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GEOSCIENCE AUSTRALIA (CCRS) LANDSAT THEMATIC MAPPER DIGITAL DATA FORMAT DESCRIPTION

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[Note :this edition contains references to Landsat 6 which should be ignored.]

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CHAPTER 1

INTRODUCTION

1.1 DESCRIPTION OF DOCUMENT

This document defines the Computer Compatible Tape (CCT) format for raw, quicklook, bulk-corrected (georeferenced) system-corrected and precision processed Landsat Thematic Mapper (TM) imagery data acquired from the Landsat 4, Landsat 5 and subsequent satellites. It also describes the CCT format for the LANDSAT-6 Enhanced Thematic Mapper (ETM). The format described herein will be applicable to Landsat TM data supplied to users, by the Canada Centre for Remote Sensing (CCRS) ground processing systems.

Chapter 1 gives a brief introduction to the Landsat TM and ETM satellite series, the Landsat TM ***and ETM*** *sensors and the satellite orbit and coverage.*

Chapter 2 describes the Landsat TM and ETM CCT products that will be supplied by CCRS.

Chapter 3 contains the detailed descriptions of the volumes, the files and record types used in the definition of the CCT format. These descriptions are provided in sufficient detail for a user to understand the tape layout.

The CCRS Landsat TM and ETM CCT products conform to the Standard format family as defined by the Landsat Ground Stations Operators' Working Group (LGSOWG) Technical Working Group (LTWG). Chapter 4 gives an overview of that family, showing the relationship between this format specification and other implementations used for remote sensing products. It indicates how the superstructure concepts provide significant potential for generating software for handling products from various sources. In addition, the format of the quadrant products conforms to the LTWG recommendations for a standard LANDSAT TM CCT format (Reference 7). The format of the full-scene products and of the geocoded products is fully compatible with that of the quadrant products.

1.2 THE LANDSAT SERIES OF SATELLITES

Five spacecraft in the Landsat series (Landsat 1-5) have been launched to date. The first three satellites in the Landsat series carried MSS (Multi Spectral Scanner) and RBV (Return Beam Vidicon) sensors. Landsat 4 and 5 carry MSS and TM sensors. Landsat 6 carries an Enhanced Thematic Mapper (ETM) which can be operated in two modes.

1.3 THE LANDSAT THEMATIC MAPPER (TM) **AND ENHANCED (ETM)** SENSOR

The TM (and ETM) sub-system is a sensor which records a continuous strip image of the earth in 7 spectral bands. The TM sensor employs an oscillating mirror to scan the earth in 185 km swaths perpendicular to the orbital track. A scan line corrector located behind the primary optics compensates for forward motion of the satellite and allows the scan mirror to produce data in both scan directions. The ETM employs an additional panchromatic band.

The nominal sample centre-to-centre spacing for bands 1 to 5 and 7 is 30 metres in both line and pixel directions and for band 6 (thermal band) the spacing is 120 metres in both directions. The instantaneous field of view (IFOV) is the same as the centre-to-centre spacing for all bands. For the panchromatic band, the nominal sample centre-to-centre spacing is 15 metres.

The nominal wavelength ranges for the seven TM spectral bands and the ETM Pan band are given below:

BAND	NOMINAL WAVELENGTH RANGE
1	0.45 TO 0.52 UM
2	0.52 TO 0.60 UM
3	0.63 TO 0.69 UM
4	0.76 TO 0.90 UM
5	1.55 TO 1.75 UM
6	10.40 TO 12.50 UM (THERMAL)
7	2.08 TO 2.35 UM
20(P)	0.5 TO 0.9 UM

There are 16 detectors for each of bands 1 to 5 and 7 and 4 detectors for band 6. Each TM swath contains data from 100 detectors. For products recorded in the multispectral mode (bands 1 to 7), Canadian ground processing systems will transform band 6 data to the same pixel size as the other bands.

For the ETM sensor, there are three modes of operation. In the first (multispectral) mode, data is recorded in bands 1 to 7 in an identical fashion to that for Landsat 4 and 5 TM data. The second and third modes include
data from the panchromatic band. There are 32 detectors for the Panchromatic band. Since there is 4 times as much data for band P as for bands 1 to 5 and 7, data from band P replaces bands 1, 2 and 3, and EITHER 5 OR 7.

Correction of TM data is more complex than correction of MSS data. This is due to the increased volume of data (250 megabytes for a TM scene as opposed to 30 megabytes for a MSS scene) and to additional geometric and radiometric errors in the TM data.

1.4 LANDSAT 4, 5 AND 6 ORBIT AND COVERAGE

Landsat 4 and 5 operate in circular, sun synchronous, near polar orbits at a nominal altitude of 705 km. The inclination of the orbit is 98.2 degrees, and the satellites circle the earth every 98.9 minutes, completing 14 9/16 orbits each day. The MSS and TM sensors view the entire earth every 16 days with a complete cycle of 233 orbits. The local time of equatorial crossing (decending orbits) is approximately 09:45 a.m. Each consecutive orbital path is shifted west of the previous orbit by 2752 km, or 24.7 degrees in longitude, at the equator. The track of each succeeding day is shifted to the west by 10.8 degrees or 1204 km at the equator. The orbital characteristics of both Landsat 4 and 5 provide ground track swaths that do not provide sidelap with the previous day's coverage, as was the case with Landsat 1, 2 and 3. However, westerly sidelapping will occur on the ninth day following that orbit. This coverage pattern provides 7.3% sidelap at the equator, increasing to 40% at 50 degrees latitude and to 84% at 80 degrees latitude.

