X-563-73-206

TMX-70426

GENERATION AND PHYSICAL CHARACTERISTICS OF THE ERTS MSS SYSTEM CORRECTED COMPUTER COMPATIBLE TAPES

JULY 1973

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

(NASA-TM-X-70426) GENERATION AND PHYSICAL CHARACTERISTICS OF THE ERTS MSS SYSTEM CORRECTED COMPUTER COMPATIBLE TAPES (NASA) 59 p HC $5.00 CSCL 05B

N73-29366

Unclas

G3/13 10997

X-563-73-206

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Valerie L. Thomas
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FOREWORD

This document discusses the multispectral scanner (MSS) computer compatible tape (CCT) which is radiometrically corrected in the Initial Image Generating Subsystem. The resulting system corrected CCT has been generally referred to as the bulk MSS CCT.

The document is designed to be useful to the person who is interested in knowing only the general information about the system corrected MSS CCT as well as the person who wants to know more details about the CCT. The overview section covers all of the general information. The second section (tape format) contains the necessary details for the data analyst or computer programmer who is interested in developing computer software which will read the system corrected MSS CCT. The appendices and the radiometric striping section contain supplemental information about the radiometric corrections made to the video data and the radiometric striping respectively.

GENERATION AND PHYSICAL CHARACTERISTICS
OF THE ERTS MSS SYSTEM CORRECTED
COMPUTER COMPATIBLE TAPES

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ABSTRACT

This document discusses the generation and format of the ERTS system corrected multispectral scanner computer compatible tapes. Included in the discussion are the spacecraft sensors, scene characteristics, the transmission of data, and the conversion of the data to computer compatible tapes at the NASA Data Processing Facility. Also included in the discussion are geometric and radiometric corrections, tape formats, and the physical characteristics of the tape.

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GLOSSARY

APT	Auxiliary paper tape
Bit	The smallest element of binary, computer-intelligible data
Byte	A unit of data consisting of eight bits
CCT	Computer compatible tape
DS	Digital subsystem
EBCDIC	Extended binary coded decimal interchange code
ERTS	Earth Resources Technology Satellite
GSFC	Goddard Space Flight Center
HDDT	High-density digital tape
IAT	Image annotation tape
ID	Identification
IIGS	Initial image generating subsystem
km	Kilometer
LLC	Line length code
MSS	Multispectral scanner
NDPF	NASA Data Processing Facility
nm	Nautical mile
Nmax	Maximum line length code
Pixel	One video data byte
RBV	Return-beam vidicon

GENERATION AND PHYSICAL CHARACTERISTICS OF THE ERTS MSS SYSTEM CORRECTED COMPUTER COMPATIBLE TAPES

OVERVIEW

SPACECRAFT SENSORS

The Earth Resources Technology Satellite (ERTS) contains in its payload two separate subsystems designed to produce spectral imagery of the earth's surface: the return-beam vidicon (RBV) camera subsystem, and the multispectral scanner (MSS) subsystem.

RBV Camera Subsystem

The RBV camera subsystem contains three individual cameras that operate in different nominal spectral bands from 0.475 to 0.830 micrometers. Each camera contains an optical lens, a shutter, an RBV sensor, a thermoelectric coder, deflection and focus coils, erase lamps, and the sensor electronics. Spectral filters in the lens assemblies provide separate spectral viewing regions for the cameras. The three cameras view the same nominal 185-kilometer square ground scene. When the cameras are shuttered, the images are stored on the RBV photosensitive surfaces, then scanned to produce video outputs.

MSS Subsystem

The MSS is a four-band scanner operating in the solar-reflected spectral region from 0.5 to 1.1 micrometers. It consists of six detectors for each of the four bands. The MSS scans crosstrack swaths 185 km wide at normal altitude, imaging six scan lines across in each of the four bands simultaneously. This is accomplished by means of an oscillating flat mirror between the ground scene and a double-reflector telescope type of optical chain. The mirror scans the crosstrack field of view as it oscillates about its nominal position.

Video outputs from each detector in the scanner are sampled, commutated, and multiplexed into a modulated stream. The commutated samples are encoded and transmitted to ground-based receiving sites. The receiving sites compile the raw data on video tapes and transmit these tapes to the NASA Data Processing Facility (NDPF) at the Goddard Space Flight Center (GSFC), Greenbelt, Maryland.

The NDPF corrects, calibrates and formats the raw MSS data and converts it to a usable binary form on computer compatible tapes (CCT). Data processing operations discussed in this document include the formatting of digitized data on the CCTs, various corrections that are applied to the data to enhance its usefulness, and additional data processing such as decompression of data, radiometric calibration, and insertion of geographic coordinate tick mark information. For a more detailed description of these and other data processing operations at the NDPF, see "ERTS Data User's Handbook" and the appendices in this document.

This document discusses only Bulk MSS CCTs.

DISCUSSION OF A SCENE

The annotated and corrected 185-km square ground scene on the CCT is a final product of the MSS. This scene provides a number of different types of information that can be of value to the data user. An understanding by the user of the several steps necessary to produce this product will aid him in obtaining fullest use of the MSS data.

Scan Lines

A scene is made up of parallel scan lines, each containing a large number of video data points. There are 2340 of these lines per completed MSS CCT scene. Each scan line covers a distance of 185 km and is comprised of from 3000 to 3450 "bytes" of video data. A byte is made up of eight binary "bits," which are the smallest units recognized by the computer. These eight-bit bytes (only six of the eight bits contain data in the linear mode, seven in the decompressed mode) are arranged in such a manner that they can represent differing radiance levels. The mirror motion since launch has thus far been highly repeatable. The scan line for a given scene has had an average of 3220 bytes per line, with a tolerance of ±2 bytes. The relationship between video data bytes and the corresponding ground area covered is discussed in Appendix A. Figure 1 shows the components of a completed ground scene.

The distance covered by a scan line varies with altitude. Experience has shown that the variations have resulted in scan line changes of approximately ±4 km in the worst case. At nominal altitude, 918.592 km (496 nm), the scan line is 185 km. Throughout the remainder of this document, nominal altitude conditions will be used.

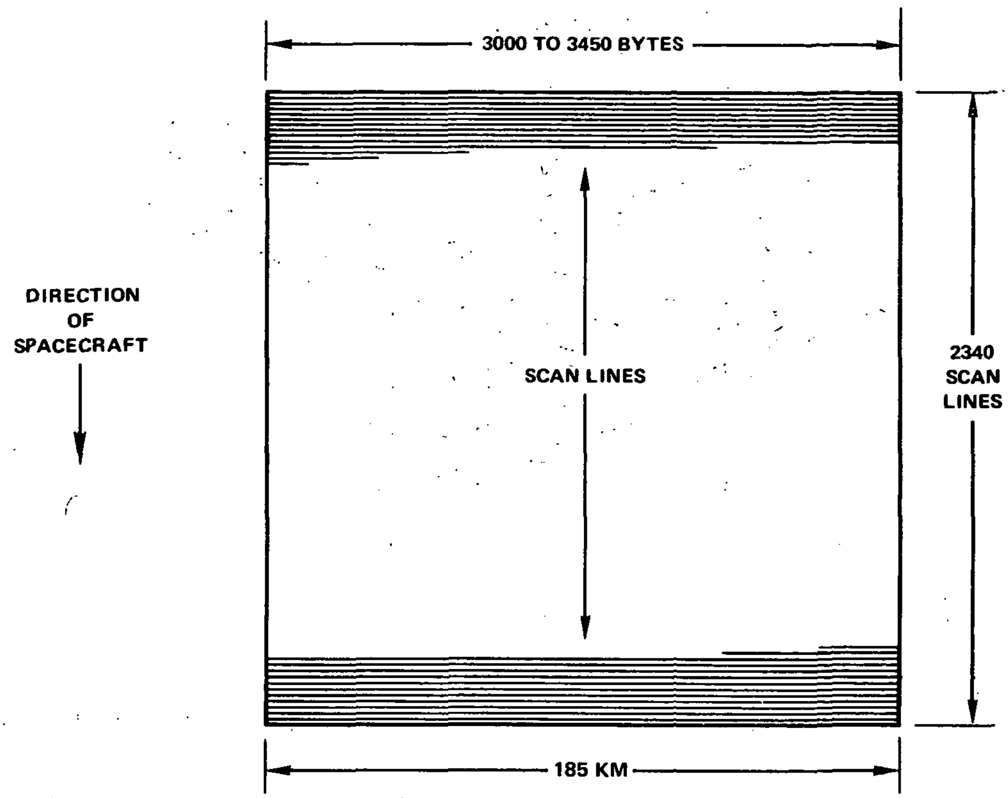


Figure 1. Components of a Completed Ground Scene as Represented on the MSS CCT

Direction of Scan

The scan mirror operates in a scan-and-retrace cycle. The active portion of the scan is in a west-to-east direction. The full scan-and-retrace cycle produces a 185-km sweep by the detectors of the ground scene beneath the satellite. Figure 2 shows the composite scan pattern of the MSS.

Direction of Flight

The spacecraft's near-polar orbital motion produces the along-track spacing between mirror sweeps. This along-track scan pattern, when combined with the scan-and-retrace cycle, provides complete coverage of the full 185-km scene.

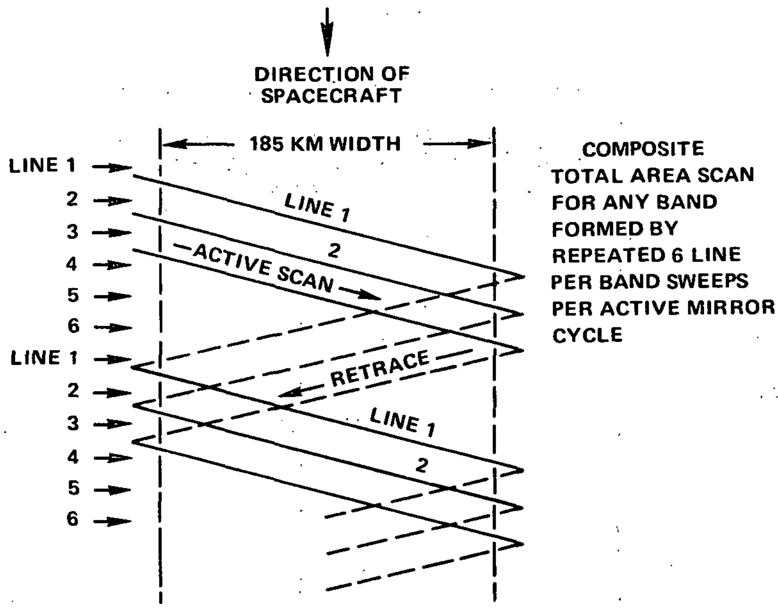


Figure 2. Ground Scan Pattern for a Single MSS Detector

Sampling Rate

The video outputs of each detector are sampled during the active west-to-east sweep of the mirror. The sampling rate is a constant 100.5 kilo samples/sec and is maintained by an internal crystal clock.

Mirror Sweep

The 11.56-degree effective crosstrack field of view is scanned as the mirror oscillates ±2.89 degrees about its nominal position, as shown in Figure 3. The mirror scans in a west-to-east direction, imaging in each mirror sweep the six scan lines from each of the four bands.

Radiance Levels

Differing levels of radiance within a scene are represented by means of various combinations of bits in the scan lines. Radiance values are registered on a scale of from 0 to 63 (minimum to maximum) in the linear mode, and from 0 to 127 in the decompressed mode. To determine which mode the data is in, see the definition of "MSS data mode/correction code" in Table 1.

