Final Report

CONVERSION OF THE BRAZILIAN LANDSAT CCT FORMAT TO NASA AND LARSYS CCT FORMAT

Submitted to

The Bolivian ERTS Program
La Paz, Bolivia
and
The U.S. Agency for International Development
Washington, D.C.

Prepared by

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INTRODUCTION

Since the beginning of 1976 all the Landsat data collected over the Bolivan territory has been received by the Brazilian ground station facility located in Cuiabá, Brazil. Therefore, future projects involving computer-aided (LARSYS) processing and analysis of Landsat MSS data collected over Bolivia will require the use of computer compatible tapes (CCT) generated by the Brazilian ground receiving station.

The Brazilian Landsat CCT's (IMPERTS) have a different format from that of the NASA CCT's. Because the Landsat data reformatting processor available at LARS is only capable of converting from the NASA CCT format to the LARSYS CCT format, in order to be able to process and analyze the Brazilian produced CCT's using the LARSYS software package (currently being implemented in a Bolivian computer facility) it was necessary to develop a pre-processing capability that could either convert the Brazilian CCT format directly into a LARSYS format, or convert from the Brazilian format into the NASA standard format. Preliminary talks between investigators from LARS and personnel from the Bolivian ERTS Program indicated that the option of converting the Brazilian CCT's into the NASA Standard Landsat CCT format was the most desirable.

This report contains the documentation of the Landsat reformatting software developed at LARS under the sponsorship of the Bolivian ERTS Program and the U.S. Agency for International Development. This reformatting software allows the format conversion of the Brazilian Landsat CCT's into the NASA Landsat CCT format and the LARSYS compatible format.

OBJECTIVE

The objective of this work included the following tasks: (1) to develop a preprocessing capability to reformat Brazilian Landsat computer compatible tapes into NASA Landsat computer compatible tape format, and (2) to write a description of the already available NASA to LARSYS reformatting software. The intent of the first portion of the objective was to produce tapes of data in as close to the NASA Landsat format as was practical. All available corresponding data from the Brazilian tape format was directly transferred to the output NASA formatted tape. The end result was the development of a system of programs to generate LARSYS formatted tapes of Landsat data from the Brazilian formatted tapes.

FUNCTIONAL REQUIREMENTS

The functional requirements for the reformatting of the Brazilian Landsat data to LARSYS format are 1) data input, 2) computational hardware to process the data, 3) software with which to define the processing, and 4) data output storage and display. While this project supplies only the bulk of the software, the Bolivian Remote Sensing Program under the direction of Dr. Carlos E. Brockmann provides the other requirements.

1. Data Input

The Brazilian receiving station will receive much of the Landsat data of interest to the Bolivian Remote Sensing Program. Additional data may be acquired if available from the Earth Resources Data Center at Sioux Falls, South Dakota. The primary source of

South American Landsat data coverage is expected to be the Brazilian receiving station. Landsat computer compatible tapes are available in the special Brazilian Inperts format which is similar in content to the NASA CCT's but are not in the exact NASA format.

2. Hardware

The hardware functional requirement typically suggests a digital computer system of at least moderate proportions. As an example, consider a minicomputer with thirty-two thousand bytes of main memory, two 'two and one-half' megabyte disks and a single tape drive. This minicomputer configuration could not perform a Landsat data reformatting job. Normal requirements for large data handling jobs such as Landsat reformatting would include memory size of approximately one hundred fifty thousand bytes of user program space, forty megabytes of available disk space, and a minimum of three nine-track, eight-hundred bits-per-inch (bpi) tape drives. Generally, this requirement would describe the class range of a midi to a large main frame computer. These classes of computers are indeed preferred because of their higher expected reliability as well as higher expected throughput capability. The Digital Equipment Model 10 which is utilized by the Bolivian remote sensing program is a unit that adequately meets these requirements. The DEC-10 is considered a representative from the large main frame class of digital computers.

3. Software

Software is used to define to the hardware the actual processing to be accomplished. The programs furnished under this project will constitute the instructions to the hardware to perform specific mathematical manipulations on the input data and to produce the desired output. Brazilian Inperts format tapes are to be converted to NASA format and subsequently from NASA format to LARSYS format. Maximum portion of a single logical Landsat data frame which may be stored on single reel of 2400 foot, 800 bpi, nine-track computer compatible tape is approximately seventy (70) percent. Tape operations software is required and is already implemented through previous efforts.

4. Data Output

Data will be outputted from such a system of programs. This brings up two requirements which are components of data output, storage and display. Although there are numerous forms of output storage, most forms as lineprinter, card, disk file and terminal are not reasonable ways to store vast quantities of data. Computer compatible tapes are a compact cost-effective way to store the tens of megabytes of data from Landsat.

While tapes store the data well, they do not display it well. Display is needed for checking the reformatted data for catastrophic errors as well as for subsequent data analysis. The header information may need checking as well. This may be accomplished by inspecting the reformatting programs printer outputs or later through utilizing the LARSYS IDPRINT function processor. The data itself may be displayed utilizing the LARSYS PICTUREPRINT function processor. This has already been implemented on the Bolivian DEC-10 computer. The result of PICTUREPRINT will be a computer paper-based character-simulated gray-level plot of the processed Landsat data.

SOFTWARE DESCRIPTION

1. General

The system of programs required to produce LARSYS formatted Landsat data from Brazilian Inperts formatted Landsat data input consists of two major components. These components are the Brazil to NASA reformatting programs known as INPERTS, and the NASA to LARSYS reformatting programs known as REFERTS. Documentation of these programs may be found in appendices D and E respectively. Documentation of the three tape formats, i.e. Brazilian Inperts format, NASA CCT format, and LARSYS format may be found in appendices A, B, and C respectively. Other documentation and listings will be noted and included as appropriate.

2. INPERTS Program Brief

This system of programs is designed to produce a NASA formatted Landsat frame from input tapes containing Brazilian Inperts formatted Landsat data. The Inperts formatted input data can be expected to locate eight physical files on two physical tapes. These files represent the eight strips of data of a single logical Landsat data frame. The files may be sequential on each tape as strips one through four on tape A and strips five through eight on tape B. In constrast, the even numbered strips may be located on tape A and the odd strips may be located on tape B. The program will recognize if the control card specifications match the tape contents for the strip location and proceed or issue an error message as appropriate. Bad data for strips will be noted in the latter manner. If a complete NASA strip or file of data cannot be constructed because of lost or bad input data, the particular strip of data will have to be eliminated from the reformatting.

The output from these programs is two tapes each containing four files corresponding to four strips of coverage of a complete logical Landsat data frame. The NASA CCT fifth file, known as the annotation file, is not being produced by INPERTS for lack of use during subsequent REFERTS processing as well as lack of available information from the Brazilian tapes. Eight hundred BPI, nine-track, 2400 foot tapes are assumed throughout the reformatting processing. The two files on each data tape will utilize a total of 80% of each tape. At most one scratch tape is utilized during INPERTS processing. The sub-routine TAPOP will handle all tape operations, and it has been previously implemented on the Bolivian DEC-10 computing system. Please refer to Appendices A and B for format documentation and appendix D for program documentation.

3. REFERTS Program Brief

This system of programs is designed to convert NASA formatted data from the Landsat satellite multispectral scanner into LARSYS version 3.1 image data format. The input data* is formatted into four logical groups which are equivalent to four physical groups of data on tape, each of which represent Landsat scanner coverage of a 25 X 100 nautical mile strip of earth's surface. Thus, together the four strips form a single logical Landsat data frame covering a 100 X 100 nautical mile area. All channels of data are recorded from each of the four channels and kept logically together for each strip. Although the LARSYS analysis package is capable of

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*Note: This description of the input data is equivalent to the data outputted by the INPERTS reformatting programs system.

handling a full Landsat data frame at once, the 800 bpi, nine-track tape density will constrain the proportion of a frame to be reformatted at one time to approximately 70 percent in the width, with full length. The constraint of 70% of a data frame still applies even after addition of a fifth tape drive at the Bolivian computing site. However, a change to 1600 bpi density, nine-track tape and the fifth tape drive will allow a full Landsat data frame to be stored on a single file of a LARSYS formatted image data tape.

Special features are built into the REFERTS programs which allow several alternative NASA tape formats with minor differences to be reformatted without special effort. In particular the program readily handles Landsat I or Landsat II data. Data may be inputted from one tape with four files at 1600 bpi, two tapes with two files each at 1600 or 800 bpi, or four tapes with one file each at 1600 or 800 bpi. Should data be acquired from non-Brazilian sources, or a change in available tape drives occur, the first and third situations might become appropriate. Scratch tapes will be necessary for both programs of the total reformatting system.

SAMPLE REFORMATTING SESSION

Input INPERTS tapes should be mounted initially to assure data is indeed present. This will also inform the programmer/reformatter of the format and file location/sequence of the eight strips on the two Brazilian input data tapes. Based on the tape dump investigation the following typical set of control cards might be constructed based on Appendix D.

```
-COMMENT EXAMPLE CONTROL CARD DECK
*INPERTS
REFORMAT FULLFRAME
INPUT TAPES(1357,2468)
OUTPUT TAPES(3668,3669)
END
```

A scratch tape may need to be available during the first phase of a normal session depending on the order of the INPERTS data files. Our example does not require them.

Following to the generation of the NASA CCT's, two control decks will need to be prepared. These jobs will reformat the left and right halves of a single logical Landsat frame to LARSYS format. The control card decks might look as follows: Refer to Appendices B and C on formats and Appendix E for control card documentation.

JOB A "LEFT"

```
$REFORMAT  INPUT(3685,3686),SCRATCH(4561,4562),ZONE(-3),TYPE(2)
76020501 3687   1528513321  BOLIV
BLOCK AREA(0,50,1,0,100,1)
END
```

JOB B "RIGHT"

```
$REFORMAT INPUT(3685,3686),SCRATCH(4563,4564),ZONE(-3),TYPE(2)
76020502 3687   2528513321 BOLIV
BLOCK AREA(50,100,1,0,100,1)
END
```

It is recommened that a LARSYS-like run number be assigned with the last two digits 01 and 02 indicating LEFT and RIGHT portions of the Landsat scene or frame. The last two digits 00 is the suggested identification for a single complete logical frame of Landsat data. Actual program loading and execution is system dependent and will need to be handled by resident installation programs.

Further check out of the output data from the jobs can be done by tape dump, LARSYS PICTUREPRINT, and LARSYS IDPRINT processors. While many procedural options exist, this represents a typical sequence of reformatting of the INPERTS formatted data to LARSYS format.

APPENDIX A

BRAZILIAN INPERTS CCT FORMAT

Em: 18/03/76 INPERTS 05/76 fl. 1

REV. A

De: Jose Luiz de Barros Aguirre - INPE IDPS Operation Manager

Para: Distribution

Assunto: INPERTS CCT Format - Update

SUBSTITUIDA FOR INPERTS 1 REV. ___ em ___/___/___

[ ] Substitui [X] Complementa INPERTS 37/75

[ ] Relatorio & Controle [ ] Manuteneão & Reparo [X] Operacão & Calibracão [ ] Sistema: Descricão & Alteracões

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One INPERTS CCT file consists of one ID record 40.bytes long, one Annotation record 340.bytes long, a number of video records with multispectral information, and one End-Of-File.

The video records can vary in number and in size from one CCT to another, depending on the length and width of the strip chosen to be recorded.

There are two different kinds of CCT: "Production" and "Non-standard". They are identical in format, but there are some differences in the meaning of some information in the ID and Annotation records between the two types. These differences are stated below in the text.

Refer to Table I (INPERTS CCT ID Record). Comments are:

(1) Type: P for Production
N for Non-Standard

Strip: 1 to 8 for Production (once that in Production each strip has a fixed starting element and a fixed width of 432 pixels, and 8 strips cover the whole MSS frame width).
- (dash) for Non-standard (once that in this case there is no commitment to pre-defined strips).

ERTS: Landsat number: 0 for test data
1 for Landsat 1
2 for Landsat 2

(2) Field 3 equals 4 times the CCT video width in pixels (due to the 4 interleaved bands) plus the 56 bytes of Calibration data that are appended to each video record.

(3) The Year is represented without the hundreds (e.g. 73, 74, 75, etc.). The former CCTs would show only the units (3, 4, 5, etc.).

(4) These fields have been recently implemented, being zeros formerly.

(5) MSSCCW: Bit 10: 1 = compressed data
11: 1 = Hi gain band 4
12: 1 = Hi gain band 5
13: 1 = Decompression (= bit 10. AND. bit 14)
14: 1 = Calibrated video
15: 1 = ICT used in the CCT generation.

Refer to Table II-A (Annotation Record - first part). Comments are:

(6) The time swath of the "Production" CCTs is determined by number of adjacent MSS frames, from 1 up to 4. These fields show the PCTs of the first and last frames present in the CCT. If the CCT is made over a single MSS frame, the first and last PCTs will be the same. One frame is 29 seconds long, each additional frame meaning plus only 25 seconds due to the overlap related to the RBV-like frame format criteria. The "Non-standard" CCTs can have any number of seconds of video, as long as it fits within the length of the tape. One 2400' reel can accomodate about 106 seconds of continuous video 432 pixels wide.

(7) The 3 least significant bits are used in this word, each corresponding to one of the cameras: bits 2, 1, 0 correspond respectively to cameras 1, 2, and 3.

Tables II-B and II-C cover the remaining of the Annotation Record of the CCT. It is a straight copy of the ICT record corresponding to the CCT midtime (field 4 of the CCT ID record).
A single comment is that when without an ICT the Sun elevation Angle (no. 21 of Table II-B) is set to a default value of 60. degrees. This was recently implemented for compatibility with some internal IDPS default standards.

The format of the video records is illustrated in Figure 3. Each record contains video belonging to one sensor. The CCT begins with sensor A and proceeds through B, C, D, E, and F and over again. Each set of six records corresponds to a sweep of the MSS. One complete MSS frame is 392 sweeps (29 seconds) long, which makes 2352 CCT video records. In terms of ground coverage, this represents about 185 kilometers (100 NM) in a strip about 25 kilometers (13.5 NM) wide, if the number of pixels is 432. The INPERTS CCTs can range from 128 up to 512 pixels per record in the Non-standard format.

General points are that our normal product is a "Production" CCT covering one complete frame, formed by 8 strips distributed in two reels of 2400' mag tape. Normally, odd strips go in one reel and even strips in the other. If we use a single tape drive during generation, the strips go sequentially 1, 2, 3, 4 in the first reel and 5, 6, 7, 8 in the second. In any case we add an extra End-Of-File after the last file in the tape, so that there will be two consecutive End-Of-Files at the end of the last strip.

We use to center the lenth of the strip over the area of interest of the user, once that the INPE IDPS is not commited to the standard RBV format centers in its products.

José Luiz De Barros Aguirre
IDPS Operation Manager

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TABLE 1 INPERTS CCT ID record

FIELD	LENGTH	TYPE	FORMAT	CONTENTS	MEANING (COMMENTS)
1	10 bytes	ASCII	EOOOOOSRRT	CCT ID	Erts-Orbit-Run-Strip-Type (1)
2	6 bytes	ASCII	bbbNbM	Sequencing number	CCT N of M
3	1 word	binary		Video Records length in bytes	(2)
4	5 words	binary	Y, D, H, M, S	CCT file center time	Year, Day, Hours, Mins, Secs (3)
5	1 word	binary		Video Width in pixels	
6	1 word	binary		Overlap in pixels	Overlap between adjacent strips
7	1 word	binary		CCT generation date	1000.x(Year - 70.) + Day (4)
8	1 word	binary		CCT generation time	Minutes since midnight (4)
9	1 word	binary		MSS Data Correction Code Word	(5)
10	1 word	binary		Starting pixel of the recorded strip	

TABLE II-A ANNOTATION RECORD - FIRST PART

FIELD	LENGTH	TYPE	FORMAT	CONTENTS	MEANING (COMMENTS)	
1	4 words	binary	D, H, M, S	First PCT if Production Start T/C if Non-Standard	(6)	
2	4 words	binary	D, H, M, S	Last PCT if Production End T/C if Non-Standard	(6)	
:::::::::::::::::::::::::::From here on the Annot. record will be all zeros if an ICT is not used:::::::::::						
3	10 bytes	ASCII	E-00000-Sb	ICT ID	Erts-Orbit-Smoothing Order	
4	4 words	binary	D, H, M, S	ICT Start Time		
5	4 words	binary	D, H, M, S	ICT End Time		
6	8 bytes	ASCII	DD-MMMYY	Exposure Date		
7	2 words			Spare		
8	1 word	binary		Type of Ephemeris Tape	1 = PFET	Ø = BFET
9	1 word	binary		Type of Video Data	1 = linear	Ø = Compressed
10	8 bytes	ASCII	INPERTSb			
11	1 word	binary		MSS Band 4 Gain Status	1 = High	Ø = Low
12	1 word	binary		MSS Band 5 Gain Status	1 = High	Ø = Low
13	1 word	binary		MSS Status	1 = On	Ø = Off
14	1 word	binary		Aperture Correction	1 = In	Ø = Out
15	1 word	binary		AMS Status	1 = On	Ø = Off
16	1 word	binary		Midscan Code Status	1 = Enabled	Ø = Disabled
17	1 word	binary		Calibration Status	1 = Enabled	Ø = Disabled
18	1 word	binary		RBV Cameras Status	1 = Enabled	Ø = Disabled (7)

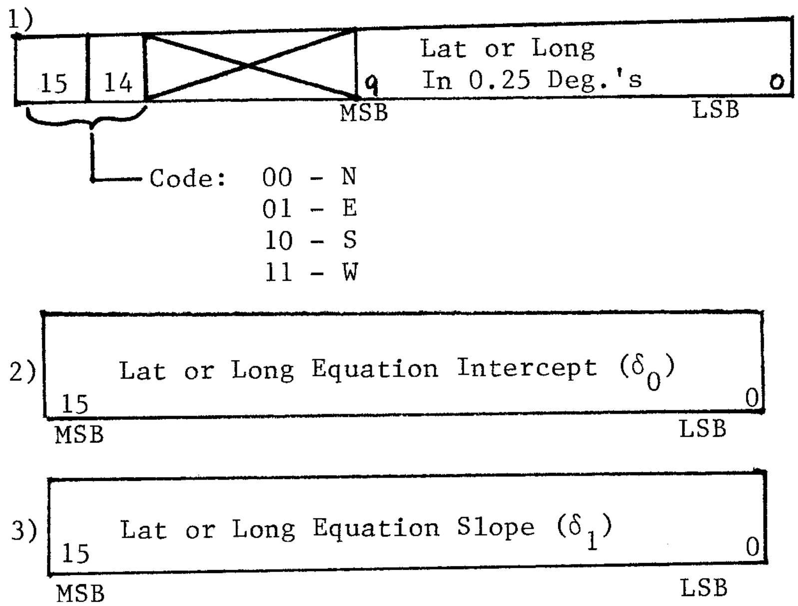
DATA WORD # (Add 41 to get right number)	PARAMETER	FORMAT	RANGE	RESOLUTION
1	S/C Time - Days	Integer	0 - 365 days	1 Day
2	S/C Time - Hrs.	Integer	0 - 23 hrs.	1 Hr.
3	S/C Time - Mins.	Integer	0 - 59 min.	1 Min.
4	S/C Time - Sec.	Integer	0 - 59 sec.	1 Sec.
5	S/C Roll (radians)	Integer	$\pm$ 0.25 radians	2^{-17} rad. LSB
6	S/C Pitch (radians)	Integer	$\pm$ 0.25 radians	2^{-17} rad. LSB
7	S/C Yaw (radians)	Integer	$\pm$ 0.25 radians	2^{-17} rad. LSB
8	Altitude (meters) (Alt.-920,000)	Integer	$10(2^{16}-1)$M	10M. LSB
9	Altitude ([ABS-NOM]/NOM)	Integer	$\pm$ 0.25	2^{-17} LSB
10	Velocity ([ABS-NOM]/NOM)	Integer	$\pm$ 0.25	2^{-17} LSB
11	Bad Data Flags (1 bit flag for data words 5 - 20)		*	
12	S/C Heading (Min.)	Integer	0 - 180 Degs	1 Min. LSB
13	RBV Exposure Duration (Sec x 10^{-3})	Integer	0 - 16 x 10^{-3} Sec.	1 x 10^{-3} Sec.
14	Image Skew Due to Earth Rotation (MM)	Integer	$\pm$19.88 MM	0.0006 MM LSB
15	Spare			
16	Spare			
17	Format Center Latitude (Min)	Integer	$\pm$5400 Min.	1 Min. LSB
18	Format Center Long. (Min.)	Integer	$\pm$10800 Min.	1 Min. LSB
19	NADIR Center Latitude (Min.)	Integer	$\pm$5400 Min.	1 Min. LSB
20	NADIR Center Long. (Min.)	Integer	$\pm$10800 Min.	1 Min. LSB
21	Sun Angle Elev. (Deg.'s)	Integer	0 - 90 Deg.	1 Deg. LSB
22	Sun Angle AZ (Deg.'s)	Integer	0 - 360 Deg.	1 Deg. LSB
23	Camera Shutter ON/OFF #1,#2,#3	Integer	------------	$2^2, 2^1, 2^0$ Unitar bit
24	IR Assembly Temperature (°C)	Integer	$\pm$50°C	0.10 °C LSB
25	1 bit flag each Bad Data Flag TIC mark set	Integer		
26-43	Spares			
44-64	7 TIC Mark Def. Top of Picture		See Next Page	
65-85	7 TIC Mark Def. Left side of picture		" " "	
86-106	7 TIC Mark Def. Right side of picture		" " "	
107-127	7 TIC Mark Def. bottom of picture		" " "	
128-129	Reserved for DEC Software use		" " "	

TABLE II-B
ANNOTATION RECORD
SECOND PART

TABLE II-C

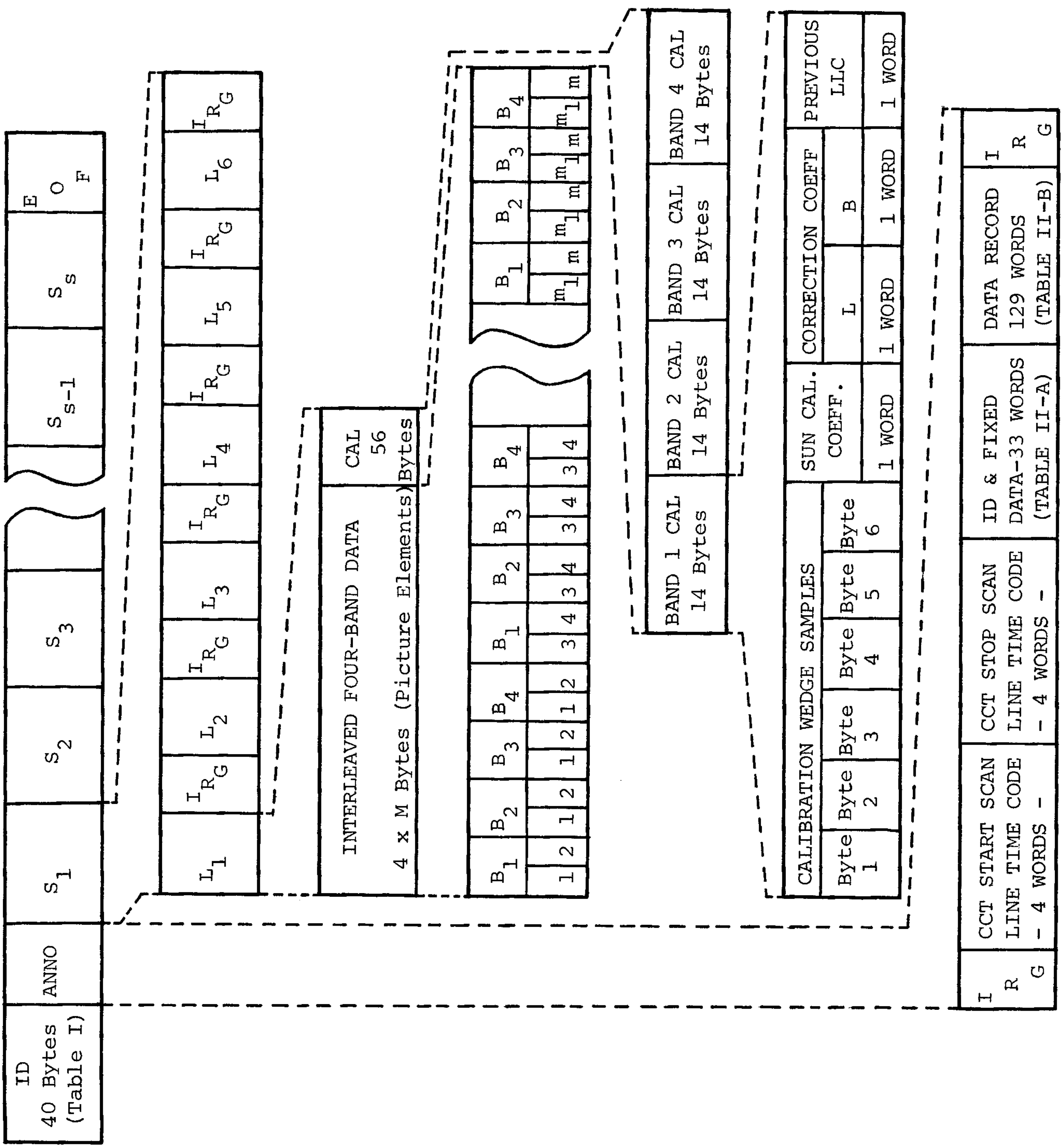
TIC MARK FORMAT DEFINITION

Three words define a TIC mark as follows:



4) TIC Mark Definition on ICT
   a) Top border: TM - 1 Closest to (0, 0) - Lat/Long, δ_0,δ_1·TM-2,···TM7.
   b) Left Side: TM - 1 Closest to (0, 0) - Lat/Long, δ_0,δ_1·TM-2,···TM7.
   c) Right side: TM - 1 Closest to (0, 0) - Lat/Long, δ_0,δ_1·TM-2,···TM7.
   d) Bottom border: TM - 1 Closest to (0, 0) - Lat/Long, δ_0,δ_1·TM-2,···TM7.