Descending (daytime) orbit paths run from northeast to southwest; whereas, ascending (nighttime) orbit paths run from southeast to northwest.

The Landsat 6 orbit and coverage are similar to those for Landsat 4 and 5. However, the equator crossing time may be different.

1.5 THE WORLDWIDE REFERENCE SYSTEM (WRS)

The Worldwide Reference System, designed by E.A. Fleming and later modified by NASA, is a global reference system for Landsat data. Satellite imagery over any portion of the earth can be referenced by specifying nominal scene centres, which are designated by "path" and "row" in the WRS system.

The Landsat 4, 5 and 6 WRS is different from the global WRS for Landsat 1, 2 and 3. Each Landsat 4 and 5 ground coverage cycle is completed in 233 orbits, hence there are 233 paths numbered consecutively from 1 to 233 moving westward around the earth. Landsat 4, 5 and 6 scene centres are *chosen at intervals of 23.92 seconds in time in order to create the same number (248) of row intervals per complete orbit as for Landsat 1, 2 and 3.*

Path 1 is defined to cross the equator at 64.6 degrees west longitude on the descending node and at 103.03 degrees east longitude on the ascending node. Row 60 coincides with the equator during the descending node while row 1 corresponds to 80.78 degrees north latitude. On the ascending node row 184 coincides with the equator and row 248 is located at 81.36 degrees north latitude, whereupon another path begins. More details on the Landsat 4 and 5 WRS are given in reference 5 - Landsat-D Worldwide Reference System (WRS) Users' Guide (NASA GSFC).

1.6 LANDSAT TM SCENE SIZE

The centre-to-centre spacing between adjacent WRS scenes on the same path is approximately 23.92 seconds, corresponding to 5328 scan lines, or 160 km in the along track direction. A full scan line of data from each TM detector contains approximately 6320 pixels, corresponding to 190 km on the ground. However, there is a misalignment of data from the individual detectors due to detector layout and sampling delay times, corresponding to approximately 6000 metres. Hence, after scan line reversal and nominal alignment, each scan line is truncated by 200 pixels. Therefore, a full WRS TM scene, with an overlap of 200 scan lines from each of the adjacent scenes above and below it, contains 5728 scan lines of 6120 pixels (nominally), which covers a ground area of 172 km by 184 km. The WRS scene centre is nominally located in pixel 3060 of scan line 2864, as shown in Figure 2.2.1-3.

Landsat 6 ETM Scenes are defined in an identical fashion. However, since the detector resolution for the P band is twice that for bands 1 to 5 and 7, a full WRS ETM P-band scene contains 11456 scan lines of (nominally) 12240 pixels.

CHAPTER 2

LANDSAT TM PRODUCT DEFINITION

2.1 INTRODUCTION

Landsat TM (and ETM) raw, quicklook , georeferenced and geocoded (after mid 1986) CCT products will be provided in the format described in this document. Raw and georeferenced products may be either quadrants or full scenes.

Raw, quicklook , georeferenced and precision- and system-corrected products will be supplied for both ascending and descending passes. Data from ascending passes will be inverted so that it will be identical in format and presentation to the data from descending passes. The only difference between the ascending and descending products will be the number of left fill pixels inserted in raw, quicklook and georeferenced products. Descending TM products will be treated in exactly the same manner as MSS products, i.e. 250 left fill pixels will be inserted in all lines of raw quadrant products and 250 left fill pixels will be inserted in the first swath of georeferenced quadrant products and the number of left fill pixels in succeeding swaths will be reduced to compensate for geometric errors, primarily earth rotation. Ascending raw TM products will also have 250 left fill pixels; however, ascending georeferenced products will have 250 left fill pixels in the last (most southerly) swath and the number of left fill pixels in each swath above will be reduced to compensate for geometric errors in the imagery. (The count of left fill pixels is increased to 500 for full-scene products.)

The count of left fill pixels for P band quadrants is 500 and for P band full scenes is 1000. The count of left fill pixels for TM band quicklook products is 80.

CCRS will supply CCT's in four product formats: Quadrant, Full-scene and Geocoded and quicklook. Quadrant products cover slightly more than one quarter of a WRS scene, are supplied in the satellite projection and are provided in both raw and georeferenced form. Geocoded products cover four 1:50000 National Topographic System (NTS) maps, are rotated and aligned to the UTM projection and will be provided in system-corrected (along-scan line and across-scan line corrections) and in precision-corrected (with ground control points (GCP's)) form. CCRS also supplies CCT products which cover a full WRS scene. These products will be supplied in raw, quicklook and georeferenced form. CCRS also supplies full pass quicklook products.

2.2 CCT PRODUCTS

2.2.1 QUADRANT PRODUCTS

Quadrant products contain 2944 lines of 3160 pixels, (5888 lines of 6320 pixels in the P band) corresponding to a ground area of 88 by 94 km. The nominal pixel size for these products is 30 (15 in the P band) metres in both line and pixel directions. To afford flexibility in the selection of TM data CCRS will provide Quadrant products for 12 separate, but overlapping, portions of each WRS scene. Figure 2.2.1-1 shows the centre location of each of the Quadrant products within the WRS scene.

