LANDSAT-data-derived surface classifications to the 1:250,000 scale V502 series maps prepared by the U. S. Army Map Service and as partial documentation of the software developed to implement the necessary techniques.

II. TRANSVERSE MERCATOR PROJECTION AND GRID SYSTEM

The 1:250,000 scale V502 series maps distributed by the United States Geological Survey, Department of Interior, are based on the Transverse Mercator Projection. A map projection is a representation on a plane (flat) surface of the meridians of longitude and parallels of latitude which are defined on the earth's spheroid surface. The Transverse Mercator Projection is not a geometric projection. but an approximation of the projection can be visualized by considering a cylinder wrapped around a sphere which approximates the earth spheroid. The cylinder is wrapped around the sphere so that the cylinder is tangent to the north and south poles of the sphere. Then, of course, the cylinder is tangent to a great circle which passes through the poles. This great circle is by definition a meridian of longitude. The meridians and parallels on the sphere are projected from the center of the sphere onto the tangent cylinder. The cylinder is unrolled onto a flat surface. The resulting pattern of meridians and parallels is a Transverse Mercator Projection whose central meridian is the meridian of tangency.

It is clear that the earth's surface, as represented on the Transverse Mercator Projection, is less distorted near the central meridian and more distorted away from the central meridian. As a consequence, starting at the 180° meridian and moving eastward the earth spheroid is divided in bands of longitude six degrees wide. The Transverse Mercator Projection used for each band in the V502 series is based on a central meridian which is located at the center of each band. For example, in the Central United States the V502 series is published on projections with central meridians at 87°, 93° and 99° west longitude. The V502 series is published on sheets which cover two degrees in longitude by one degree in latitude. Hence, the six degree band with central meridian at 93° west longitude, for example, consists of three sheets for each one degree band of latitude, the central meridian lying in the center of the middle sheet. At 90° west longitude the projection changes to one based on a central meridian at 87° west longitude and, of course, the projections do not agree at 90° west longitude.

Associated with the Transverse Mercator Projection between 80° south latitude and 84° north latitude is a square or Cartesian grid, naturally enough called the Universal Transverse Mercator (UTM) Grid. Each of the six degree bands of longitude, previously described, is sequentially numbered eastwardly from 180°. The six degree bands are then regarded as numbered grid zones. For each grid zone, a Cartesian grid is defined on the Transverse Mercator Projection for the grid zone in the following fashion. The central meridian of the zone, which is a straight vertical (north-south) line on the projection, is the vertical axis of the grid and is artificially assigned the value 500,000 meters so that the origin of the grid lies 500,000 meters west of the central meridian and outside the six degree grid zone in question. Distances measured in meters west to east from the origin are called "eastings" and by construction are always positive. The equator, which is a straight horizontal (east-west) line on the projection, is the abscissa of the grid system in the northern hemisphere; and distances measured in meters south to north are called "northings". In the Southern Hemisphere the equator is artificially assigned a value of 10,000,000 meters and the grid system decreases toward the South Pole. On most V502 series maps the UTM grid is shown at 10,000 meter intervals.

III. LANDSAT DATA GRID

LANDSAT multispectral data are collected by the four spectral band line scanner carried on the LANDSAT satellites which are in a near circular, near polar orbit. The orbital parameters are approximately the following as given in the LANDSAT Data Users' Handbook:

Semi-major axis	7285.82 km
Inclination	99.114 deg
Eccentricity	.0006
Altitude	~925 km

The scanner uses an oscillating mirror to scan in a direction perpendicular to the spacecraft heading. Over the United States, the spacecraft is traveling toward the equator during data collection, and the data collection portion of the scan is as the mirror images from west to east. Six lines of data are acquired simultaneously in each of the four spectral bands during each mirror sweep. The mirror sweeps at a rate such that the spacecraft velocity moves the scanner along track a distance corresponding to the width of the six scan lines acquired during each mirror sweep. The instantaneous field-of-view of each detector is 79 meters when the satellite is at nominal altitude and the sample rate provides for a sample every 56 meters across track. Hence, over-sampling occurs across track and approximately contiguous coverage occurs along track. The $\pm$ 2.89° oscillation of the scanning mirror results in an 11.56° field-of-view or at nominal altitude a 100 nautical mile ground distance corresponding to each scan line.

ERL uses LANDSAT system-corrected multispectral scanner computer-compatible tapes for pattern recognition. These tapes are described in detail in the Goddard Space Flight Center publication, "Generation and Physical Characteristics of the ERTS MSS System-Corrected Computer-Compatible Tapes". One LANDSAT scene which is approximately 100 x 100 nautical miles consists of 2340 scan lines; historically, each has contained an average of 3220 elements per line with a tolerance of $\pm$ 2 elements. A LANDSAT scene is stored on four computer-compatible tapes. Historically, the first tape has contained the first 810 elements of each scan line, the second tape the next 810, the third tape the next 810, and the fourth tape the remaining elements. The ERL pattern recognition software reformats the LANDSAT system-corrected computer-compatible tapes in several different ways for different purposes. The computer-compatible tapes which input to and output from the geographic referencing software are called PSUTAP's, the format of which is described in appendix C. Briefly, the PSUTAP's used on input correspond to the LANDSAT system-corrected computer-compatible tapes in that the same scan line and element referencing system is used to reference each pixel of data. The scan line number is carried explicitly on the tape--the element number is determined in a position sequential fashion for each pixel in a scan line. The information stored for each pixel is contained in a six-bit byte. If the LANDSAT data have been processed through the ERL pattern recognition system, the byte contains a surface cover classification code. It is also possible to use the ERL pattern recognition system to obtain a PSUTAP such that each byte contains a code which corresponds to surface reflectance. Such a tape is suitable for display on CRT's monitors, for filming by digitally-driven film recorders, or for display on other digitally-driven display devices.

IV. FUNCTIONAL RELATIONSHIP BETWEEN LANDSAT DATA AND UTM GRID

The functional relation between a LANDSAT pixel as defined by scan line and element and the UTM coordinate of the spot on the earth's surface that corresponds to the pixel is, in general, complicated from both theoretical and computational considerations. The computational consideration becomes particularly significant when one considers that the computation must be performed for each pixel acquired by the scanner. As is described in section VI, the functional relation used in the geographic referencing software is easily modified, and if more mapping accuracy is required such modifications should be made. However, a form of the functional relation, which is much more accurate than the relation currently compiled in the software, must be evaluated in terms of computational efficiency. The mapping formulae currently compiled into the software take the form:

$$\text{(A)} \qquad XL = A_1 + A_2 E + A_3 N$$

$$\text{(B)} \qquad XE = XE_0 + XE_{0/R} [\text{TAN}^{-1} (B_1 + B_2 E + B_3 N)],$$

where the A's and B's are the mapping formulae coefficients which must be determined for each application as indicated in section five; E and N are Eastings and Northings, respectively, in 50 meter units referenced to an arbitrary origin; XE and XL are LANDSAT element and scan line number; XE_0 is the LANDSAT element number corresponding to the LANDSAT nadir; and R is the half angle of the LANDSAT scanner in radians. These formulae model a LANDSAT multispectral scanner type data collection system passing linearly at constant altitude, roll, yaw, pitch and velocity over the UTM grid; also assumed is constant scanning and sampling rate. Motivation for the formulation can be found using figure 1 as a guide. In figure 1 (E_c, N_c) is a given northing and easting on the ground track which corresponds to a known scan line and element in the LANDSAT data, say XL_c and XE_c, respectively. Further (E, N) is a given northing and easting in the LANDSAT scene whose corresponding scan line and element, XL and XE, respectively, are to be determined. Finally, I is the distance on the ground between successive LANDSAT scan lines and D is the distance from the LANDSAT scanner to the scan line being acquired. From figure 1

$$(A^1) \quad [N_C - (XL - XL_C)\ I \sin i] - N = \tan u \left\{ E - [E_C - (XL - XL_C)\ I \cos i] \right\}$$

$$(B^1) \quad E - [E_C - (XL - XL_C)\ I \cos i] = \cos u \left[\tan \left(R\ \frac{XE - XE_0}{XE_0} \right) \right] D$$

Since the terms N_c, XL_c, I, i, u, E_c, and D are taken as constant, algebraic manipulation reduces equation (A^1) to equation (A); and, likewise, by eliminating the $(XL - XL_c)$ terms in equation (B^1) by using equation (A^1), equation (B^1) reduces to equation (B).