NOTE: CRCC & LRCC INCLUDED PRIOR TO EACH IRG



COMPUTER TAPE FORMAT

APPENDIX B

EXCERPT SECTION 4

APPENDIX D

NASA LANDSAT DATA

USERS GUIDE SETPTEMBER 2, 1976

SECTION 4
OUTPUT DATA PRODUCTS

4.1 INTRODUCTION

Landsat data products produced by the NASA Image Processing Facility (IPF) at GSFC are discussed in this section. Product availability to users through the IPF, the EROS Data Center, the U.S. Department of Agriculture Western Aerial Photo Laboratory and the NOAA Environmental Data Service is discussed in detail in Section 5.

Figure 4-1 summarizes the original output data products produced by the IPF. Within this section, they are grouped into three areas for discussion: photographic products, computer compatible tapes (CCTs) and Data Collection System products.

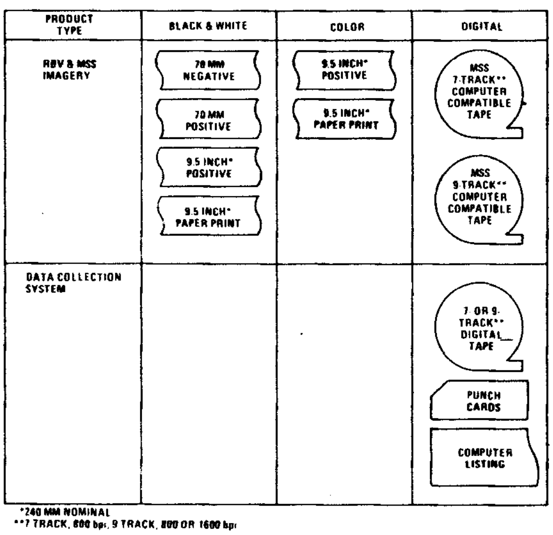


Figure 4-1. Landsat Original Output Products

4.2 PHOTOGRAPHIC PRODUCTS

The following information will be useful to users when considering Landsat photographic products:

1. All imagery contains radiometric and certain spatial corrections introduced during the process of videotape-to-film conversion. The term "system-corrected imagery," which refers to these corrections, applies to all imagery.

2. Generation number assigned to photographic products is referenced to the initial, original archival output from the electron beam recorder, which is designated as the first generation. Each successive photographic product generated adds one generation. Thus, an enlargement from a 70mm archival image is a second generation product.

3. Relationships between sensors, wavelengths, and IPF band codes are shown in Table 4-1.

Table 4-1. Sensor Band Relationships

Sensor	Wavelength (μm)	IPF Band Code
Landsat 1 and 2		
RBV	0.475 - 0.575	1
	0.580 - 0.680	2
	0.690 - 0.830	3
MSS	0.5 - 0.6	4
	0.6 - 0.7	5
	0.7 - 0.8	6
	0.8 - 1.1	7
Landsat C		
RBV	0.505 - 0.750	*
MSS	0.5 - 0.6	4
	0.6 - 0.7	5
	0.7 - 0.8	6
	0.8 - 1.1	7
	10.4 - 12.6	8

*An IPF band code will not be designated for the Landsat-C RBV. Instead, the letters A, B, C and D will be assigned to the four Landsat-C RBV images that approximately overlap one MSS image. (Refer to Figure B-11.)

4. Photographic products are available in two basic film sizes - 70mm and 9.5 inch (240mm nominal) - although facilities other than IPF have derived more sizes

from the 70mm film imagery. IPF processing uses the spacecraft altitude at "image center time" to scale each Landsat 1 and 2 and Landsat-C MSS 70mm image to 1:3,369,000. When the image on 70mm film is enlarged by a factor of 3.369 and printed on 9.5 inch film, the scale is 1:1,000,000. Scaling for corresponding Landsat-C RBV imagery is twice that of Landsat 1 and 2 and Landsat-C MSS imagery.

4.2.1 Image Production

The production flow through the IPF for each of the photographic products shown in Figure 4-1 is illustrated in Figures 4-2 through 4-4.

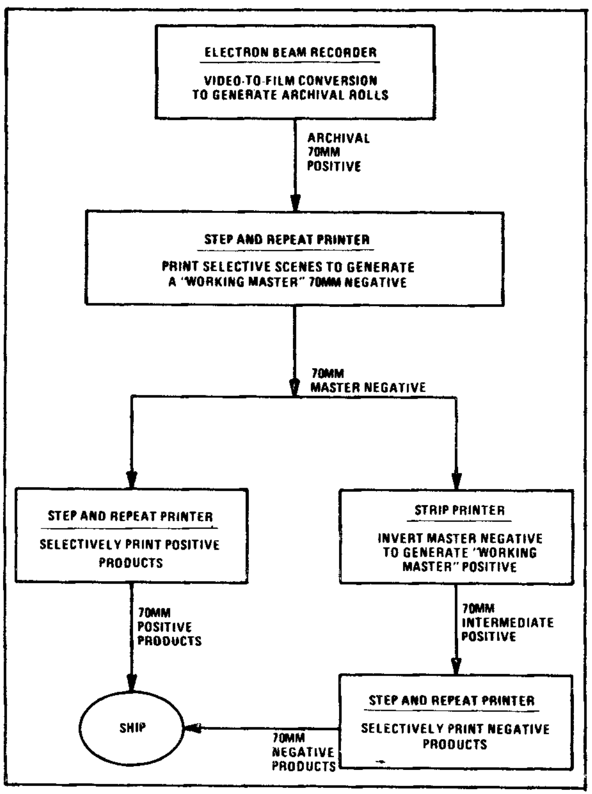


Figure 4-2. Production Flow of a 70mm Positive and Negative Product (Black and White Only)

4.2.2 Image Format and Annotation

A sample of the Landsat 1 and 2 RBV and MSS image format, including registration marks, tick marks, gray scale and alphanumeric

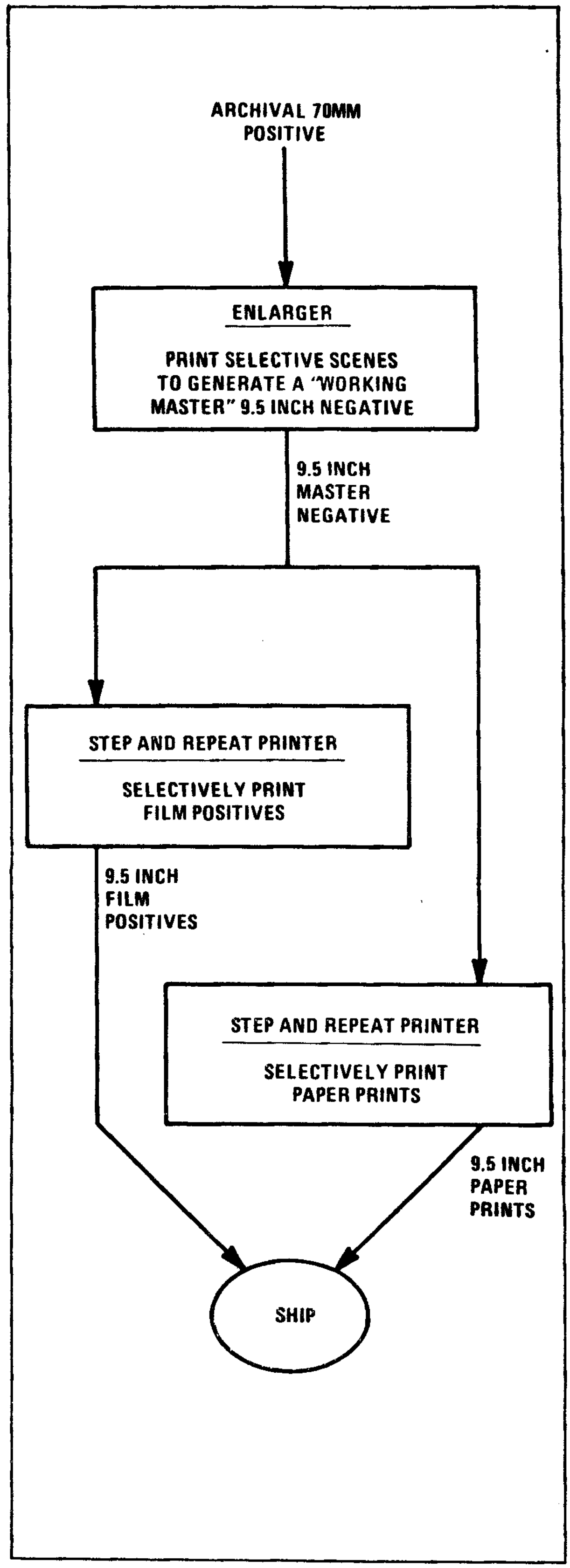


Figure 4-3. Production Flow of a 9.5-inch Black and White Film or Paper Product

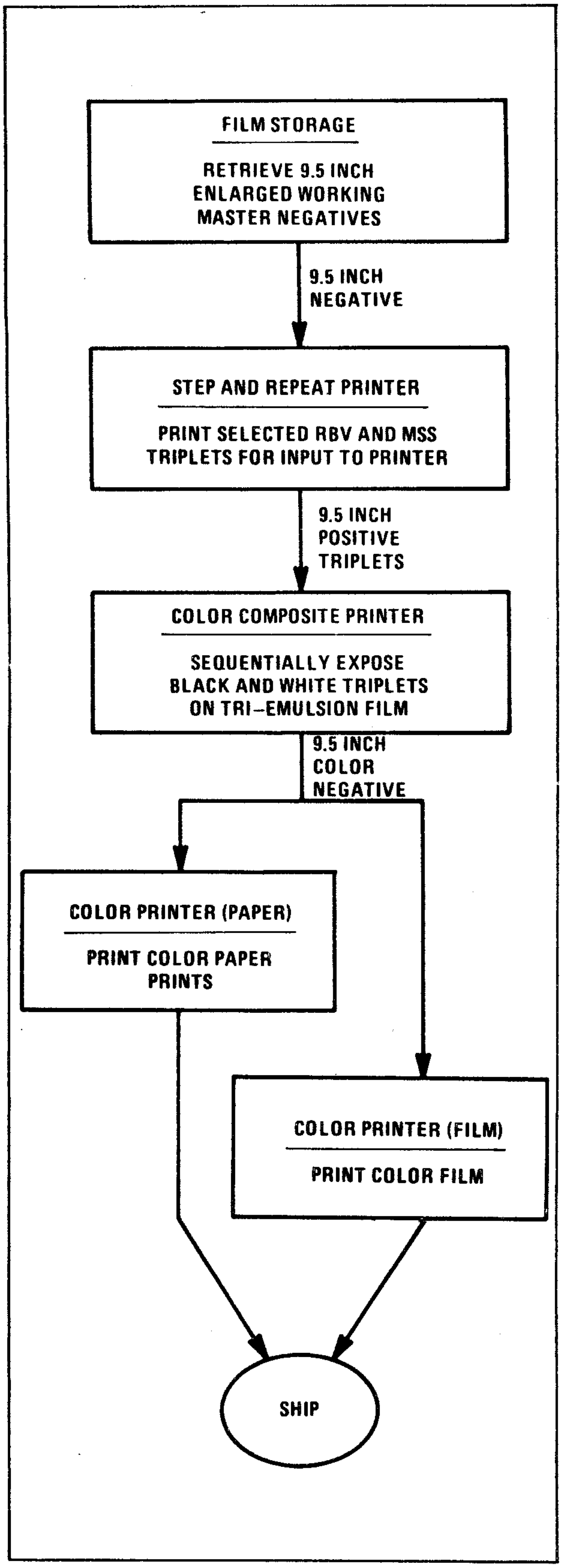


Figure 4-4. Production Flow for Color Film and Prints

annotation, is shown in Figure 4-5. The RBV image format is identical, except that it contains fiducial references (reseau and anchor marks). The spacecraft heading is always toward the annotation. The annotation for Landsat-C RBV is depicted in Figure 4-9, which shows in detail the annotation block for all film imagery.

The dimensions for the 70mm and 9.5 inch RBV and MSS film products are given in Figure 4-6.

4.2.2.1 Registration Marks

Four registration marks are placed beyond the image corners to facilitate alignment of different spectral images of the same scene from the same payload sensor. The image is positioned within the writing area so that when the registration marks from two or more spectral images are superimposed, the imagery will be registered. The dimensional details of these registration marks are shown in Figure 4-7.

The intersection of diagonals drawn through the four registration marks is the format center of the image. The format center of a scene imaged at the same time by both the RBV and MSS will be identical. Annotation not otherwise specified refers to properties at the format center.

4.2.2.2 Tick Marks

Latitude and longitude tick marks are placed outside the edge of the image writing area at intervals of 30 arc minutes. The geographic reference marks are annotated in degrees-minutes with the appropriate direction indicator. At latitudes above 60 degrees north or south, tick marks are spaced at one-degree intervals to prevent crowding.

4.2.2.3 Gray Scale

A 15-step gray scale tablet is exposed on every frame of imagery as it is produced on the electron beam recorder (EBR). This scale is subject to the same copying and processing

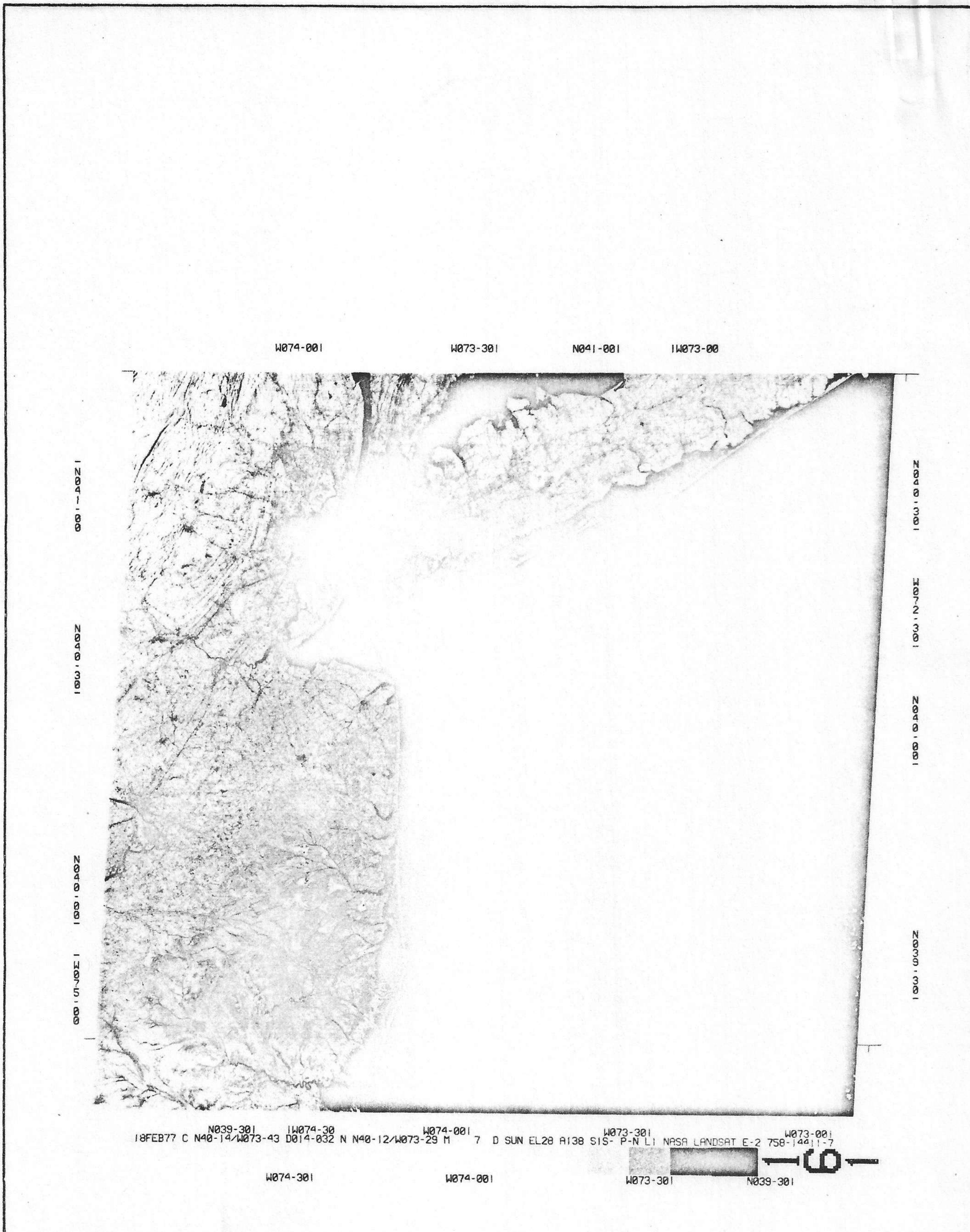
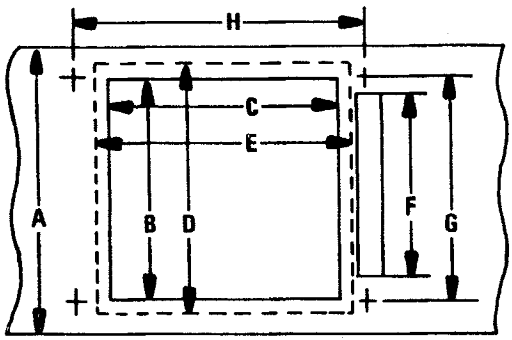


Figure 4-5. MSS Image Format – 9.5-inch Film (Not to Scale)

(5)



Dimension Code	Description	70 mm RBV	70 mm MSS	Enlarged (1) 9.5 inch RBV	Enlarged (1) 9.5 inch MSS
A	Film Width	70	70	240	240
B	Nominal Image Size (cross track)	55 (2) 58.3	55 (2)	185.3 (4) 196.4	185.3
C	Nominal Image Size (in track)	55 (2) 58.3	53 (3)	185.3 (4) 196.4	178.5
D	Writing Area (cross track)	60	60	202.2	202.2
E	Writing Area (in track)	60	55.5	202.2	190.4
F	Annotation Block Length	51.6	51.6	173.7	173.7
G	Registration Mark Separation (cross track)	58.6	58.6	197.5	197.5
H	Registration Mark Separation (in track)	64	59.5	215.7	200.5

NOTES:

(1) Processing uses spacecraft altitude at "image center time" to scale each 70 mm image to a ratio of 1:3369,000, except for Landsat-C RBV imagery which is scaled to a ratio of 1:1,684,500. The enlarging factor is 3.369 which provides a scale of 1:1,000,000 in all enlarged images indicated, except for Landsat-C RBV wherein the scale becomes 1:500,000

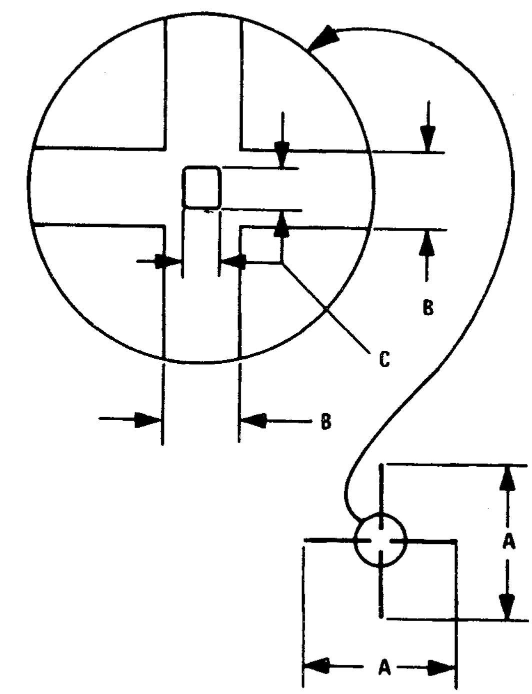
(2) 55 equivalent to 185.2 km (100 nm), except for Landsat-C RBV } at 918.6 km
58.3 equivalent to 98.2 km (53 nm) for Landsat-C RBV } (496 n.m) altitude

(3) 53 equivalent to 178.3 km (96.3 nm)

(4) 185.3 applicable, except for Landsat-C RBV
196.4 applicable for Landsat-C RBV

(5) All dimensiogs given in millimeters (mm)

Figure 4-6. Product Dimensions



Dimension	70 mm RBV	70 mm MSS	9.5 in. RBV	9.5 in. MSS
A	2.0	2.0	6.74	6.74
B	0.0532	0.0468	0.1793	0.1578
C	0.0266	0.0234	0.0896	0.0788

NOTE: Dimensions are in millimeters

Figure 4-7. Registration Mark Details

as the image to which it is attached. The gray scale gives the relationship between a level of gray on the image and the electron beam density used to expose the original image. The electron beam density is related to the sensor signal voltage which, in turn, is related to the energy incident on the sensor.

The annotation gray scale for MSS imagery corresponds to zero radiance at step 15 (black on positives) and maximum radiance as given by Figure C-5 at step 1 (white on positives). The radiance varies linearly with gray step transmission between these values with the difference between each step corresponding to 1/14th of the maximum radiance.

The transmission of the steps in the RBV annotation gray scale varies linearly with the camera voltage, between 320 and 1100 millivolts. The voltage difference between each step is 1/14th of [1100 - 320] or 55.7 millivolts. The radiance in front of the lens for a 12-millisecond exposure is obtained from Table B-3 for the voltage corresponding to the gray scale step. The radiance for the actual exposure time is found by multiplying values given for 12 ms, by 12/t, where t is the exposure derived from the image annotation, as explained in Figure 4-9, item e, considered together with Note 3 in Table 4-5.

The gray scale tablet is a macroscale tablet and cannot be used reliably for microscale image radiometry, because the areas, on the order of a few picture elements, are subject to influence by neighboring areas (modulation transfer function effects, chemical development adjacency effects) and do not supply enough data points to average noise down to a low figure.

The dimensions of the gray scale and alphanumeric annotation blocks are shown in Figure 4-8.

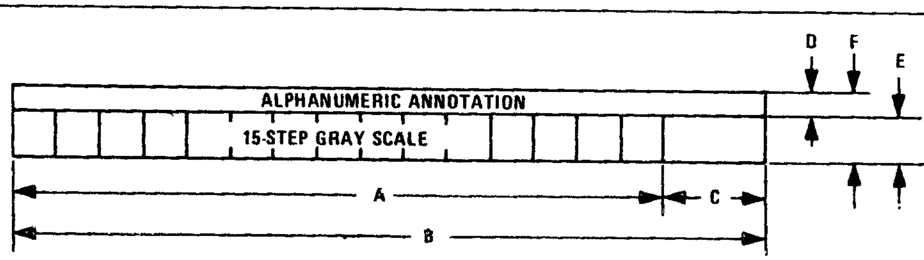
4.2.2.4 Alphanumeric Annotation

Figure 4-9 details the type of alphanumeric annotation shown at the bottom of Figure 4-5. Items a. through i. explain the data contained in this annotation.

4.2.3 Delivered Form

4.2.3.1 Landsat 1 and 2

Most photographic products are delivered in cut form. In special cases, film products are delivered in roll form. Prints are always delivered in cut form.

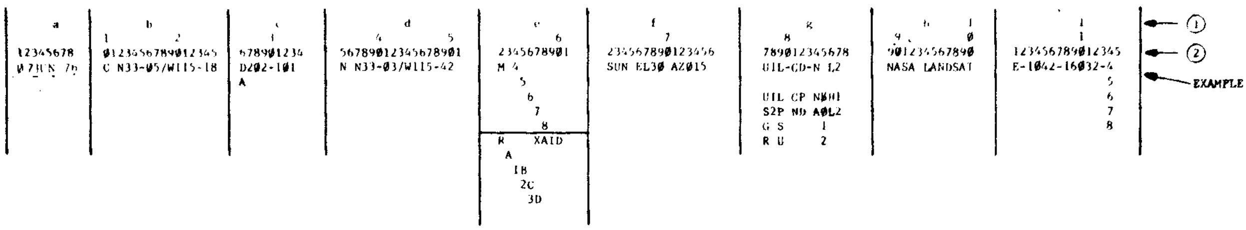


Dimension Code	70 mm	9.5 in.
A	45.0	151.6
B	51.6	173.7
C	6.6	22.1
D	0.8	2.7
E	2.0	6.7
F	2.8	9.4

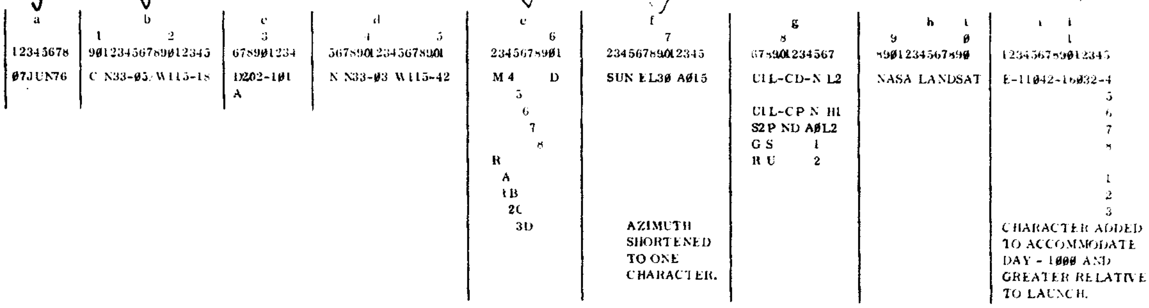
NOTE: Dimensions are in millimeters. The nominal 9.5-inch dimensions are a 3.369 enlargement of the 70-mm dimensions

Figure 4-8. Product Annotation Block Dimensions

ORIGINAL ANNOTATION



REVISED ANNOTATION (AFTER FEB. 10, 1977)



Notes (1) The letters "a" through "i" refer to items in this illustration that explain the annotation block.
(2) Character "position" in the annotation block.
(3) ƀ = blank.

a. Character Positions 01-08. Ø7 JUN 76ƀ
Day, month and year of picture exposure.

b. Character Positions 09-25.
CƀN33-05/W115-18ƀ
Format Center - Latitude and longitude at the center of the RBV and MSS image format is indicated in degrees and minutes

c. Character Position 26-34. D202-101ƀ
The "D" indicates spacecraft is descending; an "A" indicates spacecraft is ascending. Nominal path and row identifier. The 202 is path number and 101 is row number

d. Character Positions 35-51
NƀN33-03/W115-42ƀ
Nominal latitude and longitude

e. Character Positions 52-61.
Characters in this group are sensor and spectral band specific:
For RBV Images:

52-56	Sensor spectral band or Landsat-C identification code
57-59	RBV Shutter Duration Code. The "XA" refers to shutter speed
59	Aperture Correction Indicator. 1 - Aperture correction "in" 0 - Aperture correction "out"
60	"D" indicates direct transmission. "R" indicates stored data played back from the satellite WBVT recorder
61	Blank

For MSS images

52-58	The sensor spectral band identification code.
60	"D" indicates direct transmission. "R" indicates stored data played back from the satellite WBVT recorder
61	Blank

f. Character Positions 62-75. SUNƀEL30ƀ AØ15ƀ
Sun Angles - the sun elevation angle and sun azimuth angle measured clockwise from true North at the time of midpoint of MSS frame is specified to the nearest degree. Blank for ascending node coverage

g. Character Positions 76-87. U1L-CD-NƀL2ƀ

Character position 76 defines the type of geometric correction applied to the data:
"U" = uncorrected
"S" = system level
"G" = geometrically corrected based on geometric GCP's
"R" = geometrically corrected based on relative GCP's

Character position 77 indicates the scale of the image:
"1" = 185 km x 185 km (~100 nm x 100 nm)
"2" = 92.5 km x 92.5 km (~50 nm x 50 nm)

Character position 78 defines the projection:
"L" = Lambert projection
"P" = polar stereo projection
"S" = space oblique projection
"U" = UTM projection

Character position 80 indicates the resampling algorithm:
"C" = cubic
"N" = nearest neighbor

Character position 81 indicates the type of ephemeris data used to compute the image center:
"P" = predictive
"D" = definitive (for system level correction only)

Character position 83 gives the processing procedure:
"N" = normal processing procedure
"A" = abnormal processing procedure

Character position 84 defines whether an earth image or whether a RBV calibration image has been processed:
blank = earth image
Either "0", "1", or "2" = RBV Radiometric calibration images, indicating lowest to highest exposure level respectively.