Figures 2.2.1-2 and 2.2.1-3 show a WRS TM scene and the location of the first 4 Quadrant products. Table 2.2.1-1 shows the start line and pixel for all 12 CCRS Quadrant products within a WRS scene. It should be noted that products on the right edge of the WRS scene may have a slight variation in the number of pixels per scan line but will always have 2944 (5888 for P band) scan lines.

Quadrant products are supplied in raw form, where only detector offsets and scan line reversal corrections are applied and in georeferenced form where radiometric corrections and systematic corrections for along-scan line errors and along-track errors are applied. GCP's are not used to correct these products.

2.2.2 FULL SCENE PRODUCTS

Full scene products contain 5728 lines of 6120 pixels, (11456 lines of 12240 pixels in the P band) corresponding to a ground area of 172 km by 184 km. The nominal pixel size for these products is 30 (15 for the P band) metres in both line and pixel directions.

Full scene products are supplied in raw form, where only detector offsets and scan line reversal corrections are applied, and in georeferenced form, with radiometric corrections and systematic corrections for along-scan line errors and along-track errors. Quicklook products are subsampled as every eighth line and every sixth pixel (sixteenth line and twelfth pixel for the P band), where radiometric corrections and systematic corrections for along-scan line errors are applied. GCPs are not used to correct these products.

TABLE 2.2.1-1

QUADRANT PRODUCTS START LINE AND PIXEL NUMBERS AND WRS SCENE CENTRE LOCATION FOR ALL 12 CCRS QUADRANT PRODUCTS (REFERENCED TO BANDS 1 TO 5 AND 7)

QUADRANT	START LINE	START PIXEL	NOMINAL WRS SCENE CENTRE LOCATION	
			LINE	PIXEL
1	1	1	2864	3060
2	1	2961	2864	100
3	2785	1	80	3060
4	2785	2961	80	100
5	-1439	1	4304	3060
6	-1439	1481	4304	1580
7	-1439	2961	4304	100
8	1	1481	2864	1580
9	1409	1	1456	3060
10	1409	1481	1456	1580
11	1409	2961	1456	100
12	2785	1481	80	1580

Notes:

1) *Quadrants 1 through 4 are selected by dividing the nominal full scene product into 4 equal portions. Overlaps of 80 scan lines and 100 pixels from the adjacent portion within the full scene product are appended, to generate quadrant products.*

2) *Quadrants 5,6,7 and 9,10,11 are located with their nominal scene centre lines located on quadrant boundaries. Quadrant products are generated by appending overlaps of 40 scan lines*

from above and below. In addition, these quadrant products are constrained to start with the most northerly detector of a full mirror scan in the same direction as quadrant 1.

3) *Quadrants 6,8,10 and 12 are located with their nominal scene centre pixels located on quadrant boundaries. Quadrant products are generated by appending overlaps of 50 pixels from either side.*

4) *All quadrant products have total overlaps of 80 scan lines and 100 pixels.*

2.2.3 GEOCODED PRODUCTS

Geocoded products will be supplied in system-corrected form where systematic errors in both along-line and along-track directions are removed and in precision corrected form using GCP's. TM Geocoded products are fully compatible with the MSS Geocoded products.

Each Geocoded product is defined in terms of the smallest rectangle falling on a one-kilometre grid unit encompassing four 1:50000 scale NTS map sheets or one quarter of a 1:250000 scale NTS map sheet. Below 68 degrees North latitude each Geocoded product covers an area of 0.5 degrees latitude by 1.0 degrees longitude. At 68 degrees North latitude and above each product will cover an area of 0.5 degrees latitude by 20 degrees longitude. The edges may fall ONLY on 1 or .5 degree longitude boundaries and 1, 0.75, 0.5 or 0.25 degree latitude boundaries.

The ground area covered by each product is a function of latitude. It varies from 57 to 59 km in the northing direction and from 85 to 40 km in the easting direction.

In each band the pixel size is 25 m by 25 m (12.5 m by 12.5 m in the P band) registered to the 1 km grid. Expressed in resampled pixels the dimensions of a Geocoded product are from 2280 to 2360 (4560 to 4720 for the P band) lines, with between 3400 and 1600 (6800 and 3200 for the P band) pixels per line, depending on the latitude of the product. Each Geocoded product is rectangular, with each line containing an equal number of pixels. There are no left fill pixels. Right fill pixels are appended, to give a total of 3600 (7200 for the P band) image pixels. However, in the case of missing imagery, some of the pixels may be black-filled. Adjacent Geocoded products contain some common imagery due to the fact that NTS maps are non-rectangular in the UTM projection. (The only case of zero sidelap is at the centre of the UTM zone). There is an overlap of between 0 and 80 (160 for the P band) pixels and 40 and 80 (80 and 160 for the P band) lines betweeen adjacent products. The geographic position of a pixel given in UTM or Latitude-Longitude coordinates refers to the top left corner of the pixel.