These formulae become increasingly less accurate as they are extended to larger regions. It has been the experience at ERL that the equation (A) and (B) give accuracies of 100 meters RMS within 1° x 1° regions in southern Louisiana and Mississippi. These accuracies are, of course, very dependent on the choice of control, and hence on the determination of the A's and B's in equations (A) and (B).

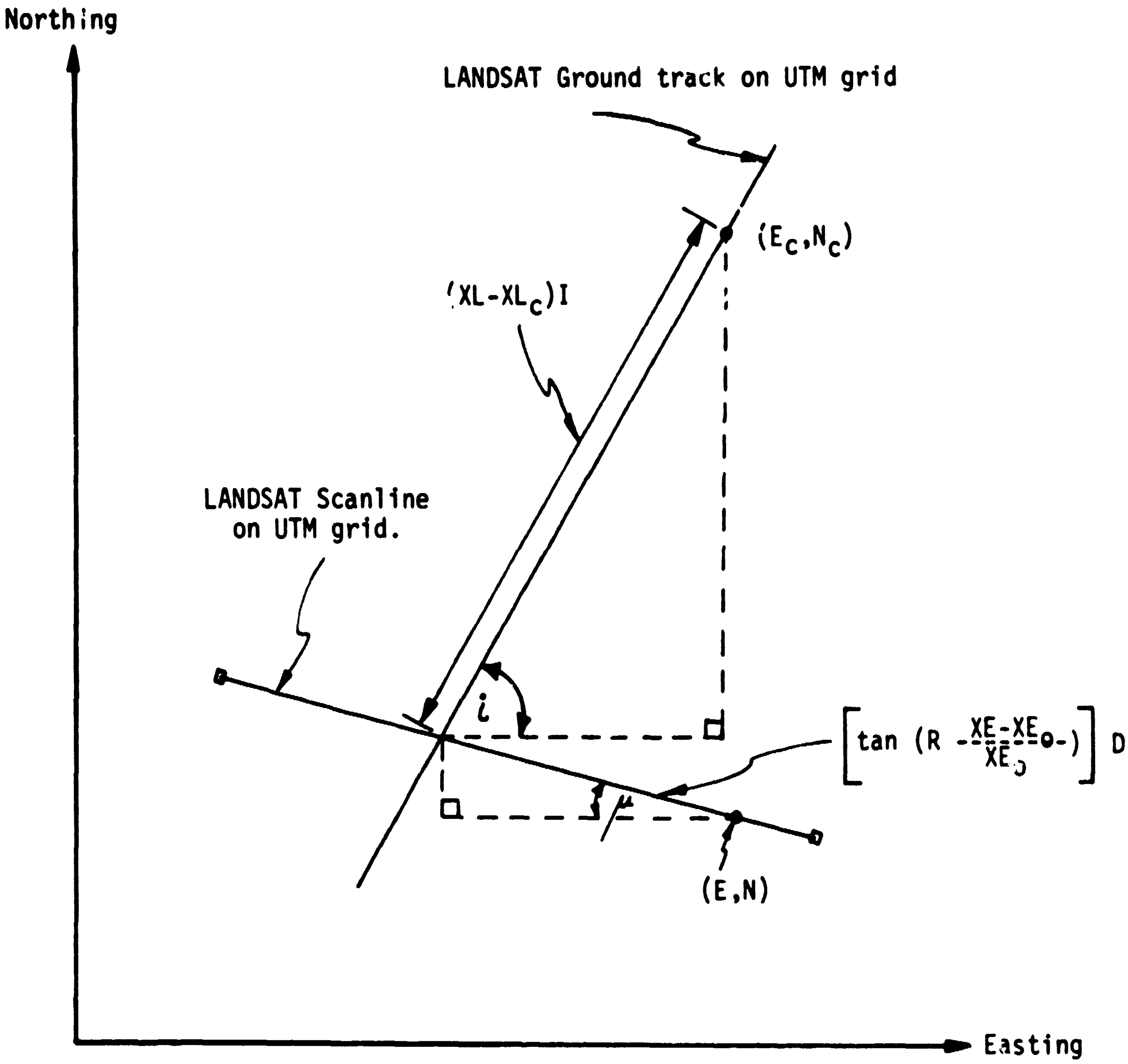


Figure 1. - LANDSAT Geometry

V. DETERMINATION OF PARAMETERS

As indicated in section IV, the mapping coefficients, the A's and B's in equations A and B, must be determined for each application. A unique set of mapping coefficients must be determined for each LANDSAT frame and for each UTM grid zone. The coefficients are also strongly correlated with latitude. Applications so far have indicated that recomputation of the coefficients for each 1° latitude band is sufficient for 100 meter accuracy.

Since there are six unknown mapping coefficients in equations (A) and (B) a minimum of three control points must be used to compute the values of the coefficients for a given application. A control point consists of the northing and easting of a place on the earth's surface whose image can be located in the LANDSAT data and the scan line and element of the image in the LANDSAT data. At ERL, control points are selected using the V502 series maps and color cathode ray tube (CRT) display devices which have a cursor which can be used to mark a particular pixel. The CRT display devices have electronic readouts of various types which indicate the scan line and element of the pixel marked. These devices are driven by the PSUTAP's generated by the ERL pattern recognition system as indicated in section III. It is, of course, possible to pick control points using the color-coded classification PSUTAP's, but this is not generally desirable because of the lack of resolution. Care in control point selection is critical in obtaining accurate mapping results. On 1:250,000 scale maps .02", the historical cartographic manual plotting standard, is equivalent to 127 meters; therefore, it is very important to select control points which can be readily identified such as intersection of roads and railroads, and bridges crossing streams. Care should be taken not to select features which tend to change position as a function of time such as river bends and field boundaries. Further features should be selected which are easily identified in the display of the LANDSAT data. The number of control points required to produce the desired result is somewhat difficult to precisely define. Three, as indicated, is the minimum required, but in order to take advantage of the least squares solution for the coefficients, which is described in the next paragraph, experience has indicated that five control points per PSUTAP per 1° by 1° region are desirable. This figure is flexible and is largely dependent upon the relation between the region in question and the LANDSAT coverage. For instance, if three PSUTAP's from a single LANDSAT frame cover the region in question, two of which predominate, the third required only to fill in a corner of the region, ten control points from the two predominant tapes would suffice. Finally, the control points should be as evenly distributed, geographically, as possible.

Since it is not possible to choose control point coordinates without error and since the mapping formulae do not exactly model the LANDSAT geometry, a least squares technique is used to estimate the mapping coefficients. Assume M control points $\left\{N_i, E_i, XL_i, XE_i\right\}_{i=1}^{M}$ which have been chosen as previously described and consider equations A and B cast in the following form

$$XL \cong A_1 + A_2E + A_3N$$

$$\tan\left[R\left(\frac{XE - XE_0}{XE_0}\right)\right] \cong B_1 + B_2E + B_3N$$

Then consider the two sums

$$\sum_{i=1}^{M} \left[XL_i - A_1 + A_2E_i + A_3N_i\right]^2$$

$$\sum_{i=1}^{M} \left[\tan \; [R \; (\frac{XE_i - XE_0}{XE_0})] - B_1 + B_2E_i + B_3N_i\right]^2$$

The unknown coefficients, the A's and B's are chosen to make the sums a minimum using elementary calculus. That is, the equations are differentiated with respect to the six unknowns. The resulting six equations in the six unknowns are set equal to zero and solved simultaneously. The values obtained for the A's and B's are then used as the coefficients in the mapping formulae for the application at hand.