Character position 85 indicates the sensor gain options:
"H" = high gain
"L" = low gain

Character position 86 shows the type of MSS transmission:
"1" = linear mode
"2" = compressed mode

h. Character Positions 88-100
NASAƀLANDSATƀ
Identifies the agency and the project

i. Character Positions 101-115
E-11042-16032-4
Frame identification number. Each image or frame will have a unique identifier which will contain encoded information consiting primarily of time of exposure relative to launch. Its format is E-ADDDD-HHMMS-B and is interpeted as follows:

"E"	- Encoded Project Identifier
A	- Landsat Mission: 1 - Landsat 1; 2 - Landsat 2; 3 - Landsat 3
DDDD	- Day number relative to launch at time of observation
HH	- Hour at time of observation
MM	- Minute at time of observation
S	- Tens of seconds at time of observation
B	- NDPF identification code (RBV A, B, C, D; MSS 4, 5, 6, 7, 8) 1, 2, 3

Figure 4-9. Details of Annotation Block

CHANGED
April 1, 1977

Roll form products appear as shown in Figure 4-10. Note that the MSS images are grouped by spectral band; that is, sequentially adjacent images on the roll are for sequential geographical areas. These images are followed by the same sequence of adjacent images in the next spectral band, etc.

4.2.3.2 Landsat-C

Landsat-C imagery data will be processed through the Image Processing Facility (IPF), converted to High Density Tape and supplied to the Landsat Data Distribution Centers in digital form either via communication links or shipment of High Density Tape copies. High Density Tape, computer compatible tape and photographic products will also be provided by the IPF to selected special tasks and special users.

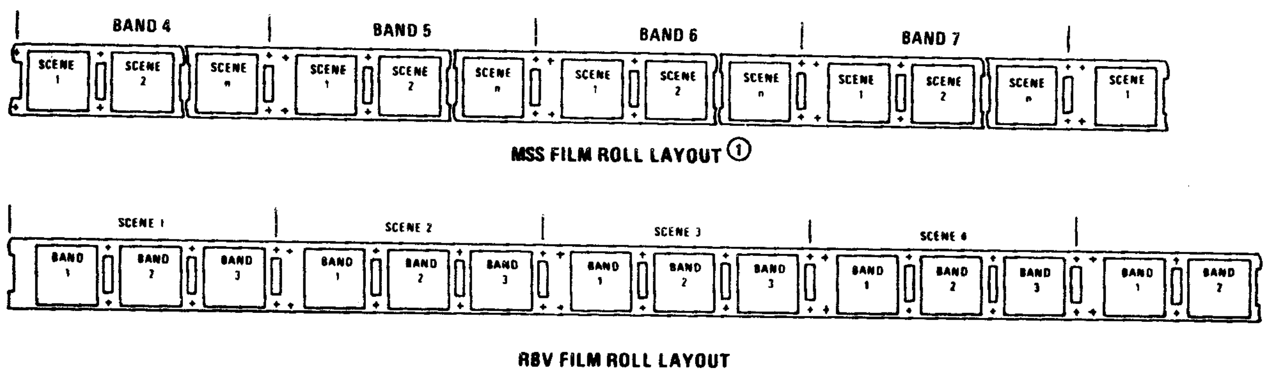
4.3 MSS COMPUTER COMPATIBLE TAPES

Digital data are available in the form of computer compatible tapes (CCTs). These tapes are standard 0.5-inch polyester-base magnetic tapes, whose physical characteristics are given in Figure 4-11 and Table 4-2; logical characteristics are discussed in Subsection 4.3.2. One, two, or four CCTs, comprising a set, contain one scene of digital imagery. The external label on each tape contains the arrangement and type of information shown in Figure 4-12. Additional information may be found in NASA/GSFC Document X-563-75-223, "Generation and Physical Characteristics of the Landsat 1 and 2 MSS Computer Compatible Tapes."

4.3.1 CCT Physical Format

CCTs are in two basic physical formats:

1. Nine-track, 1600 or 800 bpi - For the nine-track CCT, the alphanumeric data are in EBCDIC and the video data are in binary. Three 8-bit bytes are contained in three frames. (Frames are



NOTE: ① THE MSS VIDEO TAPE-TO-FILM CONVERSION PERFORMED BY THE BULK PROCESSING ELECTRON BEAM RECORDER (EBR) "GROUPS" THE IMAGES ON THE ARCHIVAL FILM ROLL BY SPECTRAL BANDS AS ILLUSTRATED. THE NUMBER OF IMAGES, n, IN A SPECTRAL "GROUP" IS DETERMINED BY THE NUMBER OF SCENES ON THE MSS VIDEO TAPE. THIS NUMBER CAN VARY FROM SOME NOMINAL MINIMUM OF, SAY 12, TO A MAXIMUM OF 48. [A SCENE MEANS ONE 25-SECOND, 185.2 BY 178.3 km (100 BY 96.3 nm) OBSERVATION]. THE INTEGRITY OF THIS SPECTRAL GROUP WILL BE MAINTAINED IN THE ROLL-FORM PRODUCTS THAT ARE SENT TO THE USER. A GIVEN ROLL WILL CONTAIN ALL SPECTRAL IMAGES FOR EACH SCENE.

Figure 4-10. Landsat 1 and 2 Corrected Roll Film Scene/Band Layout

Table 4-2. MSS CCT Operational Data Format Definitions

		Tape Recording
Tape:		0.5 inch wide; 2400 ft. long, 1.5 mil thick, Mylar or polyester base.
Load Point Marker (LPM)		Placed parallel to and not more than 1/32 inch from the edge of the tape nearest the operator when reel is mounted, providing a leader of at least 10 feet.
End of Tape Marker (EOT)		Placed parallel to and not more than 1/32 inch from the edge of the tape nearest the tape unit when the tape is mounted, providing a leader of at least 14 feet. Phase encoding for 1600 bits per inch (bpi).
Recording Method:		NRZ 1 (non-return to zero, change on ones) for 800 bpi.
7-track	Interchange code:	Video data, packed binary; alphanumeric ID data in packed binary EBCDIC.
	Recording format:	7 channels, 6 information bits plus parity, packed binary.
	Recording density:	800 bpi.
9-track	Interchange code:	Video data, binary; alphanumeric ID data, EBCDIC.
	Recording format:	9 channels, 8 information bits plus parity, binary.
	Recording density:	1600 or 800 bpi.
		Tape Records
Data Records:		Records of logical data are separated by inter-record gap.
Record Size:		Minimum: 12 bytes; maximum: limited by computer memory.
Initial Gap: (IG)		0.94 inch after load point marker.
Inter-record Gap: (IRG)		0.06 + 0.15, - 0.10 inch.
Tape Mark (End of File, EOF):		3.5 inch, followed by one byte (x '13'), followed by a longitudinal check character (LRC) only.
		Validity Checks
Vertical:		Odd parity is used.
Longitudinal:		Longitudinal redundancy check (LRC), cyclic redundancy check (CRC) characters written automatically following data records.
Physical Spacing		Refer to Figure 4-11 for description.

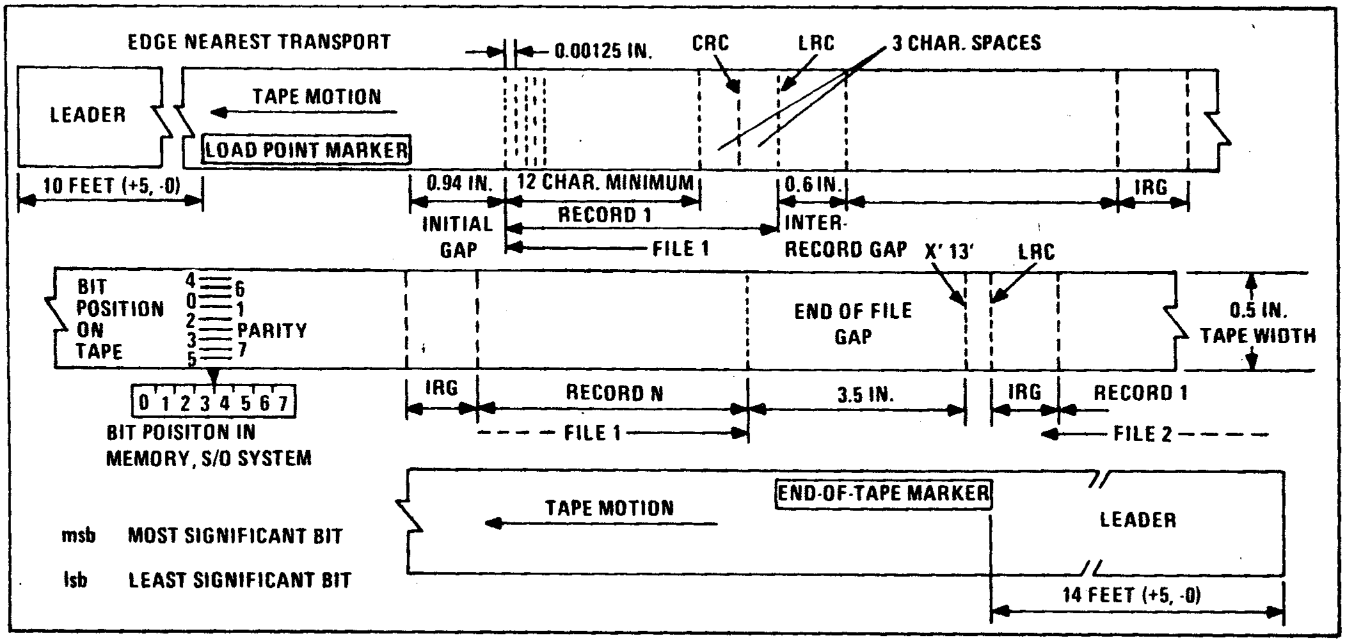


Figure 4-11. Physical Spacing of Records on MSS CCTs

areas; each is one recording position in length, extending across the tape, perpendicular to the direction of tape movement.)

2. Seven-Track, 800 bpi - The seven-track CCT contains packed binary video data and packed EBCDIC alphanumeric data. In the "packed" configuration, three 8-bit bytes are contained in four frames. The record layout and bit structure are identical to the layout and structure of the nine-track CCT.

9-TRACK COPY CCT DATE . . . / . . . . . / . . .
W.O. #. . . . . USER ID . . . .
SCENE ID . . . . -MB
REELS 1&2 OF 4 BPI. . . . .

Figure 4-12. MSS CCT External Tape Label

4.3.2 Logical Format and Data Content of CCTs

The full frame 185.2-by-185.2 km (100-by-100 nm) image is segmented into four 46.3-by-185.2 km (25-by-100 nm) strips in the direction of spacecraft heading, for conversion into CCT format.

4.3.2.1 Video Data Format and Content

The video data are spectrally interleaved. The interleaving is done in groups of 8 bytes, 2 bytes from each spectral band. The absence of an expected scan line is identified on a CCT by the use of a special code that does not occur in ordinary imagery. Missing scan lines are identified by the occurrence of the byte X 'CC' (11001100) at the start of the ordinary scan line byte sequence on the CCT. An ordinary scan line byte sequence is defined as the first quarter scan line of video data.

Radiometric calibration data for each spectral band is also inserted as a 56-byte calibration group following each block of 3n 8-byte groups of interleaved video data. The letter "n" is used to represent that multiplier of the number "24" which is needed to calculate the adjusted video data scan line length (LLA). The resulting multiple of 24 is constrained to be the smallest such multiple which is at least as great as the maximum line length code (LLC) determined for a given scene, plus 6. All line lengths are, of course, measured in pixels, or bytes. Additional detail will be found in Appendix D of this handbook.

Figures 4-13 through 4-15 illustrate the CCT video data format and content; symbols used in these illustrations are defined in Table 4-3.

The video data word consists of eight bits, of which only six are used if the data mode is linear and seven are used if the data mode is decompressed. All video data-bit words are right-justified. Bits which are not used for video data are used as flags, as when 11111111 is used as the spatial registration fill character (X 'FF'). The decompressed mode arises when data has been transmitted from the satellite in a compressed mode. The decompressed mode yields radiance values represented by byte values ranging from 0 to 127, instead of 0 to 63, as with the linear mode.

4.3.2.2 Identification (ID) Record

The ID record contains a combination of binary and EBCDIC information that is used to identify the video data of each file. This 40-byte record is therefore the first record on a CCT, and appears thereafter at the start of each file if there is more than one file on the tape. Figure 4-16 shows the organization of the ID record.

The first word in the ID record is the scene/frame ID, given in terms of days, hours, minutes, and tens of seconds since launch. In addition, this record indicates the spectral band (Landsats 1 and 2 = bands 4-7, set to zero), sequential subframe ID (subframes unavailable, set to zero), and by character 1, whether the data are from Landsat 1 or Landsat 2. Characters 13-16 contain the sequencing numbers; e.g., 1 of 2, 2 of 2, which would distinguish the tapes in a set of two. Characters 17-18 contain the data record length in binary, i.e., the length of the adjusted scan line plus 56 bytes of calibration information. Characters 19-26 contain the binary frame ID, which is the binary representation of the scene/frame ID and must be broken into days, hours, minutes, seconds, etc., to be read. Characters 27-28, the binary strip ID, are not used and are set to zero. Characters 29-36 contain the image annotation tape (IAT) ID, which identifies the IAT used in making the CCT. Characters 37-38 contain the MSS data mode/correction code, which is a digital word that indicates the characteristics of the data such as decompression, calibration, and line length adjustment. (See Table 4-4 for the complete definition of the MSS data mode/correction code.) Characters 39-40 contain the MSS adjusted line length. All of the above information is defined in more detail in Table 4-4.

4.3.2.3 Annotation Record

The annotation record contains binary and EBCDIC data that provide information about the scene such as the format center, nadir and sun elevation. This record also includes tick mark location information that associates the digitized scene with the latitude and longitude coordinate system. The annotation record is the second record of each file, thus occurring once or more per tape dependant upon format, and contains 624 characters. This record is actually a composite of two records taken directly from the image annotation tape. The first 144 characters comprise the annotation block, and the next 480 characters comprise the image location record. Figure 4-17 defines the sequence of information in the annotation record.

4.3.2.3.1 Annotation Data Block

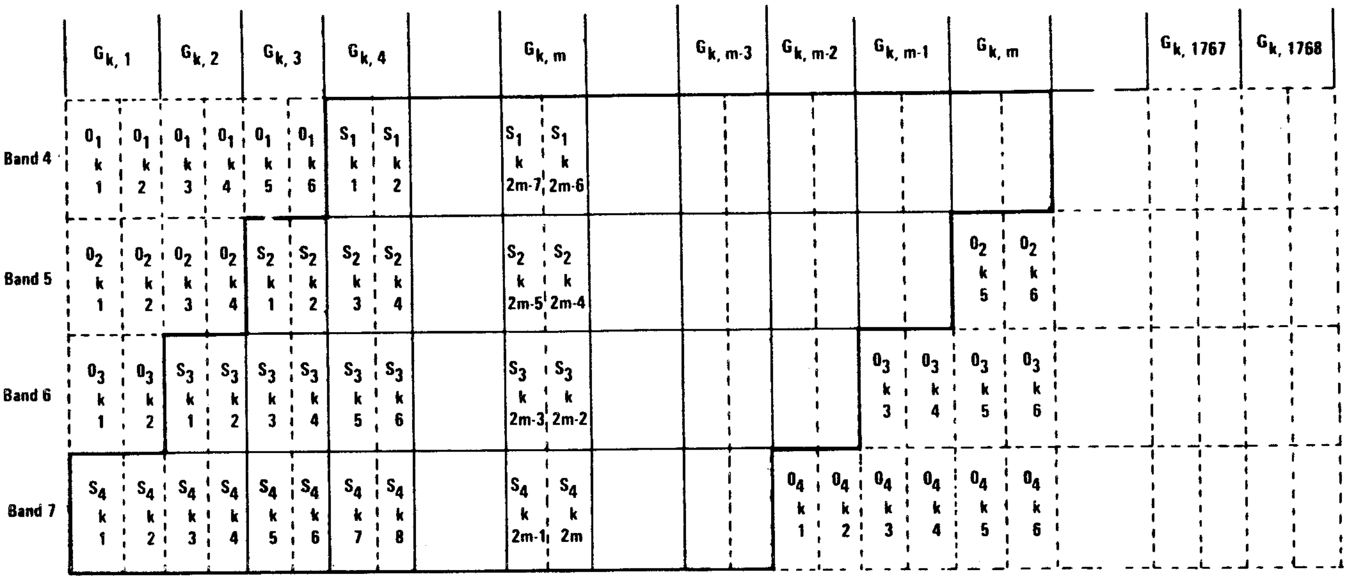
The information included in the image annotation data block allows user interpre-

Table 4-3. Explanation of Symbols Used (Figure 4-13 through 4-15)

Item/Symbol	Description
S_{bkj}	Sample within a scan line corresponding to a specified video picture element (pixel) location where: b = Spectral band designator $(1 \leq b \leq 5)$ k = Sequential scan line index j = Sample number within line, length-adjusted scan line S_{bkj} Comprise 6 or 7 bits of video right justified in an 8-bit byte
$G_{k,m}$	Group of 8 spectrally interleaved, spatially registered samples, 2 bytes from each of bands 4-7, where: k = Sequential full frame scan line index m= Sequential group within an interleaved scan line $G_{k,m}$ contains video samples S_{bkj} in the order:
	$S_{1,k,2m-7}$ $S_{1,k,2m-6}$ $S_{2,k,2m-5}$ $S_{2,k,2m-4}$ $S_{3,k,2m-3}$ $S_{3,k,2m-2}$ $S_{4,k,2m-1}$ $S_{4,k,2m}$
	An interleaved entire scan line may contain a maximum of 1768 $G_{k,m}$ groups.
$CAL_{b,k}$	Calibration data and line length information for scan line k of band designated b. Each $CAL_{b,k}$ is a 14-byte string.
R_{ik}	Record corresponding to a specific set of S_{bkj} comprising a segmented interleave scan line where: i = Image segment and computer compatible tape (CCT) file number k= Sequential scan line index
B_{ik}	Fifth spectral band record where: i = Image segment and CCT file number k= Sequential spectral band (designated 5) scan line index
$L_{i,p}$	Line set number assigned to a set of three 4-band* records (plus one 5th band record for Landsat-C) where: i = Image segment and CCT file number p= Sequential line set number. For Landsat-1 and 2, each L_{ip} contains three 4-band records. For Landsat C, each L_{ip} contains three 4-band records plus one fifth band record.
IDA	Two data records consisting of scene and annotation data for each image strip recorded on CCT.
EOF	End of file

*"4-band" refers to MSS bands 4-7;
"5th band" refers to MSS band 8

Note: Spectral band designators 1-5 refer to MSS bands 4-8, respectively.



Notes: 1. BAND-TO-BAND 2-BYTE SPATIAL MISREGISTRATION IS CORRECTED BY INSERTION OF DUMMY BYTES, $0_{k,j}$ RECORDED ON CCT AS $0_{k,j}$ = FF (HEXADECIMAL).

2. VIDEO DATA SAMPLES RECEIVED (EITHER VARIABLE OR ADJUSTED LENGTH SCAN LINES) ARE DENOTED S_{bkj} WHERE:
   - b = MSS SPECTRAL BAND DESIGNATOR(1, 2, 3, 4)
   - k = FULL FRAME SCAN LINE NUMBER (1, 2,...2340)
   - j = SAMPLE INDEX PER SCAN LINE

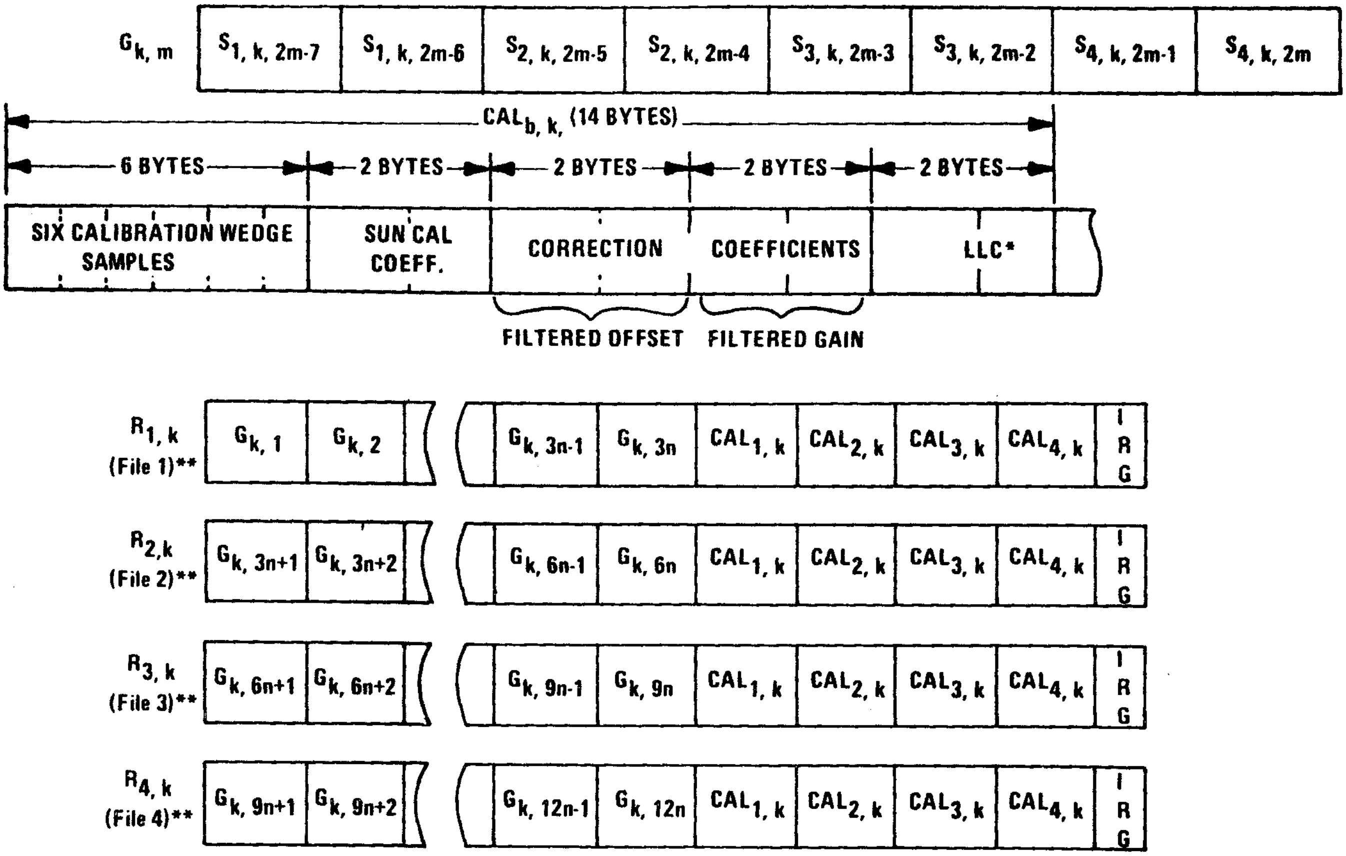
3. SPECTRAL BAND INTERLEAVING ON CCT IS ACCOMPLISHED BY RECORDING $G_{k,m}$, GROUPS IN THE SEQUENCE

S_1	S_1	S_2	S_2	S_3	S_3	S_4	S_4
k	k	k	k	k	k	k	k
(2m-7)	(2m+6)	(2m-5)	(2m-4)	(2m-3)	(2m-2)	(2m-1)	(2m)

WHERE m = GROUP INDEX (1, 2...., (M-1), M)
M = NUMBER OF MEMORY ADDRESS LOCATIONS ASSIGNED PER INPUT SCAN LINE, MAXIMUM VALUE OF M = 1768 LOCATIONS

THE VIDEO DATA SAMPLE INDEX j IS A FUNCTION OF THE GROUP INDEX, m, DUMMY SAMPLES ARE INSERTED FOR THE CONDITIONS: $j(m)<1$ OR $j(m)>(2M-6)$

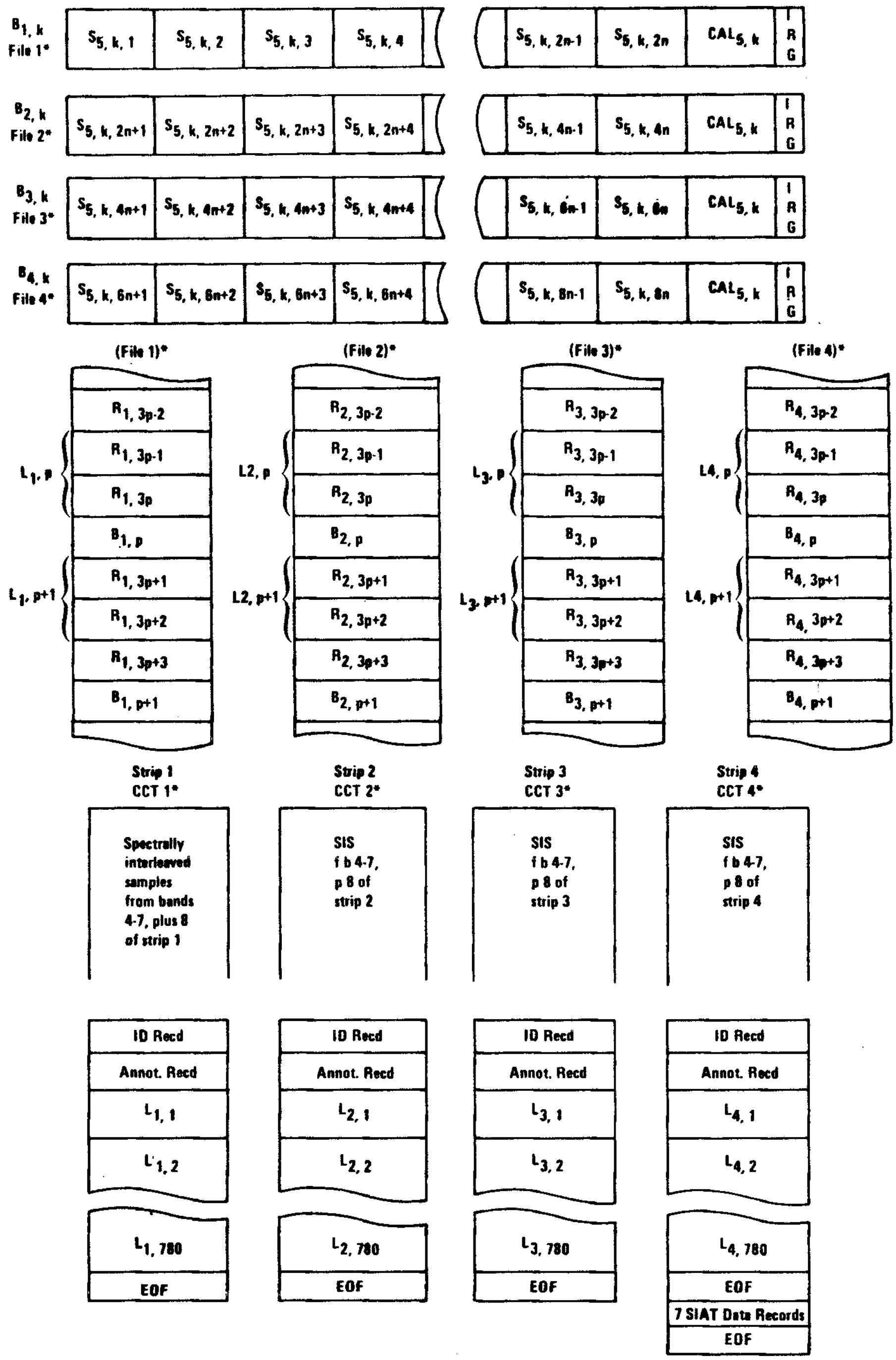
Figure 4-13. MSS Spatial Registration Illustration, Bands 4 through 7, k^{th} Scan Line



*LLC is a two-byte number denoting the number of video data samples per uncorrected (raw) scan line.