2.3 DATA ORGANIZATION

The data organization may be Band Interleaved by Line (BIL) or Band Sequential (BSQ) (BIL only for quicklook products). In the BIL organization which contains only one imagery data file, the imagery data for one scan line for each of the requested spectral bands is grouped together BEFORE providing data for the next scan line. In the BSQ organization, the imagery data for ALL scan lines of one spectral band are grouped together in one imagery data file BEFORE providing imagery data for the next spectral band in a subsequent file.

In both cases, each imagery data file is preceded by a leader file and followed by a trailer file which contains scene statistics for the associated imagery data. The leader file for each imagery data file contains scene introductory information, such as the identification of the WRS scene, Quadrant, Full-scene or Geocoded product identification, sensor and mission definition, geographic referencing data, processing parameters, and the radiometric transformation tables.

2.3.1 LOGICAL VOLUME ORGANIZATIONS

Quadrant, Full-scene and Geocoded CCT's contain two logical volumes, namely, the imagery logical volume and the supplemental logical volume. These two volumes may be considered independently *from each other, from both the product definition and data processing points of view, since both can exist independently as valid data sets.*

2.3.1.1 IMAGERY LOGICAL VOLUME -

The first logical volume, termed the Imagery logical volume, contains the imagery data itself and related image-synchronized information, plus ONLY that support data related to the scene. Ephemeris and attitude data are specifically excluded from this volume, as is station-specific information such as annotation data. Existing users of Landsat MSS data as supplied in the standard format by CCRS will note the very close correspondence between the MSS logical volume and the TM imagery logical volume. For example, each consists of one leader file, one imagery file and one trailer file, where each file is comprised of fixed length records only. Figure 2.3.1.1-1 shows a comparison of the MSS and TM file formats. Moreover, quadrant TM and bulk MSS image records are the same length and corresponding support data is in identical locations. If no supplemental information is required, then the data set may consist of an imagery logical volume only.

2.3.1.2 SUPPLEMENTAL LOGICAL VOLUME -

The Supplemental logical volume contains station-related processing data, such *as annotation, ephemeris and attitude data, GCP and Payload Correction (PCD) information. Users should expect to find differences in the definition of this logical volume as supplied by different agencies.*

The CCRS Supplemental logical volume consists of one data file only, containing raw PCD, mission telemetry, annotation and GCP data relevant to the image data supplied. The content of each PCD record is defined in relation to one major frame of PCD data, which, in turn, can be linked to the imagery data by means of the satellite time code. One major frame of PCD data corresponds to approximately 57 swaths (or 912 lines) of TM image data. The supplemental logical volume is optional (user's choice) and may come before or after the Imagery logical volume. The number of PCD records included in the supplemental file will cover (TBD number of) WRS scenes.

2.4 STANDARD FORMAT FAMILY CONVENTIONS

The simplest general construction of one TM product occupying one physical tape only would consist of the following files:

FIRST VOLUME DIRECTORY FILE - (for imagery logical volume).
- describes relationship of this logical volume to the complete data set
- AND gives details of the construction of the first logical volume.

LEADER FILE

IMAGERY FILE

TRAILER FILE

SECOND VOLUME DIRECTORY FILE - (for supplemental logical volume).
- describes relationship of this logical volume to the complete data set
- AND gives details of the construction of the second logical volume.

SUPPLEMENTAL FILE

NULL VOLUME DIRECTORY - terminates the volume set.

However, when the volume set spans multiple physical volumes, specifically where a logical volume spans more than one tape, the volume directory file for that logical volume is repeated at the start of the new tape. Certain fields within that file are updated to indicate, for example, the new physical volume sequence number, which file is split, and the record sequence number of the first data record on the new volume. (If it is necessary to split a data file across tapes, the file descriptor record is NOT repeated).

2.5 PHYSICAL TAPE LAYOUTS

Figures 2.5-1 to 2.5-9 inclusive show the layouts of all combinations of Quadrant and Geocoded CCT products that will be supplied by CCRS.

Table 2.5-1 summarizes the number of CCT's required for each of the quadrant and geocoded products and recording densities supported by CCRS.

Table 2.5-2 summarizes the number of CCT's required for each of the full-scene products and recording densities supported by CCRS.

Table 2.5-3 summarizes the number of records found on each tape set defined in Table 2.5-1 and in Table 2.5-2.

2.6 LEVELS OF CORRECTION

In order to adequately specify the level of corrections applied to the data contained on a CCT, it is necessary to subdivide the preprocessing corrections into four types, namely, geometric, radiometric, resampling and projection. Table 2.1 gives an overview of the eleven processing levels established by the LTWG. A flag designed to reflect these levels is found in the leader file scene header record.

2.6.1 RADIOMETRIC CORRECTION

Absolute radiometric calibration can be applied using the calibration data supplied in the imagery data stream (all bands), the calibration shutter and blackbody temperatures from the PCD (thermal band only), and prelaunch absolute calibration constants (bands 1 through 5 and 7 only). When insufficient calibration data is available in the imagery data stream absolute calibration will be performed using pre-flight calibration data only. There are processing flags in the scene header record to identify the calibration method, any sun angle illumination or haze correction and any enhancements. For radiometrically corrected products, coefficients required to convert the calibrated data to engineering units will be found in the radiometric calibration ancillary record. The calibration data is also stored in the suffix area of the imagery data record. Destriping may be performed using scene statistics as an integral part of the radiometric correction process.