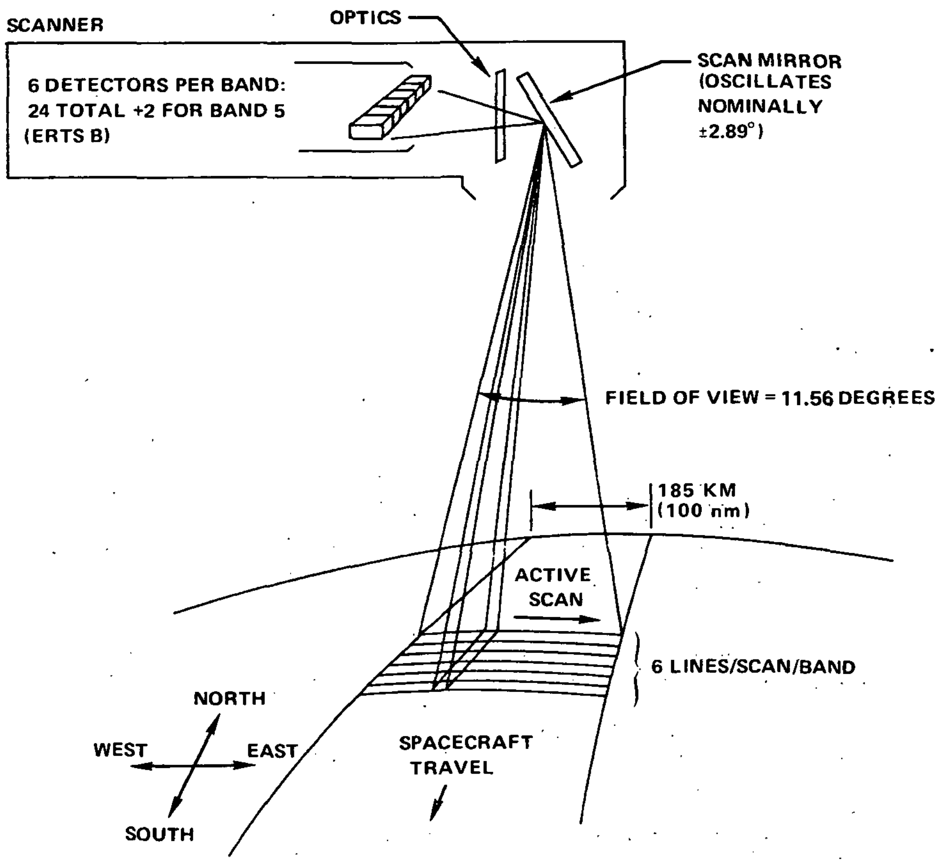


Figure 3. MSS Scanning Arrangement

Comparison of CCT Scene to Film Scene

The NDPF transmits completed ground scenes to data users on four separate CCTs. Each of these CCTs contains image data for one 46.25- by 185-km strip. The CCTs contain more image data than does the corresponding film print. The additional data consists of 42 scan lines preceding and 42 scan lines following the data from which the film scene was made (the film contains 2256 scan lines). Figure 4 shows a scene as contained on four CCTs. The CCT scene and the film scene contain the same annotation data. Both the film and the CCT have the same algorithm applied to radiometrically calibrate the data; however, only the film is corrected for the mirror velocity profile. The film and CCT are both corrected for line length variation. The CCT is not geometrically corrected for effects such as skew as a function of earth rotation or mapping projection.

Seven- and Nine-track CCTs

Data users should request either seven- or nine-track CCTs according to the requirements of their computer. This and other physical characteristics of magnetic tapes are discussed in Appendix B.

Table 1
ID Record Information Definitions

Char.	Information	Format	Code
1-12	Scene/Frame ID B = spectral band identifier N = sequential subframe ID b = blank char.	EDDD-HHMMSBN*	EBCDIC
13-16	Tape Sequencing Numbers Tape N of M	bNbM	EBCDIC
17-18	Data Record Length (bytes)	nn	Binary
19-26	Binary Frame ID	nnnnnnnn**	Binary
27-28	Binary Strip ID	nn	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
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
B — NDPF Identification Code (RBV: 1, 2, 3; MSS: 4, 5, 6, 7, 8)

**The Binary Frame ID is the binary representation of the Scene/Frame ID.

Char.	
19	Encoded Project Identifier
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
25	Spectral Band Identifier
26	Sequential Subframe ID

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

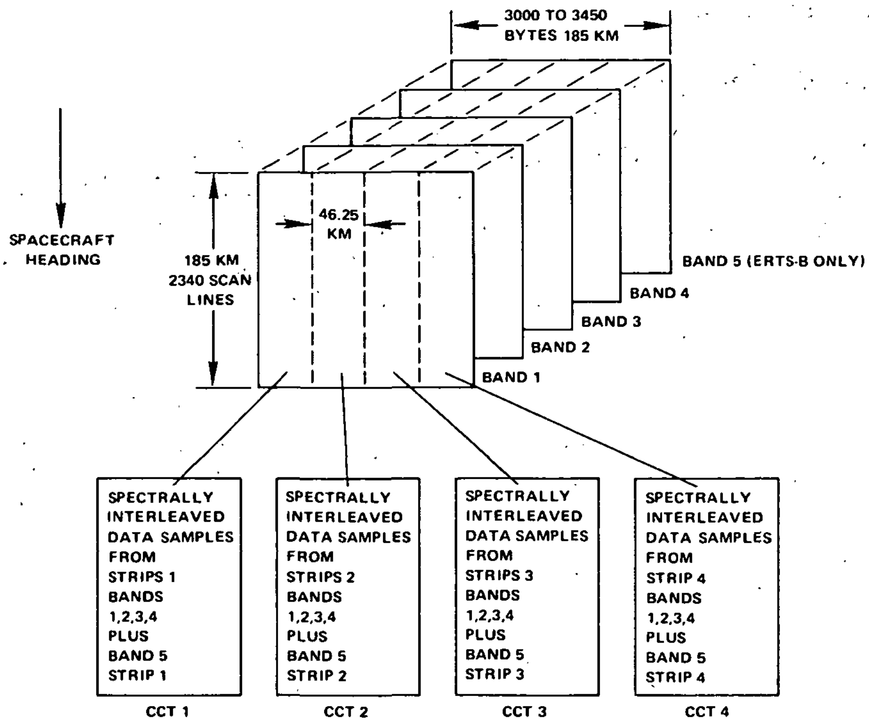


Figure 4. Bulk MSS Image-to-CCT Conversion

Spectral Range for Each Band

The MSS subsystem is used on two missions. For ERTS-1, the four spectral bands are as follows:

Band 1	0.5 to 0.6 micrometers
Band 2	0.6 to 0.7 micrometers
Band 3	0.7 to 0.8 micrometers
Band 4	0.8 to 1.1 micrometers

Bands 1 through 3 use photomultiplier tubes as detectors; Band 4 uses silicon photodiodes.

For the ERTS-B mission, a fifth band will be added that operates in the thermal (emissive) spectral region from 10.4 to 12.6 micrometers. This band uses mercury-cadmium-telluride, long-wave infrared detectors.

TRANSMISSION OF DATA

Registration of Scan Lines

The MSS detectors are sampled sequentially at a constant rate; therefore, the corresponding detectors of each band for the same ground field of view are not simultaneously sampled. Since the same ground field of view is not sensed by the detectors for each band at the beginning of the sampling, individual band pictures are misregistered in the along track scan direction by whole data samples.

The NDPF corrects for this slight variation by inserting registration fill characters (which contain no useful video data) at the ends of the lines. Registration fill characters correspond to bytes, and the number added to a given scan line is always six. These six characters are inserted at either or both ends of a scan line, as shown in Figure 5. Fill characters are added to the scan lines of each of the four spectral bands.

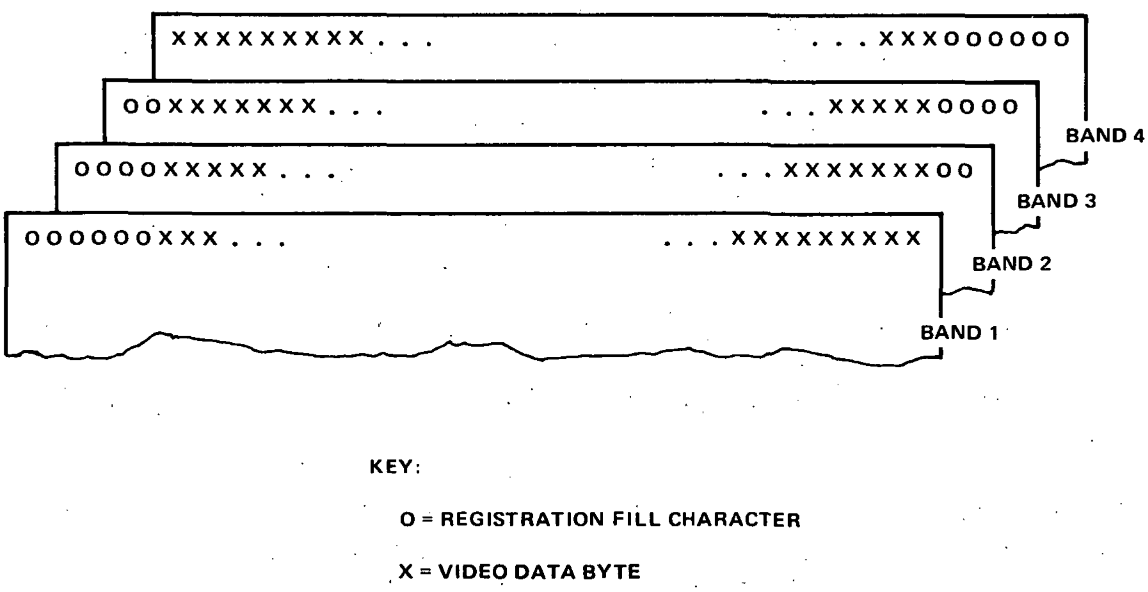


Figure 5. Position of Registration Fill Characters in Spectral Bands

Line Length Adjustment

Because the length of the scan lines that comprise a scene may vary slightly due to small variations in the period of the mirror, NDPF performs a line length adjustment operation on the computer to adjust all scan lines on ground scenes to the same length. The scan lines are lengthened by inserting "synthetic" bytes at regular intervals as needed to attain the length of the adjusted lines. The "synthetic" byte is a duplicate of the last byte preceding it on the scan line. This line length adjustment produces negligible distortion of the imagery. See Appendix C for a discussion of how line length adjustment is calculated.

Radiometric Calibration

During every other retrace interval a shutter wheel closes off the optical fibers viewing the earth and an artificial light source is projected into them through a variable neutral density filter on the shutter wheel. This process introduces a calibration wedge into the video data stream of Bands 1 through 4. The nominal shape of this calibration wedge, referred to as the gray wedge, is shown in Figure 6. The actual shape and level vary somewhat among the four spectral bands.

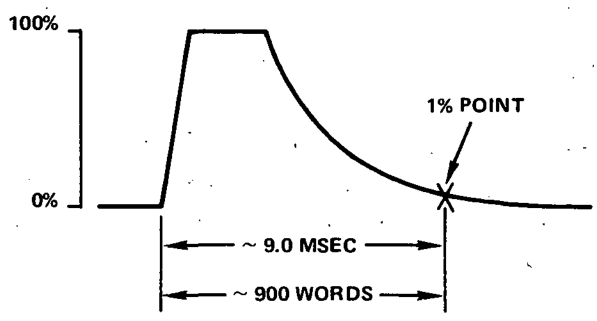


Figure 6. Nominal Calibration Wedge Output

The fact that the calibration lamp intensity profile is constant makes it possible to check the relative radiometric levels, and also to equalize gain changes which may occur in the six detectors of a spectral band. Corrections are performed at the NDPF to equalize these levels so that striping will be avoided. Appendix D provides an explanation of the radiometric calibration procedure.

Decompression of Data

The signal compression mode is normally used for the data from Bands 1 through 3 (photomultiplier tubes) since these bands have a better signal-to-noise performance than Band 4 (silicon photodiodes). By compressing the higher light levels and expanding the lower levels, the quantization noise more nearly matches the detector noise. Because of the performance characteristics of silicon photodiodes, no signal compression is performed on Band 4.

Decompression of MSS data at the NDPF consists of converting the data points to an expanded format that is easier to use. The MSS data are decompressed by means of a computer program which utilizes a decompression look-up table. This decompression table appears in Appendix E.

Annotation

The annotation record on CCTs is in two parts. The first part is background information concerning conditions under which the data were taken such as sun angles, spacecraft heading, etc. The second part provides tick mark location information so that the ground scene can be located in terms of geographic coordinates. The annotation record follows the ID record on the CCT and immediately precedes the video data.

INTERLEAVING OF DATA

Data from the four spectral bands are combined on the CCT through a process called interleaving. Bytes of data from the bands are interspersed by twos to produce an eight-byte "Group." The Group is the smallest element of interleaved data.

In addition, the first and last three Groups of each scan line contain registration fill characters to correct for misregistration among spectral bands. This registration process is discussed more fully in the Tape Format Section of this document.

TAPE FORMAT

The MSS CCT is made up of three basic types of records: ID, annotation and video data. The ID record contains a combination of binary and EBCDIC information which is used to identify the video data on the CCT. The annotation record contains binary and EBCDIC data which provide additional information about the scene such as the format center, nadir and sun elevation. This record also includes tick mark location information which associates the digitized scene with the latitude and longitude coordinate system. The video data record contains scene information which has been digitized so that each data point is represented by a radiance value which varies from 0 to 63 if the data are linear, and from 0 to 127 if the data are decompressed.