**Each file contains one 46.3 by 185.2 km (25 by 100 nm) strip of the scene as described in Section 4.3.2. For the one-CCT format, the four files follow sequentially on one CCT 2400 feet in length with a bit density of 1600 bpi. For the two-CCT format, files 1 and 2 follow sequentially on CCT 1 and files 3 and 4 on CCT 2. These tapes are 2400 feet in length with a bit density of 800 bpi. For the four-CCT format, each of the four files corresponds to a like-number CCT, 2400 feet in length with a bit density of 800 bpi. All formats include an ID record and an annotation record as the first and second records, respectively, of each film, and special image annotation tape (SIAT) information (used in original CCT generation) is included after the last file of each scene.

Figure 4-14. Full Scene Interleaved Record Format



***LLC** is a two-byte number denoting the number of video data samples per uncorrected (raw) scan line.

**Each file contains one 46.3 by 185.2 km (25 by 100 nm) strip of the scene as described in Section 4.3.2. For the one-CCT format, the four files follow sequentially on one CCT 2400 feet in length with a bit density of 1600 bpi. For the two-CCT format, files 1 and 2 follow sequentially on CCT 1 and files 3 and 4 on CCT 2. These tapes are 2400 feet in length with a bit density of 800 bpi. For the four-CCT format, each of the four files corresponds to a like-number CCT, 2400 feet in length with a bit density of 800 bpi. All formats include an ID record and an annotation record as the first and second records, respectively, of each film, and special image annotation tape (SIAT) information (used in original CCT generation) is included after the last file of each scene.

Figure 4-15. Full Scene, Four-CCT Format

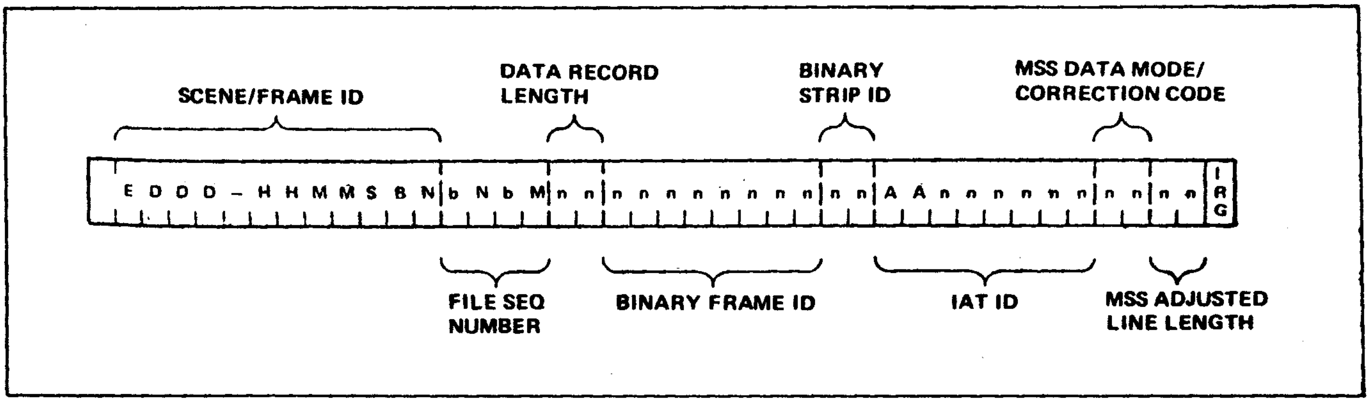


Figure 4-16. ID Record Organization (40 Characters, EBCDIC and Binary Code)

Table 4-4. ID Record Information Definitions

Char.	Information	Format	Code
1-12	Scene/Frame ID	EDDD-HHMMSBN*	EBCDIC
13-16	File Sequencing Numbers File N of M (b = blank char.)	bNbM	EBCDIC
17-18	Data Record Length (bytes)	nn	Binary
19-26	Binary Frame ID	nnnnnnnn**	Binary
27-28	Binary Strip ID	oo	Binary
29-36	IAT Identification (from Header record on IAT)	AAnnnnnn	EBCDIC
37-38	MSS Data Mode/Correction Code*** Unitary Code	nn	Binary
39-40	MSS Adjusted Line Length	nn	Binary

*E – Encoded Project Identifier (Landsat 1 - 1 or 5; Landsat 2 - 2 or 6)
DDD – Day number relative to launch at time of observation
HH – Hour at time of observation
MM – Minute at time of observation
S – Tens of seconds at time of observation (truncated not rounded numbers)
B – IPF Identification Code (Landsat 1 and 2, bands 4&7, set to zero)
N – Sequential Subframe ID (only full frame available, set to zero)
**The Binary Frame ID is the binary representation of the Scene/Frame ID.

Character	
19	Encoded Project Identifier (Same as *E above)
20-21	Days since launch; this number is determined by extracting the six right-most bits from bytes (characters) 20 and 21 and combining them into one word (six bits from byte 20 followed by six bits from byte 21)
22	Hour at time of observation
23	Minute at time of observation
24	Tens of seconds at time of observation (truncated, not rounded numbers)
25	Spectral Band Identifier (IPF Identification Code, set to zero)
26	Sequential Subframe ID (set to zero)

For characters 22 through 26, the six right-most bits are used.

***Bits 0-7 of this two-character word are zero.
Bits 8-15 have the following significance:

Bit		
8	= 1 for Sun Cal Data,	= 0 otherwise
9	= 1 for Calibration Wedge,	= 0 otherwise
10	= 1 for Compressed Data,	= 0 otherwise
11	= 1 for Hi gain on band 1,	= 0 otherwise
12	= 1 for Hi gain on band 2,	= 0 otherwise
13	= 1 for Decompression,	= 0 otherwise
14	= 1 for Calibration,	= 0 otherwise
15	= 1 for Line Length Adjust,	= 0 otherwise

tation of the imagery. These data are specified at the time of the center scan line of the MSS frame; all decimal points and special characters are included. The annotation block data format consists of 144 EBCDIC characters (72 sixteen-bit words), whose format and content are defined in Table 4-5.

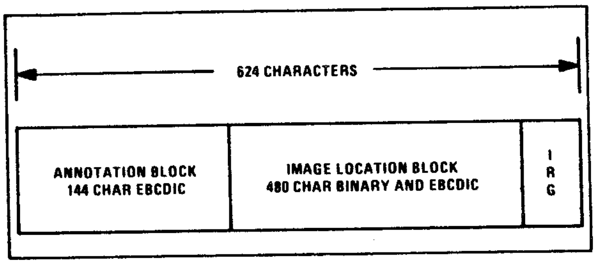


Figure 4-17. Annotation Record Information Sequence

4.3.2.3.2 Image Location Data Block

The image location data consist of 240 sixteen-bit words that describe the tick marks that associate the scene with latitude and longitude. There can be a maximum of six tick marks per side (i.e., left side, right side, top and bottom), and the image location data includes this tick mark information for RBV as well as MSS data.

The tick mark location data consist of four types: the tick position, the special tick character, the direction (N, S, E or W), and the value in degrees and minutes. Each tick mark is denoted by a 16-bit signed binary integer fraction that specifies its position along the edge of the scene, followed by eight EBCDIC characters.

The 16-bit signed integer fraction represents the location of the tick mark along the edge of the scene and takes on values from +1/2 to -1/2. The most significant bit of the integer fraction indicates the sign of the fraction. If the bit is a one, the fraction is negative; if it is a zero, the fraction is positive. The tick mark reference system has been chosen so that the origin is at the format center. The corners of the scene writing area may be designated A (1/2, -1/2), B(-1/2, -1/2), C(1/2, 1/2) and D(-1/2, 1/2), as in Figure 4-18. The value that locates the tick marks along the edges is therefore given in terms of a 16-bit binary integer fraction with the binary point to the left of bit position 1.

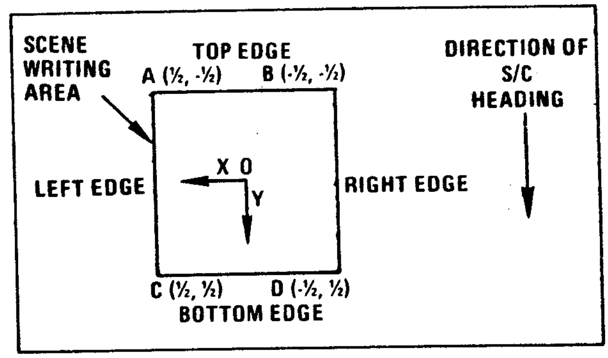


Figure 4-18. Tick Mark Reference System

The special tick characters are either an X'4F', an EBCDIC vertical bar that is used along the top and bottom edges of the scene, or an X'7E', an EBCDIC equals sign that is used to represent the ticks on the left and right sides of the scene. The direction is represented by an EBCDIC character that represents north, south, east, or west (N, S, E or W). The value of the latitude or longitude is given in degrees (3 characters) and minutes (2 characters).

There are two formats used to represent the location of tick marks. The tick marks are usually written first and are followed by the value of the latitude or longitude. If there is not enough room on any one of the sides for the last tick mark, then the value of the latitude or longitude is written first and is followed by the tick character for the last tick mark. An illustration of the two tick mark formats follows:

Format 1

Position: 16-bit signed binary fraction

Tick mark annotation:

- Tick mark character: X'4F' or X'7E'
- Direction, one character: N, S, E or W
- Value
  - Degrees, three characters:
  - Constant: '—'
  - Minutes, two characters: 00 or 30

Format 2

Position: 16-bit signed binary fraction
Tick mark annotation:

Direction, one character: N, S, E or W
Value, six characters: same as Format 1
Tick mark character: X'4F' or X'7E'

Each of the eight tick mark tables (one for each MSS and RBV edge) contains the tick mark data arranged in positional order from the top of the table downward with the top edge tick mark table being given first. The unused tick mark locations are signified by a zero in the position words and X'FF' in all of the annotation characters.

The tick mark record format defined in the 16-bit words is as follows:

RBV tick mark set:

Character	Description
B(1)	Position, tick mark No. 1
B(2)-B(5)	Annotation, tick mark No. 1
B(6)	Position, tick mark No. 2
B(7)-B(10)	Annotation, tick mark No. 2
B(11)	Position, tick mark No. 3
B(12)-B(15)	Annotation, tick mark No. 3
B(16)	Position, tick mark No. 4
B(17)-B(20)	Annotation, tick mark No. 4
B(21)	Position, tick mark No. 5
B(22)-B(25)	Annotation, tick mark No. 5
B(26)	Position, tick mark No. 6
B(27)-B(30)	Annotation, tick mark No. 6
B(31)-B(60)	Left edge tick mark table
B(61)-B(90)	Right edge tick mark table
B(91)-B(120)	Bottom edge tick mark table

MSS tick mark set:

Character	Description
B(121)-B(240)	Format is the same as that for the RBV tick mark set

It should be noted that the scene on the CCT contains 2340 scan lines (2256 scan lines for the film image, plus 42 scan lines of data preceding the film image and 42 scan lines following the film image). The tick marks are applied to the film image as shown in Figure 4-19.

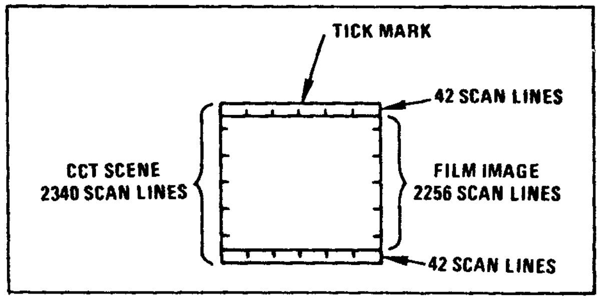


Figure 4-19. CCT and Film Image Comparison

4.3.2.4 Special Image Annotation Tape (SIAT) Data File

This file consists of seven records. The first record is a 2048 byte record which contains the SIAT logical tape header. The second record contains 216 bytes of Processing Information Data. The third record contains 204 bytes of Spacecraft and Sensor Performance Data. The fourth record contains 144 bytes of Annotation Block Data (Table 4-5). The fifth record contains 76 bytes of RBV Computational Data. Record six contains 326 bytes of MSS Computation Data. The seventh record contains 480 bytes of Image Location Data.

Detailed descriptions of each of these records are shown in Tables 4-6A through 4-6G.

4.4 DATA COLLECTION SYSTEM PRODUCTS

The IPF produces three types of Data Collection System (DCS) data products: punched cards, computer listings and magnetic tapes. These products along with their contents and formats are described in Figures 4-20 through 4-22. DCS data transmission format is listed in Table 4-7.

Table 4-5. Annotation Block Data

Characters	Description
	(Day, Month, Year of Exposure – The date at Greenwich, month, and year of picture exposure)
1-2	Date of Exposure, day of month, numerals
3-5	Date of Exposure, month of year, abbreviated to three alpha characters
6-7	Date of Exposure, year, abbreviated to two numerals
8-10	Constant: 'bCb' (signifies Format Center). (Format Center – The center of the RBV and MSS image format is indicated in terms of latitude and longitude in degrees and minutes. The MSS format center is identical to the corresponding RBV format center. Format center is defined as the point of contact with the earth, of the geometric extension of the spacecraft yaw attitude sensor axis to the earth's surface.)
11	Latitude direction, 1 alpha, N or S
12-13	Latitude, degrees, two numerals
14	Constant: '–'
15-16	Latitude, minutes, two numerals
17	Constant: '/'
18	Longitude, direction, 1 alpha, E or W
19-21	Longitude, degrees, three numerals
22	Constant: '–'
23-24	Longitude, minutes, two numerals
25-27	Constant: 'bNb' (signifies Nadir) (Nadir – The latitude and longitude of the nadir (the intersection with the earth's surface of a line from the satellite perpendicular to the earth ellipsoid) is indicated in degrees and minutes)
28	Latitude direction, 1 alpha, N or S
29-30	Latitude, degrees, two numerals
31	Constant: '–'
32-33	Latitude, minutes, two numerals
34	Constant: '/'

Table 4-5. Annotation Block Data (Continued)

Characters	Description
35	Longitude, direction, 1 alpha, E or W
36-38	Longitude, degrees, three numerals
39	Constant: '–'
40-41	Longitude, minutes, two numerals
42	Constant: 'b'
43-54	Blank Field 1 (12 characters long)
55-60	Constant: 'SUNbEL'
61-62	Sun elevation, degrees, two numerals (Sun Elevation – The sun elevation angle at the time of mid-point of MSS frame is indicated to the nearest degree)
63-65	Constant: 'bAZ'
66-68	Sun aximuth, degrees, three numerals (Sun Azimuth – The sun azimuth angle from true North at the time of midpoint of MSS frame is indicated to the nearest degree)
69	Constant: 'b'
70-72	Satellite Heading (including yaw), degrees, three numerals (Satellite Heading – The satellite true heading is indicated to show the orientation of the imagery. The heading includes yaw and is indicated to the nearest degree)
73	Constant: '–'
74-77	Revolution number, four numerals (Rev Number – The consecutive rev number for the Landsat spacecraft is indicated.)
78	Constant: '–'
79	MSS data acquisition site, abbreviated to one alpha, A, G, or N (Data Acquisition Site – A one-letter acronym designates the data acquisition site. This will be either Alaska, (A), Goldstone, (G), or NASA Tracking and Training Facility (N).)
80	Constant: '–'
81	Constant: '1'

Table 4-5. Annotation Block Data (Continued)

Characters	Description
82	Constant: '–'
83-84	Blank Field 2 (two characters long)
85	Type of orbit data: Predicted = P; Definitive = D
86	Constant: '–'
87-88	Blank Field 5 (two characters long)
89-101	Constant: 'bNASAbERTSbE-' Frame Identification (Frame Identification Number – Each image or frame has a unique identifier that contains encoded information. This identifier is used for an information retrieval system and consists primarily of time of exposure relative to launch information. The Initial Image Generating Subsystem adds the appropriate spectral band number. Also part of the frame identification number is a "regeneration of images" identifier, which is added to the imagery by Initial Image Generation when appropriate.)
102	Landsat mission number = S
103-105	Day number relative to launch = DDD S = 1 for Landsat 1, DDD $\leq$ 999 S = 5 for Landsat 1, DDD > 999 S = 2 for Landsat 2, DDD $\leq$ 999 S = 6 for Landsat 2, DDD > 999
106	Constant: '–'
107-108	Hour at time of observation
109-110	Minutes
111	Tens of seconds
112	Constant: '–'
113	Blank Field 3 (one character long)
114	Blank for earth images (RCI Images – A 0, 1, or 2 indicates one of the 3 exposure levels for radiometric calibration, where 0 corresponds to the minimum exposure level, and 2 corresponds to the maximum. A blank signifies no RCI images)
115-116	Blank Field 4 (two characters long) During Initial Image Generation Processing, the sensor code will be inserted on the imagery into Blank Field 1; the gamma (normal 'N-', or abnormal 'A-') into Blank Field 2; the spectral identifier into Blank Field 3; the regeneration number of the processed image (when necessary) into Blank Field 4; and the type of MSS signal encoding ① into Blank Field 5.

Table 4-5. Annotation Block Data (Continued)

Characters	Description
117-140	24 blank characters if RBV② is off
141-144	4 blank characters if MSS is off
	Otherwise:
117-121	Direct or recorded data: '1bbDX' or 1bbRX'
122-123	Shutter Setting③ and Aperture Correction Indicator,④ RBV 1; aa
124-129	Direct or recorded data: 'bb2bDX' or 'bb2bRX'
⑤ 130-131	Shutter Setting and Aperture Correction Indicator, RBV 2; aa
132-137	Direct or recorded data: 'bbb3DX' or 'bbb3RX'
138-139	Shutter Setting and Aperture Correction Indicator, RBV 3; aa
140	Constant: 'b'
141-142	Direct or recorded MSS data: 'Db' or 'Rb'
⑥ 143-144	MSS data acquisition site, 'A-', 'G-', or 'N-'

① MSS signal code:
- 1 = Linear data mode
- 2 = Compressed data mode

} Not applicable for band 7

- H = High gain option
- L = Low gain option

} Not applicable for bands 6 and 7

② No requirement for CCTs for Landsat 1 and 2 RBV imagery

③ Shutter setting code, applicable to Landsat 1 and 2 RBV annotation only:

Setting	Duration of Exposure (ms)		
	Camera 1	Camera 2	Camera 3
A	4.0	4.8	6.4
B	5.6	6.4	7.2
C	8.0	8.8	8.8
D	12.0	12.0	12.0
E	16.0	16.0	16.0

④ Aperture correction indicator:
- I = aperture correction in
- O = aperture correction out

⑤ Blank Field 1 data

⑥ MSS data for characters 79-80, as applicable

Table 4-6A. SIAT Data File Records; Record 1 - SIAT Logical Tape Header

Byte	Length	Content	Format
1	8	SIAT Number	EBCDIC (ttadddnn)
9	10	Date of Tape Preparation	EBCDIC (ƀddƀmmmƀyy)
19	10	Zero	Binary
29	8	SIAT Number	EBCDIC (ttadddnn)
37	8	RBV Tape Number	EBCDIC (ttadddnn or blanks)
45	8	MSS Tape Number	EBCDIC (ttadddnn or blanks)
53	2	Number of Data Files on Logical SIAT	Integer
55	2	Zero	Binary
57	2	Zero	Binary
59	2	Number of RBV/VTC	Integer
61	2	Number of MSS/VTC	Integer
63	2	Number of RBV/TFC	Integer
65	2	Number of MSS/TFC	Integer
67	2	Zero	Binary
69	2	1st-64th RBV Scene ID's	EBCDIC addd-hhmmsƀƀ
837	768	1st-64th MSS Scene ID's	EBCDIC addd-hhmmsƀƀ
1605	444	Zero	Binary

Table 4-6B. SIAT Data File Records; Record 2 - Processing Instruction Data

Starting Byte No.	and Length (Bytes)	Information	Format
1	2	No. of Scenes Remaining, RBV/VFC	Binary
3	2	No. of Scenes Remaining, MSS/VFC	Binary
5	2	No. of Scenes Remaining, RBV/VTC	Binary
7	2	No. of Scenes Remaining, MSS/VTC	Binary
9	2	Not Used	Binary Zero
11	2	Not Used	Binary Zero
13	10	Scene ID	EBCDIC ndd-hhmms
23	10	Preceding Closest RCI ID from W.O.	EBCDIC ndd-hhmms
33	10	Succeeding Closest RCI IF from W.O.	EBCDIC ndd-hhmms
43	1	Mission No. (1 or 2)	Binary
44	1	Day Number from Launch	Binary (most significant part; least signif. bit is 2^6)
45	1	Day Number from Launch	Binary (6-bit least signif. part; 6 bits avail.)
46	1	Hours of Day	Binary
47	1	Minutes of Hour	Binary
48	1	Tens of Seconds	Binary
49	2	Not Used	Binary Zero
51	8	Band 1 Information from PIAT W.O.	EBCDIC 1aaaaabb
59	8	Band 2 Information from W.O.	EBCDIC 2aaaaabb
67	8	Band 3 Information from W.O.	EBCDIC 3aaaaab
75	8	Band 4 Information from W.O.	EBCDIC 4aaaaaab
83	8	Band 5 Information from W.O.	EBCDIC 5aaaaaab
91	8	Band 6 Information from W.O.	EBCDIC 6aaaaaab
99	8	Band 7 Information from W.O.	EBCDIC 7aaaaabb
107	8	Band 8 Information from W.O.	EBCDIC 8aaaaabb
115	72	Special Instructions to Precision Processing Operator from W.O.	EBCDIC
187	1	Mission No.	Binary
188	1	Day No. from Launch	Binary (most signif. part; least signif. bit is 2^6)
189	1	Day No. from Launch	Binary (6-bit least signif. part; 6 bits avail.)
190	1	Hours of Day	Binary
191	1	Minutes of Hour	Binary
192	1	Tens of Seconds	Binary
193	1	Not Used	Binary Zero
194	1	Not Used	Binary Zero
195	6	Output Frame ID	Same as Item 38
201	1	Not Used	Binary Zero
202	1	Not Used	Binary Zero
203	2	Processing Code from SIAT Generation Work Order	Binary
205	2	Processing Code for MSS	Binary
207	2	Polar Stereo Projection	Hexadecimal
209	8	Flag	Binary Zero
216	Total Bytes		
Inter-Record Gap			