Research at CCRS has shown that the background DC reference level varies from scan line to scan line. Correction for this effect is made on both the calibration and image data at all stages of the calibration process. A summary of the CCRS radiometric correction procedure is given in Appendix B.

2.6.1.1 FAILED DETECTOR REPLACEMENT -

For Quadrant products and Full-scene products the imagery data for a failed detector will be replaced with data from an adjacent detector.

For Geocoded products replacement of the imagery data for failed detectors will be done using spatial interpolation from adjacent detectors within the same band.

Flags indicating the replacement technique, the detectors, bands and interpolator used for the replacement of data from the failed detectors will be stored in the scene header record.

2.6.2 GEOMETRIC CORRECTION

2.6.2.1 QUADRANT PRODUCTS AND FULL SCENE PRODUCTS

2.6.2.1.1 RAW

Geometrically raw products contain the original TM imagery data samples BUT with the following corrections applied. These products correspond to processing level 0 in Table 2.1.

1) The imagery data for individual detectors are shifted by an integral number of pixels, on a line by line basis, to account for detector layout geometry and multiplexer sampling times. Residual sub-pixel misalignments may remain. Pixels corresponding to geographic locations NOT sampled by all detectors, on both the forward and the reverse sweeps, are discarded. (In order for forward and reverse sweeps to be nominally aligned, the start of line code for band 1 odd detectors on the forward sweep is aligned with the end of line code for band 1 odd detectors on the reverse sweep. The raw image record contains, in addition to the count of the ACTUAL number of pixels supplied in the record, the total count of pixels in the ORIGINAL fullscan line. It also contains the raw line length code information required for subsequent mirror velocity profile corrections. Full details of detector alignments and line length codes are given in Reference 1 and in Reference 6.

2) The reverse scan is inverted such that the forward and reverse scans are nominally registered.

3) The pixels for band 6 (thermal band) are each replicated four times within the scan line, and scan lines are replicated four times, such that the pixel to pixel centre spacing is nominally the same for all spectral bands.

4) The pixels for the PAN band are always left at full resolution and are not stored in the same file as any other band.

2.6.2.1.2 GEOREFERENCED

Georeferenced quadrant products are corrected using a priori information and PCD data. They are resampled in the along-scan line and along-track direction and GCP's are not used to correct them.

2.6.2.1.3 FULL-SCENE GEOREFERENCED

Georeferenced full-scene products are corrected using a priori information and PCD data. They are resampled in the along-scan line and along-track direction and GCPs are not used to correct them.

2.6.2.1.4 QUICKLOOK

Quicklook full-scene products and full pass products are corrected using a priori information and PCD data. They are subsampled in the along-scan line and along-track direction and GCP's are not used to correct them.

2.6.2.2 GEOCODED PRODUCTS -

2.6.2.2.1 SYSTEM-CORRECTED -

System-corrected Geocoded products are corrected for systematic errors in both the along-scan line and across-scan line directions using a priori information and PCD data. These products are rotated and aligned to the UTM projection and are oversampled to a 25 metre pixel size (12.5 metres for the PAN band) in both directions. GCP's are not used to correct these products.

2.6.2.2.2 PRECISION-CORRECTED -

Precision-corrected Geocoded products are fully corrected (except for elevation correction with a Digital Terrain Model) in both the along-scan line and across-scan line directions using GCP's. These products are rotated and aligned to the UTM projection and are oversampled to a 25 metre pixel size (12.5 metres for the PAN band) in both directions.

TABLE 2.1 - PROCESSING LEVELS

The following is a definition of the processing levels defined by the LTWG:

LEVEL 0 - "RAW" UNCORRECTED, RADIOMETRICALLY AND GEOMETRICALLY RAW SCAN LINE REVERSAL AND DETECTOR OFFSETS APPLIED

LEVEL 1 - "BULK CORRECTED" RADIOMETRICALLY CORRECTED, SCAN LINE REVERSAL AND DETECTOR OFFSETS APPLIED

LEVEL 2 - RADIOMETRICALLY RAW, ALONG-SCAN LINE GEOMETRIC CORRECTION TABLES APPENDED
(These products will not be supplied by CCRS.)

LEVEL 3 - "BULK CORRECTED" RADIOMETRICALLY RAW, ALONG-SCAN LINE

GEOMETRIC CORRECTIONS APPLIED

LEVEL 4 - "BULK CORRECTED" RADIOMETRICALLY CORRECTED, ALONG-SCAN LINE GEOMETRIC CORRECTIONS APPLIED

LEVEL 5 - RADIOMETRICALLY AND GEOMETRICALLY CORRECTED, TWO DIMENSIONAL RESAMPLING, SOM OR MAP PROJECTION, NO GROUND CONTROL POINTS "GEOREFERENCED"

LEVEL 6 - RADIOMETRICALLY AND GEOMETRICALLY CORRECTED, WITH TWO DIMENSIONAL RESAMPLING, GROUND CONTROL POINTS AND SOM OR MAP PROJECTION "GEOREFERENCED"

LEVEL 7 - RADIOMETRICALLY AND GEOMETRICALLY CORRECTED, WITH TWO DIMENSIONAL RESAMPLING, GROUND CONTROL POINTS, SOM OR MAP PROJECTION AND DIGITAL TERRAIN MODEL "GEOREFERENCED"