VI. SYNOPSIS OF EACH SOFTWARE MODULE

The software used for keying LANDSAT-data-derived products to the V502 series maps consists of five modules. Three of these modules, CONSTANTS, DATBAS and BASTAP, are the modules required to produce an output file in the RMD-DISC file (appendix B), containing the geographically referenced data. The other two modules, FILE COPY and ACREAGE, serve various other auxiliary purposes as described in the following paragraphs. The software modules are in Fortran IV and operate on a Varian 73 operating under VORTEX II, and operate on other systems as described in the ERL report "Low-Cost Data Analysis Systems for Processing Multispectral Scanner Data". Each module requires a line printer and a card reader. All modules except CONSTANTS require a disc which can contain 23,000 blocks of 120 words (16 bits) each. The disc storage is for storage of the geographically referenced data corresponding to 100,000 meters east-west by 115,000 meters north-south. All modules except CONSTANTS and ACREAGE require a tape drive. However, the module ACREAGE operates on data stored on disc and a tape drive may be required to create the disc data. In addition, a display device which can be driven by a PSUTAP and which creates a display that is suitable for determining the LANDSAT scan line and element number of control points is required. Such a display device would also be used for editing and inspecting final products. The CONSTANTS module requires a card punch.

The CONSTANTS module, which requires 17,777 octal (8,191 decimal) words (16 bit) of storage, accepts an arbitrary number (greater than three) of control points as input. These control points are used to determine the mapping coefficients in equations (A) and (B) as described in section V. The mapping coefficients are then used with the northing and easting of each control point in the right side of equations A and B to compute the predicted scan line and element number for such control point. The predicted value of the scan line and element is compared to the value measured when the control points were identified by scan line and element in the LANDSAT data. The root-mean-square, i.e., the square root of the average of the squares of the differences between the measured and predicted value, is computed. This value is used to determine the expected geometric accuracy of the application and is used as a guide to possible blunders in selection of control, i.e., control points which indicate large differences in measured and predicted value should be examined for the cause of such differences. Finally the program punches on five cards information which is read by the DATBAS module and used by the DATBAS module to set up the mapping formulae. In the event that the mapping formulae in the DATBAS module were changed to some other map projection, the CONSTANTS module would also have to be changed to reflect such modification. It should be noted that the CONSTANTS module assumes that the 1610^{th} element in each LANDSAT scan line is the element that corresponds to the nadir of the scanner. This information is reflected in line forty-eight of the program. It should be noted that this value is not so critical since the field-of-view of the scanner is so narrow, a translation term is included in the mapping formulae and the angle distance between successive samples is small.

The DATBAS module, which requires 60,000 octal (24,576 decimal) words (16 bit) of storage, accepts LANDSAT-data-derived information as stored on a PSUTAP, information computed by the module CONSTANTS, scan line and element numbers which define the rectangular portion of the data on the PSUTAP which is to be processed, and numbers which define the origin of the geographically referenced data which are to be generated. The geographically referenced data are stored on disc in the format indicated in appendix B. The disc storage or data base should be considered in terms of a square grid orientated north-south and east-west. Using the mapping formulae currently compiled in the module the grid size is 50 meters. The origin of the grid relative to the UTM grid is defined by the input parameters IBIAS and BIAS (appendix B); that is, the northing of the centers of all elements in the first scan line is given by 50 (BIAS + 1) in the Northern Hemisphere, and in general the northing of the N^{th} scan line ($1 \geq N \geq 2300$ per data base) is given by 50 (BIAS + 1 + N). Further the easting of the center of the first element in each scan line is given by 500,000 - 50 (IBIAS - 2) and in general the easting of the M^{th} ($1 \geq M \geq 2000$) element in any scan line is given by 500,000 - 50 (IBIAS - 2 + N). With these definitions the convention is that if IBIAS is negative the origin moves to the east, if positive the origin moves to the west. The values BIAS and IBIAS are stored as real variables in words seven and eight, and nine and ten, respectively, on the first record of each data base when the data base is first initialized.

The area represented by each data base is somewhat larger than 1° by 1°, i.e., 115,000 meters north-south by 100,000 meters east-west. The DATBAS module expects to find this region represented on disc. If the data base has not been previously used the DATBAS module must be instructed to initialize the data base which it does by placing a no operation code (-1) in each location. The DATBAS module then considers the rectangular region defined by scan lines and elements in the LANDSAT coordinates system, which is to be used to update the data base. The inverses of the mapping formulae (A) and (B) are used to determine the region in the data base which is to be updated. The information stored in the data base for the region to be updated is read into core. The mapping formulae (A) and (B) are then used to compute the LANDSAT scan line and element of each grid cell in the region to be updated. Using the LANDSAT data at the nearest scan line and element to the one computed, the data base grid cell is updated. This process continues to completion and the updated data base information is placed back on disc in the appropriate location--the result being LANDSAT-data-derived information stored in a rectangular array which corresponds to a 50 meter UTM grid except for a translation factor which is known. This information can be accessed as a function of northing and easting and can be portrayed on a plotter to overlay maps on Universal Transverse Mercator projections, and can be updated as the occasion may demand.

The mapping formulae occupy well-defined areas in the DATBAS module. The mapping formulae A and B are coded at lines 360-362 and the inverses of these formulae are coded at lines 237-240. These formulae can easily be changed if one suitably defines the variables IBIAS and BIAS and considers the storage limitations on the disc being used.

The BASTAP module requires 22,000 octal (9,216 decimal) words (16 bit) of storage. This program is used to extract any rectangle region from a disc data base and to place the information on a PSUTAP. Further the program will embed a rectangular array of cross-shaped tick marks in the data. These tick marks can be defined to be a UTM grid or can be used for registration purposes if the PSUTAP so generated is to be used to drive a plotting device.

The FILE copy module requires 16,000 octal (7,168 decimal) words (16 bit) of storage and is used to copy a data base file from disc to a PSUTAP or from a PSUTAP to disc.

The ACREAGE module requires 25,000 octal (10,752 decimal) words (16 bit) of storage. The module assumes a current data base residing on disc. In order, either clockwise or counter clockwise, the data base coordinates (scan line for north-south, element for east-west) of a polygonal region are entered. The module computes the number of grid cells in each class within the polygonal region and prints out the corresponding acreage of each class within the polygon.

REFERENCES

1. Data Users Handbook, Goddard Space Flight Center, Greenbelt, MD, Document No. 71504249.

2. Thomas, Valerie L.: Generation and Physical Characteristics of the ERTS MSS System Corrected Computer Compatible Tapes, Goddard Space Flight Center, Greenbelt, MD, X-563-73-206, July 1973.