Table 4-6C. SIAT Data File Records; Record 3 - Spacecraft Performance Data

Starting Byte No. and Length (Bytes)		Information	Format
1	8	RBV 1 Mode of Transmission	EBCDIC RBVb1bba
9	2	RBV 1 Exposure Duration	EBCDIC Xa
11	2	RBV 1 Aperture Correction Indicator	EBCDIC ab
13	8	RBV 2 Mode of Transmission	EBCDIC RBVbb2ba
21	2	RBV 2 Exposure Duration	EBCDIC Xa
23	2	RBV 2 Aperture Correction Indicator	EBCDIC ab
25	8	RBV 3 Mode of Transmission	EBCDIC RBVbbb3a
33	2	RBV 3 Exposure Duration	EBCDIC Xa
35	2	RBV 3 Aperture Correction Indicator	EBCDIC ab
37	12	MSS 4 Mode of Transmission	EBCDIC MSSb4bbbbbab
49	12	MSS 5 Mode of Transmission	EBCDIC MSSbb5bbbbab
61	12	MSS 6 Mode of Transmission	EBCDIC MSSbbb6bbbab
73	12	MSS 7 Mode of Transmission	EBCDIC MSSbbbb7bbab
85	12	MSS 8 Mode of Transmission	EBCDIC MSSbbbbb8bab
97	2	MSS Sensor Gain	Binary, bits 1 & 2 for bands 4 & 5 respect., 1 = high Bits 3-16 are zero
99	1	MSS Sensor Encoding	Binary, bits 1-3 for bands 4-6 respect. 1 = compressed. Bits 4-8 are zero
100	1	Not Used	Binary Zero
101	8	SPDT Tape ID	EBCDIC SPndddnn
109	4	MSS SUN CAL DAY	EBCDIC 0DDDD
113	48	MSS SUN CAL's SENSORS 1-24	Binary Scaled 2^{-12}
151	36	Not Used	Binary Zero
197	4	MSS SUN CAL DAY desired	EBCDIC 'bbb' 'Fill' or 'BADb'
201	4	MSS SUN CAL FLAG	EBCDIC 'DDD'
204	Total Bytes		
Inter-Record GAP			

Table 4-6D. SIAT Data File Records; Record 4 - Annotation Block Data

Starting Byte No.	and Length (Bytes)	Information	Format
1	2	Day of Month Exposure	EBCDIC nn
3	3	Month of Exposure	EBCDIC aaa
6	2	Year of Exposure	EBCDIC nn
8	3	Constant	EBCDIC bCb
11	6	Latitude of Format Center	EBCDIC ann-nn
17	1	Constant	EBCDIC /
18	7	Longitude of Format Center	EBCDIC annn-nn
25	3	Constant	EBCDIC bNb
28	6	Latitude of Nadir	EBCDIC ann-nn
34	1	Constant	EBCDIC /
35	8	Longitude of Nadir	EBCDIC annn-nnb
43	12	Blank Field 1	EBCDIC blanks
55	8	Sun Elevation at Nadir (Deg)	EBCDIC SUNbELnn
63	6	Sun Azimuth at Nadir (Deg)	EBCDIC bAZnnn
69	4	Satellite Heading (Deg)	EBCDIC bnnn
73	6	Rev. Number	EBCDIC -nnn-
79	4	RBV Data Acquisition	EBCDIC a-1-
83	2	Blank Field 2	EBCDIC bb
85	2	Type of Orbit Data (Pred. or Defin.)	EBCDIC a-
87	2	Blank Field 5	EBCDIC bb
89	13	Constant	EBCDIC bNASAbERTSbE-
102	10	Scene Identification	EBCDIC nddd-hhmms
112	1	Constant	EBCDIC -
113	1	Blank Field 3	EBCDIC b
114	1	RCI Images Calibration Level	EBCDIC n (or blank)
115	2	Blank Field 4	EBCDIC bb
117	5	RBV 1 Mode (Direct or Recorded)	EBCDIC 1bbaX (or blanks)
122	2	RBV 1 Shutter Setting, Aperture Correction Indicator	EBCDIC aa (or blanks)
124	6	RBV 2 Mode	EBCDIC bb2baX (or blanks)
130	2	RBV 2 Shutter Setting, Aperture Correction Indicator	EBCDIC aa (or blanks)
132	6	RBV 3 Mode	EBCDIC bbb3aZ (or blanks)
138	2	RBV Shutter Setting, Aperture Correction Indicator	EBCDIC aa (or blanks)
140	5	MSS Mode (Direct or Recorded) and Acquisition Site	EBCDIC baba- (or blanks)
144	Total Bytes		
Inter-Record GAP			

Table 4-6E. SIAT Data File Records; Record 5 - RBV Computational Data

Starting Byte No.	and Length (Bytes)	Information	Format
1	8	Spacecraft Time of Exposure	4-bit BCD 00000dddhhmmsscc
9	8	Greenwich Mean Time of Exposure	4-bit BCD 000dddhhmmssmmm0
17	2	Normalized Altitude Change	Binary fraction
19	10	GMT Date of Exposure	EBCDIC bddbmmmbyy
29	8	GMT Time of Exposure	EBCDIC bhhmm:ss
37	4	Latitude of Format Center	Binary
41	4	Longitude of Format Center (10^{-6} Radians)	Binary
45	4	Latitude of Nadir (10^{-6} Rad)	Binary
49	4	Longitude of Nadir (10^{-6} Rad)	Binary
53	4	Spacecraft Altitude (meters)	Binary
57	4	GMT of Exposure (Milliseconds of Day)	Binary
61	4	S/C Flight Path Heading (10^{-6} Rad)	Binary
65	4	Pitch (10^{-6} Rad)	Binary
69	4	Roll (10^{-6} Rad)	Binary
73	4	Yaw (10^{-6} Rad)	Binary
76 Total Bytes			
Inter-Record GAP			

Table 4-6F. SIAT Data File Records; Record 6 - MSS Computational Data

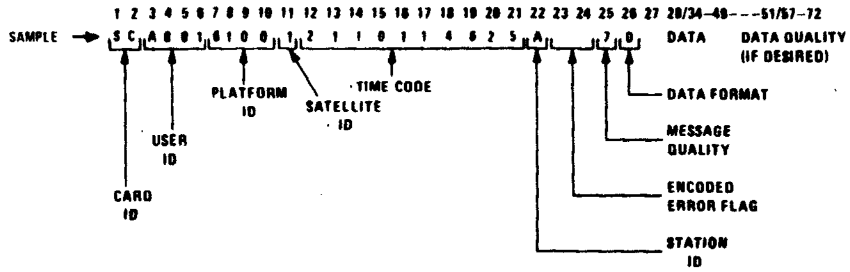
Starting Byte No. and Length (Bytes)		Information	Format
1	8	Spacecraft Time of Scene Center	4-bit BCD 00000dddhhmmsscc
9	8	GMT of Scene Center	4-bit BCD 000dddhhmmssmmm0
17	2	Normalized Altitude Change at Image Center - 13.80300	Binary fraction
19	2	Same as 102 at I.C. - 10.35225	Binary fraction
21	2	Same as 102 at I.C. - 6.90150	Binary fraction
23	2	Same as 102 at I.C. - 3.45075	Binary fraction
25	2	Same as 102 at I.C. Time	Binary fraction
27	2	Same as 102 at I.C. + 3.45075	Binary fraction
29	2	Same as 102 at I.C. + 6.90150	Binary fraction
31	2	Same as 102 at I.C. + 10.35225	Binary fraction
33	2	Same as 102 at I.C. + 13.80300	Binary fraction
35	2	Altitude (N.M./32) at time of 102	Binary
37	16	8 Values of Alt. at the times of Items 103-110, respectively	Binary, 2 bytes per value
53	2	Vehicle Roll at Image Center Time (Rad.)	Binary fraction
55	2	Vehicle Pitch at I.C. (Rad)	Binary fraction
57	2	Vehicle Yaw at I.C. (Rad)	Binary fraction
59	2	Roll at Time of Item 102 (Rad)	Binary fraction
61	16	8 Values of Roll at the times of Items 103-110, respectively	Binary fraction, 2 bytes per value
77	2	Pitch at time of Item 102 (Rad)	Binary fraction
79	16	8 Values of Pitch at the times of Items 103-110, respectively	Binary fraction, 2 bytes per value
95	2	Yaw at Time of Item 102 (Rad)	Binary fraction
97	16	8 Values of Yaw at the Times of Items 102-110, respectively	Binary fraction, 2 bytes per value
118	2	Image Skew (Rad)	Binary fraction
115	2	Normalized Velcoity Change	Binary fraction
117	4	Mean Pitch (10^{-6} Rad)	Binary
121	4	Mean Roll (10^{-6} Rad)	Binary
125	4	Mean Yaw (10^{-6} Rad)	Binary
129	4	Mean Pitch Rate (10^{-6} Rad/Sec)	Binary

Table 4-6F. SIAT Data File Records; Record 6 - MSS Computational Data (Continued)

Starting Byte No. and Length (Bytes)		Information	Format
133	4	Mean Roll Rate (10^{-6} Rad/Sec)	Binary
137	4	Mean Yaw Rate (10^{-6} Rad/Sec)	Binary
141	4	Mean Altitude (meters)	Binary
145	4	Mean Altitude Rate (Meters/Sec)	Binary
149	4	GMT Milliseconds of Day at ICT - 25 sec	Binary
153	4	GMT Milliseconds of Day at ICT - 25 sec	
157	4	GMT Milliseconds of Day at ICT - 15 sec	Binary
161	4	GMT Milliseconds of Day at ICT - 10 sec	Binary
165	4	GMT Milliseconds of Day at ICT - 5 sec	Binary
169	4	GMT Milliseconds of Day at ICT	Binary
173	4	GMT Milliseconds of Day at ICT + 5 sec	Binary
177	4	GMT Milliseconds of Day at ICT + 10 sec	Binary
181	4	GMT Milliseconds of Day at ICT + 15 sec	Binary
185	4	GMT Milliseconds of Day at ICT + 20 sec	Binary
189	4	GMT Milliseconds of Day at ICT + 25 sec	Binary
193	44	Eleven Values of Nadir Latitude at Times of Items 160-170 (10^{-6} Rad)	Binary
237	44	Eleven Values of Nadir Longitude at Times of Items 160-170 (10^{-6} Rad)	Binary
281	44	Eleven Values of Altitude at Times of Items 160-170 (Meters)	Binary
324	Total Bytes		
Inter-Record GAP			

Table 4-6G. SIAT Data File Records; Record 7 - Image Location Data

Starting Byte No.	and Length (Bytes)	Information	Format
1	10	RBV, Top Edge, Tick Mark No. 1 Position and Annotation	Binary fraction and EBCDIC
11	50	5 More Tick Marks as Above for the Same Edge	↓
61	60	Same as Items 204 and 205 for the Left Edge	↓
121	60	Same as Above for the Right Edge	↓
181	60	Same as Above for the Bottom Edge	↓
241	240	Same as Items 204-208 for the MSS	
480 Total Bytes			
END OF FILE			



CARD COLUMN	CONTENT
1-2	CARD ID { VC TO INDICATE VARIABLE REQUEST; SC TO INDICATE STANDING REQUEST
3-6	USER ID-CONSISTING OF 4 ALPHANUMERIC CHARACTERS
7-10	PLATFORM ID-CONSITING OF OCTAL DIGITS RANGING FROM 6001-7750
11	SATELLITE ID, 1 FOR ERTS A, 2 FOR ERTS B
12-21	TIME CODE-REPRESENTING THE GREENWICH MEAN TIME WHEN THE PLATFORM TRANSMITTED THE DATA. THE FORMAT IS YDDDHHMMSS WHERE: Y = YEAR OF RECEPTION, LAST DIGIT OF YEAR RANGING FROM 1 TO 9; DDD = JULIAN DAY OF YEAR; HH = HOUR OF DAY; MM = MINUTES; SS = SECONDS
22	RECEIVING STATION ID WHERE: A = FAIRBANKS, ALASKA; G = GOLDSTONE, CALIFORNIA; N = GREENBELT, MARYLAND (NTTF)
23-24	ENCODED ERROR FLAG WHERE: 32 = INVALID RECEIVING STATION ID; 16 = INVALID PLATFORM ID; 8 = POOR PLATFORM QUALITY; 4 = INVALID TIME CODE; 2 = DUPLICATE MESSAGE; 1 = REDUNDANT MESSAGE; 0 = NO ERROR DETECTED. A SUMMED VALUE TO INDICATE ANY COMBINATION OF THE ABOVE; 63 = ALL OF THE ABOVE CONDITIONS EXIST

CARD COLUMN	CONTENT
25	MESSAGE QUALITY WHERE: 0 = LONG OR SHORT MESSAGE DEPENDING UPON SYNCHRONIZATION; 1-7 = TO INDICATE LOWEST TO HIGHEST QUALITY
26	DATA FORMAT FLAG WHERE: 0 = OCTAL DIGITS (22 COLUMNS); H = HEXIDECIMAL DIGITS (16 COLUMNS)
28 - 49	FOR OCTAL DIGITS,
34 - 49	FOR HEXADECIMAL DIGITS
51 - 72	QUALITY DIGITS (IF DESIRED) FOR OCTAL
57 - 72	QUALITY DIGITS (IF DESIRED) FOR HEXADECIMAL

NOTE: PRESENCE OF QUALITY BITS IS OPTIONAL, SUB ECT TO USER REQUEST
OCTAL DIGITS ARE GIVEN FOR 66 BITS WHERE LAST TWO BITS ARE ALWAYS ZERO.
OCTAL PLATFORM ID IS BASED ON 12 BIT SYNC/ID BIT PATTERN

Figure 4-20. DCS Data Card Format

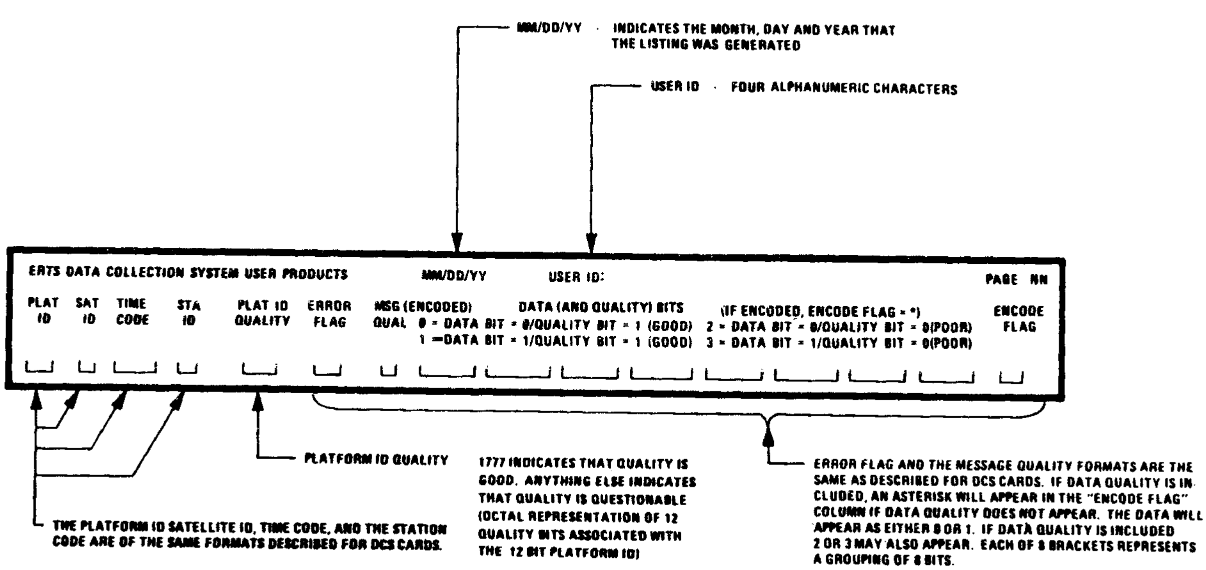
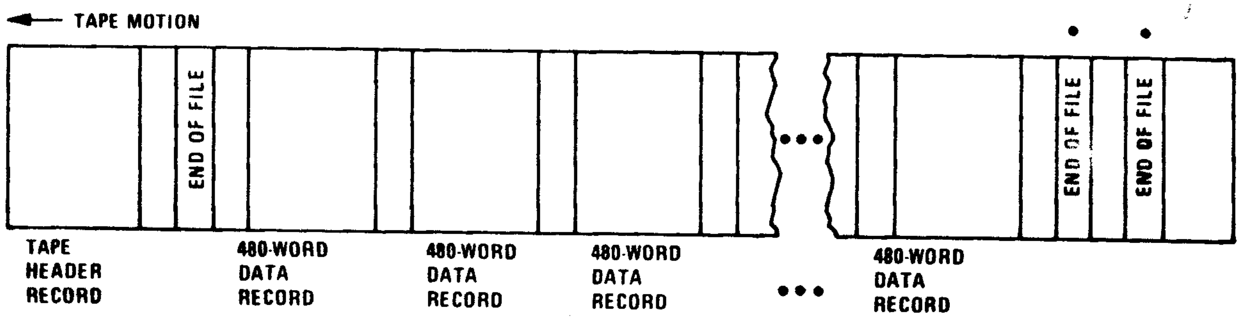


Figure 4-21. DCS Computer Listing Format



HEADER RECORD FORMAT: SEE BELOW
RECORDS CONSISTS OF 60 DATA BLOCKS (480 WORDS).
EACH DATA BLOCK CONSISTS OF ONE DATA TRANSMISSION (8 WORDS).
EACH DATA TRANSMISSION IS IN THE FORMAT SHOWN IN TABLE 3-6.

HEADER RECORD FORMAT:

STANDING REQUEST TAPE: STaDDDnnUUUUYY/MM/DD
VARIABLE REQUEST TAPE: VTaDDDnnUUUUYY/MM/DD

WHERE:

a	=	SATELLITE NUMBER (1 OR 2)
DDD	=	DAYS SINCE LAUNCH (OF TAPE GENERATION)
nn	=	SEQUENCE NUMBER (BINARY)
UUUU	=	USER ID
YY/MM/DD	=	DATE OF PROCESSING (STANDING ORDER) OR DATE OF REQUEST (VARIABLE REQUEST)

Figure 4-22. DCS Magnetic Tape Format

Table 4-7. DCS Data Transmission Format

Word	Bit	Item	Mode	Format
1	0-15	Platform ID	Binary	XXXX
	16-23	Satellite ID	EBCDIC	1 or 2
	24-31	Station ID	EBCDIC	A/G/N
2	0-15	Days (GMT)	Binary	1-366
	16-31	Days Since Launch	Binary	1-N
3	0-7	Hours (GMT)	Binary	0-23
	8-15	Minutes (GMT)	Binary	0-59
	16-23	Seconds (GMT)	Binary	0-59
	24-31	Year (GMT)	EBCDIC	0-9
4	0-5	Not Used	Binary	0
	6-15	Platform ID Quality	Binary	'3FF'
	16-17	Not Used	Binary	0
	18-23	Error Flags:		
		Invalid Station Code	Bit 18	(1=set)
		Invalid Platform ID	Bit 19	(1=set)
		Poor Platform ID Quality	Bit 20	(1=set)
		Invalid Time Code	Bit 21	(1=set)
		Duplicate Message	Bit 22	(1=set)
		Redundant Message	Bit 23	(1=set)
	24-28	Not Used		
	29-31	Message Quality	Binary	0-7
5	0-31	Data Bits	Binary	
6	0-31	Data Bits	Binary	
7	0-31	Quality Bits	Binary	
8	0-31	Quality Bits	Binary	

APPENDIX D
MSS COMPUTER COMPATIBLE TAPE

D.1 INTRODUCTION

MSS data are acquired at a real-time rate of approximately 600 kilobits/second per channel on an Ampex FR1928 multi-track recorder. Conventional computer systems and peripherals operate in the range of 0.25 to 1 megabit/second. Computer compatible tape (CCT) products must therefore be recorded at substantially lower bit rates. This is accomplished by means of an off-line process in order to maintain the IPF information handling capacity at the 600 kilobits/channel rate for the generation of photographic film products.

As a first step in the off-line process, the MSS data are reproduced at the 600 kilobit/channel rate, reformatted and recorded on a high density digital tape recorder (HDTR). The resulting high density digital tape (HDT) is then reproduced at a substantially lower tape speed to achieve the necessary bit-rate reduction for CCT generation. This HDT is the principal data input to the IPF Digital Subsystem that generates CCT products of selected MSS scenes for the user community.

In the original IPF configuration, MSS video tapes were reformatted and recorded on a Newell HDTR. This recorder and associated data reformatting equipment have been superseded by Ampex FR2014, 14-track recorders and new formatting and interface electronics that produce the exact equivalent of the Newell HDT. A block diagram of the previous and present configuration is illustrated in Figure D-1.

The Newell HDT format consists of four data tracks that are simultaneously accessible. In all, 16 tracks are available, four at a time. Each track, in a group of four, represents one spectral band of MSS data (for Landsat 1 and 2). Scan lines are in a sequential (series) format on each track. For Landsat-C, quarter scan lines of band 8 are interleaved after every three full scan lines in each track. The serial scan line format permits simultaneous

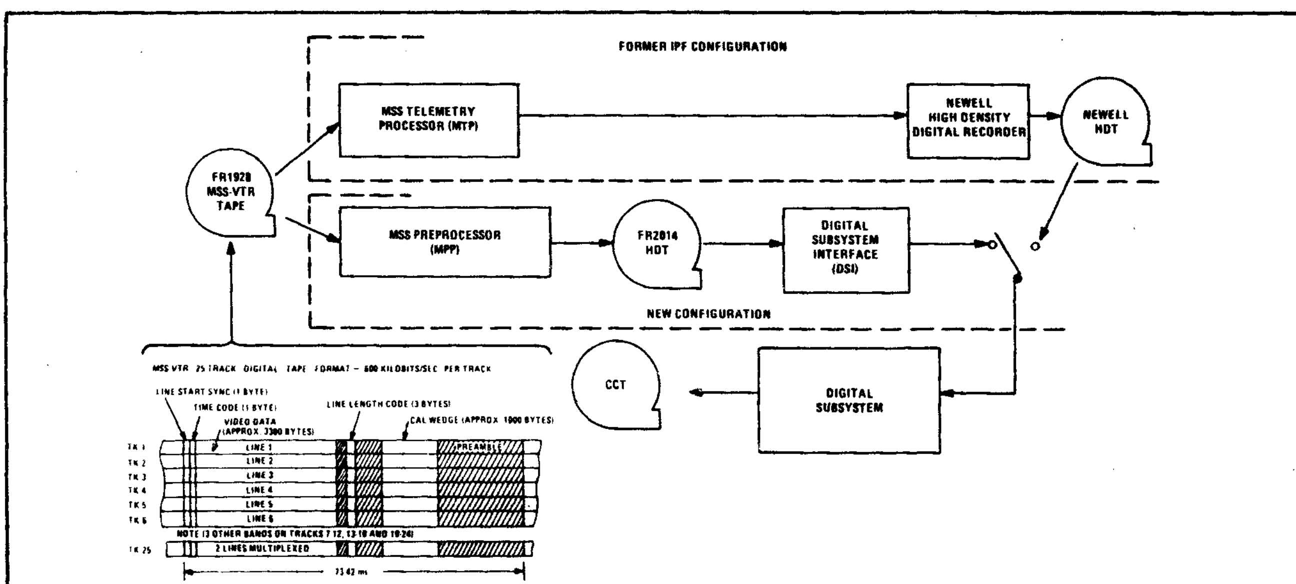


Figure D-1. Previous and Current Equipment Used to Produce Computer Compatible Tape Products access to picture elements in each of the four spectral bands as required to implement the spectral interleaving format of CCTs.

The Newell HDT format differs from the FR1928 format in a number of additional aspects. During the reformatting process, spacecraft time code is removed. In place of time code, a frame identification (Frame ID) is inserted at the beginning of each frame of data to uniquely identify the center point of the image and the time of imaging. Time code per se is no longer of interest because the "framing" of the MSS continuous strip image is performed in response to a specific user request. Each group of scan lines is also preceded by the appropriate six words of calibration coefficients and line length corrections prior to processing of the scan line data. All pixels remain encoded as six-bit bytes (whether acquired in compressed, linear, high or low gain modes). Decompression (if required), calibration and line length correction remain to be accomplished within the Digital Subsystem. As recorded, the HDT MSS data also retain the data as acquired with spatial misregistration.

The Digital Preprocessor Subsystem (DPPS), FR2014 recorders and Digital Subsystem Interface (DSI) produce an output to the Digital Subsystem identical to that produced by the Newell HDT; however, the DPPS permits extensive quality control and data screening not possible in the earlier subsystem. For example, detection of substandard scan line data automatically results in substitution of the previous scan line. "Quick-look" assessment of digital imagery is also provided by means of a cathode-ray tube display and storage tube for image retention. Although the DPPS removes spatial misregistration and retains time code for high speed tape search, the output signals from the DSI are again spatially deregistered and stripped of time code to match the Newell format.

D.2 NEWELL HDT FORMAT STRUCTURE

To assist in understanding the production of CCTs, the Newell HDT format, now simulated by the FR2014 recorder and DSI as seen by the Digital Subsystem, is described.

An MSS scene is defined as an area of 185.2 x 185.2 km (100 x 100 nm) represented by four spectral bands of video data for Landsat 1 and 2 and by five bands of data for Landsat-C. In digital terminology, spectral band and frame have become synonymous. The Newell HDT, or its equivalent, generally contains up to five scenes. Each spectral band or frame of the scene is made up of 390 successive spacecraft mirror sweeps. Each mirror sweep results in six scan lines of video per spectral band (Landsat 1 and 2). Therefore, each band or frame contains 2340 scan lines (390 x 6). For Landsat-C, bands 4, 5, 6 and 7 each contain 2340 scan lines. Band 8, using two detectors, is represented by two scan lines per mirror scan. Therefore, 780 scan lines of band 8 represent a 185.2 x 185.2 km area.

Previously, the spacecraft scan mirror frequency was stated to be 13.620 Hz/second. Nevertheless, the angular velocity of the mirror is subject to perturbations during the active scan period. This period was established by two angular position sensors that initiate and preempt detector sampling. The result is a slight variation in the number of bytes (samples or pixels) per scan line. Landsat 1 performance typically results in 3,216 ± 6 and Landsat 2 in 3,247 ± 5 bytes/scan line. The digital systems within the IPF can accommodate up to 3800 bytes per band 4 through 7 scan line.