LEVEL 8 - "SYSTEM-CORRECTED GEOCODED" RADIOMETRICALLY AND GEOMETRICALLY CORRECTED, WITH TWO DIMENSIONAL RESAMPLING, GEOCODED (ROTATED AND ALIGNED TO THE UTM PROJECTION)

LEVEL 9 - "PRECISION-CORRECTED GEOCODED" RADIOMETRICALLY AND GEOMETRICALLY CORRECTED, WITH TWO DIMENSIONAL RESAMPLING, USING GROUND CONTROL POINTS, GEOCODED (ROTATED AND ALIGNED TO THE UTM PROJECTION)

LEVEL 10 - RADIOMETRICALLY AND GEOMETRICALLY CORRECTED WITH TWO DIMENSIONAL RESAMPLING, GEOCODED, GROUND CONTROL POINTS AND DIGITAL TERRAIN MODEL

Table 2.1A

Processing Flags Set For CCRS Non-Standard TM Products

LEVEL	0	1	3	4
LEVEL NAME	RAW	RADIOMETRICALLY CORRECTED ONLY	GEOMETRICALLY CORRECTED ONLY	BULK (Before 1987)
RADIOMETRIC CALIBRATION (FLAG 36)	NONE	1 (or 2), 7, 9	NONE	1(0r 2) 7,9
SCENIC RADIOMETRIC CORRECTION (FLAG 38)	1	2	1	2
GEOMETRIC CORRECTION (FLAG 39)	1,2	1, 2	1,2,3,4,5,7,8, 11,12	1,2,3,4,5, 7,8,11,12
RESAMPLING DESIGNATOR (FLAG 40)	1	1	3	2

Notes: Level 4 'Bulk-corrected' products were the standard level of processing prior to 1987, and were characterized by full radiometric corrections and by along-scan line geometric corrections. However, any distortions affecting line-centre to line-centre spacing were not corrected. (These include satellite altitude.)

(However, the line-centre to line-centre spacing was calculated using in-flight data, and the value was given in Field 24 of the Map Projection record.)

TABLE 2.1B

PROCESSING FLAGS SET FOR CCRS STANDARD TM PRODUCTS

LEVEL	*5*	*6*	*8*	*9*
LEVEL NAME	*SYSTEMATIC GEOREFERENCED*	*PRECISION GEOREFERENCED*	*SYSTEMATIC GEOCODED*	*PRECISION GEOCODED*
RADIOMETRIC	*1 (or 2), 7, 9*	*Same as Level 5*	*1 (or 2), 7, 9*	*Same as Level 8*
SCENIC RADIOMETRIC CORRECTION (FLAG 38)	*2*	*Same as Level 5*	*2*	*Same as Level 8*
GEOMETRIC CORRECTION (FLAG 39)	*1,2,3,4,5, 7,8,11,12*	*Same as Level 5, plus Flag 10*	*1,2,3,4,5,6, 7,8,9,11,12*	*Same as Level 8 plus Flag 10*
RESAMPLING DESIGNATOR (FLAG 40)	*3*	*3*	*3*	*3*

Notes: 1. Level 5 'Systematic georeferenced' products are characterized by full radiometric corrections and by along-scan and along-satellite-track geometric corrections. Pixels and lines are resampled to give nominally square pixels, with a centre-to-centre spacing of 30 metres.

2. Level 8 'Systematic geocoded' products differ from 'systematic georeferenced' products in three important aspects. Firstly, they are resampled and rotated to the specified map projection, such that lines and pixels align with the projection axes. Secondly, they are resampled to a 25 metre square pixel size. Thirdly, the residual geometric distortions caused by sensor and platform jitter as measured by the Angular Displacement Sensor [ADS], and those resulting in non-even displacement between adjacent mirror swaths, called 'scan gap' are also corrected. The absolute geometric location accuracy of both level 5 and level 9 is identical, being limited by the accuracy of the in-flight orbital parameters.

3. Level 6 (Level 9) 'precision' products differ from their 'systematic' counterparts in that ground control points have been used, to more precisely locate the products relative to the map. Sub-pixel accuracy can be expected for these products.

2.7 IMAGERY LOGICAL VOLUME OVERVIEW

The only file classes used for the CCRS Landsat TM imagery logical volume are LEADER FILE, IMAGERY FILE and TRAILER FILE, with the corresponding four-character file class codes of LEAD, IMGY and TRAI respectively. The following sub-sections describe the file descriptor record variable segments and the constituent record types for each of the three file classes. The record types are tabulated in Table 4.1.

2.7.1 LEADER FILE

The construction of the leader file and of its constituent records has been defined in detail by the LTWG, and the CCRS implementation conforms precisely to the LTWG definition. (Those fields which have been allocated by the LTWG as for local use are clearly identified as such in the appropriate record definition).

Leader files contain the following record types:

File descriptor record;
Scene header record;
Map projection (scene-related) ancillary record;
Radiometric transformation ancillary record.

All leader file records contain the standard twelve bytes of record introductory data, stored in binary, (namely, record sequence number, record type and sub-types, and record length). All leader file records are of a fixed length of 4320 bytes, and contain alphanumeric (ASCII) fields or numeric strings stored as 8-bit binary bytes.