ID RECORD

The 40-byte ID record is the first record on the tape, and appears only once per tape. Figure 7 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, sequential subframe ID, and whether the data are from ERTS-1 or ERTS-B. Characters 13-16 contain the sequencing numbers, i.e., 1 of 4, 2 of 4, etc., which distinguish the tapes in the set of four. 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. See Figure 8 for a computer printout of a sample ID record. The binary strip ID is stored in characters 27-28; however, this ID is not used for Bulk MSS CCTs. 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

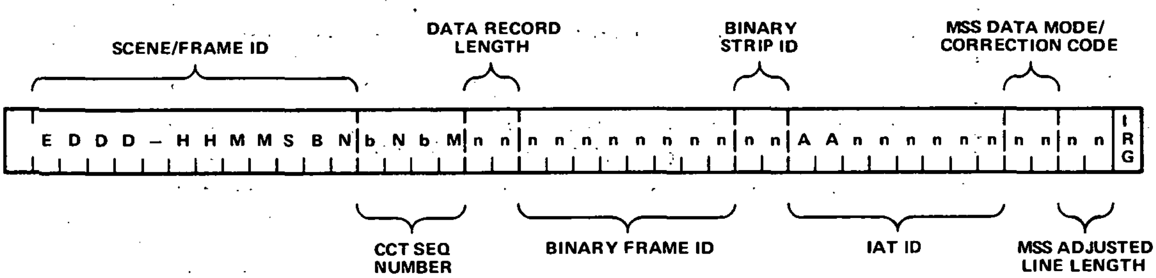


Figure 7. ID Record Organization (40 Characters, EBCDIC and Binary Code)

```
******* ID RECORD ********

SPECTRAL BAND 0  SUBFRAME 0  SCENE/FRAME ID: 037D 16H 24M 4S

CCT SEQ. NO.  3 OF 4   DATA RECORD LENGTH  3296

BINARY FRAME ID 1 371624400          BINARY STRIP ID   0

IMAGE ANNOT. ID  SI110069

MSS DATA MODE/CORRECTION CODE 00100111

MSS ADJUSTED LINE LENGTH  3240
```

Figure 8. Computer Printout of a Sample ID Record

characteristics of the data such as decompression, calibration, and line length adjustment. See Table 1 for the complete definition of the MSS data mode/correction code. Characters 39-40 contain the MSS adjusted line length.

ANNOTATION RECORD

The annotation record is the second record on the tape. It occurs once per tape and contains 624 characters. The annotation record is 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 9 defines the sequence of information in the annotation record.

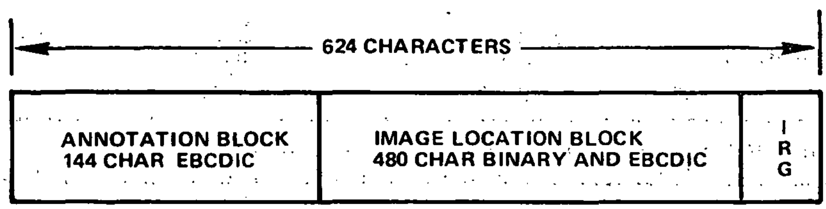


Figure 9. Annotation Record Information Sequence

Annotation Data Block

The information included in the human-readable annotation data to allow user interpretation of the imagery are taken from the image annotation tape. These data are specified at the time of RBV exposure or at the center 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). The format and content of the characters are defined in Table 2. Sample output from the Val Dump program (Figure 10) illustrates the type of information that is available in the first 144 characters of the annotation record.

```
     **** ANNØTATIØN RECØRD ****

AGENCY: NASA  PRØJECT: ERTS-1  FRAME ID: 037DY 16HR 24MN 4S

EXPØSURE   FØRMAT CENTER       NADIR
  DATE      LAT.   LØNG      LAT.   LØNG
 29AUG72   N30-15 W095-20   N30-13 W095-13

SUN ANGLES     S/C     ØRBIT  STATN   IMAGE      EPHEM.
 EL    AZ    HEADING    REV            SIZE       DATA
 55   121    189DEG    0515          100X100NM      D

                         RBV 1    RBV 2    RBV 3
SHUTTER SETTING
DUR. ØF EXP.              ***      ***      ***
APERT. CØRR. IND.
TRANSM.

 MSS DATA    ACQUIS.
              SITE
    D          G
```

Figure 10. Sample Output from the Val Dump Program

Table 2
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 shall be identical to the RBV format center. Format center is defined as 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) shall be 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 2
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 RBV exposure or midpoint of MSS frame shall be specified to the nearest degree.
63-65	Constant: 'bAZ'. Sun azimuth, degrees, three numerals. Sun Azimuth — The sun azimuth angle from true North at the time of RBV exposure or midpoint of MSS frame shall be specified to the nearest degree.
69	Constant: 'b'.
70-72	Heading of orbital path, including yaw, degrees, three numerals. Satellite Heading — The satellite heading shall be specified to indicate the orientation of the imagery. The heading includes yaw and is specified to nearest degree.
73	Constant: '-'.
74-77	Revolution number, four numerals. Rev Number — The consecutive rev number for the ERTS spacecraft shall be specified.
78	Constant: '-'.
79	RBV 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 2
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: bNASAbERTSb-'.
	Frame Identification
	Frame Identification Number — Each image or frame has a unique identifier which contains encoded information. This identifier shall be used for an information retrieval system and will consist primarily of time of exposure relative to launch information. The Bulk Processing Subsystem will add the appropriate spectral band number. Also part of the frame identification number is a "regeneration of images" identifier. This identifier will also be added by Bulk Processing to the imagery when appropriate.
102	ERTS Mission 1 or 2.
103-105	Day number relative to launch.
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, and 2 to reflect 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).
	<u>During Bulk Processing</u>, 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 into Blank Field 5.

Table 2
Annotation Block Data (continued)

Characters	Description
117-140	24 blank characters if RBV is off.
141-144	4 blank characters if MSS is off.
	Otherwise:
117-121	Direct or recorded data: '1bbDX' or 1bbRX'.
122-123	Shutter Setting* and Aperture Correction Indicator, ** RBV 1; aa
124-129	Direct or recorded data: 'bb2bDX' or 'bb2bRX'.
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; aa
140	Constant: 'b'.
141-142	Direct or recorded MSS data: 'Db' or 'Rb'.
143-144	MSS data acquisition site, 'A-', 'G-', or 'N-'.

*Shutter setting code, applicable to RBV annotation only:

Setting	Duration of exposure		
	camera 1	camera 2	camera 3
A	4.0	4.8	6.3
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

**Aperture correction indicator:

I = Aperture correction in
O = Aperture correction out

Image Location Data

The image location data consist of 240 sixteen-bit words which 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 Bulk RBV as well as Bulk 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 integer fraction which specifies its position along the edge of the scene, followed by eight EBCDIC characters. See Table 2 for a detailed description of the tick mark location information.

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. See Appendix F for a discussion of the tick mark reference system.

The special tick characters are either an X'4F', an EBCDIC vertical bar which is used along the top and bottom edges of the scene, or an X'7E', an EBCDIC equals sign which is used to represent the ticks on the left and right sides of the scene. The direction is represented by an EBCDIC character which 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. 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

Figure 11 is a Val Dump printout of the MSS tick mark location information.

VIDEO DATA RECORD

Data Word

The 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. The following illustrates the data word for the two modes:

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).

The value of the data within the data word varies from 0 to 63 in the linear mode and from 0 to 127 in the decompressed mode, and represents the variation of the radiance level (0 represents black, 63 or 127 represents white and the values in between represents all the shades of gray).

MSS TICK MARK LOCATIONS

	********* TOP EDGE *********				******* LEFT EDGE *********			
	POSIT.	DIRECT	TICK CHAR	VALUE	POSIT.	DIRECT	TICK CHAR	VALUE
1	14290	W	I	096-00	12294	N	•	031-00
2	5769	W	I	095-30	63515	N	•	030-30
3	-2777	W	I	095-00	8254	N	•	030-00
4	56028	N	I	031-00	0			-
5	0			-	0			-
6	0			-	0			-

******* RIGHT EDGE *********				******* BOTTOM EDGE *******			
POSIT.	DIRECT	TICK CHAR	VALUE	POSIT.	DIRECT	TICK CHAR	VALUE
-8371	N	•	030-30	9553	N	I	029-30
1970	N	•	030-00	8871	W	I	096-00
12309	N	•	029-30	195	W	I	095-30
0			-	57026	W	I	095-00
0			-	0			-
0			-	0			-

Figure 11. Val Dump Printout of MSS Tick Mark Location Information

Group

In order to obtain a video data record which includes information from all four spectral bands, the data from the bands are combined in a process called interleaving. This is an operation in which two bytes of data from each band are interleaved to produce an eight-byte "group," which is the smallest element of interleaved data. Figure 12 shows the scheme used to interleave the four bands of MSS data. The data samples in the group are registered and represent the same two points on the ground, as sensed by each of the spectral bands.

Registration fill characters are included in the first and last three groups; i.e., the first three groups of each quarter scan line on tape 1 of 4 and the last three groups of each quarter scan line on tape 4 of 4. In the illustration of these groups which follows, the O's represent registration fill characters and the X's represent video data bytes:

First three groups

OO OO OO XX   OO OO XX XX   OO XX XX XX

Last three groups

XX XX XX OO   XX XX OO OO   XX OO OO OO

Since the length of scan lines varies slightly, the adjusted scan line length is used to determine the number of groups (3n eight-byte groups) per scan line. The n referred to is the same n that is used in adjusting the scan line length. See Appendix C for an explanation of the line length adjustment.

Video Data Record for ERTS-1

The ERTS-1 video data record ($R_{i,k}$) consists of 3n eight-byte groups and four 14-byte calibration groups. Figure 13 illustrates the record format; i denotes the image segment and the CCT tape number, and k is the sequential scan line index.

The four 14-byte calibration groups contain calibration data for each of the four MSS bands. Each group contains six calibration wedge samples, a sun calibration coefficient, correction coefficients (filtered offset and filtered gain), and the value of the unadjusted line length for a band. Figure 14 gives the breakdown of the calibration data. The b denotes the band and the k denotes the scan line. Figure 15 shows the Val Dump printout of the calibration data. The cal wedge samples are printed out in hexadecimal (Appendix G gives the decimal conversion of the values) and the other numbers are printed out in decimal.