For illustrative purposes, 3220 pixels (bytes or samples) will be chosen for use in the following HDT format discussion. Each band 8 detector, having one-third the resolution of band 4 through 7 detectors, will generate

1073 bytes per scan line. Band 8 data are to be added into each track of the four track HDT in the form of one quarter scan line (QSL) which will therefore be composed of 268 bytes. The digital equipment was designed to accept up to 300 bytes per QSL. Figures D-2A & D-2B show the encoding of one scan line of video data. If calibration data were acquired during the mirror scan that is associated with that scan line, six of the calibration wedge bytes precede the scan line. If no calibration was present, six bytes of all zeros are substituted (Landsat 1 and 2). It is important to appreciate that each video scan line was generated from a specific spacecraft detector. During prelaunch calibration, six bytes of calibration wedge data were uniquely selected for that detector. Therefore, the six bytes of calibration data preceding the scan line on the HDT are unique to that scan line (and subsequent scan lines derived from the same detector); however, when a defective scan line is replaced by the DPPS, incorrect calibration of that scan line will occur. Calibration bytes associated with band 8 are also listed as six bytes; however, only two levels corresponding to two temperatures, that of the cold (self-look) reference and the hot (shutter housing) reference, will be obtained.

Figure D-2A pertains to any scan line in bands 4 through 7 of Landsat 1 or 2. Figure D-2B details the format for a band 8 scan line.

The complexity of the scan line format can be explained as follows: Preamble A is present to permit byte synchronization prior to acquisition of line synchronization (LS). Line synchronizations 1, 2 and 3 establish that calibration data are about to be presented followed by line length code LLC. Gap A provides a time period during which computations can be performed to arrive at radiometric calibration gain and offset coefficients as well as a computation of the number of bytes to be permitted in the next scan line to be processed. Preamble B again establishes byte synchronization and LS 1, 2 and 3 are precursors of data. Using the value of 3220 bytes per scan line and the maximum design value of 3600 picture elements, there will be 3220 bytes of video followed by 380 bytes of fill code. (In practice, the number of bytes per scan line on the HDT is a variable that is to be subsequently given a fixed value during CCT generation). The 3600 bytes of video and fill code are followed by an End of Line

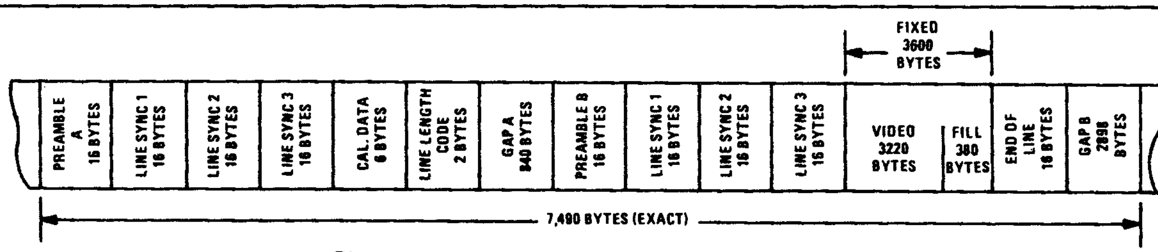


Figure D-2A. Bands 4, 5, 6 & 7 Scan Line Format

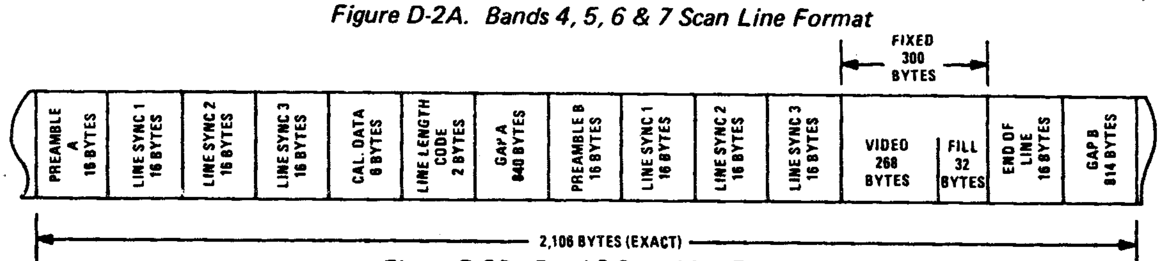


Figure D-2B. Band 8 Scan Line Format

PREAMBLE A: 001010
LINE SYNC 1: 100001
LINE SYNC 2: 110111
LINE SYNC 3: 000100

CAL. DATA: 6 BIT BYTES
LINE LENGTH CODE: 6-BIT BYTES
GAP A: 101010
PREAMBLE B: 001101

VIDEO: 6-BIT BYTES
FILL: 011110
END OF LINE: 011110
GAP B: 101010

Figure D-2. MSS Scan Line Format on HDT

Code (ELC). Gap B, 2898 bytes of 101010 permits retention of byte synchronization prior to receipt of the next Preamble A. For Landsat 1 and 2 the total number of bytes per scan line, with necessary computer synchronizing codes and gaps, amounts to 7490 bytes/track (where four tracks represent the four spectral bands). For Landsat-C, band 8 video is multiplexed into the four data tracks. After every three full scan lines (bands 4 through 7), a quarter scan line of band 8 video is inserted. Because the resolution of the band 8 detectors is one-third that of detectors in bands 4 through 7, approximately 1073 samples (per detector) were acquired during one mirror scan. A QSL therefore contains about 268 bytes. These 268 bytes of video are followed by 32 bytes of fill. Again, the number of actual video bytes will vary with mirror velocity, as indicated by the line length code and will be set to a fixed value/mirror scan during CCT generation. Detector A and detector B video for band 8 are alternated. That is, the first QSL will represent detector A data. After three full scan lines of bands 4 through 7 data, a QSL of detector B data in the format shown in Figure D-2B will be present. Each QSL of band 8 format will contain exactly 2106 bytes.

The four HDT data tracks are depicted in Figure D-3. Misregistration of the video data between spectral bands still exists but is not illustrated.

Figure D-4 depicts the HDT scene format. Each scene is preceded by a scene gap code that establishes synchronization of the computer at the bit level. Scene synchronization establishes synchronization at the byte level. Scene ID identifies the image in terms of the time of acquisition measured from the day of spacecraft launch, in days since launch, hours, minutes and seconds; the spacecraft is also identified.

The 185.2 x 185.2 kilometer scene required 390 spacecraft mirror scans. Each mirror scan generated six scan lines in each of the four spectral bands, bands 4 through 7. Each of these scan lines is encoded as 7490 bytes. In band 8, two scan lines are produced per mirror scan. One quarter scan line is encoded as 2106 bytes. Therefore one track of video data on the HDT contains (390 x 6 x 7490 + 390 x 2 x 2106) = 19,169,280 bytes (exactly).

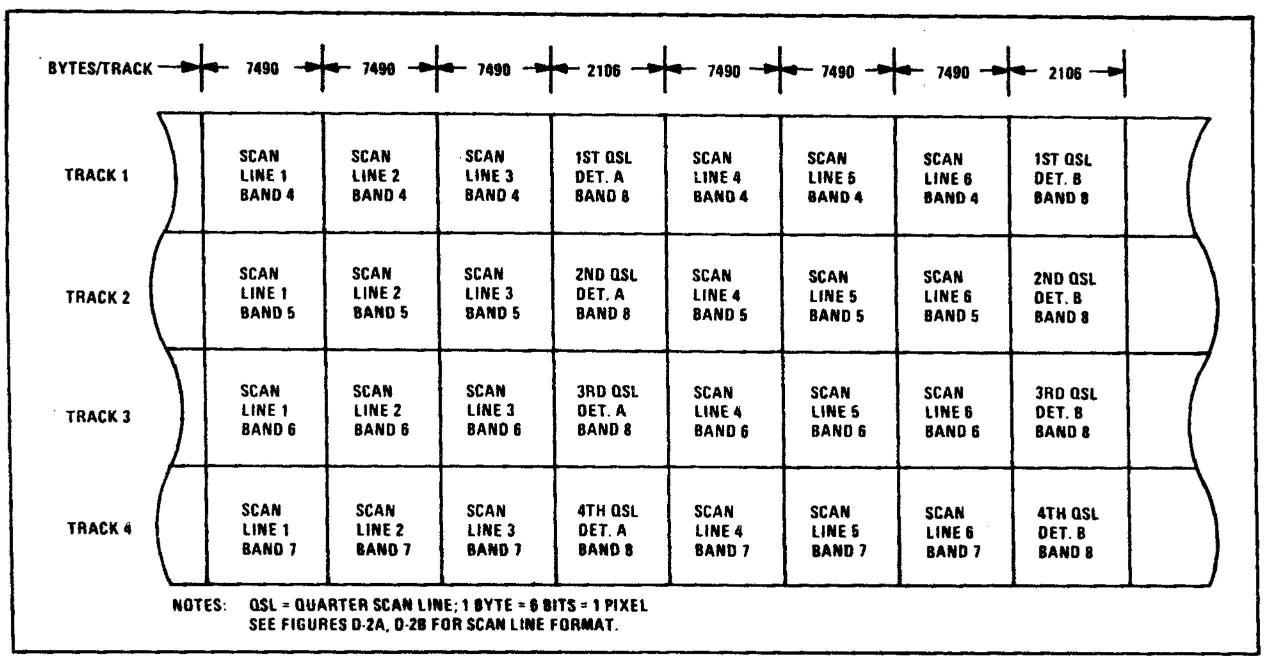


Figure D-3. Newell MSS HDT Format

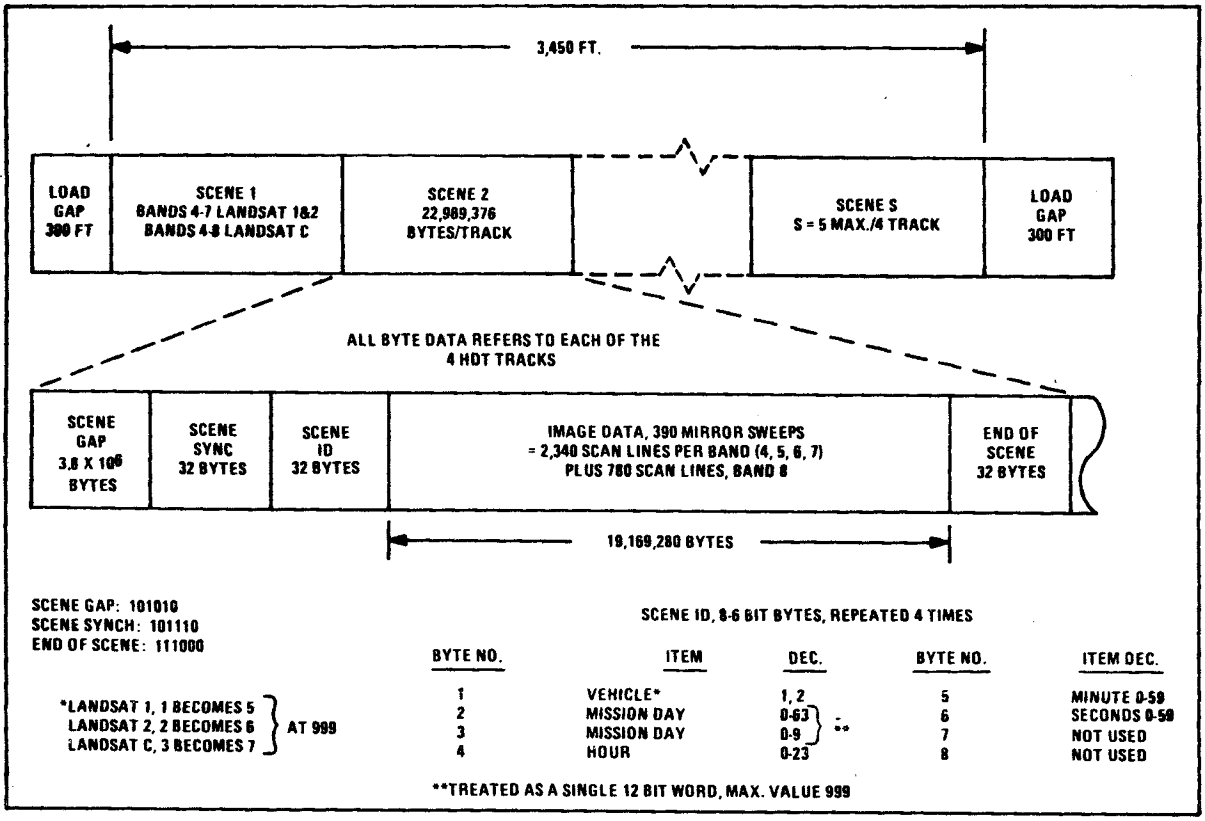


Figure D-4. MSS HDT Scene Format

The next step in CCT production is to use the HDT, or its equivalent, as the input to the Digital Subsystem with a playback tape speed such that the bit rate/track will be nominally 250,000 bits/second.

D.3 DIGITAL SUBSYSTEM

The Digital Subsystem processes selected MSS scene data into computer compatible tape (CCT) form. The MSS data input is either the Newell HDT or its equivalent from the MSS preprocessor (MPP) FR2014 as modified to the Newell format by the Digital Subsystem Interface Unit. Input bit rate is 250,000 bits/second/track, which is accomplished by reducing tape playback speed relative to recording speed.

The Digital Subsystem accomplishes the following:

1. Band-to-band spatial registration
2. Line length correction
3. Data decompression (if required) and subsequent radiometric correction
4. Interleaving of the spectral data
5. Annotation of each tape
6. Detection and printout of processing errors for CCT quality control

A block diagram of the Digital Subsystem is shown in Figure D-5. In addition to the MSS video input, other inputs include an auxiliary paper tape, punched cards, teletype instructions and an eight-track image annotation tape. Output consists of four computer compatible tapes per four-band input scene. Each output tape represents a 25 x 100 nautical mile area of the imaged scene and contains all spectral data associated with that image segment.

The auxiliary paper tape informs the Digital Subsystem of the number of bytes in the longest scan line in each scene to be process-

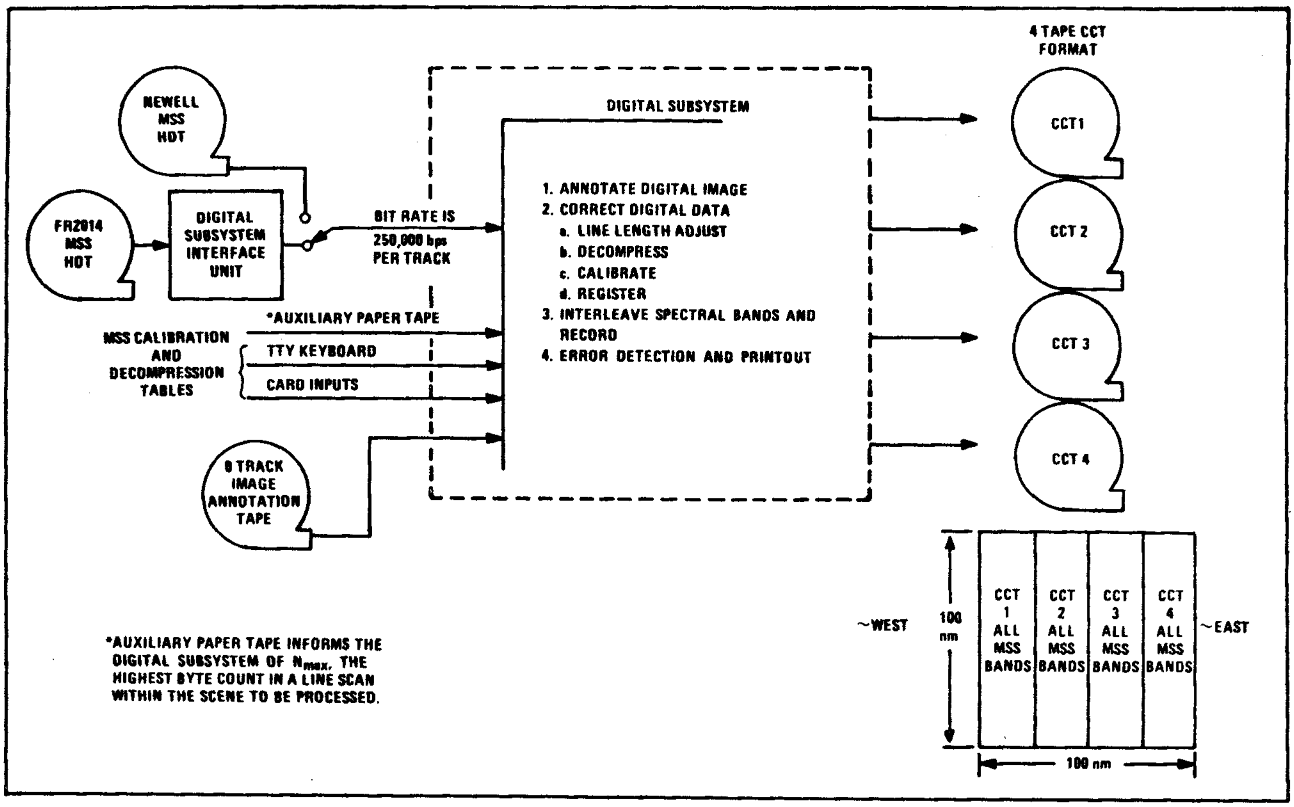


Figure D-5. Overview of Digital Subsystem

ed. Actual line length of each scan line is encoded on the HDT.

The teletype permits error printouts as well as being the means of entering non-standard processing instructions. Both the teletype and punched card input can be used to load the subsystem with prelaunch and/or modified sensor calibration data.

The first step in processing the data is to extract calibration wedge and line length codes so that these data precede the scan line data to which they are to be applied.

D.3.1 Band-to-Band Spatial Registration

As previously described with regard to MSS sensor sampling, there is a two byte delay between data in adjacent spectral bands. Consequently, band 4 data precede band 7 data by six bytes. Registration is re-established by inserting dummy bytes at the beginning and end of the scan line as illustrated in Figure D-6.

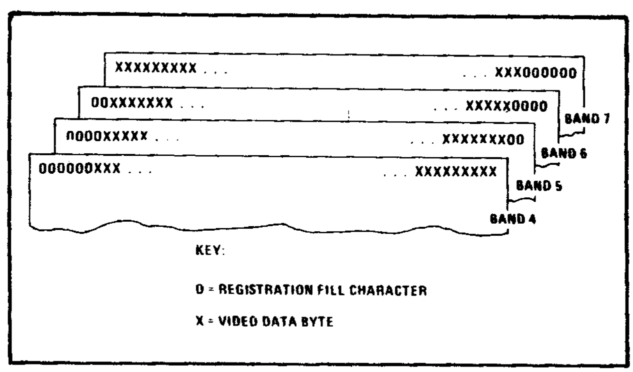


Figure D-6. Position of Registration Fill Characters in Spectral Bands

D.3.2 Line Length Correction

Line length correction is applied to each MSS scene as it is processed. During previous processing of the scene by the Initial Image Generation Subsystem, a determination was made of the greatest number of bytes associated with a scene scan line. This number, N_{max}, which is supplied by the auxiliary paper tape input, is used as follows:

N_{max} = Number of bytes in the longest scan line
LLC = Number of bytes in the scan line to be processed
CLL = Corrected line length

The corrected line length must be a multiple of eight because the output CCT format contains two bytes each from bands 4 through 7 interleaved as eight-byte groups. The CLL must also be a multiple of three because band 8 data have one-third the resolution of bands 4 through 7 data, and a quarter scan line of band 8 data is to be multiplexed into the output tape after every three full scan lines of bands 4 through 7 interleaved data (across four tapes). Therefore the CLL must be a multiple of 24.

After insertion of six dummy bytes, to restore band-to-band registration, the number of bytes in the longest scan line is $N_{max} + 6$.

The CLL is expressed as 24 times the largest integer in

$$\frac{N_{max} + 6 + (23)}{24}$$

where 23/24 provides high roundoff.

The correction to the individual scan lines is accomplished by the addition of synthetic video bytes at regular intervals within a line. The interval between bytes is the integer value of

$$\Delta = \frac{LLC}{CLL - (LLC + 6)}$$

The initial deltas must be adjusted to maintain spectral registration. Let

$$\Delta_b = 14 - 2b$$

where b is the spectral band number (4, 5, 6 or 7). Then

$$\Delta_{initial} = \Delta - \Delta_b$$

The synthetic byte is inserted by repeating the preceding byte. Because the byte count, as determined by the mirror period, remains constant over many months, comparisons of multi-temporal data in user change detection processing will seldom if ever exhibit the presence of synthetic bytes.

D.3.3 Decompression

If data are acquired in the compressed mode, the inverse of the spacecraft compression is applied to both video and calibration wedge signals before calibration. Regardless of whether the data were acquired in linear or compressed form, one byte contains six bits. Decompression is accomplished in the Digital Subsystem computer by means of a table look-up routine. The input byte, value 0-63, is output as 0-127. Two decompression tables are employed. One table serves band 4 and 6 data. The second table serves band 5. Both bands 7 and 8 are acquired linearly and do not require decompression.

To permit interleaving of spectral data, as eight-bit binary words, linear and decompressed data are represented as indicated below.

LINEAR

o	o	x	x	x	x	x	x
1	2	3	4	5	6	7	8

DECOMPRESSED

o	x	x	x	x	x	x	x
1	2	3	4	5	6	7	8

THE X'S REPRESENT THE VIDEO DATA BITS IN THE WORD. THE BITS IN THE DIAGRAM WHICH CONTAIN THE O'S ARE USED TO INDICATE FLAGS (E.G., 11111111 IS USED AS THE REGISTRATION FILL CHARACTER).

D.3.4 Calibration

From preflight calibration tests, during which the MSS detectors were used as transfer devices between a standard radiance source and the MSS internal calibration lamp, the radiance at selected calibration word counts and the maximum radiance to be assigned to each spectral band were determined. R_{cwi} is the internal calibration lamp radiance as modified by the calibration wedge at word count "i". R_{max} is the maximum radiance assigned to a specific spectral band and that value of radiance produces a digital count of 63 for linearly acquired data and a digital count of 127 for decompressed data.

The "best fit" straight line relating relative radiance R_{cwi}/R_{max}, at calibration wedge word "i" is determined by a six point regression analysis for each detector.

$$V_{cwi} = a + b \frac{R_{cwi}}{R_{max}}$$

$$b = \sum_{i=1}^{6} D_i V_{cwi} \text{ (gain coefficient)}$$

$$a = \sum_{i=1}^{6} C_i V_{cwi} \text{ (offset coefficient)}$$

where

$$D_i = \frac{6 \frac{R_{cwi}}{R_{max}} - \sum_{i=1}^{6} \frac{R_{cwi}}{R_{max}}}{6 \sum_{i=1}^{6} \left(\frac{R_{cwi}}{R_{max}}\right)^2 - \sum_{i=1}^{6} \left(\frac{R_{cwi}}{R_{max}}\right)^2}$$

$$C_i = \frac{\sum_{i=1}^{6} \left(\frac{R_{cwi}}{R_{max}}\right)^2 - \frac{R_{cwi}}{R_{max}} \sum_{i=1}^{6} \frac{R_{cwi}}{R_{max}}}{6 \sum_{i=1}^{6} \left(\frac{R_{cwi}}{R_{max}}\right)^2 - \left(\sum_{i=1}^{6} \frac{R_{cwi}}{R_{max}}\right)^2}$$

Note that D_i and C_i are solely dependent on prelaunch determined radiance values. The C_i and D_i values can therefore be calculated and stored in table look-up form. For each of the 24 detectors there are six pairs of C_i and D_i values.

Due to the presence of noise on received calibration voltage values, the values of "a" and "b" are smoothed according to the following equations. "n" is the number of the estimate and corresponds to the number of calibration wedges that have been processed to the current position in the scene.

$\hat{a}_s(1) = a(1)$ = value of "a" computed from the first calibration wedge data encountered at scene processing initiation (n = 1).

$$\hat{a}_s(n) = \hat{a}_s(n-1) + 1/n \left[a(n) - \hat{a}_s(n-1) \right]$$
for $1 < n \leqslant 16$

$$\hat{a}_s(n) = \hat{a}_s(n-1) + 1/16 \left[a(n) - \hat{a}_s(n-1) \right]$$
for $16 < n \leqslant 195$ (calibration wedges)

where $\hat{a}_s(n)$ = n th estimate of "a"

$a(n)$ = calculation of "a" based solely on the n th set of calibration data received.

Up to and including n = 16, the successive values of $\hat{a}_s$ are the average of all the computed values of a(n). That is

$$\hat{a}_s(n) = \frac{a(1) + a(2) + \ldots + a(n),\ n \leqslant 16}{n}$$

Similarly,

$\hat{b}_s(1) = b(1)$ = value of "b" computed encountered at scene processing initiation.

$$\hat{b}_s(n) = \hat{b}_s(n-1) + \frac{1}{n}\,[b(n) - \hat{b}_s(n-1)]$$

for $1 < n \leqslant 16$

$$\hat{b}_s(n) = \hat{b}_s(n-1) + 1/16\,[b(n) - \hat{b}_s(n-1)]$$

for $n \geqslant 16$

The best fit straight line is now expressed as

$$V_{cwi} = \left[\hat{a}_s(n) + \hat{b}_s(n)\frac{R_{cwi}}{R_{max}}\right]$$

Note that the values of $\hat{a}_s(n)$ and $\hat{b}_s(n)$ are constant if the calibration wedge voltages are absolutely constant. In practice, the presence of noise on the V_{cwi} will result in considerable variation in $\hat{a}_s(n)$ and $\hat{b}_s(n)$ until the filter has averaged over many V_{cwi} inputs. Therefore, one should not expect that radiometric corrections at the beginning of a scene will be similar to those in later portions of the scene. Whenever HDT processing is initialized, this effect will be observed. Adjacent scenes in the same orbit can exhibit this effect in start-up and overlap regions if processing of the southernmost scene required a change in input HDT.