2.7.1.1 LEADER FILE DESCRIPTOR VARIABLE SEGMENT -

The leader file variable segment gives the number and length of each of the three different types of record in the leader file, namely, scene header, map projection ancillary and radiometric ancillary. In addition, locators are given, supplying the location and format of thirteen important data fields within the leader file.

Locators for the leader file are made up in the following way from sixteen bytes: 6 bytes - the sequence number of the record containing the field; 6 bytes - the byte number of the first byte of the field; 3 bytes - the length of the field (in bytes); 1 byte - a code for the type of data in the field.

The codes are:
A = alphanumeric in ASCII
N = numeric in ASCII
B = binary.

2.7.1.2 SCENE HEADER RECORD -

The scene header record used by CCRS conforms precisely to the recommendations of the LTWG and contains five sets of information. The first four are contained in that area of the record defined explicitly by the LTWG and the fifth occupies the area allocated for local use.

The first set defines the product which is contained within the logical volume, and the full scene of which the product forms a part, the second relates to fixed information about the mission, the third defines the sensor parameters and the fourth indicates the processing options. The fifth tabulates constant geometric parameters for the sensor, namely, the mirror velocity profile coefficients for the forward and reverse sweeps, the nature of any detector substitutions for missing data, the smoothing technique used on data from detectors whose signal-to-noise response was judged to be outside specifications, and the detector adjustments applied for layout geometry and multiplexer sampling delays.

2.7.1.3 ANCILLARY RECORDS -

There are two types of ancillary record, namely map projection and radiometric ancillary records.

2.7.1.3.1 MAP PROJECTION ANCILLARY RECORD -

The map projection ancillary record provides information about the geometric characteristics of the input (raw) and processed imagery data.

2.7.1.3.2 RADIOMETRIC ANCILLARY RECORD -

The radiometric ancillary records contain the radiometric transformation tables used in converting the raw (8 bit) data to the 8 bit form as stored on this tape. In addition, the records contain the information required to convert linear digital data to the scene radiance in watts/m2sr. Since different radiometric transformation tables are required for the forward and reverse scans, two records per band will be provided, where the first relates to the forward scan and the second relates to the reverse scan.

2.7.2 IMAGERY FILE

The construction of the imagery file and of its constituent records has been defined in detail by the LTWG, and the CCRS implementation conforms precisely to the LTWG definition. (Those fields which have been allocated by the LTWG as for local use are clearly identified as such in the appropriate record definition.)

The imagery file contains data records, each of which contains not only the image data, but also support data such as scan line identification and quality codes. This support data is physically separated into the prefix data (which precede the image data pixels), and suffix data (which follow the image data pixels).

The organization of the imagery file may be Band Sequential (BSQ), where the file contains image data for one spectral band only, or Band Interleaved by Line (BIL), where the file contains image data for one or more spectral bands. The imagery file contains one file descriptor record, and image records containing portions of scan lines and sensor-related support data.

All imagery file data records contain the standard twelve bytes of record introductory data (namely, record number, record type and sub-types, and record length). All imagery data file records are of a fixed length (of 3600 bytes for Quadrant products or 7020 bytes for Full-scene products or 3780 bytes for Geocoded products). For the PAN band, quadrant products are 7020, full scene products are 13500 bytes and geocoded products are 7380 bytes long.

In addition, all image data records are recorded in binary only. Any binary fields occupying more than one byte are stored with the bytes in descending order of significance with the most significant being stored first on the tape.

2.7.2.1 IMAGERY FILE DESCRIPTOR VARIABLE SEGMENT -

The imagery file variable segment gives the number and length of the image records. In addition, locators are given, supplying the format, and location within the prefix or suffix area, of nine important data fields. Locators for the imagery file are constructed from 8 bytes in the following way:

4 bytes - the byte number, within the prefix or suffix, of the first byte of the field;
2 bytes - length of the field in bytes;
1 byte - a letter indicating that the information is stored in the prefix (P) or suffix (S);
1 byte - a code for the type of data in the field.
The codes are:
A = alphanumeric in ASCII
N = numeric in ASCII
B = binary.

The remainder of the variable segment contains detailed information on how the image pixels are packed within groups of bytes, the range and justification of individual pixels, the size (if any) of left, right, top and bottom borders, the size of the prefix and suffix data, and finally the nature of the packing of multispectral lines. This information is explained in detail in Reference 2.

For CCRS Landsat TM data, each image pixel is ALWAYS stored as one 8-bit byte, and each portion of the scan line, as defined in the product definition, for each detector occupies one complete physical record.

2.7.2.2 IMAGE RECORD -

Each image record contains the following groups of data:

1. *The twelve bytes of standard record introductory data (i.e. record number, record type and sub-types, and record length)*
2. *Twenty bytes of prefix data*
3. *EITHER 3500 (or 6920 for the P band) bytes of image data for Quadrant products. It consists of all of the image data of one half scan line of one detector, and includes left fill and right fill pixels.*
   OR
   3600 (7200 for the P band) bytes of image data for Geocoded products. Each line contains all the data for 1 band, for 1 easting line of a Geocoded product.
   OR
   6920 (or 13400 for the P band) bytes of image data for Full-scene products. It consists of all of the image data of one full scan line of one detector, and includes left fill and right fill pixels.
   OR
   1100 bytes of image data for subsampled quicklook products.
4. *Sixty eight bytes of suffix data for Quadrant, **Georeferenced, Quicklook** or Full-scene products*
   or
   148 bytes of suffix data for Geocoded products.