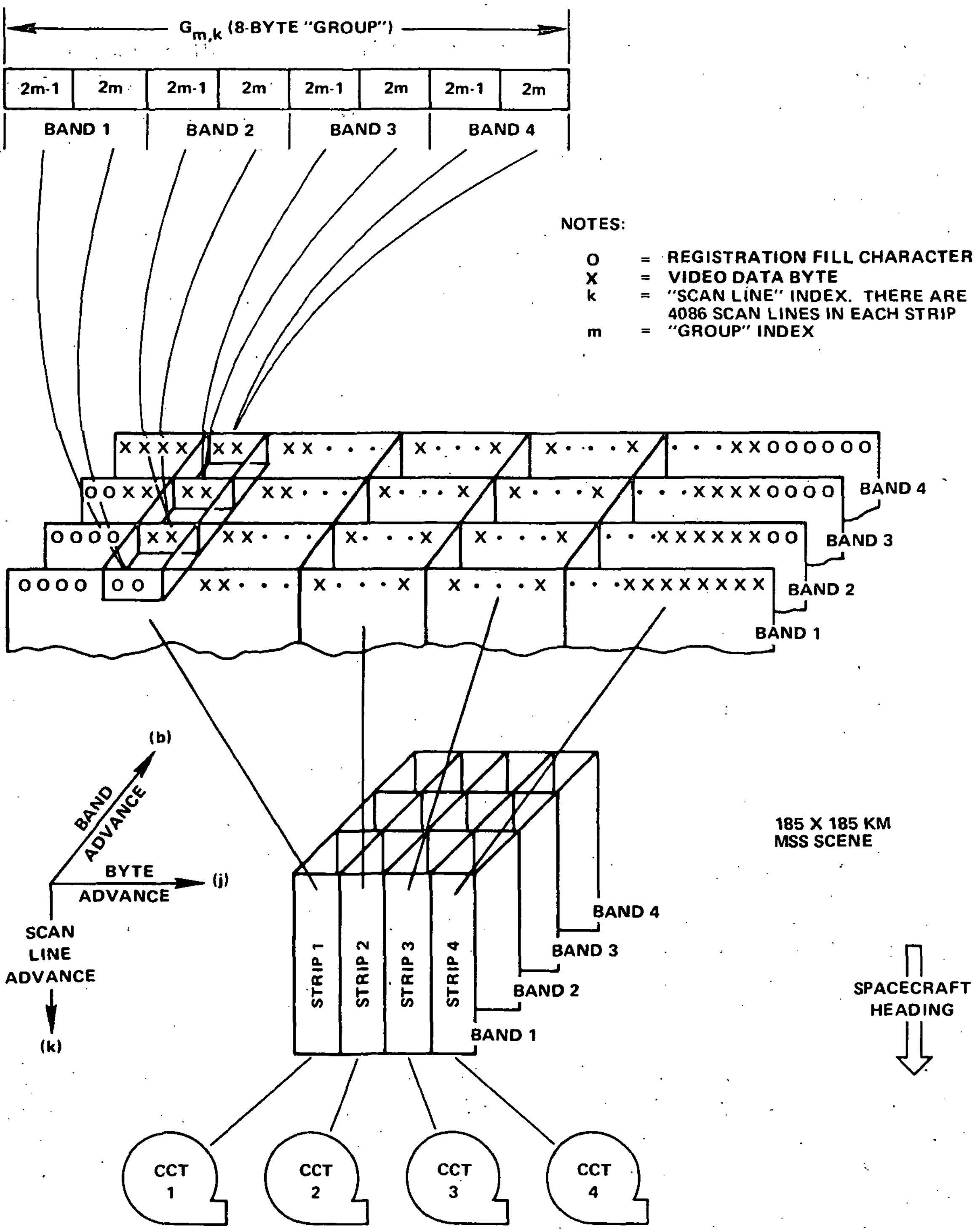


Figure 12. Bulk MSS Four-Band Scene to Interleaved CCT Conversion

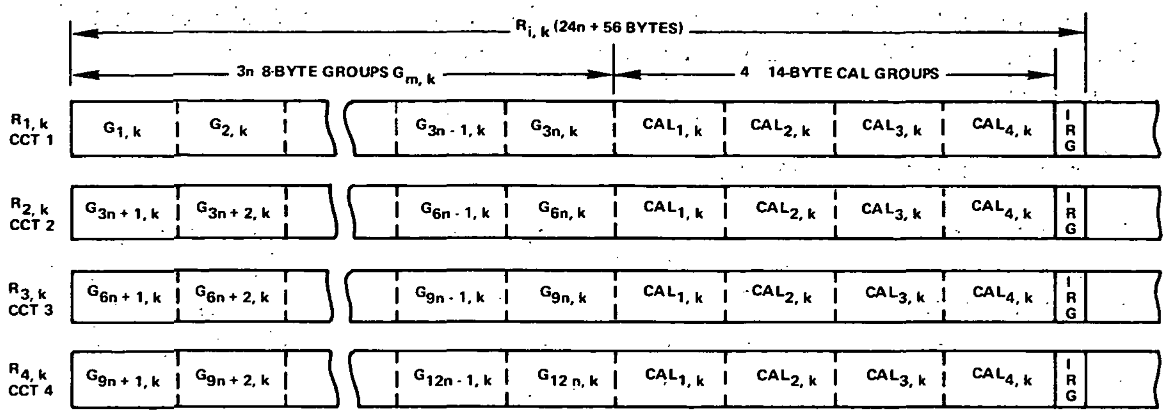
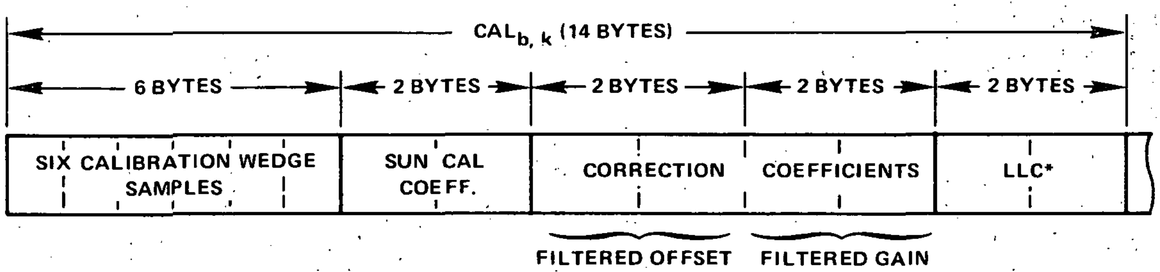


Figure 13. Bulk MSS Full Scene Interleaved Record Format (Line Length Adjusted to N=24n Samples)



*LLC is a 2-byte binary number denoting the number of video data samples per uncorrected (raw) scan line.

Figure 14. Bulk MSS Calibration Group Detail

BAND, LINE	CAL WEDGE	SUN CAL COEFF	CORRECTION COEFFS.		LLC
CAL1, 157	2C 28 13 0F 07 03	2048	4821	3347	3220
CAL2, 157	32 2E 18 15 0E 0B	2048	261	4761	3220
CAL3, 157	32 2D 26 11 0E 0B	2048	5434	7450	3220
CAL4, 157	2A 1D 15 08 05 05	2048	0	6384	3220

Figure 15. Val Dump Printout of Calibration Data

Figure 16 is a sample Val Dump output of an MSS video data record. The printout is in hexadecimal. Note that in this example, tape 1 of 4 is used; therefore, the registration fill characters (X'FF') appear within the first data bytes.

Video Data Record for ERTS-B

The special fifth band video data record $B_{i,k}$ contains 2n (the same n used in calculating the adjusted line length) video data points and 14 bytes of calibration data for the fifth band. The format for the cal data is the same as that for the other bands. Figure 17 is a diagram of the $B_{i,k}$, where k is the sequential Band 5 scan line index and i is the image segment and computer-compatible tape number.

******** VIDEO DATA FROM THE FIRST MSS INTERLEAVED SCAN LINE ********

BANDS

1		**2**		**3**		**4**		**1**		**2**		**3**		**4**		**1**		**2**		**3**		**4**		**1**		**2**		**3**		**4**	
FF	FF	FF	FF	FF	FF	12	12	FF	FF	FF	FF	29	29	13	12	FF	FF	2D	2D	29	29	12	12	2C	2B	2E	2D	28	28	11	11
28	2B	28	28	28	24	11	10	28	28	26	26	23	23	0F	0F	28	28	26	28	23	23	0F	10	28	28	28	28	26	26	10	10
28	28	28	2D	29	28	11	11	2B	2B	28	2D	28	2B	11	12	2C	2C	2E	2E	2D	2D	12	13	2C	2C	2D	31	2D	2B	13	13
2F	2F	31	31	2F	31	13	14	2F	2F	31	31	2D	2F	14	14	2F	2F	31	31	2F	2D	15	14	2C	2C	31	33	2D	2F	14	14
32	2F	33	2F	2F	2F	14	14	2F	32	31	33	2D	2D	13	13	2F	2F	33	31	2F	2F	14	13	2F	2F	2E	2E	2D	2D	14	14
2F	2F	2F	31	2F	2F	13	14	32	2F	36	33	31	31	14	15	2F	32	31	36	31	31	14	16	34	32	36	38	32	32	17	18
34	34	38	38	37	35	18	17	34	32	38	36	35	35	17	17	34	34	36	3B	35	35	18	18	34	37	38	3B	37	37	19	18
3A	3A	3D	3B	3A	3A	18	18	3C	3F	3D	41	3A	3C	19	1A	41	43	41	41	3E	3F	1B	1B	43	43	41	45	41	41	1C	1C
46	46	48	48	41	44	1C	1D	46	46	48	48	41	41	1D	1C	49	46	48	48	44	44	1D	1D	49	46	48	45	44	41	1D	1C
46	43	45	45	3E	3F	1C	1B	43	43	45	41	41	3C	1B	1B	43	43	41	45	41	41	1B	1B	43	43	45	41	41	3E	1C	1C
43	49	48	45	41	41	1C	1D	46	43	48	45	41	41	1C	1C	43	46	48	45	41	41	1C	1D	49	46	48	45	44	41	1D	1D
43	43	45	45	3E	3F	1B	1B	43	43	41	45	3E	41	1A	1B	46	49	45	48	44	41	1C	1C	49	49	48	48	41	41	1B	1D
49	49	48	48	41	44	1D	1D	4B	4B	48	4B	44	47	1D	1F	4B	4F	48	4B	44	47	1D	1E	4F	52	4B	4F	47	4A	1F	20
4F	4F	4B	4B	4A	47	1F	1F	4F	4B	4F	4B	47	44	1E	1D	4B	4F	48	4F	4A	4A	1E	20	52	4F	4F	4B	4A	47	20	1F
4B	49	4B	48	44	47	1F	1D	49	49	48	48	44	44	1E	1D	46	46	48	45	44	44	1E	1C	43	49	41	48	41	41	1C	1D
49	4B	48	48	44	47	1D	1F	4F	52	48	53	47	47	1F	20	52	4F	53	4F	4C	4C	20	1F	4B	4F	4B	4B	47	47	1E	1E
4B	49	4B	4B	47	44	1E	1F	49	49	48	48	44	3E	1D	1D	49	4F	48	48	44	44	1D	1D	52	52	4B	4F	4A	4A	1F	20
4F	4B	4B	4F	4A	4A	1E	1F	4F	4B	4B	4B	44	47	1F	1F	4F	4F	4B	4B	44	4A	1D	1E	4B	4B	4F	48	4A	44	1E	1E
4B	4B	48	4B	44	44	1D	1D	4B	4F	4F	4B	4A	47	1F	20	52	4F	4B	4B	4A	4A	20	20	4F	4F	4F	4F	47	4C	1E	20
4F	52	53	53	4C	4C	20	20	56	56	53	55	4E	4E	22	22	52	52	55	4F	4E	4C	20	20	52	4F	4F	4F	47	4A	20	20
4F	4F	4F	4F	4C	4A	20	1F	52	56	4F	55	4A	51	21	21	59	59	55	55	51	4E	21	22	59	59	59	59	4E	4E	22	24
59	5D	59	59	54	51	23	23	59	59	55	55	51	51	22	22	59	59	55	59	4E	4F	23	23	59	59	59	59	51	51	23	22
56	56	53	55	4E	4C	21	22	59	59	55	55	51	4E	23	23	5D	5D	59	59	51	54	24	24	59	56	55	53	54	4E	24	21
56	56	53	55	4E	4F	21	22	56	59	55	59	51	51	22	23	59	5D	59	5C	51	54	23	23	59	59	59	59	54	51	23	23
59	56	55	59	4E	51	23	23	59	59	55	59	51	54	22	23	5D	5D	59	5C	54	54	23	24	59	59	59	59	4E	51	23	23
59	56	59	59	4E	4C	23	22	59	56	59	55	51	51	22	22	56	56	55	53	4E	4F	22	22	4F	4F	53	4F	4C	4A	20	20
4B	4B	4B	4B	47	47	1E	1F	4F	4F	4B	4F	47	4A	1F	20	52	56	55	55	4C	4F	21	22	56	56	59	55	4E	4E	22	22
56	59	55	59	51	51	23	22	59	56	55	55	51	51	23	23	56	52	55	4F	4E	4C	22	20	4F	52	4F	53	4C	47	20	20
4F	4F	53	4F	4A	4C	20	20	4F	52	53	53	4C	4C	20	21	56	52	55	53	4C	4C	21	21	52	52	53	55	4C	4C	21	21
56	52	55	53	4C	4C	21	22	52	52	53	53	4C	4C	21	21	52	56	53	55	4E	4F	21	22	56	52	53	55	4E	4E	23	22
56	56	55	55	4C	4F	23	22	52	52	53	53	4C	4A	21	22	52	56	53	59	51	51	22	23	59	59	59	59	54	57	24	24
59	59	59	59	51	51	23	24	59	59	59	59	51	54	24	24	56	56	55	55	51	4F	23	22	4F	4F	53	4F	4C	4C	21	21
4F	4B	4F	4F	4C	47	20	1F	4B	4B	4B	4B	47	4A	1F	1F	49	46	4B	48	47	47	1E	1E	46	49	48	48	44	44	1F	1E
46	46	48	45	44	41	1D	1D	43	41	45	41	3E	3E	1C	1B	41	3E	3F	3F	3E	3C	1B	1B	3E	3E	3F	41	3C	3E	1A	19
3E	3C	3F	3F	3C	3C	1A	1A	3C	3A	41	3D	3E	3A	1A	1A	37	37	3D	3D	3A	37	1A	19	34	37	3B	3B	37	37	19	18
37	37	3D	3D	3A	3C	18	19	3A	3A	3D	3D	3A	3E	19	1A	3A	37	3D	3D	3C	3A	1A	18	37	37	3B	3B	3A	3A	19	18
34	32	3B	36	37	37	18	19	34	32	38	36	3C	35	1A	19	32	2F	38	33	37	32	18	17	2C	2F	2E	31	31	31	16	16
34	37	36	3D	37	3A	18	19	37	34	38	3B	3A	3A	18	19	34	2F	3B	33	3A	32	19	17	2C	2C	31	33	31	32	16	17
32	37	38	3B	35	37	17	18	37	3A	3D	3F	3A	3A	1A	1A	37	34	3F	3B	3C	35	19	17	34	34	3B	3B	37	37	18	18
34	34	3B	3D	3A	3A	19	19	34	34	3D	38	3C	37	1A	1A	34	37	38	3D	37	3A	18	19	37	32	3D	38	3A	3A	19	18
32	32	36	38	37	3A	19	19	34	34	38	3B	3A	3C	19	1B	37	37	3D	3D	3C	3A	1A	1A	37	3A	3B	3D	3C	3A	1A	19
37	37	3D	3D	3A	3A	19	19	3A	37	3D	3B	3A	3A	19	19	37	37	3B	3B	37	37	18	18	37	3A	3B	3D	37	37	19	18
37	3A	3B	3B	3A	37	18	18	37	37	38	38	37	37	17	17	37	37	36	38	35	37	18	17	37	37	38	38	35	32	17	16
37	34	38	36	35	32	16	15	32	34	38	36	31	31	16	16	34	32	36	33	31	32	14	15	32	34	36	33	32	31	14	15
32	2F	33	31	2F	2D	14	13	2F	2C	2F	2F	2D	2D	13	12	2F	2F	31	31	2D	2B	13	13	2F	2F	2D	2D	2B	2B	13	13
2C	2C	2D	2D	2B	29	12	12	2C	2C	2D	2B	2B	2B	12	11	2C	2C	2B	2B	29	29	12	11	2C	2C	2B	2D	29	26	12	11
2C	2B	2D	28	29	28	11	11	2B	2B	28	28	26	28	10	10	2B	2B	2B	28	28	26	11	11	2B	2B	2B	2D	28	28	11	11
28	28	2D	2B	29	29	11	11	2B	2B	28	2B	29	28	12	12	2B	2B	2D	2D	29	29	12	12	2B	2C	2D	2E	29	2D	11	13