The relation between V_{cwi} and R_{cwi}/R_{max} allows correction of actual scene data. Assuming linear system operation,

$$R_{cwi} = \frac{R_{max}}{\hat{b}_s(n)}\left[V_{cwi} - \hat{a}_s(n)\right]$$

or for scene radiance values R,

$$R = \frac{R_{max}}{\hat{b}_s(n)}\left[V_r - \hat{a}_s(n)\right]$$

where V_r is received scene voltage. The correct value of V_r, V_c, that should have been received in response to scene radiance R, is

$$V_c = K_o\frac{R}{R_{max}}$$

K_o = 63 for linearly acquired data and 127 for compressed data. Then

$$R = \frac{V_c\,R_{max}}{K_o}$$

Equating the two values of R

$$\frac{V_c\,R_{max}}{K_o} = \frac{R_{max}}{\hat{b}_s(n)}\left[V_r - \hat{a}_s(n)\right]$$

from which

$$V_c = \frac{K_o}{\hat{b}_s(n)}\left[V_r - \hat{a}_s(n)\right]$$

The Digital Subsystem performs the above correction on the output of each detector. If detector-to-detector striping is present, the C_i and D_i values must be slightly altered from the preflight calibration values.

D.3.5 Sun Calibration

Up to this point in the calibration process, it has been assumed that the internal MSS calibration lamp emits constant radiance for the life of the spacecraft. In practice, lamp radiance is likely to exhibit a long term drift. Provision has been made to monitor calibration lamp versus sun radiance on a once per orbit basis. In this technique, an image of the sun is recorded and the resulting detector voltages are observed. Any overall drift in detector voltages may be attributed to changes in internal calibration lamp radiance. The drift can be accommodated by altering the scale factor for scene voltage correction.

$$V_c = \frac{K_s\,K_o}{\hat{b}_s(n)}\left[V_r - \hat{a}_s(n)\right]$$

where K_s is computed from the sun calibration process. On Landsat 1, reliable sun calibration data could not be obtained because the sun imaging optics were apparently fogged by contaminants released from nearby spacecraft components. The problem was rectified on Landsat 2. Operational use of sun calibration data is anticipated for Landsat-C and may yet be activated on Landsat 2. For the present, $K_s = 1$.

D.4 FINAL PROCESSING STEPS TO CCT

The final steps in Landsat video to CCT processing are spectral interleaving, separating the resulting data streams into four adjacent geographical strips and producing the four CCTs. Each Landsat scene consists of 2340 scan lines containing an equal number of bytes. At the output of the Digital Subsystem, all video and calibration data are in eight-bit/byte form. Spectral interleaving is accomplished by selecting two successive bytes from each of the four spectral bands and forming an eight-byte serial group. This group then contains all of the spectral information associated with two adjacent scene picture elements (pixels). Interleaving is illustrated in Figure D-7 for any scan line "k". "m" is the group "G" index and the pixels associated with the group are numbers 2m-1 and 2m, from scan line "k".

Figure D-8 illustrates the CCT format for scan line "k" and the incorporation of calibration data associated with scan line "k" in the four bands. The interleaved data is quartered and one quarter is placed on each of the CCTs. The total number of video bytes in scan line "k" is 24n. Interleaving the four bands results in 4 x 24n bytes associated with scene scan line "k". Since eight bytes form a group, the number of groups is $\frac{4 \times 24n}{8}$. The number of groups associated with a quarter scan line

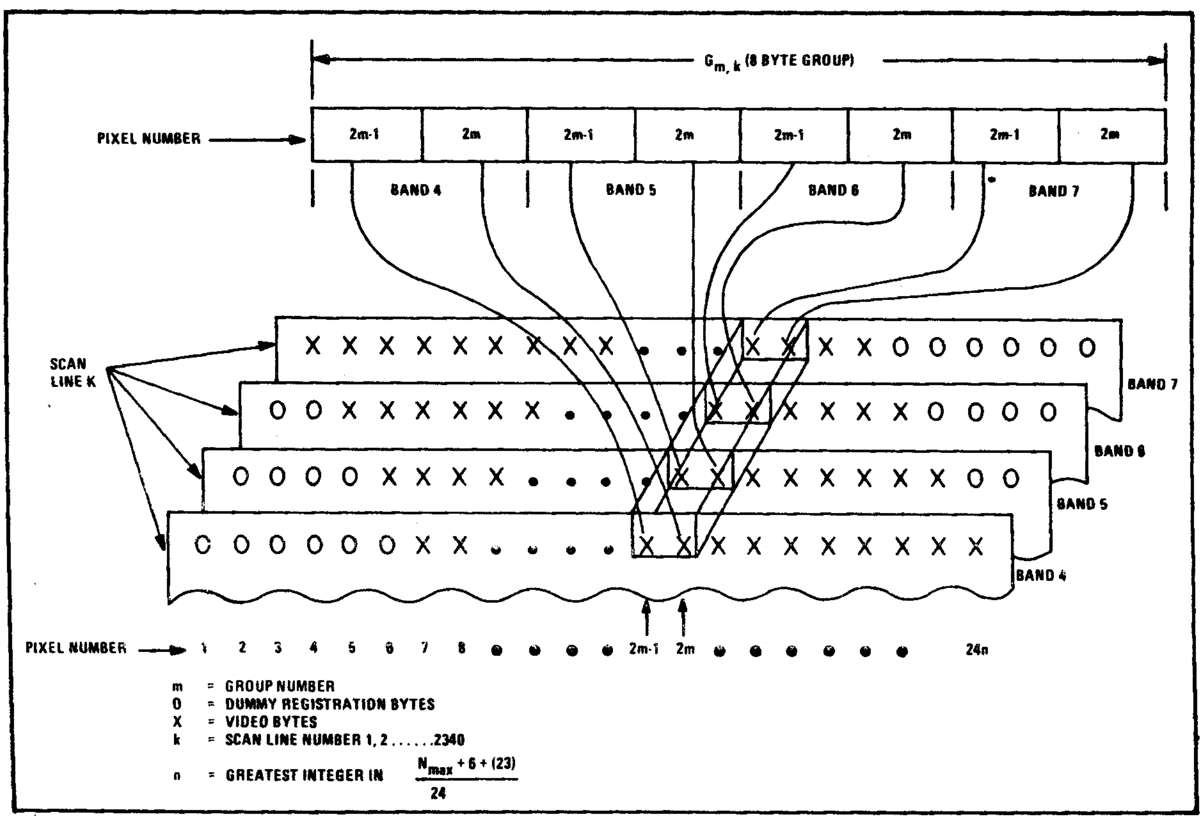


Figure D-7. Four-Band MSS Scan-to-Interleaved Byte Conversion

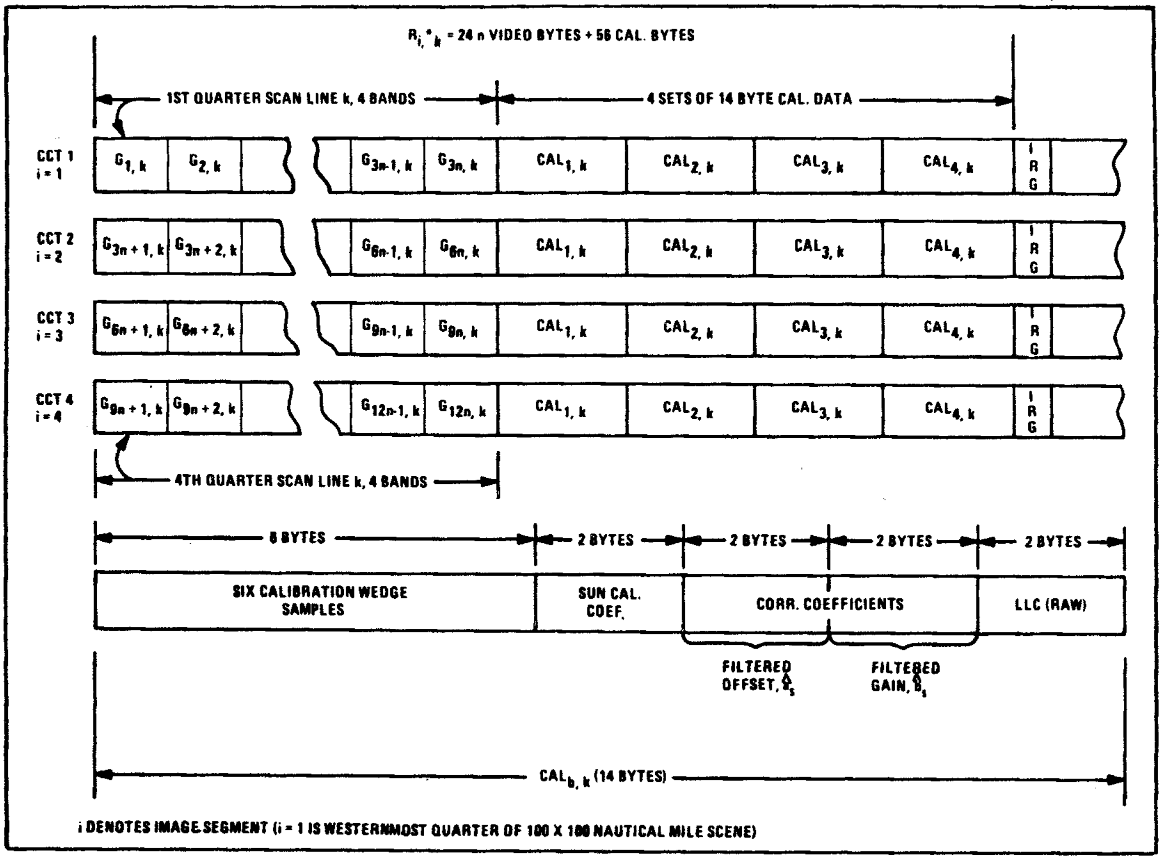


Figure D-8. MSS Full Scene Interleaved Record Format

is then 3n. CCT number 1 contains groups 1 through 3n. CCT number 2 contains groups 3n + 1 through 6n, etc. All of these groups are associated with scan line "k". Continuing this process for all scan lines results in the western-most 25 nautical mile north-to-south image segment being represented by CCT number 1. CCT number 4 represents the eastern-most 25 nautical mile strip. Strip length extends 100 nautical miles north and south.

The quarter scan line of four-band spectrally interleaved data plus four-band calibration data contains 24n video bytes and 56 calibration bytes. This data string is designated as a tape record $R_{i,k}$. "i" denotes the image segment (same as CCT number) and "k" designates the scan line number. Every record is separated from every other record by an inter-record gap (IRG).

D.5 ADDITION OF BAND 8 TO THE CCT FORMAT

Band 8 video and calibration are spatially registered and added as independent records. They are not spectrally interleaved with band 4 through 7 data. In a complete MSS scene of 390 mirror sweeps, 780 scan lines of band 8, 390 for detector A and 390 for detector B, are generated. These scan lines are adjusted to 24n - 3 = 8n video byte lengths. One quarter scan line, or 2n bytes, is added to each CCT after every three quarter-scan lines of interleaved spectral data from bands 4, 5, 6 and 7. The first band 8 record is from detector A. After three quarter-scan lines of interleaved spectral data from bands 4, 5, 6 and 7, a second band 8 record, representing the output of detector B, is added. Each band 8 record consists of 2n bytes of video plus 14 bytes of calibration data per CCT.

Format of the calibration data is the same as for the other bands; however, it is expected that there will be only two calibration word values repeated three times to fill the 6 bytes allocated for six calibration words. A typical band 8 record, either detector A or B, is illustrated in Figure D-9. "k" is the scan line. $S_{8k1} \ldots S_{8k2n}$ are the individual video bytes constituting one quarter of scan line "k".

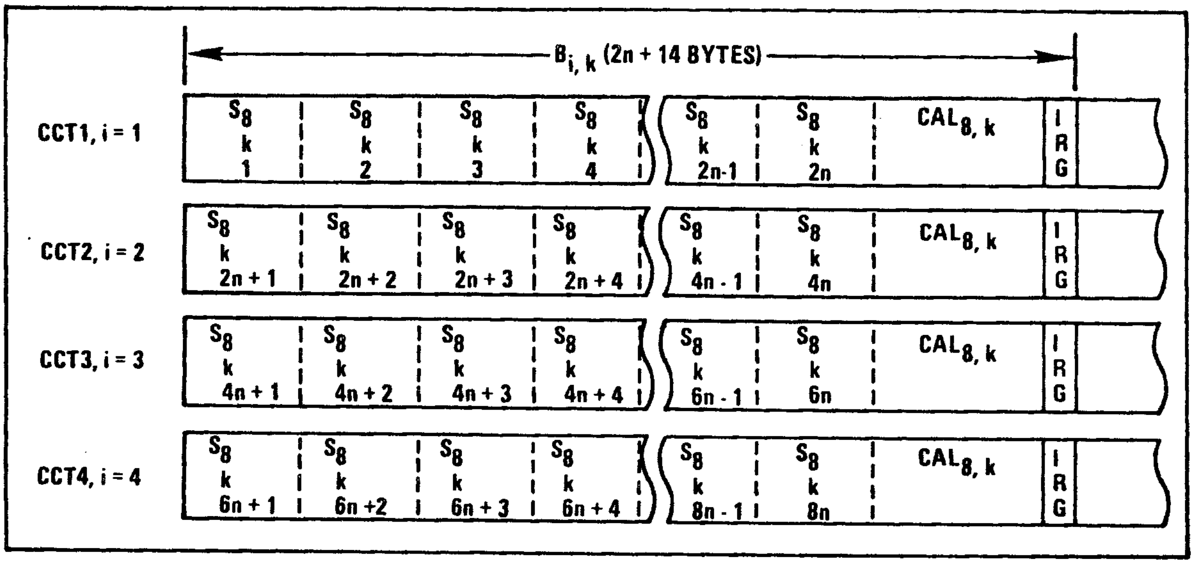


Figure D-9. Band 8 Format as Inserted Into the CCT Format

APPENDIX C

LARSYS MULTISPECTRAL

IMAGE TAPE FORMAT

Excerpt From LARSYS System Manual

MULTISPECTRAL IMAGE STORAGE TAPE (DSRN 11,12)

The format of this tape requires that each data run be completely identified, and that each data sample be stored as an eight-bit integer. This permits sample data values stored on the tape to range between 0 and 255. The data samples and calibration measurements from all channels for each scan line, along with the line number, are stored in a data record. The linear calibration procedure used in LARSYS can be used to restore the tape data values back to the irradiance. (Refer to Appendix IV of the LARSYS User's Manual for details on calibration.)

The file is often positioned for use through the TAPOP module. GETRUN (which uses TAPOP) positions the tape to the correct file and always reads the identification information.

GADLIN, also using TAPOP, is then used to read the data record for each line and to calibrate the data. GETRUN and GADLIN are used by 11 of the 18 LARSYS Processing Functions.

There are four types of physical records on the tape. They are:

1. ID record - 200 fullwords, fixed length
2. Data record - variable length
3. End-of-Tape record - 200 fullwords, fixed length
4. End-of-File mark - IBM Standard

A single tape may contain one or more data runs, each of which consists of an ID record, multiple data records and an End-of-File

Mark (a special record written by the I/O control software, which indicates end of file). After the last data run on the tape, a single End-of-Tape record and two End-of-File Marks are written. The physical tape format is IBM 9-track standard with 1600 bits per inch density. No system tape leaders or trailers are used.

Figure 5-1, on the following page, graphically illustrates the format of the tape, at the top of the figure, the overall tape containing several runs (files) is depicted. The format for the data of an entire run, a single line, and a single channel of a line are shown in three successive "exploded" views as the reader proceeds down the figure. Each "exploded" area is shaded on the figure. This figure should be referenced in conjunction with the descriptions of all of the individual fields. Note that the notation ID(n) is used on the figure to reference the nth word in the ID record. For purposes of this presentation, a word is defined to be 32 bits and a byte to be 8 bits; a record refers to a physical tape block followed by an inter-record gap.

Excerpt From LARSYS System Manual

1. ID record (200 fullwords, fixed length)

The run identification record is the first record of each data run (and thus, the first record of a multi-spectral image storage tape is always an ID record). The ID record contains parameters required by the LARSYS processors and information of value to data analysts. The ID record is a fixed length record of 200 32-bit words with the following definitions:

WORD	FORMAT	DESCRIPTION
ID(1)	INTEGER	LARS Tape Number (e.g., 102, etc.)
ID(2)	INTEGER	Number of the file on this tape
ID(3)	INTEGER	Run number (8 digits aabbbbcc) aa - last 2 digits of the year bbbb - serial number for the year data was taken cc - uniqueness digits for runs which would otherwise have the same number
ID(4)	INTEGER	Continuation Code A value of 0 means the first line of data follows this ID record. A value of X means that the data following this ID record is a continuation of a flightline started on tape X.
ID(5)	INTEGER	Number of Data Channels (Spectral Bands) on tape (30 maximum)
ID(6)	INTEGER	Number of data samples per channel per line. This number includes the six calibration samples. Due to certain hardware constraints at LARS, the number of samples must be adjusted so that ID(6) is a multiple of 4.
ID(7-10)	EBCDIC	Flightline Identification (16 characters)
ID(11)	INTEGER	Month Data was Taken
ID(12)	INTEGER	Day Data was Taken
ID(13)	INTEGER	Year Data was Taken
ID(14)	EBCDIC	Time Data was Taken (Local, Military)

WORD	FORMAT	DESCRIPTION
ID(15)	INTEGER	Altitude of sensor platform
ID(16)	INTEGER	Ground Heading of sensor platform
ID(17-19)	INTEGER	Date Data Run was Generated on this Tape (12 characters MMMM DD, YYYY) MMMM - 4 letter month abbreviation DD - day YYYY - year
ID(20)	INTEGER	Number of Lines in this Run
ID(21-50)	INTEGER	All zero (to be defined later)
ID(51)	REAL	Lower Limit in Micrometers of the first Spectral Band on Tape
ID(52)	REAL	Upper Limit in Micrometers of the first Spectral Band on Tape
ID(53)	REAL	The suggested Value of "C_0" calibration pulse for the first spectral band
ID(54)	REAL	The suggested Value of "C_1" calibration pulse for the first spectral band
ID(55)	REAL	The suggested Value for "C_2" calibration pulse for the first spectral band
ID(56-200)	REAL	Repeat of words 51-55 for the number of channels shown in word 5, in order of appearance in Data Records. NOTE: words 51-200 All bits set to zero if data channels do not exist

Word formats: INTEGER words are 32 bit Two's complement signed binary numbers. EBCDIC indicates 8 bit characters, 4 characters per word in IBM 360/370 internal code. REAL format indicates IBM 360/370 floating point numeric representation.

2. Data Record

The data records for a run follow the run ID record and comprise the text of the data run. The number of data records following the ID record is specified in ID(20). Each data record is a physical record block on the tape

Excerpt From LARSYS System Manual

containing the data samples for the ID(5) (see ID record) channels of one scan line. The first half-word (bytes 1 & 2) of each data record contain the data record or scan line number where the first data record has number one. The second half-word (bytes 3 & 4) contain the remote sensing platform roll parameter indicating the relative position of the roll of the platform for this scan line of data. If the roll parameter is not known, it should be set to 32,767. Setting the roll parameter to -32,767 indicates that the data for the current line does not exist.

The fifth byte of the data record is the first data sample of the first channel; the sixth byte, the second sample from channel one and so on through ID(6) samples and ID(5) channels. Thus, byte 4 _ 2*ID(6) + 1 (in FORTRAN notation) is the first sample of channel three. A data record will be ID(5) * ID(6) + 4 bytes long. NOTE: since ID(6) must be a multiple of four, a data record will contain a multiple of 4 bytes. The scan lines appear on the tape in time sequence as they were collected by the sensor. Sample one of each channel is the right-most resolution element from the sensor field of view as the observer faces forward with respect to platform movement.

Each of the ID(6) data samples from each channel will be from the scanner's field of view except the last six bytes. The last six are the calibration values in this order of appearance:

1. C_0 "0" or dark level
2. VC_0 Variance of C_0
3. C_1 Calibration source C_1
4. VC_1 Variance of C_1
5. C_2 Calibration source C_2
6. VC_2 Variance of C_2

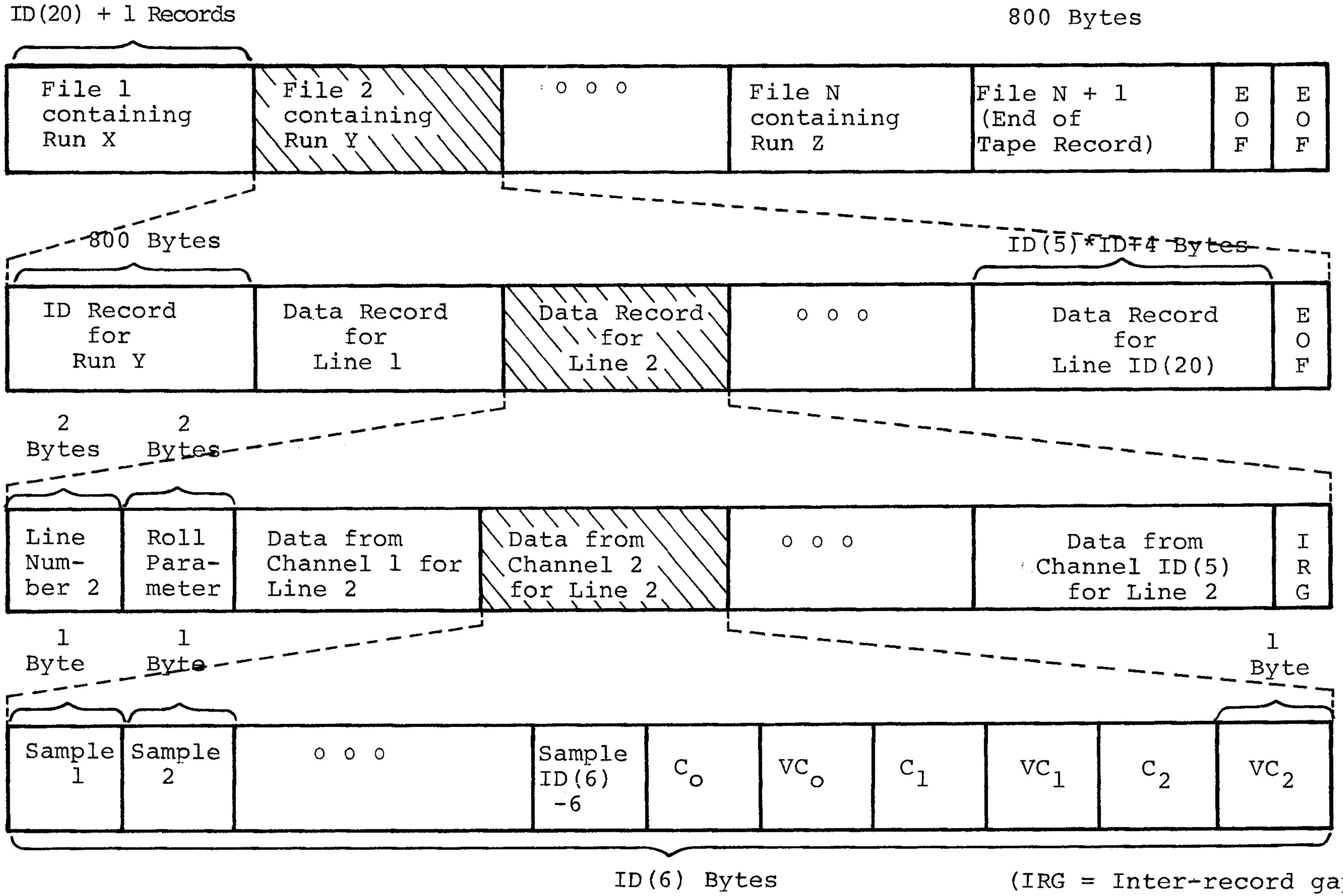
where C_i = value of calibration source i and VC_i - variance of samples used to calculate value of source i. During the calibration and reformatting process, a record may become invalid due to tape of other errors. When this occurs, the roll parameter is set to -32,767 and the six calibration samples of each channel are set to 0 for the bad record.

Data sample values are in the range 0 to 255 (8 bits) with no sign bit. Sensor sample values of 0 and 255 should be considered invalid due to number range saturation. Valid data values then range from 1 to 254 with 1 indicating low relative sensor response and 254 indicating high relative sensor response.