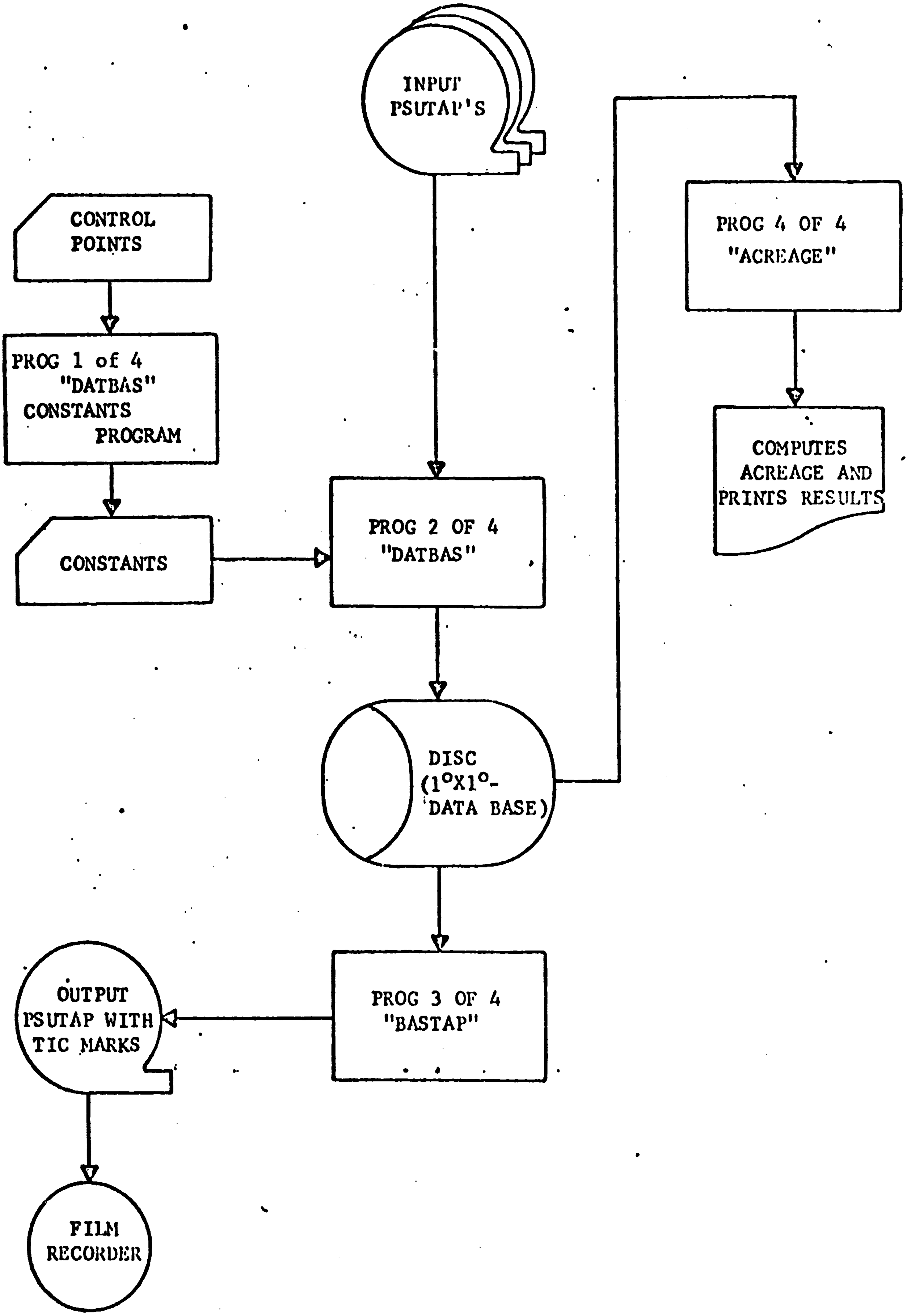
3. Whitley, Sidney L.: Low-Cost Data Analysis Systems for Processing Multispectral Scanner Data. ERL Report #157, 1976.

4. PATREC Software Documentation, Earth Resources Laboratory, Lyndon B. Johnson Space Center, Houston, Texas

APPENDIX A

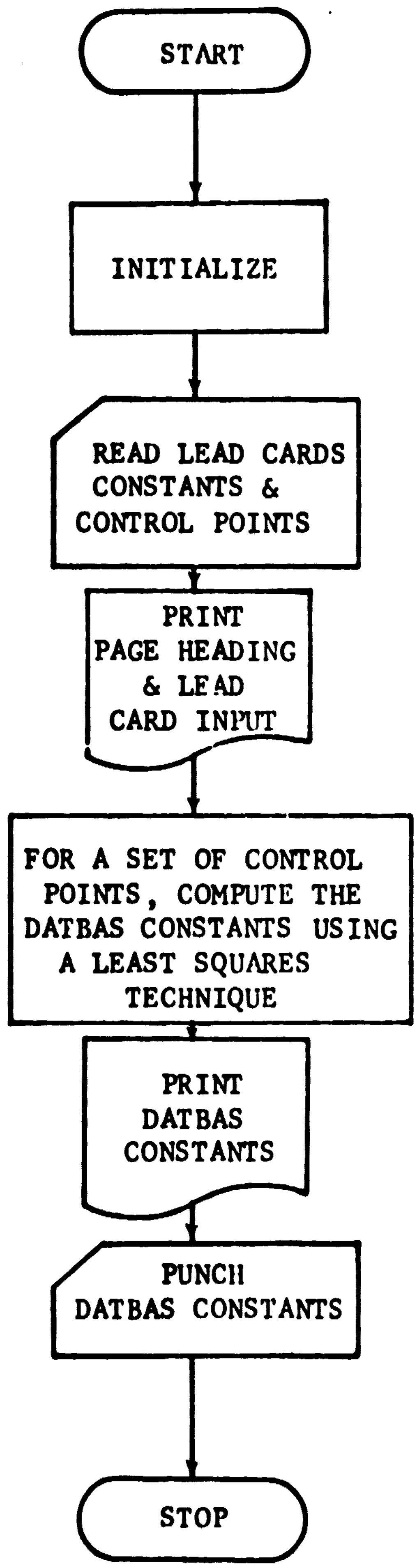
FLOW DIAGRAMS AND LEAD CARD SET UP

The following flow diagram shows the relation between the four modules CONSTANTS, DATBAS, BASTAP and ACREAGE. The module FILE COPY is used to transfer RMD-DISC FILE from tape to disc or from disc to tape.



The following pages show flow diagrams and the lead cards each module expects to find following execution.

FLOW CHART FOR MODULE CONSTANTS



LEAD CARD SET UP FOR MODULE CONSTANTS

CARD NO. 1

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-10	I10	N	Number of control points in solution.
				If N = 0, run is terminated.
2	11-20	E10.0	R	Angular distance in radians between
				successive scanner samples. (= .10088)
				for LANDSAT A and B.
3	21-80	30A2	COM	Comments placed at the top of each page.
				If the two characters 'NO' appear in
				columns 79 and 80, no punch output is
				generated.

Comments

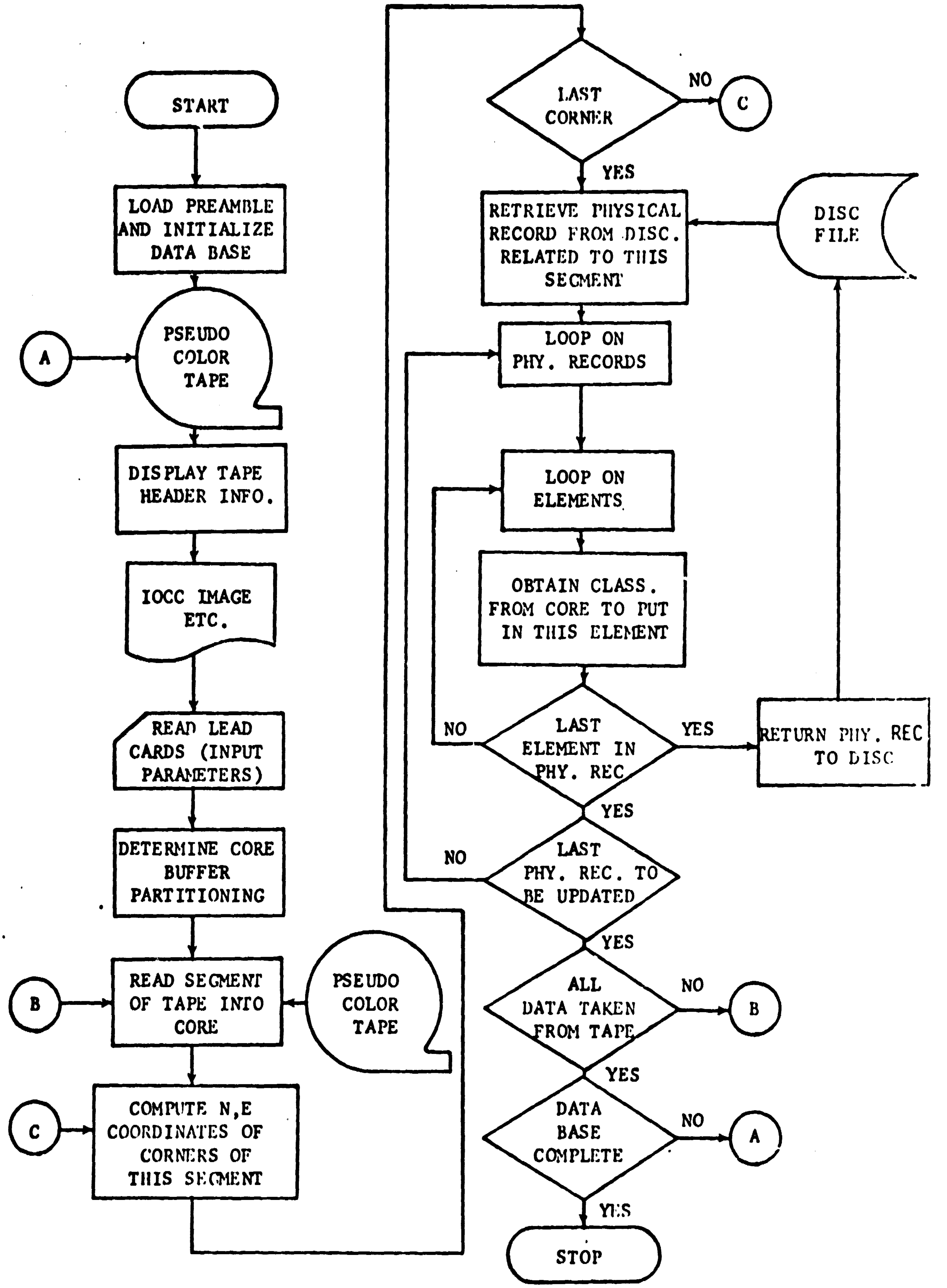
LEAD CARD SET UP FOR MODULE CONSTANTS

CARD NO. 2-N (number of control points)