Figure 16. Sample Val Dump Output of an MSS Video Data Record
(See Appendix G for hexadecimal-to-decimal conversion.)

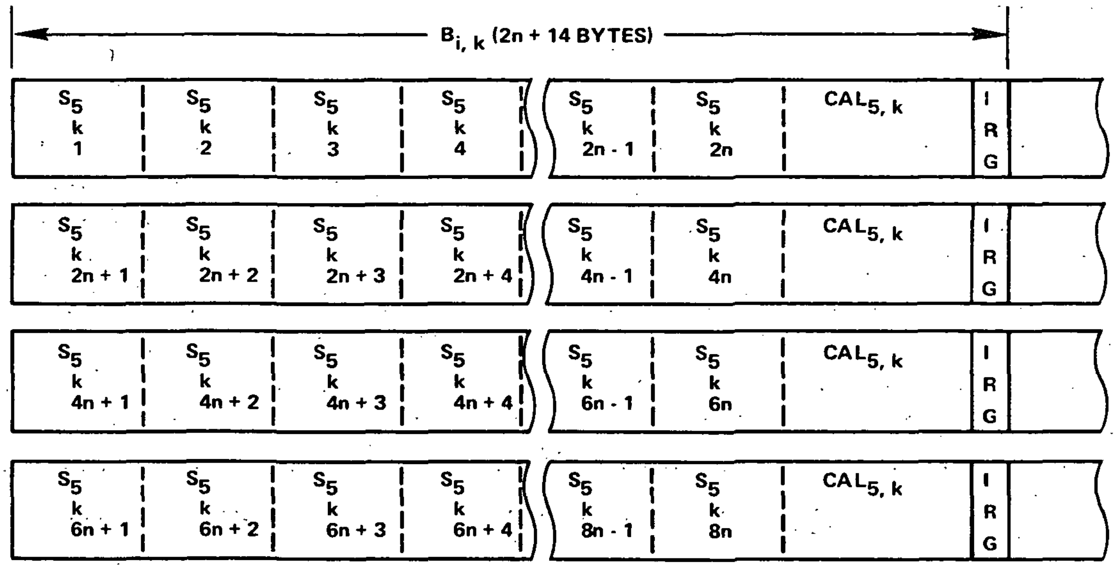


Figure 17. Bulk MSS Full Scene Fifth-Band Data Record

Missing Data Flags

If data for a scan line is lost while making a CCT, a flag (X'CC' or, in the binary representation, 1100 1100) is inserted at the beginning of the scan line (on tape 1 of 4 only) and at the end of the scan line (on tape 4 of 4 only).

Line Set

The line set ($L_{i,p}$) is the scheme used for including the video data from the fifth band which will be on ERTS-B. A line set consists of three regular video data records and a fourth special record which contains the fifth band's video and cal data. Figure 18 is a diagram of the line set. For ERTS-1 there is no fourth record—just the regular video data records.

The Total Set of CCTs

One CCT contains an ID record, an annotation record, 780 line sets of video data (which represent the interleaved data for a 42.25 by 185 km strip of the scene, for the four MSS spectral bands for ERTS-1 and includes the fifth band for ERTS-B) and an end of file. See Figure 19 for a diagram of the tape format. Since a 185 by 185 km scene is divided into four 46.25 by 185 km strips, a complete set consists of four CCTs (one for each strip).

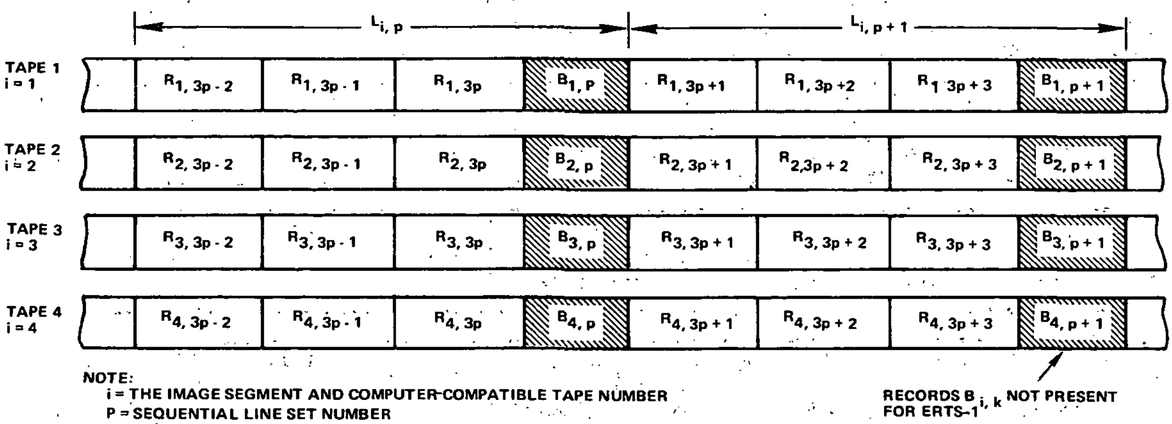


Figure 18. Bulk MSS Full Frame Line Set, ERTS-B

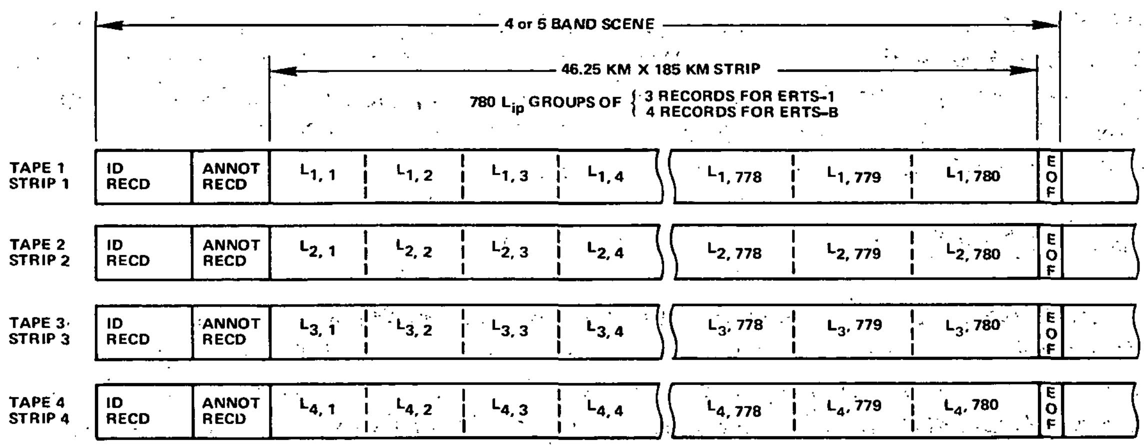


Figure 19. Bulk MSS Full Scene, Four-CCT Format

RADIOMETRIC STRIPING WITHIN VIDEO DATA ON CCTs

Striping problems in CCT video data can be divided into three basic types: radiometric striping, sixth line striping, and intermittent problems which appear to be striping.

RADIOMETRIC STRIPING

Radiometric striping is characterized by variations in the film density of imagery which should be uniform. These variations are repeatable and are present in the digital data in the same manner.

This type of striping is due to slight differences in sensitivity among the detectors. To compensate for this variation in detector output, gains and offsets are used which are calculated from regression coefficients that operate on the cal wedge of each detector.

The regression coefficients used before April 1973 were based on prelaunch evaluations. Radiometric sensitivity, however, changed slightly after launch, causing a striping problem. In April 1973, new regression coefficients were selected which effectively eliminated the radiometric striping problem.

Appendix H provides information on detector-to-detector radiometric accuracy.

SIXTH LINE STRIPING

This striping is characterized by a variation in every sixth scan line of six quantum levels or more from the average quantum level of the other scan lines. This striping problem was caused by an intermittent hardware problem in the MSS controller in IIGS, and was corrected through modification of the software in April 1973.

INTERMITTENT PROBLEMS

This class of problems occurs so intermittently that a solution has not been determined to correct for them. These problems include partial sync loss, full sync loss, track loss or disable, bit slips, and demux noise. These problems, along with their causes and effects, are listed in Table 3.

Table 3
Causes and Effects of Intermittent Striping Problems

Problem	Cause	Effect
Track loss or disable	Inoperative track on FR1928 tape recorder or MSS controller unable to find sync	Zeros are stored on the CCT for a detector or detectors, line length code, cal wedge, etc.
Partial sync loss	Complete loss of data/sync for one or several scan lines	Zeros stored on the CCT for a detector
Bit slips	Data not decoded properly by the FR1928 tape recorder	Missing scan line, or portion of scan line contains zeros
Demux noise	The demultiplexer occasionally adds noise to the data as it is being transferred to the ground from the spacecraft	Intermittent zeros appear in the video for a detector
Full sync loss	Loss of sync for all six detectors of a band	All zeros on the CCT for video data, line length code and cal wedge

APPENDIX A

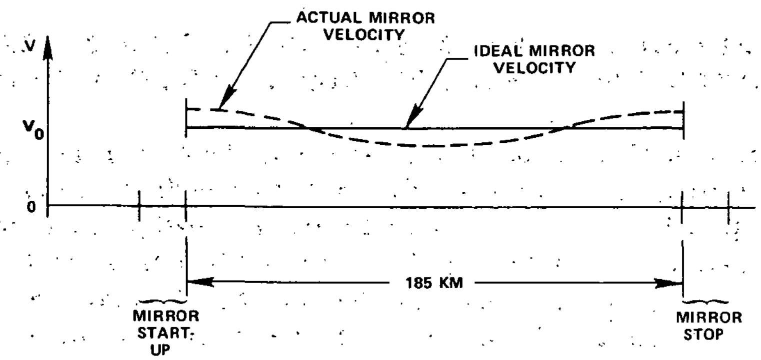
DISTANCE BETWEEN MSS CCT VIDEO DATA BYTES AND THE CORRESPONDING GROUND AREA COVERED*

During the MSS scan of the ground, the video data bytes correspond to 260 by 260 foot areas which, if the mirror velocity were constant, would have a constant overlap of 71.5 feet. The actual mirror velocity is not constant because of the speeding up and slowing down of the mirror. A realistic representation of the mirror velocity versus time is very nearly a cosine curve during the active scan, as shown in Figure A-1. Since the mirror velocity is not constant, the amount of overlap is also variable, but is negligible for most applications of the data. Figure A-2 shows the variable overlap, exaggerated to illustrate this characteristic.