3. End-of-Tape Record

The End-of-Tape Record signifies that no more data runs are contained on the current Multispectral Image Storage Tape. It is positioned behind the End-of-File mark of the last LARSYS run on the tape. The End-of-Tape Record is very similar to the ID Record with 200 full words in the following format:

WORD	FORMAT	DESCRIPTION
1	INTEGER	LARS tape number
2	INTEGER	File number on this tape
3	INTEGER	Set equal to 0
4	INTEGER	Continuation Code A value of 0 means the end of data. A value of X means the data in the previous file is continued on tape X.
5-50	INTEGER	All zero (May be defined later)
51-200	REAL	0.0 (May be defined later)



(IRG = Inter-record gap)
(EOF = End of File Mark)

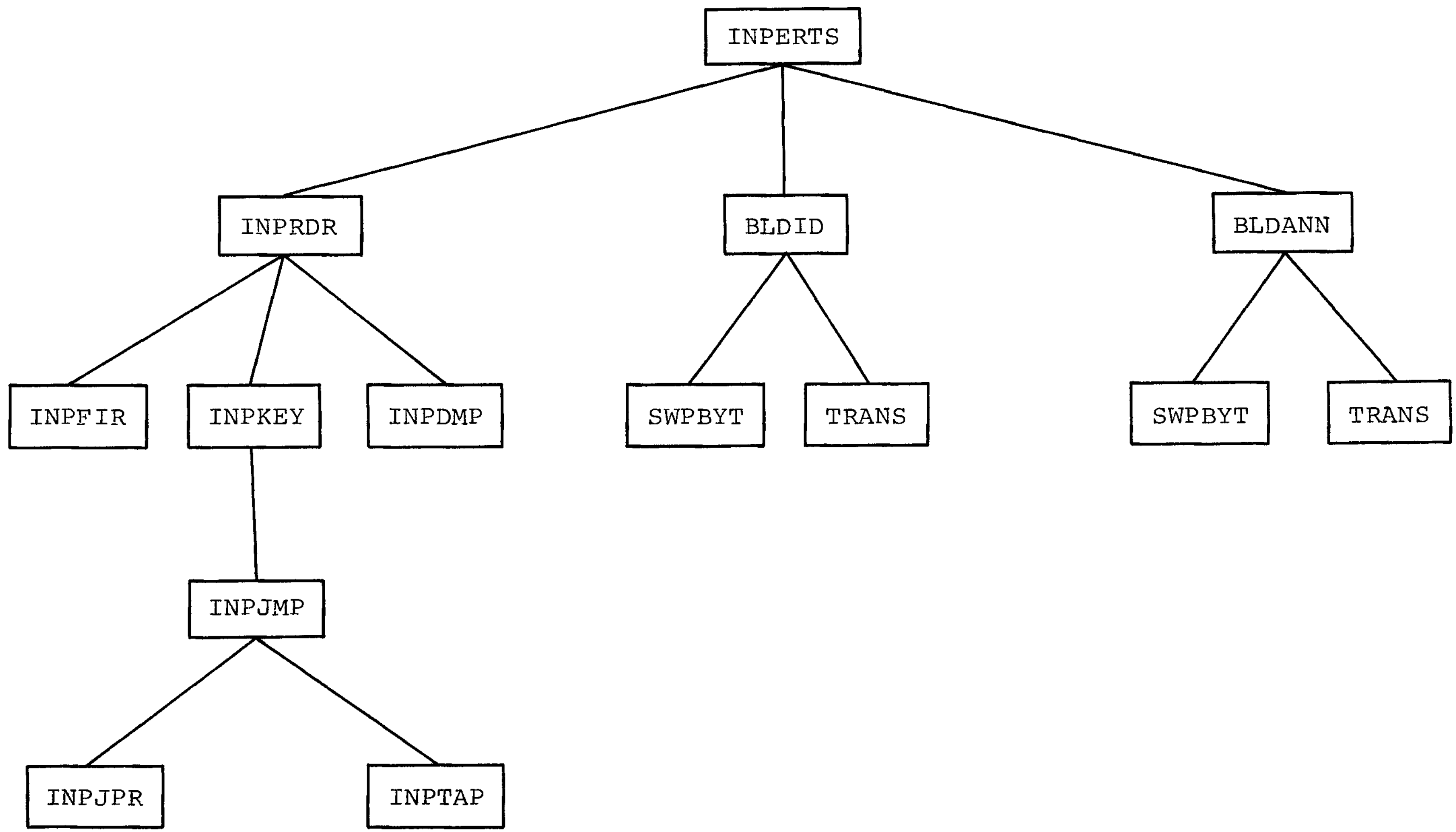
Figure 5.1 Multispectral Image Storage Tape Format
(Revised)

APPENDIX D

INPERTS PROGRAM CALLING SEQUENCE

INPERTS PROGRAM ABSTRACTS

INPERTS PROGRAM CALLING SEQUENCE



LARS Program Abstract ______

MODULE IDENTIFICATION

Module Name: INPERTS **Function Name:** INPERTS Reformatting

Purpose: Converts INPERTS formatted CCTS to NASA formatted CCTS.

System/Language: CMS/FORTRAN

Author: Bill M. Shelley **Date:** 02/01/78

Latest Revisor: Bill M. Shelley **Date:** 03/12/78

MODULE ABSTRACT

INPERTS is a FORTRAN main routine which converts INPERTS formatted computer compatible tapes to NASA formatted computer compatible tapes.

1. Module Usage

INPERTS is the main routine used to reformat INPERTS CCTS to NASA CCTS.

2. Internal Description

INPERTS is divided into seven major sections. The first section does one time initialization. The second section reads and interprets control cards. The third section mounts the input tape and determines the data format. The fourth section build the NASA CCT ID record. The fifth section builds the NASA CCT Annotation record. The sixth section mounts the output tape and reformats the data. The seventh section handles errors that may have occurred in the other sections.

3. Input Description

The input to INPERTS consists of a control card deck and INPERTS formatted CCTS.

4. Output Description

The output of INPERTS is NASA formatted CCTS.

REQUIRED	KEY WORD (COL. 1)	CONTROL PARAMETER	FUNCTION	DEFAULT
+	*INPERT	(NONE)	SELECT REFORMAT FROM BRAZILIAN CCT TO NASA CCT FUNCTION.	(NONE)
+	REFORMAT	STRIP(X)	SPECIFY A STRIP X TO BE CONVERTED WHERE X MUST BE BETWEEN 1 AND 8.	(NONE)
		FULL FRAME	SPECIFY STRIPS 1 THROUGH 8.	
		LEFTHALF	SPECIFY STRIPS 1 THROUGH 4.	
		RIGHTHALF	SPECIFY STRIPS 5 THROUGH 8.	
+	INPUT	TAPE(X)	SPECIFY AN INPUT TAPE X IN BRAZILIAN CCT FORMAT.	(NONE)
		TAPE(X,Y)	SPECIFY TWO INPUT TAPES X AND Y IN BRAZILIAN CCT FORMAT.	
	SCRATCH	TAPE(X)	SPECIFY A SCRATCH TAPE X.	*NO SCRATCH TAPE USED
+	OUTPUT	TAPE(X)	SPECIFY AN OUTPUT TAPE X TO BE IN NASA CCT FORMAT.	(NONE)
		TAPE(X,Y)	SPECIFY TWO OUTPUT TAPES X AND Y TO BE IN NASA CCT FORMAT	
	-COMMENT	(NONE)	COMMENT CARD	(NONE)
+	END	(NONE)	END OF FUNCTION	(NONE)

* A SCRATCH TAPE IS NEEDED IF THE INPERTS CCTS CONTAIN STRIPS 1 THROUGH 4 ON ONE TAPE AND STRIPS 5 THROUGH 8 ON THE OTHER, AND MORE THAN ONE STRIP IS BEING REFORMATTED.

LARS Program Abstract ________

MODULE IDENTIFICATION

Module Name: INPRDR Function Name: INPERTS Reformatting

Purpose: To read and interpret control cards for INPERTS reformatting job.

System/Language: CMS/FORTRAN

Author: Ken Dickman Date: 02/02/78

Latest Revisor: Ken Dickman Date: 04/09/78

MODULE ABSTRACT

INPRDR is a subroutine called by the main program INPERTS. CTLWRD, CTLPRM, and IVAL are called to read keywords, control-parameters, and integer values respectively. Other subroutines called within the control-card system are:

- INPFIR - to read the first card of one set of INPERTS control-cards.
- INPKEY - to read the rest of the control-cards, of the set, after the '*INPERTS' card and up to the 'END' card.
- INPJMP - to process the individual keywords using a jump-table method.
- INPJPR - to process the control parameters for the 'REFORMAT' card using a jump-table method.
- INPTAP - to process the control-parameter 'TAPE' and the tape numbers.
- INPERR - to help communicate errors found in the control cards.
- INPDMP - to dump important values needed for the reformatting process.

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1. Module Usage

INPRDR

CALL INPRDR (IEOF)

Input Arguments:

none

Output Arguments:

IEOF - I*4, End-of-file flag.
= 0 not end-of-file, processing continues with information received from the COMMON block CCINFO.

= 1 end-of-file TRUE, processing halts.

INPRDR processes one set of INPERTS control-cards beginning with the '*INPERTS' card, and returning after the 'END' card.

2. Internal Description

INPRDR Calls subroutine INPFIR to read the first card of the set. This first card should be either an '*INPERTS' card or an end-of-file.

If no end-of-file was reached, then subroutine INPKEY is called to read the rest of the set until an 'END' card is read. If there is an error in the set, reading the rest of the set is attempted and then execution is halted when the 'END' card is reached or end-of-file.

INPFIR Calls CTLWRD to read the first card of the set. Checks for the conditions of: '*INPERTS' card, other legal cards, end-of-file.

INPKEY Calls CTLWRD to read the rest of the set of cards until an 'END' card is reached. Checks for end-of-file, or a valid keyword. If a valid keyword is detected, subroutine INPJMP is then called to further process the card.

INPJMP This subroutine is simply a jump-table using a computed-GOTO to give control to the proper section to further process the card. The REFORMAT section calls CTLPRM to read the card's control parameter, then calls the jump-table subroutine INPJPR to further process. The section 'INPUT TAPE' and 'OUTPUT TAPE' call INPTAP to read the tape numbers. If only single parameters are given at a time.

eg:

```
INPUT TAPE(1234)
INPUT TAPE(5678)
```

then the values are toggled in, so that the second card will be the second parameter, and will be equivalent to:

INPUT TAPE(1234, 5678)

For more complex combinations see Figure 1. The 'SCRATCH TAPE' section calls INPTAP and expects only one tape number. The 'END' card section checks whether all required information has been interpreted.

INPJPR This subroutine is a jump-table using a computed-goto to process the control parameters. The 'REFORMAT STRIP' section requires one parameter, interpreted by the entry point IVAL of the subroutine BDCVAL, with a value between 1 and 8. The 'FULL', 'LEFT', and 'RIGHT' control parameters set the first strip and last strip variables accordingly.

INPTAP Subroutine CTLPRM reads the control-parameter 'TAPE' then entry point IVAL of subroutine BDCVAL reads one or two integer numbers. If there are two numbers present then the variable VECSZ is set to 2, otherwise VECSZ is set to 1.

INPERR If there were no previous errors, then an error flag is set. Output the card in error to the terminal, and place a dollar sign, beneath the card, under the column that points to the error, as long as it is not redundant to do so.

INPDMP Dump routine to display strips, tape numbers, and number of tapes specified.

3. Input Description

(See control card description)

4. Output Description

CTLWRD prints the control card image read in, and some error messages when appropriate. An end-of-file flag is passed as an argument, and the following information is passed via the COMMON block CCINFO:

FSTRIP - parameter telling which strip is the first to be reformatted.

LSTRIP - parameter telling which strip is the last to be reformatted.

INTAP - input tape parameter.
(1) - first input tape number.
(2) - second input tape number (optional depending on the task specified).

SCRATC - scratch tape parameter (optional).

OUTAP - output tape parameter.
(1) - first output tape number.
(2) - second output tape number (optional depending on the task specified).

LARS Program Abstract ____________

MODULE IDENTIFICATION

Module Name: BLDID **Function Name:** INPERTS Reformatting

Purpose: Builds NASA CCT ID record.

System/Language: CMS/FORTRAN

Author: Bill M. Shelley **Date:** 02/01/78

Latest Revisor: Bill M. Shelley **Date:** 03/12/78

MODULE ABSTRACT

BLDID is a subroutine which constructs a NASA CCT ID record from the header information available on an INPERTS CCT.

1. Module Usage

BLDID

CALL BLDID (INPID, CCTID, INSTRP)

Input Arguments:

INPID - Integer *2 array containing 20 elements. Contains the INPERTS CCT ID record.

INSTRP - Integer *4, contains the INPERTS strip number of the strip the ID record came from.

Output Arguments:

CCTID - Integer *2 array containing 20 elements. Contains the NASA CCT ID record.

2. Internal Description

BLDID moves common information from the INPERTS ID record to the NASA ID record. It then calculates the remaining parameters found in the NASA ID record from the parameters found in the INPERTS ID record.

LARS Program Abstract

MODULE IDENTIFICATION

Module Name: BLDANN **Function Name:** INPERTS Reformatting

Purpose: Builds NASA CCT Annotation Record.

System/Language: CMS/FORTRAN

Author: Bill M. Shelley **Date:** 02/01/78

Latest Revisor: Bill M. Shelley **Date:** 03/12/78

MODULE ABSTRACT

BLDANN is a subroutine which constructs a NASA CCT Annotation record from the header information available on an INPERTS CCT.

1. Module Usage

BLDANN

CALL BLDANN (INPANN, CCTANN, CCTID)

Input Arguments:

INPANN - INTEGER * 2 array containing 170 elements. Contains the INPERTS Annotation record.

CCTID - INTEGER * 2 array containing 20 elements. Contains the previously calculated NASA ID record.

Output Arguments:

CCTANN - INTEGER * 2 array containing 312 elements. Contains the NASA CCT Annotation record.

2. Internal Description

BLDANN moves common information from the INPERTS Annotation record to the NASA Annotation record. It then calculates the remaining parameters found in the NASA Annotation record from the parameters found in the INPERTS ID and Annotation records.

LARS Program Abstract ____________

MODULE IDENTIFICATION

Module Name: SWPBYT Function Name: INPERTS Reformatting

Purpose: Swaps adjacent bytes.

System/Language: CMS/FORTRAN

Author: Bill M. Shelley Date: 02/01/78

Latest Revisor: Bill M. Shelley Date: 03/12/78

MODULE ABSTRACT

SWPBYT is a subroutine which swaps adjoining bytes. This is done since DEC orders bytes differently than does IBM.

1. Module Usage

SWPBYT

CALL SWPBYT (ARRAY, COUNT)

Input Arguments:

ARRAY - LOGICAL * 1 array containing values to be swapped.

COUNT - INTEGER * 4, number of bytes to be swapped.

Output Arguments:

ARRAY - LOGICAL * 1 array containing swapped values.

2. Internal Description

SWPBYT first insures that COUNT is even and then proceeds to swap the bytes.

LARS Program Abstract ______

MODULE IDENTIFICATION

Module Name: TRANS **Function Name:** INPERTS Reformatting

Purpose: Translates ASCII character codes to EBCDIC character codes.

System/Language: CMS/BAL

Author: Bill M. Shelley **Date:** 02/01/78

Latest Revisor: Bill M. Shelley **Date:** 03/12/78

MODULE ABSTRACT

TRANS is a subroutine which translates ASCII character codes to EBCDIC character codes.

1. Module Usage

TRANS

CALL TRANS (ARRAY, COUNT)

Input Arguments:

ARRAY - LOGICAL * 1 array containing ASCII character codes to be translated to EBCDIC.

COUNT - INTEGER * 4, number of characters to be translated.

Output Arguments:

ARRAY - LOGICAL * 1 array containing the EBCDIC character code.

2. Internal Description

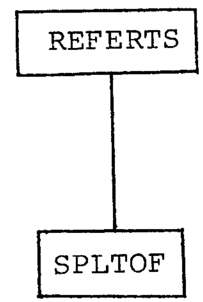
TRANS uses a table-look-up procedure to translate from ASCII to EBCDIC.

APPENDIX E

REFERTS PROGRAM CALLING SEQUENCE

REFERTS PROGRAM ABSTRACTS

REFERTS PROGRAM CALLING SEQUENCE



LARS Program Abstract

1. Serial Number: LARSYS 1176

   Title: ERTS Bulk MSS to LARSYS Reformatting

   Deck Name: REFERTS

2. Abstract:

REFERTS is a program used to convert Earth Resources Technology Satellite (ERTS) Bulk Multispectral Scanner (MSS) data tapes into LARSYS Version III formatted data storage tapes. REFERTS may be used to produce a subframe from a 100 nautical mile X 100 nautical mile ERTS bulk full frame. Subframes may be specified by latitude and longitude coordinates, by line and column numbers and by nautical mile coordinates; each referenced to the full ERTS frame.

3. Originator: William R. Simmons
James L. Kast

   Latest Revisor: Charles R. Smith

4. Date: November 18, 1977

5. Memory Requirements: 146598 bytes

6. Input: REFERTS control cards and ERTS bulk MSS tapes

7. Output: Selected subframe on data storage tape plus pertinent information concerning the reformatting including all necessary log information and RUNTABLE cards.

8. System: IBM System 360/Model 67 CMS FORTRAN IV

FUNCTION:

This routine should be used to convert ERTS bulk MSS data tapes into LARSYS-3 formatted data tapes. REFERTS requests mounting of output tape and one ERTS bulk MSS tape; these tape numbers are specified on control cards. The program then examines the ERTS bulk tape ID and annotation records and the REFERTS control cards to determine which other bulk MSS tapes must be mounted. After all required tapes are mounted, the program produces the requested LARSYS-3 data tape and prints out the run ID information and punches cards needed by the RUNTABLE data set. The program then looks for another set of control cards. If they are found, the run specified is generated; if not, the program is finished. It should be noted that only about 60% of the total data samples from an ERTS frame can be stored on a single 800 BPI LARSYS formatted tape. At 1600 BPI a full ERTS frame takes about 71% of a LARSYS formatted tape.

CONTROL CARDS:

For each run, REFERTS requires four control cards: a $REFORMAT card, a RUNTABLE card, a BLOCK card and an END card. An optional FORMS card may proceed the $REFORMAT card if the user wishes to specify the number of data storage tape forms to be printed.

The first control card is the $REFORMAT card, containing a keyword and up to four parameters. The card has the following format:

```
$REFORMAT INPUT (TAPE1, TAPE2, TAPE3, TAPE4), SCRATCH (S1, S2, S3),
                ZONE (ZZ), TYPE (N)
```

$REFORMAT must start in column one, followed by at least one blank space. TAPE1 through TAPE4 are NASA CCT bulk input data tapes. TAPE1 contains strip 1 of 4, TAPE2 contains strip 2 of 4, etc. S1 through S3 are user defined scratch tapes to be used during the reformatting process. If the user does not specify a sufficient number of scratch tapes for a given input processing mode (to be described under the runtable card), REFERTS will print an error message indicating the deficiency and processing will end. The ZONE is the time zone displacement from Greenwich, England to the area in the frame center. This value is negative for points west of Greenwich, positive for points east of Greenwich. The TYPE should be 1 if the NASA CCT AID format was produced prior to February 18, 1977. TYPE should be Z if the AID record format is more recent than February 18, 1977.

The RUNTABLE card, for REFERTS purposes, needs to contain six blocks of information:

1. The LARSYS data run number in columns 1-8.
2. The number of the tape to receive the reformatted data right justified in columns 14-17.
3. The file number to receive the new run, right justified in columns 14-17.
4. The run identifier code, a 16 character "flight line id" (title) in columns 18-33.

5. A strip pointer in column 64. This number indicates the strip (1-4) of the full frame contained in the first tape specified in the INPUT parameter of the $REFORMAT card. For example, if the first tape indicated in the INPUT parameter is tape 2 of a 4 tape series, a 2 should be placed in column 64. If column 64 is left blank, the first tape in the INPUT parameter is assumed to be the first tape of the four tape series.
6. Input processing mode in column 70. This indicates to the program how the user will be inputing the data. The value in column 70 should be:

   0 - If the frame is contained on four INPUT tapes.
   1 - If the frame is contained on 1 INPUT tape which contains 4 files, one strip each file (3SCRATCH tapes <u>must</u> be specified).
   2 - If the frame is contained on INPUT tapes which each contain 2 files, one strip on each file. (2 SCRATCH tapes <u>must</u> be specified).
   3 - Special processing option. All INPUT tapes required for reformatting the frame are indicated by the INPUT parameter of the $REFORMAT card. The first tape listed in the INPUT parameter is assumed to be the first tape in the series unless specified with a non-zero strip pointer in column 64.

The runtable card may also contain several other blocks of data, which if given, will over-ride the information contained in the ERTS ID and annotation records. The optional blocks are:

1. The month the data were collected (a 2-digit number; e.g. 01, 09, 10, 11) columns 34-35.
2. The day the data were collected (a 2-digit number; e.g. 01, 09, 11, 21, 31) columns 36-37.
3. The time the data were collected (a 4-digit number; e.g. 0930, 0700, 2130, 1430; specifying the local time) columns 39-42.
4. The ground heading (a 3-digit number; e.g. 194, 099, 204; denoting the heading from north) columns 50-52.

The third control card is the block card. These are three forms of the BLOCK card depending upon which method is used to specify the area of the subframe. One and only one block card must be present for each run processed.
ALL BLOCK cards are of the form:

BLOCK OPTION(PARAMETERS)

with the word "BLOCK" starting in column 1 and with at least one blank separating "BLOCK" from the option selected. Following the OPTION control word the various parameters for that option are contained within parenthese and separated by commas. The three block options are "area", "sample", and "coordinate".

The "area" option specifies the area of the full frame used to produce the subframe using nautical miles as a coordinate system. The card is of this form;

BLOCK AREA(X_I,X_L,SINT,Y_I,Y_L,LINT)

Where X_I,X_L,SINT,Y_I,Y_L,LINT are integer values.

- X_I - the displacement in nautical miles from the left of the full frame of the left-most point of interest to be contained in the subframe.
- X_L - the displacment in nautical miles from the left of the full frame of the right-most point of interest to be contained in the subframe.
- SINT - the sample interval; e.g. SINT=1 means every sample of bulk data is considered; SINT=2, every other sample, etc.
- Y_I - the displacement in nautical miles from the top of the full frame of the upper-most point of interest to be in the subframe.
- Y_L - the displacment in nautical miles to the lower-most point of interest from the top of the full frame.
- LINT - LINT interval; e.g. LINT=1 consider each line; LINT=2 consider every second line, etc.

The "sample" option specifies the subframe by line and column numbers.
The card is of this form:

BLOCK SAMPLE(ISAM,LSAM,SINT,ILIN,LLIN,LINT)

Where ISAM,LSAM,SINT,ILIN,LLIN, and LINT are integer values.

- ISAM - the first sample (or column) of the ERTS full frame to be used in the subframe.
- LSAM - the last sample to be considered.
- SINT - sample interval
- ILIN - the initial line of the full frame to be used in the subframe.
- LLIN - the last line of the full frame which is to be used in the subframe.
- LINT - line interval.

It should be noted that the number of lines in a full frame is 2340 (constant), but that the number of samples/line is not. It would be best to know the number of samples before using this option if less than a full frame wide area is desired. A condensed version of the full frame may be produced using this option by setting ILIN and ISAM to 1,LLIN= 2340,LSAM=3232, and selecting appropriate values for SINT and LINT.

The "coordinate" option is used to select a rectangle whose north-west and south-east coordinates are specified in degrees and minutes of latitude and longitude. Since the satellite does not orbit directly north to south, these rectangels will be contained in larger rectangles whose sides are parallel to the heading of the satellite. The BLOCK card is of this form:

BLOCK COORDINATE (LG_{UD},LG_{UM},LT_{UD},LT_{UM},LG_{LD},LG_{LM},LT_{LD},LT_{LM}

SINT,LINT)

Where all parameters are integers. Positive parameters indicate degrees of longitude west and latitude north. Negative parameters indicate south latitude and east longitude.

LG_{UD} - longitude degrees of the north-west subframe corner.

LG_{US} - longitude minutes of the north-west subframe corner.

LT_{UD} - latitude degrees of the north-west subframe corner.

LT_{UM} - latitude minutes of the north-west subframe corner.

LG_{LD} - longitude degrees of the south-east subframe corner.

LG_{LS} - longitude minutes of the south-east subframe corner.

LT_{LD} - latitude degrees of the south-east subframe corner.

LT_{LM} - latitude minutes of the south-east subframe corner.

SINT - sample interval.

LINT - line interval.

The last control card is the "END" card. The "END" card tells the program that all control cards have been read for the run. It consists of the word end starting in column 1.

After the end card may come another set of control cards for another run.

REFERTS CONTROL CARDS

The following is a description of the reformat ERTS data (REFERTS) control cards.

There are two basic types of REFERTS control cards . . . .

1. The RUNTABLE cards which is fixed format and has the following format:

COLUMN

```
                   1   1                   3   3        5      6    7
  1        9       4   8                   4   9        0      4    0

* AAAAAAAABBBBBCCCCDDDDDDDDDDDDDDDEEFF GGGG      HHH     I    J
```

WHERE:

* AAAAAAAA - is the run number

* BBBBB - right justified output tape number

* CCCC - right justified file number to receive data

* DDDDDDDDDD - 16-character flightline ID code

EE - month data taken

FF - day data taken

GGGG - time data taken

HHH - heading of satellite

I - indicates strip of frame contained on first tape in input parameter of $REFORMAT card. E.g., if 1st tape indicated is tape 2 of 4 of series, a 2 should be placed in column 64.

J - Input processing mode. Value in column 70 should be:
- 0 - if frame contained on 4 input tapes
- 1 - if frame contained on 1 tape of 4 files, each file 1/4 frame strip
- 2 - if frame is received on 2 tapes of 2 files. Each file 1/4 frame strip.
- 3 - special option. All tapes required for reformatting the frame are indicated in the input parameter of the $REFORMAT card. First tape indicated is assumed to be first tape in series unless indicated in column 64.

* (parameter is required)

The RUNTABLE card is placed immediately following the $REFORMAT card in the control card deck set up.

2. The supervisor control cards. These cards initialize the program and specify processing options. They are free format and must end with an "END" card. All key words must start in column 1 and be followed by at least one blank space.

Key Word	REQ	Option	Parameters	Function	Default
FORM		(None)	NN	Prints NN Forms	7 Forms
$REFORMAT	*	Input	(T1,T2,T3,T4)	Tapes used for input T1 - first tape in series T2 through T4 as required	(None)
		Scratch	(S1,S2,S3)	Scratch tapes to be used if split off is necessary. Up to 3 tapes may be specified.	(None)
		Zone	(ZZ)	Time zone displacment from 0 degrees longitude, specified in 15 degree increments	(ZZ=0)
		Type	(N)	N = 1 if data taken before 2/18/77 N = 2 if data taken after 2/18/77	(N=1)
BLOCK	1	Area	($X_I X_L$,SINT, Y_I,Y_L,LINT)	Reformat the area from X_INM to the right of the frame boundry to X_LNM	(None)
	1	Sample	(X,Y,Z,A,B,C)	Reformat ERTS frame from col. X to col. Y by every Zth col. and from line A to line B by every Cth line.	(None)
	1	Coordinates	(A,B,C,D,E, F,G,H,I,J)	Reformat the rectangle whose north-west coordinate is $A^oB'W/D'N$ and whose south-east coordinate is $E^oF'W/G^oH'N$, taking every Ith col. and Jth line.	(None)
END	*	(None)	(None)	END RUN	(None)

Identification List Control Cards

The printout of ID and ANNOTATION information from an ERTS Bulk MSS CCT may be obtained by using a $IDPRINT card. Like the $REFORMAT card, $IDPRINT parameters are in free format. Unlike control cards in the $REFORMAT sequence, $IDPRINT cards are not followed by END cards. All the information needed for an IDPRINT is contained on the $IDPRINT card in this format:

Keyword	Parameters
$IDPRINT	TP,RUNN,TZD,DD,MM,YY,TYPE

TP = Library tape no. assigned to the bulk CCT
RUNN = Run number assigned to the frame data
TZD = Time zone displacement
DD = Day frame received
MM = Month frame received
YY = Year frame received
TYPE = Type of AID format = 1 if tape produced before 2/18/77
2 if produced after 2/18/77