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-10	I10	PT	Control point number
2	11-30	E20.0	EAS	Control point easting
3	31-50	E20.0	NOR	Control point northing
4	51-60	E10.0	LI	LANDSAT scan line number of control point
5	61-70	E10.0	EL	LANDSAT element number of control point
6	71-75	E5.0	WL	Weight associated with scan line
7	76-80	E5.0	WE	Weight associated with element

Comments If 'WL' or 'WE' are entered as zero they are put equal to 1

FLOW CHART FOR MODULE DATBAS



LEAD CARD SET UP FOR MODULE DATBAS

CARD NO. 1

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-40	20A2	ICOM	Comments to be placed at the top of
				each page (max. of 40 characters)
2	45	I1	IZERO	=0 , will not initialize Data Base
				=1 ,*will initialize (zero out) and
				load preamble

Comments *Do not inadvertently zero out an already constructed Data Base.

LEAD CARD SET UP FOR MODULE DATBAS

CARD NO. 2

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-6	3A2	ICB(I), I=8,10	File name of the RMD-disc for the
				output Data Base file (6 characters).
2	7	1X	,	Separator (,)
3	8,9	I2	IDISC	Logical Unit Number (RMD-disc) for
				the output Datá Base file.

Comments

LEAD CARD SET UP FOR MODULE DATBAS

CARD NO. 3

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-6	3A2	IFCB(I), I-8,10	File name (RMD-disc) or reel number
				tape) for the input PSUTAP
2	7	1X	,	Separator (,)
3	8,9	I2	INTAP*	Logical Unit Number (LUN) for the
				input PSUTAP.

Comments *INTAP = 0 (blank) signals end of all processing

LEAD CARD SET UP FOR MODULE DATBAS

CARD NO. 4

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-5	I5	SCANST*	Starting scan line number on the input
				PSUTAP.
2	6-10	I5	STOPSN	Ending scan line number on the input
				PSUTAP.
3	11-15	I5	ELEST	Starting element number on the input
				PSUTAP
4	16-20	I5	ELESP	Ending element number on the input
				PSUTAP.
5	21-30	F10.0	IBIAS	IBIAS-2 is distance in 50 meter units
				between eastern edge of data base and
				UTM grid zone center. Positive is west
				of zone center, negative is east.
6	31-40	F10.0	BIAS	BIAS+1 is distance in 50 meter units
				between equator and southern edge of
				data base.

Comments *SCANST = 0(blank) signals end of processing for an input tape.

This card is repeat for each region to be used after card 9* (note card 5* - 9* are included only once per input PSUTAP)

LEAD CARD SET UP FOR MODULE DATBAS

CARD NO. 5*

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-20	E20.0	C1	Using mapping formulae (A)
				$C1 = A_3$, $C2 = A_1/A_3$ and $C3 = A_2/A_3$
2	21-40	E20.0	C2	"
3	41-60	E20.0	C3	"

Comments This card is punched as output from the DATBAS CONSTANTS Program

*Cards 5-9 are only entered once for each input tape.

LEAD CARD SET UP FOR MODULE DATBAS

CARD NO. 6*

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-20	E20.0	R1	Using mapping formulae (B) $R1 = B_3$
				$R_2 = B_2/B_3$ $R_3 = B_2/B_3$
2	21-40	E20.0	R2	"
3	41-60	E20.0	R3	"
4	61-80	E20.0	CE	Scanner element corresponding to
				scanner nadir

Comments This card is punched as output from the DATBAS CONSTANTS Program(MSSX27)

*Cards 5-9 are only entered once for each input tape.

LEAD CARD SET UP FOR MODULE DATBAS

CARD NO. 7*

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-20	E20.0	CSUB1	Terms computed by module CONSTANTS used
				in the inverse of mapping formulae
				(A) and (B)
2	21-40	E20.0	CSUB2	"
3	41-60	E20.0	CSUB3	"

Comments This card is punched as output from the DATBAS CONSTANTS Program(MSSX27)

*Cards 5-9 are only entered once for each input tape.

LEAD CARD SET UP FOR MODULE DATBAS

CARD NO. 8*

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-20	E20.0	RSUB1	Terms computed by module CONSTANTS used
				in the inverse of mapping formulae
				(A) and (B)
2	21-40	E20.0	RSUB2	"

Comments This card is punched as output from the DATBAS CONSTANTS Program (MSSX27).

*Cards 5-9 are only entered once for each input tape.