If the distance covered on the ground and the sweep time of the mirror are plotted for a constant mirror velocity and for a variable mirror velocity, the relationship between the two is similar to that shown in Figure A-3. The straight line shows a constant velocity of the mirror versus the distance covered on the ground. The curved line shows the actual variable velocity of the mirror versus the distance covered on the ground. The difference between the two lines indicates the corrections necessary to make points on the CCT reflect accurately the distance covered on the ground.

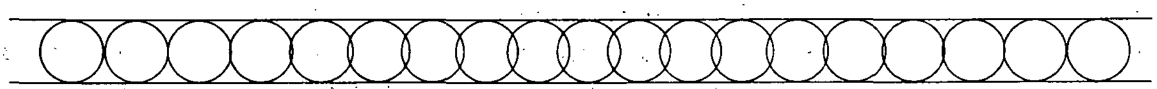
Figure A-4 shows a mirror velocity profile curve which plots the summation of the ground error versus the 185 km of ground covered. The maximum accumulated error is approximately ±400 meters (i.e., approximately 1300 feet, which is about 5 pixels). It should be noted that the mirror velocity profile curve shows the accumulated error at any point across the scan line. The accumulated error at 46.25 km is close to the maximum; however, at 92.5 km the accumulated error is zero. When interpreting the distance between two points on the ground corresponding to the distance between video data bytes on the CCT, one must remember that the error accumulated from the beginning of the scan line to the point located at 46.25 km is approximately 400 meters. The distance represented by a quarter of a digital scan line is not 46.25 km; it is 46.25 km minus approximately 400 meters; whereas, half of the digital scan line corresponds to 92.5 km.

*This discussion is based on nominal spacecraft conditions (such as spacecraft altitude) and does not consider negligible perspective errors.



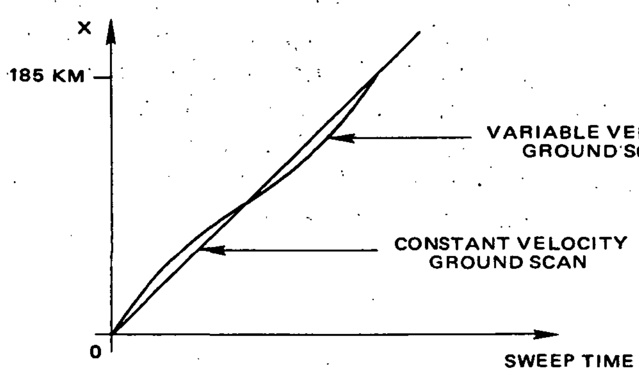
NOTE: Not drawn to scale

Figure A-1. Comparison of the Constant Mirror Velocity and the Variable Mirror Velocity



NOTE: 1. Pixels are represented by circles for ease of illustration; they are actually squares.
2. Not drawn to scale

Figure A-2. Overlay of Pixels, Corresponding to a Variable Mirror Velocity



NOTE: 1. **X** = the easterly scan of the ground
2. Not drawn to scale

Figure A-3. Comparison of Distance Covered on the Ground for a Constant Mirror Velocity and a Variable Mirror Velocity

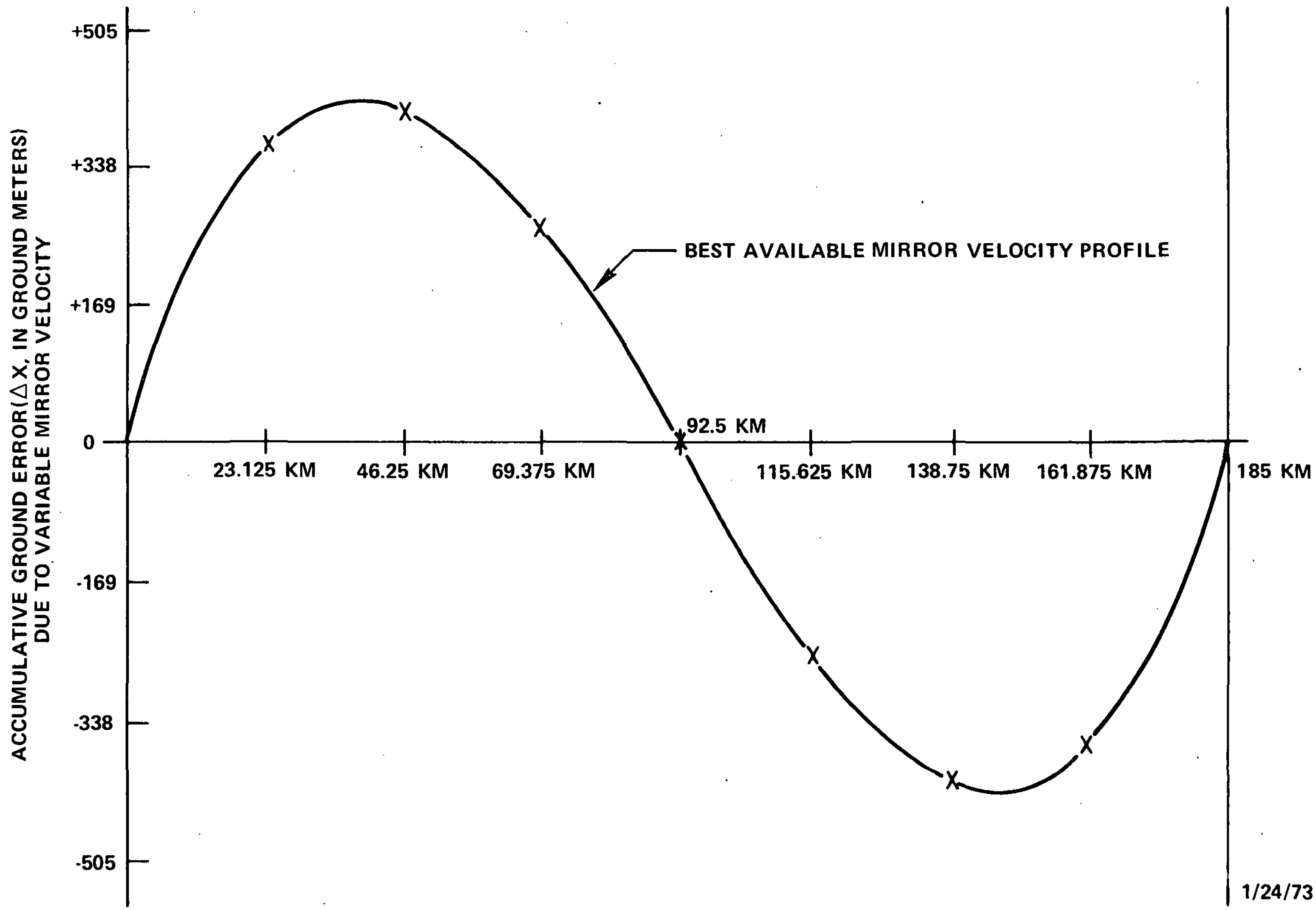


Figure A-4. Mirror Velocity Profile for the Active Mirror Scan

APPENDIX B

MAGNETIC TAPE PHYSICAL CHARACTERISTICS

Computer-compatible tapes (CCTs) are standard one-half-inch polyester-base magnetic tapes. The physical characteristics of CCTs are given in Figure B-1 and Table B-1.

There is one scene of digital imagery for each set of four CCTs. The external label on each tape contains the information shown in Figure B-2.

CCTs are available in two basic formats:

Nine-track, 800 bpi

For the nine-track CCT, the alphanumeric data are in EBCDIC and the video data are in binary.

Seven-track, 800 bpi

The seven-track CCT contains packed binary video data and packed binary EBCDIC alphanumeric data. The record layout and bit structure are identical to the layout and structure of the nine-track CCT. The standard product is a seven-track, 800-bpi CCT, but a seven-track, 556-bpi CCT may be ordered by special request. The format is the same as for the 800-bpi CCT.

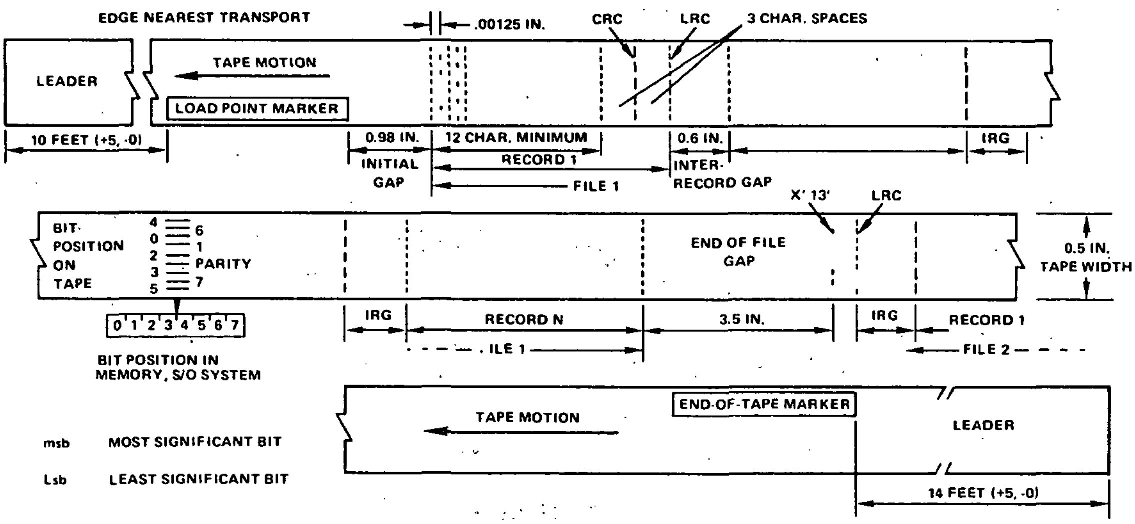


Figure B-1. Physical Spacing of Records on Tape

Table B-1

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.
Recording Method:		NRZ 1 (non-return to zero, change on ones).
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 is standard; 556 bpi by special request.
9-track	Interchange code:	Video data, binary; Alphanumeric ID data, EBCDIC.
	Recording format:	9 channels, 8 information bits plus parity, binary.
	Recording density:	800 bits per inch.
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)		0.60 + 0.15, -.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 B-1 for description.

```
CCT DATE: / /        SCENE DATE: / /
NDPF ID:

              1052-17470-MP

TRACK: #9                DENSITY: 800
REEL 1 OF 4              USER ID: A328
```

Figure B-2. External Tape Label

APPENDIX C

LINE LENGTH ADJUSTMENT

When the MSS video tape is processed in IIGS in the video-to-tape mode, a comparison is made while each scan line is being read to determine the maximum line length code (LLC) for the scene. The maximum LLC, referred to as Nmax, is stored on an auxiliary paper tape (APT) which is used by the digital subsystem (DS) to compute the adjusted line length.

To compute the adjusted line length, DS uses the Nmax from the APT and LLC, a code denoting the number of video data samples per uncorrected (raw) scan line, referred to as LLC raw, which is provided to the DS in the calibration data. In computing the adjusted line length, LLC raw is confined to boundaries as follows:

$$2650 < \text{LLC raw} \leq 3480$$

If LLC raw extends beyond these boundaries, DS uses the value of LLC raw from the previous scan line. Next, Nmax minus LLC raw is computed; if it is equal to zero, no line length corrections are made. LLA (adjusted line length) is converted to the smallest multiple of 24 which satisfies the following condition:

$$\text{LLA} > \text{Nmax} + 6$$

where 6 corresponds to the number of registration fill characters added to each interleaved scan line

or

$$\text{LLA} = 24n$$

where n = greatest integer of:

$$E = \frac{\text{Nmax} + 6 + 23}{24}$$

23/24 provides high roundoff.

The multiple of 24 is selected as the smallest integer which is divisible by both six and eight, the six representing six bytes maximum for spatial registration, the eight representing bytes for interleaving (two bytes per band, multiplied by four bands).

After calculating the LLA, a computation is made to determine the interval for interspersing synthetic bytes. To obtain equal line lengths, synthetic bytes are interspersed with data bytes at a specific interval. The value assigned to the synthetic byte is equal to the actual quantum level of the last video data byte immediately preceding the synthetic byte. The interval is calculated as follows:

$$\Delta = \frac{LLC}{LLA - (LLC+6)} \qquad \text{(integer part only)}$$

This interval is set into a counter. The counter is decremented with each transfer of video data (bytes). When the counter reaches zero, the last data byte transferred is repeated. The counter is then reset and the process is repeated until the scan line is complete.

All deltas in the count sequence are the same with the exception of the initial deltas, which must be adjusted to correct for spectral band misregistration. As the data is transmitted from the sensor, each MSS band is spatially offset from the preceding band by two video data bytes (a function of sensor operation). Therefore, to register the video data on the CCT, Band 1 data is offset by six bytes, Band 2 by four bytes, and Band 3 by two bytes relative to Band 4. This is accomplished by adding registration fill characters of X'FF' data.

To adjust the delta for the initial count for each scan line, the quantity Δ_b is subtracted, where:

$$\Delta_b = 8 - 2 * b$$

where b is the spectral band number; i.e.,

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

APPENDIX D

RADIOMETRIC CALIBRATION

Figure D-1 shows the data flow through the initial image generating subsystem (IIGS) and the digital subsystem (DS) of the NASA Data Processing Facility. The MSS video data is entered into the IIGS where either a 70-mm film image or high-density digital tape (HDDT) is made. The HDDT contains the uncalibrated data, line length code values for each scan line and the radiometric calibration wedge samples. The HDDT is the input to the DS. The DS reformats the data, calibrates the data and generates the CCT.

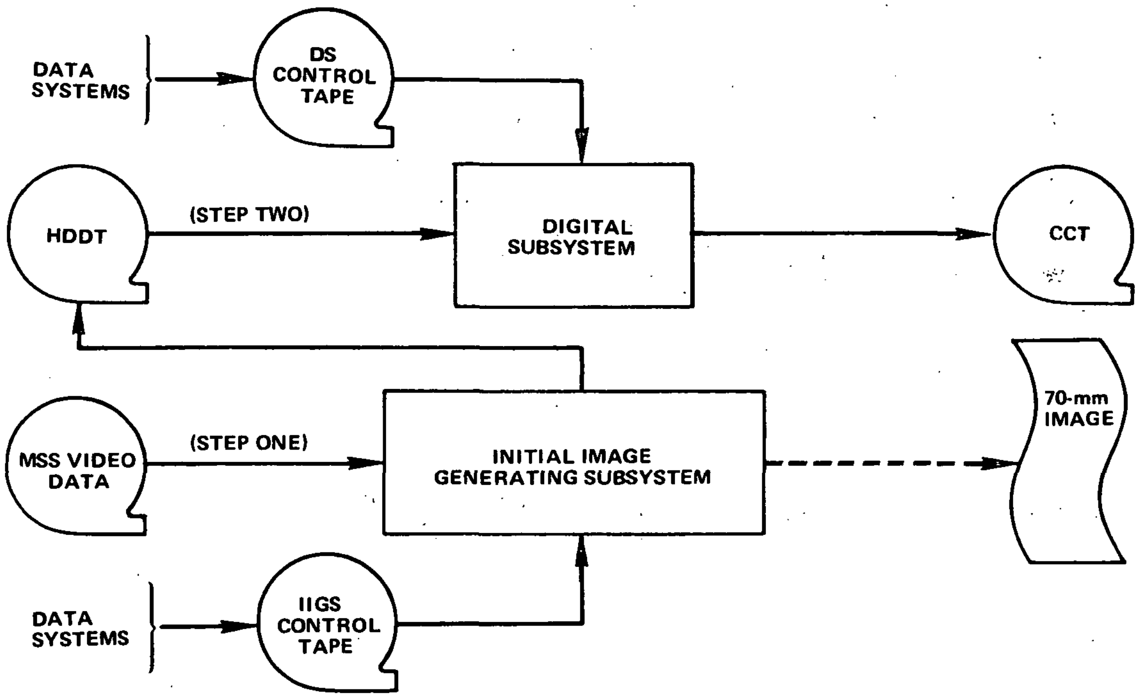


Figure D-1. Data Flow through IIGS and DS

Figure D-2 is a flowchart of the radiometric calibration procedure (used for the first three MSS bands; the fourth band is uncalibrated) which takes place in the DS. A detailed explanation of the equations, calibration wedge word counts, maximum specified radiance and the sun calibration procedure is provided in the ERTS Data Users' Handbook. Note that the sun calibration is not used at present; the sun cal coefficient K_S is set equal to one.

The calibration data from the HDDT scan line record is entered into the system. At this point, either a compressed or decompressed mode is selected. Next, an estimate is made for $\hat{a}$ and $\hat{b}$ from the calibration data. The equations used in making this estimate are the following:

$$\left.\begin{aligned}\hat{a} &= \sum_{i=1}^{6} C_i V_i \\ \hat{b} &= \sum_{i=1}^{6} D_i V_i\end{aligned}\right\} \quad \text{Linear regression}$$

V_i is the input value of the cal wedge word i, and C_i and D_i are regression coefficients. See Table D-1 for the new C_i's and D_i's. $\hat{a}$ and $\hat{b}$ are then filtered, yielding $\hat{a}_s$ and $\hat{b}_s$, which are referred to as the filtered offset and filtered gain respectively. The filter equations are as follows:

$$\left(\hat{a}_s\right)_n = \begin{cases} \hat{a}_n & \text{, for } n = 1 \\ (\hat{a}_s)_{n-1} + W_n^a \left[\hat{a}_n - (\hat{a}_s)_{n-1}\right] & \text{, for } n > 1 \end{cases}$$

and

$$\left(\hat{b}_s\right)_n = \begin{cases} \hat{b}_n & \text{, for } n = 1 \\ (\hat{b}_s)_{n-1} + W_n^b \left[\hat{b}_n - (\hat{b}_s)_{n-1}\right] & \text{, for } n > 1 \end{cases}$$

where

$$W_n^a = \begin{cases} 1/n, & \text{for } n \le N_a \\ 1/N_a, & \text{for } n > N_a \end{cases}$$

and

$$W_n^b = \begin{cases} 1/n, & \text{for } n \le N_b \\ 1/N_b, & \text{for } n > N_b \end{cases}$$

N_b is the control number for the gain filter. The present value for N_a and N_b is 32.

Finally, calibrated values are produced by applying the following equation:

$$\hat{U}_{s_n} = \frac{K_S}{(\hat{b}_S)_n} \left[X\ (U) - (\hat{a}_s)_n \right]$$

K_S is the sun cal coefficient and U is the gray scale level (0 to 63).

The transformation X (U) may be the decompression transform or it may be the identity transform. Values of U_S are rounded to integers before being loaded into the look-up table.

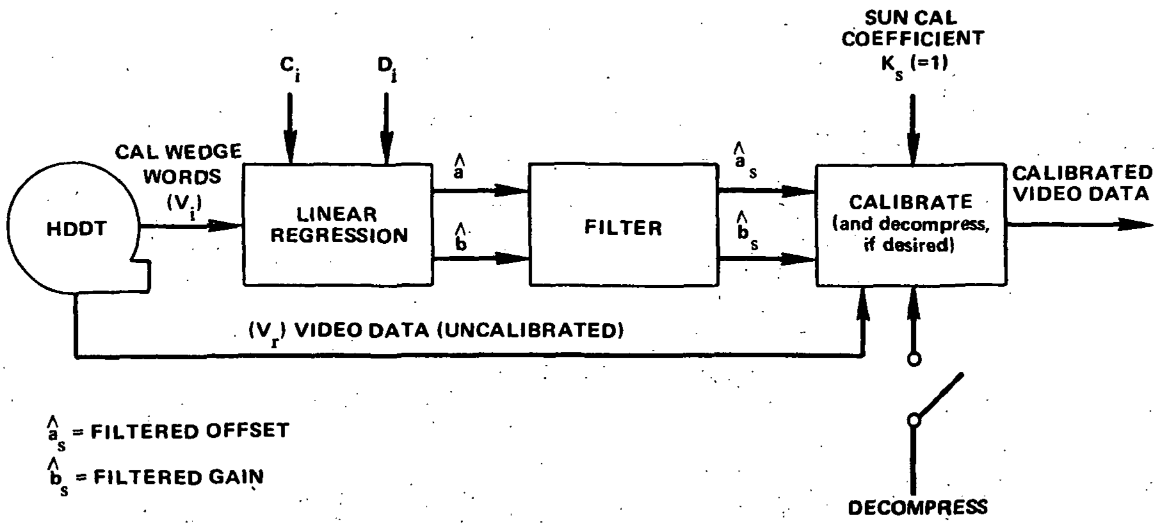


Figure D-2. DS Radiometric Calibration Flowchart

Table D-1

New C_i's and D_i's - 3/21/73

LOW GAIN DECOMPRESSED

Sensor	D_1	C_1	D_2	C_2	D_3	C_3	D_4	C_4	D_5	C_5	D_6	C_6
Band 1												
1	1.036367	-.108559	.854871	-.066100	-.247688	.1918311	-.353022	.216473	-.601840	.274681	-.688688	.294998
2	1.047573	-.188607	.862823	-.114458	-.251801	.332891	-.357539	.375328	-.606960	.475432	-.694096	.510404
3	1.117120	-.1402285	.913688	-.0850522	-.274113	.237111	-.383433	.266762	-.640955	.336609	-.732306	.361386
4	1.0095862	-.1316502	.8261825	-.0774573	-.2503755	.2406487	-.3490800	.2698143	-.5786456	.3376474	-.6576675	.3609971*
5	1.096431	-.1410693	.894228	-.0838316	-.273376	.2466820	-.379107	.2766114	-.625897	.346470	-.712279	.370923
6	1.114457	-.171481	.914577	-.1026711	-.272260	.305906	-.382795	.343958	-.641920	.433164	-.732058	.464194
Band 2												
7	1.062738	-.108358	.754876	-.045005	-.293886	.170814	-.367118	.185884	-.537174	.220878	-.619436	.237807
8	1.057555	.211961	.7652791	.0937949	-.284166	-.330492	-.361581	-.361791	-.543908	-.435505	-.633180	-.471598
9	1.049898	-.195312	.750594	-.082862	-.287566	.307182	-.361447	.334940	-.533855	.399715	-.617624	.431187
10	1.077621	-.163970	.777104	-.071763	-.291141	.255994	-.369147	.279928	-.552425	.3361606	-.642012	.363648*
11	1.042215	-.125037	.745033	-.053924	-.284900	.192533	-.358323	.2101025	-.530078	.2512025	-.613948	.271272
12	1.092350	-.212788	.784239	-.0936214	-.296354	.324314	-.374436	.354514	-.557884	.425465	-.647915	.460286
Band 3												
13	1.118713	.630063	.769285	.247272	.2406098	-.331881	-.6480508	-1.30539	-.703262	-1.36588	-.777294	-1.44698**
14	1.1051712	-.0081213	.7736310	-.0033265	.259543	+.0041084	-.647728	.017230	-.706085	.018074	-.784532	.019208
15	1.146694	-.1706714	.805765	-.070376	.274165	+.086012	-.673831	.364896	-.735174	.382942	-.817619	.407197*
16	1.285862	.383025	.9023324	.153361	.304500	-.204633	-.755619	-.839452	-.823300	-.879981	-.913775	-.934159
17	1.256174	-.1660734	.873618	-.0647405	.284740	.0912436	-.733807	.3610404	-.797704	.3779654	-.883020	.4005644*
18	1.15733	-.175141	.808707	-.07025	.270821	.092646	-.677541	.379852	-.738034	.398173	-.819017	.422698

*Data did not change

**D_i's did not change

APPENDIX E

DECOMPRESSION TABLES USED BY DIGITAL SUBSYSTEM PRIOR TO CALIBRATION

The following tables are used for decompressing the video data from Bands 1, 2 and 3. Band 4 is linear and requires no decompression.

The values of the compressed video data vary from 0 to 63; after decompression, the video data values vary from 0 to 127. The decompressed values, gains and offsets are used to determine the calibrated values of the video data. To reverse the process and obtain compressed values from the decompressed values on the CCT, the user must have the gain and offset values in addition to the values in the decompression table.

<u>MSS Bands 1 and 3</u>

Input	Output	Input	Output	Input	Output
0	0	17	17	28	34
1	1	18	18		35*
2, 3	2	19	19	29	36
4	3		20*		37*
5	4	20	21	30	38
6	5	21	22		39*
7	6		23*	31	40
8	7	22	24		41*
9	8	23	25	32	42
10	9		26*	33	43
11	10	24	27		44*
12	11		28*	34	45
13	12	25	29		46*
14	13	26	30	35	47
15	14		31*		48*
	15*	27	32	36	49
16	16		33*		50*

*Prior to calibration these quantum levels are not used. After calibration (individual detector offset and gain adjustment) different quantum levels may be used, while others are unused.