LEAD CARD SET UP FOR MODULE DATBAS

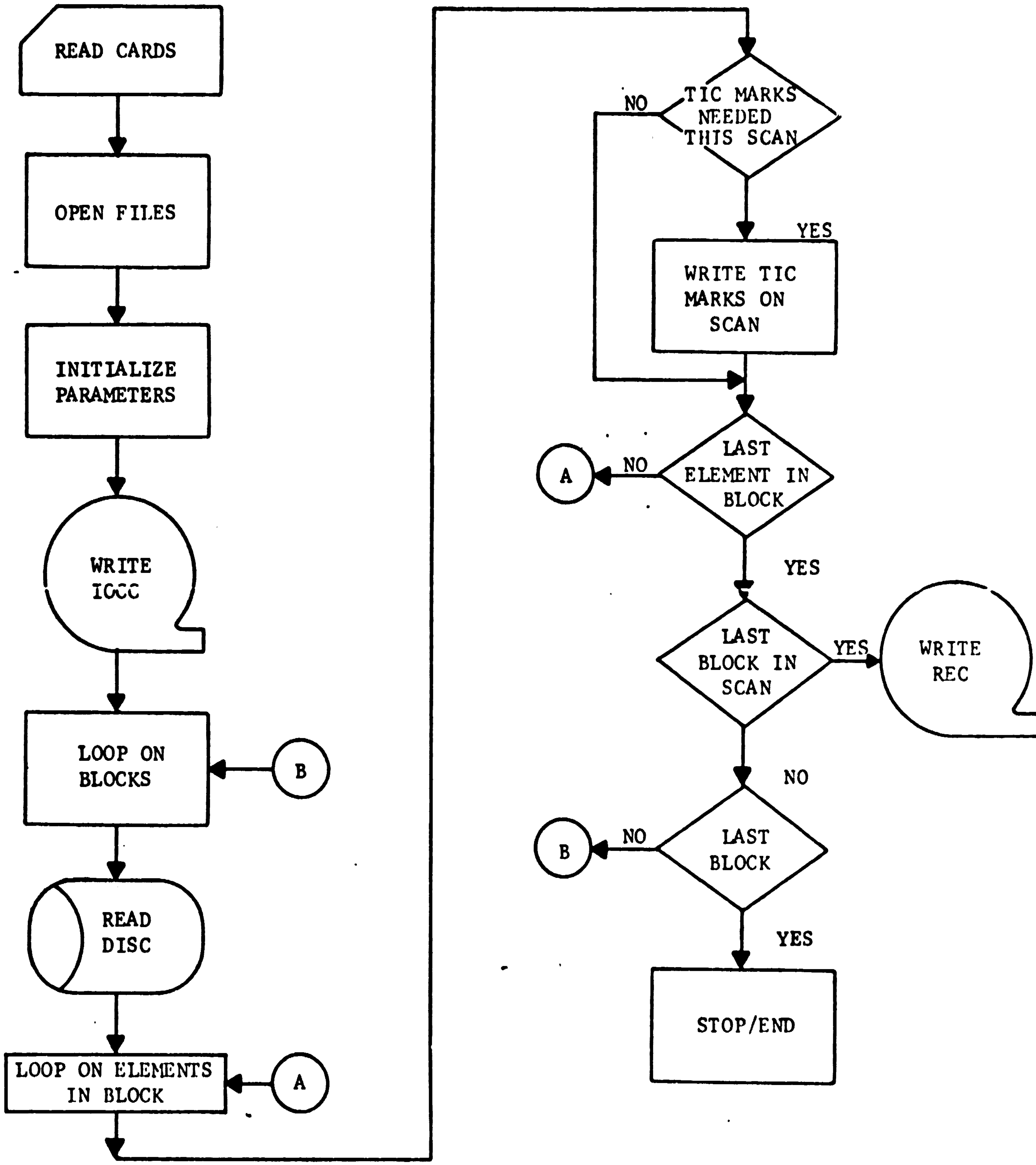
CARD NO. 9*

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-20	E20.0	P1	Terms computed by module CONSTANTS used
				in the inverse of mapping formulae
				(A) and (B).
2	21-40	E20.0	P2	"
3	41-60	E20.0	P3	"

Comments This card is punched as output from the DATBAS CONSTANTS Program (MSSX27).

*Cards 5-9 are only entered once for each input tape.

FLOW CHART FOR MODULE BASTAP



LEAD CARD SET UP FOR MODULE BASTAP

CARD NO. 1

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-40	20A2	ICOM	Comments to be placed at the top of each page.

Comments ______________________________

LEAD CARD SET UP FOR MODULE BASTAP

CARD NO. 2

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-6	3A2	IFCB(I),	File Name (RMD-disc) or "blanks" for
			I=8,10	reel number (magnetic tape) for the
				output PSUTAP.
2	7	1X	,	Separator (,)
3	8,9	I2	INTAP	LUN for the output PSUTAP
4	10	1X	,	Separator (,)
5	11-50	20A2	IFCB	Tape labeling comments or accounting
				information (40 characters) for the
				output PSUTAP

Comments

LEAD CARD SET UP FOR MODULE BASTAP

CARD NO. 3

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-6	3A2	ICB(I), I=8,10	File name of Data Base File on Disc
				(6 characters)
2	7	1X	,	Separator (,)
3	8,9	I2	IDISC	LUN of the Disc File