MSS Bands 1 and 3

Input	Output	Input	Output	Input	Output
37	51		76*		102*
	52*		77*		103*
38	53	47	78	56	104
	54*		79*		105*
	55*		80*	57	106
39	56	48	81		107*
	57*		82*		108*
40	58	49	83	58	109
	59*		84*		110*
	60*		85*		111*
41	61	50	86	59	112
	62*		87*		113*
42	63		88*		114*
	64*	51	89	60	115
	65*		90*		116*
43	66		91*		117*
	67*	52	92	61	118
	68*		93*		119*
44	69		94*		120*
	70*	53	95	62	121
	71*		96*		122*
45	72		97*		123*
	73*	54	98	63	124
	74*		99*		125*
46	75		100*		126*
		55	101		127*

*Prior to calibration these quantum levels are not used. After calibration (individual detector offset and gain adjustment) different quantum levels may be used, while others are unused.

MSS Band 2

Input	Output	Input	Output	Input	Output
0	0	26	30	41	60
1	1		31*		61*
2, 3	2	27	32		62*
4	3		33*	42	63
5	4	28	34		64*
6	5		35*		65*
7	6	29	36	43	66
8	7		37*		67*
9	8	30	38		68*
10	9	31	39	44	69
11	10		40*		70*
12	11	32	41	45	71
13	12		42*		72*
14	13	33	43		73*
15	14		44*	46	74
	15*	34	45		75*
16	16		46*		76*
17	17	35	47	47	77
18	18		48*		78*
19	19	36	49		79*
	20*		50*	48	80
20	21	37	51		81*
21	22		52*		82*
22	23	38	53	49	83
	24*	39	54		84*
23	25		55*		85*
	26*		56*	50	86
24	27		57*		87*
25	28	40	58	51	88
	29*		59*		89*
					90*

*Prior to calibration these quantum levels are not used. After calibration (individual detector offset and gain adjustment) different quantum levels may be used, while others are unused.

APPENDIX E (continued)

MSS Band 2

Input	Output	Input	Output	Input	Output
52	91		103*	60	115
	92*	56	104		116*
	93*		105*	61	117
53	94		106*		118*
	95*	57	107		119*
	96*		108*	62	120
54	97	58	109		121*
	98*		110*	63	122
	99*		111*		123*
55	100	59	112		124*
	101*		113*		125*
	102*		114*		126*
					127*

MSS Band 4

Data from MSS Band 4 are not decompressed.

*Prior to calibration these quantum levels are not used. After calibration (individual detector offset and gain adjustment) different quantum levels may be used, while others are unused.

APPENDIX F

TICK MARK REFERENCE SYSTEM

The Bulk MSS film image is used in establishing the tick mark reference system. The scene on a 70-mm film image is 55 mm in the X direction and 53 mm in the Y direction. The area represented by the scene is 185 km by 178.36 km; this scene consists of 2256 scan lines.

The tick mark reference system has been chosen so that the origin is at the format center. The corners of the scene are designated A (1/2, -1/2), B (-1/2, -1/2), C (1/2, 1/2) and D (-1/2, 1/2). See Figure F-1.

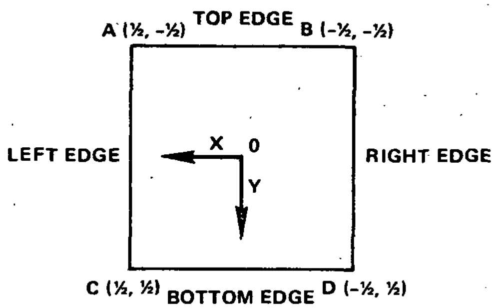


Figure F-1. Tick Mark Reference System

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 0.

It should be noted that the scene on the Bulk MSS 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 F-2.

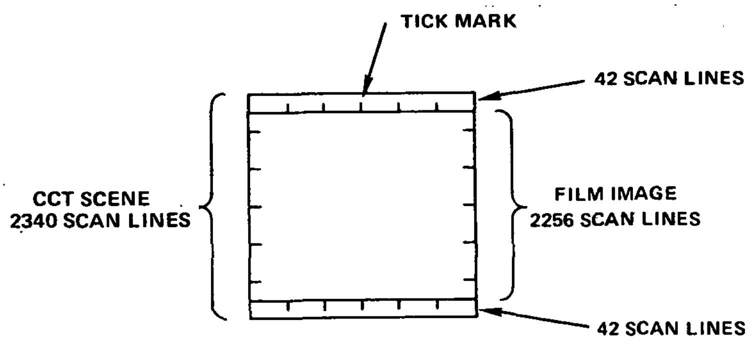


Figure F-2. CCT Film Image

APPENDIX G

CONVERSION TABLE: BINARY/OCTAL/DECIMAL/HEXADECIMAL

Binary	Octal	Decimal	Hexadecimal
00000000	0	0	0
00000001	1	1	1
00000010	2	2	2
00000011	3	3	3
00000100	4	4	4
00000101	5	5	5
00000110	6	6	6
00000111	7	7	7
00001000	10	8	8
00001001	11	9	9
00001010	12	10	A
00001011	13	11	B
00001100	14	12	C
00001101	15	13	D
00001110	16	14	E
00001111	17	15	F
00010000	20	16	10
00010001	21	17	11
00010010	22	18	12
00010011	23	19	13
00010100	24	20	14
00010101	25	21	15
00010110	26	22	16
00010111	27	23	17
00011000	30	24	18
00011001	31	25	19
00011010	32	26	1A
00011011	33	27	1B
00011100	34	28	1C
00011101	35	29	1D
00011110	36	30	1E
00011111	37	31	1F
00100000	40	32	20
00100001	41	33	21
00100010	42	34	22
00100011	43	35	23
00100100	44	36	24

APPENDIX G (continued)

Binary	Octal	Decimal	Hexadecimal
00100101	45	37	25
00100110	46	38	26
00100111	47	39	27
00101000	50	40	28
00101001	51	41	29
00101010	52	42	2A
00101011	53	43	2B
00101100	54	44	2C
00101101	55	45	2D
00101110	56	46	2E
00101111	57	47	2F
00110000	60	48	30
00110001	61	49	31
00110010	62	50	32
00110011	63	51	33
00110100	64	52	34
00110101	65	53	35
00110110	66	54	36
00110111	67	55	37
00111000	70	56	38
00111001	71	57	39
00111010	72	58	3A
00111011	73	59	3B
00111100	74	60	3C
00111101	75	61	3D
00111110	76	62	3E
00111111	77	63	3F
01000000	100	64	40
01000001	101	65	41
01000010	102	66	42
01000011	103	67	43
01000100	104	68	44
01000101	105	69	45
01000110	106	70	46
01000111	107	71	47
01001000	110	72	48
01001001	111	73	49
01001010	112	74	4A
01001011	113	75	4B

APPENDIX G (continued)

Binary	Octal	Decimal	Hexadecimal
01001100	114	76	4C
01001101	115	77	4D
01001110	116	78	4E
01001111	117	79	4F
01010000	120	80	50
01010001	121	81	51
01010010	122	82	52
01010011	123	83	53
01010100	124	84	54
01010101	125	85	55
01010110	126	86	56
01010111	127	87	57
01011000	130	88	58
01011001	131	89	59
01011010	132	90	5A
01011011	133	91	5B
01011100	134	92	5C
01011101	135	93	5D
01011110	136	94	5E
01011111	137	95	5F
01100000	140	96	60
01100001	141	97	61
01100010	142	98	62
01100011	143	99	63
01100100	144	100	64
01100101	145	101	65
01100110	146	102	66
01100111	147	103	67
01101000	150	104	68
01101001	151	105	69
01101010	152	106	6A
01101011	153	107	6B
01101100	154	108	6C
01101101	155	109	6D
01101110	156	110	6E
01101111	157	111	6F
01110000	160	112	70
01110001	161	113	71
01110010	162	114	72

APPENDIX G (continued)

Binary	Octal	Decimal	Hexadecimal
01110011	163	115	73
01110100	164	116	74
01110101	165	117	75
01110110	166	118	76
01110111	167	119	77
01111000	170	120	78
01111001	171	121	79
01111010	172	122	7A
01111011	173	123	7B
01111100	174	124	7C
01111101	175	125	7D
01111110	176	126	7E
01111111	177	127	7F

APPENDIX H

DETECTOR-TO-DETECTOR RADIOMETRIC ACCURACY

Tests have been made using a computer program (EVAL) to evaluate the video data on the Bulk MSS CCT. The radiance levels have been sorted into three ranges (referred to as regions and corresponding to the intervals 0 to 20, 21 to 60 and 61 to 127). As part of the evaluation, a confidence check is used which requires at least 50 data points within a region for each detector in a mirror sweep. If a detector has fewer than 50 data points for a region, then none of the data in that region are used in evaluating the data for that particular mirror sweep. The computer output includes an area which lists the number of samples for each detector. These samples refer to the number of mirror sweeps for which the data satisfy the confidence check. The results of EVAL have been useful in detecting striping problems and in comparing detector-to-detector radiometric accuracy.

Two CCTs have been chosen to demonstrate the usefulness of the program's output. One CCT has video data which have not been radiometrically corrected using the new regression coefficients C's and D's). The video data on the other CCT have been radiometrically corrected using the new C's and D's. These tapes are referred to as "before" and "after" CCTs respectively.

Figure H-1 shows, in summary form, the average radiance level for each detector. The averaging is calculated for each mirror sweep, which consists of six scan lines. As can be seen in Figure H-2, the difference in radiance levels among the detectors for a given region is not more than two quantum levels. By referring to Figures H-1 and H-2, the detector-to-detector radiometric accuracy of the "before" and "after" CCTs can be compared. It will be noticed that the ranges of values on "before" and "after" CCTs are quite different. This is because slightly different areas are represented on each CCT; however, a comparison of the differences between detectors is meaningful. For example, note that detectors 2 and 4 of band 3, region 3 were quite high and low respectively on the "before" CCT. The corresponding detectors on the "after CCT show considerable improvement.

BULK MSS CCT
SCENE/FRAME ID 198-07441
CCT SEQ. NO. 4 OF 4
CONFIDENCE LIMIT 50

	AVR RADIANCE LEVEL FOR EACH DETECTOR						NO. OF SAMPLES FOR EACH DETECTOR					
	1	2	3	4	5	6	1	2	3	4	5	6
BAND 1												
REGION 1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
REGION 2	41.6	42.2	41.4	42.0	40.8	40.4	50	50	50	50	50	50
REGION 3	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
BAND 2												
REGION 1	11.6	11.7	12.0	11.5	12.1	11.9	15	15	15	15	15	15
REGION 2	45.2	44.9	44.9	44.2	44.3	44.7	50	50	50	50	50	50
REGION 3	69.0	68.8	67.9	67.4	67.8	66.9	47	47	47	47	47	47
BAND 3												
REGION 1	8.9	9.1	8.9	7.4	7.7	8.2	18	18	18	18	18	18
REGION 2	43.1	43.1	43.7	42.9	43.6	43.6	50	50	50	50	50	50
REGION 3	74.2	79.3	75.7	71.3	78.0	74.6	15	15	15	15	15	15
BAND 4												
REGION 1	12.9	12.9	12.7	12.7	12.7	12.7	50	50	50	50	50	50
REGION 2	23.2	23.2	23.3	23.3	23.7	23.2	50	50	50	50	50	50
REGION 3	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0

STOP 0

Figure H-1. Average Radiance Levels for the "before" CCT

BULK MSS CCT
SCENE/FRAME ID 198-07441
CCT SEQ. NO. 4 OF 4
CONFIDENCE LIMIT 50

	AVR RADIANCE LEVEL FOR EACH DETECTOR 1	2	3	4	5	6	NO. OF SAMPLES FOR EACH DETECTOR 1	2	3	4	5	6
BAND 1												
REGION 1	17.1	16.9	16.6	16.9	17.1	16.2	17	17	17	17	17	17
REGION 2	33.7	34.0	34.1	34.3	34.1	34.2	50	50	50	50	50	50
REGION 3	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
BAND 2												
REGION 1	14.4	14.5	14.0	14.1	14.3	14.0	27	27	27	27	27	27
REGION 2	39.3	39.5	39.4	39.7	39.4	39.1	50	50	50	50	50	50
REGION 3	71.8	72.3	71.4	73.4	72.5	72.1	22	22	22	22	22	22
BAND 3												
REGION 1	14.0	14.5	14.2	14.1	13.2	13.9	44	44	44	44	44	44
REGION 2	38.1	37.8	38.3	38.1	38.0	37.5	50	50	50	50	50	50
REGION 3	76.8	77.9	77.6	77.1	78.3	76.7	22	22	22	22	22	22
BAND 4												
REGION 1	12.7	12.7	12.4	12.4	12.7	12.4	50	50	50	50	50	50
REGION 2	24.9	25.1	25.1	25.2	25.3	25.1	50	50	50	50	50	50
REGION 3	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0

STOP 0

Figure H-2. Average Radiance Levels for the "after" CCT