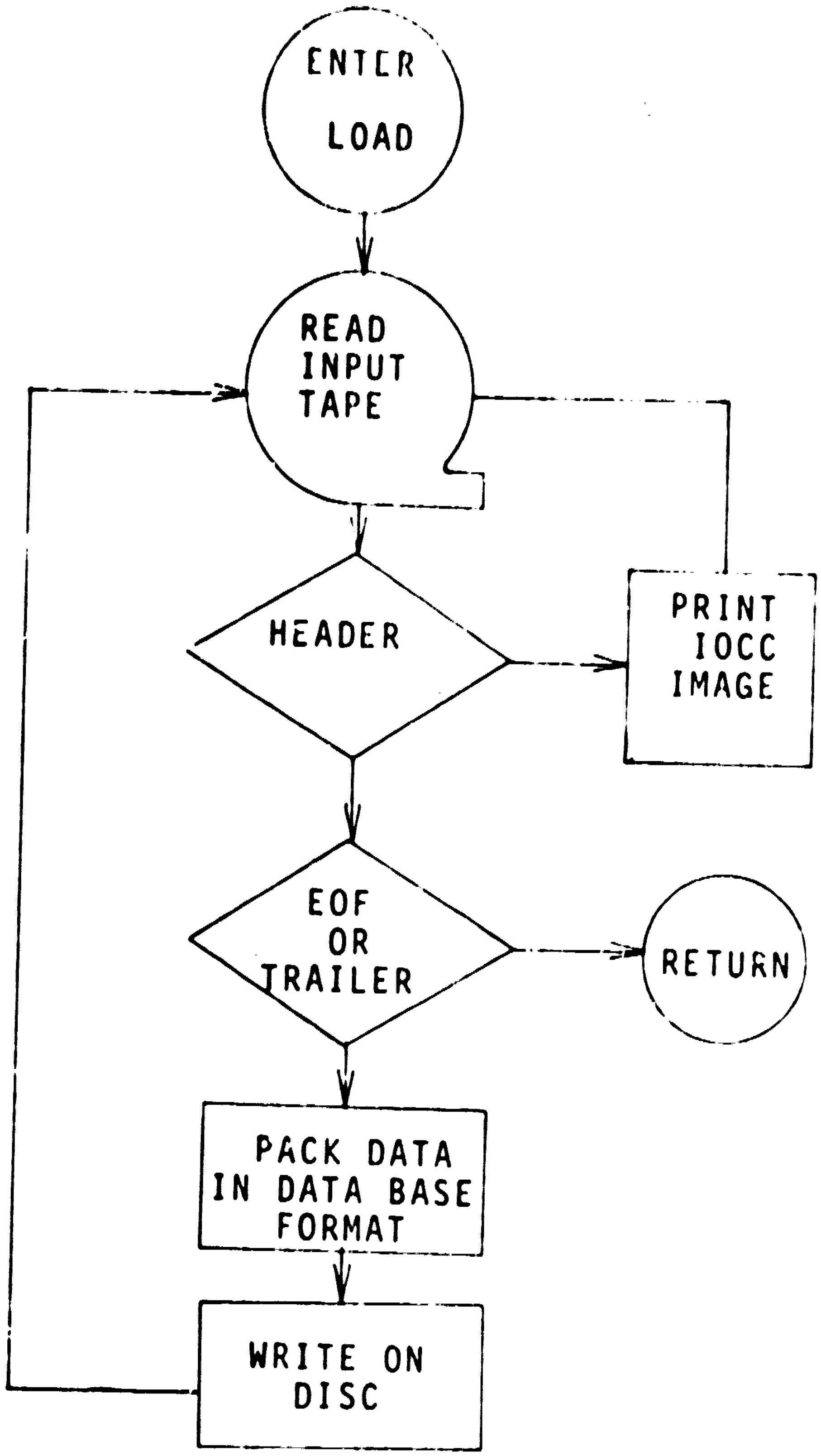
Comments

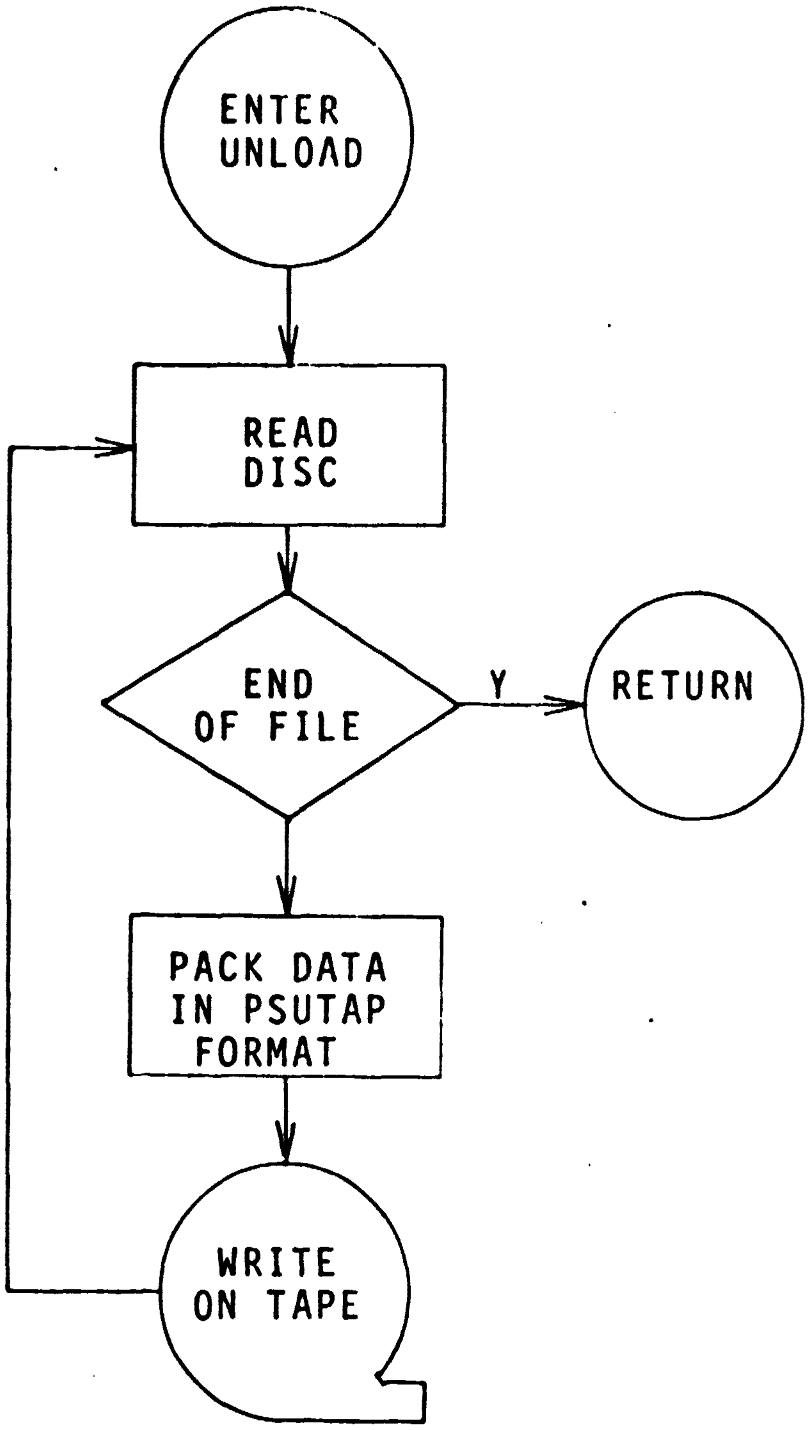
LEAD CARD SET UP FOR MODULE BASTAP

CARD NO. 4

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-5	I5	ISTRT	Start scan number for PSUTAP output
2	6-10	I5	ISTOP	Stop scan number for PSUTAP output
3	11-15	I5	ITIC	Increment for Tic Marks (i.e.:a 50
				would produce a tick mark every 50
				data base elements (Northings and
				Eastings), there is a restriction that
				15 ≤ ITIC < 2000)
4	16-20	I5	IXBIAS	Data base element at which Tic Marks
				begin.(Eastings) element one is eastern
				edge of data base.
5	21-25	I5	IYBIAS	Data base scan line at which Tic Marks
				begin.(Northings) scan line one is
				southern edge of data base.

Comments


ENTER
LOAD
READ
INPUT
TAPE
HEADER
PRINT
IOCC
IMAGE
EOF
OR
TRAILER
RETURN
PACK DATA
IN DATA BASE
FORMAT
WRITE ON
DISC


ENTER UNLOAD
READ DISC
END OF FILE
Y
RETURN
PACK DATA IN PSUTAP FORMAT
WRITE ON TAPE

LEAD CARD SET UP FOR MODULE FILE COPY

CARD NO. 1

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-40	20A2	ICOM	Comment for page heading
2	45	I1	PATH	=0 - Copy tape to disc
				=1 - Copy disc to tape

Comments

LEAD CARD SET UP FOR MODULE FILE COPY

CARD NO. 2

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-6	3A2	TCB(8...10)	PSUTAP, Tape number for input
				Blank for output
2	7	1X	,	Separator
3	8,9	I2	LUT	Logical unit for PSUTAP file.
4	10	1X	,	Separator
5	11-51	20A2	LBLT	Label for PSUTAP file

Comments

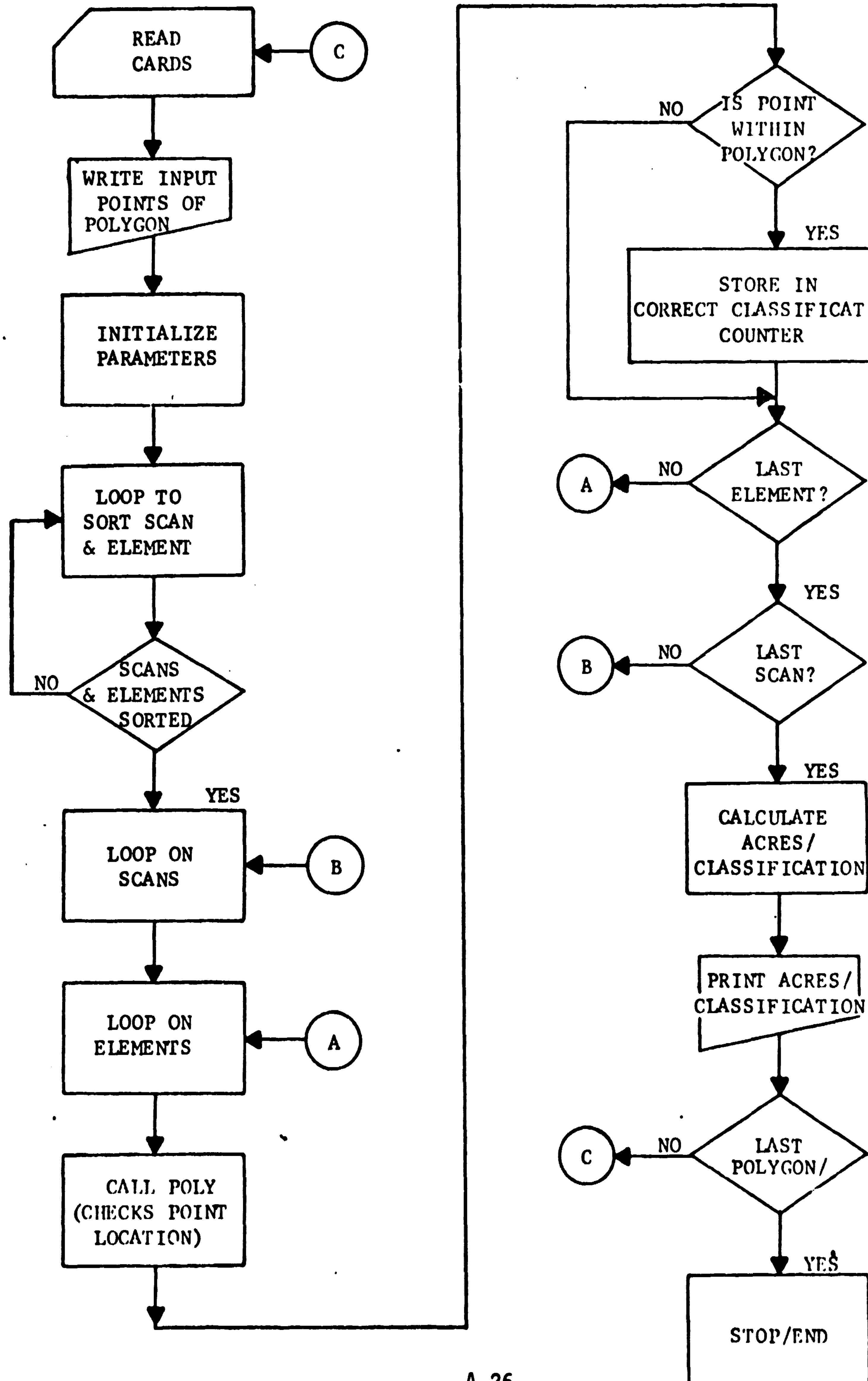
LEAD CARD SET UP FOR MODULE FILE COPY

CARD NO. 3

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-6	3A2	DCB(8...10)	DATBAS RMD-file name
2	7	1X	,	Separator
3	8,9	I2	LUD	Logical unit for RMD-file
4	10	1X	,	Separator
5	11-51	20A2	LBLD	Label for RMD-file

Comments

FLOW CHART FOR MODULE ACREAGE



LEAD CARD SET UP FOR MODULE ACREAGE

CARD NO. 1

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-40	20A2	ICOM	Comments to be placed at the top of
				each page.

Comments

LEAD CARD SET UP FOR MODULE ACREAGE

CARD NO. 2

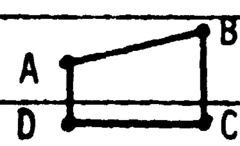
FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-6	3A2	ICB(I)	File name of Data Base on disc
			I=8,10	(6 characters)
2	7	1X	,	Separator (,)
3	8-9	I2	IDISC	LUN for Data Base disc file

Comments

CARD NO. 3

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-10	F10.0	X(I)	X - coordinate of first point (Easting)
2	11-20	F10.0	Y(I)	Y - coordinate of first point (Northing)
				*Repeat cards until last point of
				polygon has been satisfied. When
				this happens enter the below card
				which signifies end of point list.
				(max. of 100 coordinates)
1	1-10	F10.0	X(I)	Where X(I) = 8888.
				Repeat the above procedure until all
				polygons are finished.

Comments *Note: It is most important that the points be entered by order of occurrence(i.e., either clockwise or counterwise): as:



APPENDIX B

DATBAS RMD-DISC FILE

The DATBAS FILE is the standard disc format utilized by Varian 73 GEOREF Data Base System. The data is stored in fifty (50) meter UTM coordinates. A typical DATBAS FILE contains approximately the area for a $1^{o} \times 1^{o}$ area (2300 scan x 2000 elements) or approximately one-half (1/2) of a 1:250,000 series map.

The Data Base located on the disc contains $23{,}000_{10}$ blocks.

The format of each block, containing 120 words, is as follows:

Word 1	Scanline number		
Word 2	Starting element number		Total of 200 elements
Word 3	Ending element number		
Word 4 - 10	Reserved for later use		
Word 11	n (bits 15–8)	n+1 (bits 8–0)	where n = starting element number
Word 12	n+2	n+3	
•	•		
•	•		
•	•		
Word 110	n+198	n+199	
Word 111 - 120	All equal zero.		

In order to store a complete scan line of 2000 elements/pixels a total of ten (10) 120-word sectors of RMD-disc is required. The data is stored utilizing Varian's V$OPEN and FORTRAN I/O.

APPENDIX C

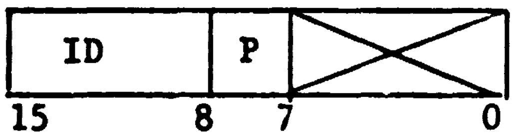
ERL - PSEUDO - COLOR - TAPE

The ERL - PSEUDO - COLOR - TAPE is ERL standard Display Tape for displaying MSS or video type data on the off-line PIDS. This format is also utilized for storing all classified data processed through the various Pattern Recognition Systems. Data stored in this format can be recorded on the Varian 620f strip film recorder. The format is specified in 16-bit words. Each record type has an 11-word preamble at the start of each physical record followed by the applicable video data. This tape contains logical records consisting of only one physical record.

Record #1 - Standard Header Record (Record Length = 411 16-bit words)

(appears only at the start of each tape)

WORD	FORMAT	DESCRIPTION
1	Bin	Record Type Identification (Hi-order 8-bits = 0100_8)



Where ID = 0100 Record ID

P = Bit 7 acts as a special EOFILE for the ERL-PIDS system.

P = 1, automatically continue displaying the scan line on the PIDS

P = 0, EOFILE or stop displaying the scan line on the PIDS (Note: normally P = 0)

WORD	FORMAT	DESCRIPTION
2	I	Record length (=411 16-bit words)

WORD	FORMAT	DESCRIPTION
3	I	Number of physical data records per complete scan line (i.e. the number of data or type #2 records per scan contained on this DASTAP or contained within this EDIT). Should equal 1.
4-11	-	Not used (reserved for future uses)
12-411	400A2	Special 800-character ID - information containing the DAS IOCC-screen image (ASCII 2-characters/word) (Note: The 800-character should be printed on 20 lines of 40-characters each.) See tape format 2, ERL-DASTAP, Header Record #1 for a detailed description.

Record #2 - Video Data Record (maximum record length - 2411 16-bit words which consists of a 11-word preamble and a maximum of 2400 video data words or pixels)

(Note: Each record #2 contains all the video data or pixels for one complete scan line.)

WORD	FORMAT	DESCRIPTION
1	Bin	Record Type Identification

ID	P	X	NO
15	8 7		4 0

Where: ID = 0000_8 Record ID

NO = Hi-order scan line digit 10000s digit in 4-bit code (actually for ERTS data this is the ERTS tape number, 1-4)

P = Bit 7 acts as a special EOFILE for the ERL-PIDS system

P = 1, automatically continue displaying the scan line on the PIDS (Note: normally P = 1)

WORD	FORMAT	DESCRIPTION
		P = 0, EOFILE or stop displaying the scan line on the PIDS
2	Bin	Scan line number-last 4-digits in 4-bit code

(Note: total scan number $\leq$ 99999, the 10000s digit (WORD 1) plus the remaining digits described below)

1000s	100s	10s	1s
15	12	8	4 0

WORD	FORMAT	DESCRIPTION
3	I	Data length or number of samples (8-bit bytes) contained in this particular physical record. (maximum number is 4800 bytes, which corresponds to 2400 pixels)
4-6	3A2	Training field name or Ground Truth Code - Maximum of 6 ASC-II characters. (Should be ASC-II blanks if not utilized)
7-9	Bin	Scan line IRIG-A time in 4-bit code as indicated below (should be zeroes if not utilized).

where D = day
H = hour
M = minute
S = second

D	D	D	H
15	12	8	4 0

H	M	M	S
15	12	8	4 0

S	.1S	.01S	.001S
15	12	8	4 0

WORD	FORMAT	DESCRIPTION
10	I	Start element number for entire scan line
11	I	End element number for entire scan line
		(Note: Both the Start and End Element numbers refer to the total scan line and not just to this physical record, unless a scan line of data consists of only one physical record)

The video data is described below:

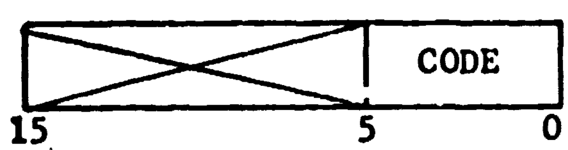
12	Bin	Pixel 1 data
13	Bin	Pixel 2 data
14	Bin	Pixel 3 data
•	•	•
•	•	•
•	•	•
M	Bin	Pixel N data

Where N $\leq$2400 pixels (determined by taking the inclusive difference between word 11 and 10 or by dividing word 3 by 2.)

M = N + 11 - word preamble

M $\leq$2411 16-bit words

Data Word Format: Pseudo Color Mode

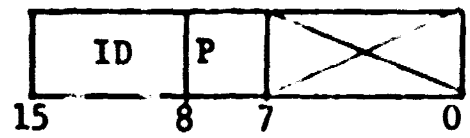


Where, CODE contains the 6-bit pseudo color number (0-63).

Record #3 - END-OF-EDIT (Record length = 411 16-bit words)

(appears at one end of each edit or tape)

WORD	FORMAT	DESCRIPTION
1	BIN	Record Type Identification (Hi-order 8-bits = 0377_8)



where, ID = 0377_8 Record ID

P = Bit 7 acts as a special EOFILE for the ERL-PIDS System

P = 1, automatically continue displaying the scan line on the PIDS

P = 0, EOFILE or stop displaying the scan line on the PIDS.

(note: normally P = 0)

WORD	FORMAT	DESCRIPTION
2	I	Record length (=411 16-bit words)
3	I	Number of physical data records per complete scan line (i.e. the number of data or type #2 records per scan contained on this DASTAP or contained within this EDIT).
4-11	-	Not used (reserved for future uses)
12-411	400A2	Special 800-character ID-information containing the DAS IOCC-screen image (ASC-II 2-characters/word). (Note: The 800-characters should be printed on 20 lines of 40-characters each) See Header-record #1 for description

Record #4 - Tape Mark (END-OF-FILE)

Appears after each END-OF-EDIT Record

(Note: 2 consecutive E-O-FILES indicates End-OF-TAPE.)