Most of the prefix data and suffix data are located by the file descriptor record variable segment for the imagery file. It should be noted that the location of such data is IDENTICAL to that for MSS data supplied by CCRS. In order to achieve nominal geometric registration between adjacent scan lines from different detectors from various spectral bands, the detector adjustments (recorded in the header record *of the leader file) have been made to compensate for layout geometry and multiplexer sampling delays. (A flag to indicate this correction is available in the header record of the leader file).*

2.7.3 TRAILER FILE

The construction of the trailer file has been defined in detail by the LTWG, and this implementation conforms precisely to the LTWG definition. (Those fields which have been allocated by the LTWG as for local use are clearly identified as such in the appropriate record definition).

Trailer files follow image data files, supplying information associated with the image data which could not always be ascertained before writing the image data. This includes data quality, recording quality and data summaries. One trailer file is associated with each imagery file. Hence, for BSQ structures, which contain one imagery file for each band, there is one trailer file for each band. For BIL structures, which contain one imagery file accommodating more than one spectral band, there is only one trailer file.

Each trailer file contains the following records:

File descriptor record;
Trailer records containing trailer data for all bands of imagery in the associated imagery file.

All trailer file records contain the standard twelve bytes of record introductory data stored in binary (namely, record number, record type and sub-types, and record length). All trailer file records are of a fixed length of 4320 bytes. All data fields are stored either as alphanumeric or numeric strings recorded in ASCII, or as 32-bit binary values. Any binary fields occupying more than one byte are stored with the bytes in descending order of significance with the most significant being stored first on the tape.

2.7.3.1 TRAILER FILE DESCRIPTOR VARIABLE SEGMENT -

The trailer file variable segment gives the number and length of trailer records. In addition, locators are given, supplying the location and format of two important data fields.

Locators for the trailer file are constructed, in an identical manner to those for the leader file, from 16 bytes in the following way:

- *6 bytes - the record number of the record containing the field;*
- *6 bytes - the byte number of the first byte of the field;*
- *3 bytes - the length of the field (in bytes);*
- *1 byte - a code for the type of data in the field.*
  - *The codes are:*
  - *A = alphanumeric in ASCII*
  - *N = numeric in ASCII*
  - *B = binary.*

2.7.3.2 TRAILER RECORD -

There are two sets of four trailer records for each of the bands accommodated in the related image data file, where the first set relates to the forward mirror sweep and the second set corresponds to the reverse mirror sweep. Trailer records contain the parity error count and a quality summary, stored in ASCII. In addition, each trailer record contains the histogram of the raw data for four detectors, where each histogram entry is stored as a 32-bit binary number.

2.8 SUPPLEMENTAL LOGICAL VOLUME OVERVIEW

The only file class used in the CCRS TM Supplemental logical volume is SUPPLEMENTAL FILE, with the coresponding four-character class code, SUPP. The following sub-sections describe the file descriptor record variable segment and the constituent record types.

2.8.1 SUPPLEMENTAL FILE

The LTWG has not defined in detail the construction of the supplemental file, since the contents of the file depend heavily on individual station processing techniques. However, the variable segment of the file descriptor record for the supplemental file has been designed by the LTWG and is used by CCRS.

Supplemental files, as used by CCRS, contain the following records:

File descriptor record;
Interval header record;
TM housekeeping data record;
Ephemeris and attitude data record;
Raw jitter measurements data record;
Mission telemetry data record;
Annotation data record;
Ground Control Point data record.

All supplemental file records contain the standard twelve bytes of record introductory data, stored in binary, (namely, record sequence number, record type and sub-types, and record length). The number of records in the supplemental logical volume and in the imagery logical volume are independent of each other. (However, the data within one logical volume may be correlated with the data in the other logical volume by using the time code information supplied in each).

2.8.1.1 SUPPLEMENTAL FILE DESCRIPTOR RECORD VARIABLE SEGMENT -

The supplemental file variable segment gives the number and length of each of the twelve different types of record in the supplemental file. In addition, locators are given, supplying the location and format of two important data fields within the supplemental file.

Locators for the supplemental file are constructed from sixteen bytes in the following way:
6 bytes - the sequence number of the record containing the field;
6 bytes - the byte number of the first byte of the field;
3 bytes - the length of the field (in bytes);
1 byte - a code for the type of data in the field.
The codes are:
A = alphanumeric in ASCII (or EBCDIC)
N = numeric in ASCII (or EBCDIC)
B = binary.

2.8.1.2 INTERVAL HEADER RECORD -

The interval header record defines the start and stop times of the PCD data supplied within the supplemental logical volume.

2.8.1.3 TM HOUSEKEEPING DATA ANCILLARY RECORD -

Each TM housekeeping data record contains all the information required to interpret thirty two elements from the TM housekeeping telemetry data, as supplied in the PCD. In addition, the expanded content of five serial words is also supplied. Since there is only one block of TM housekeeping telemetry data in a set of four PCD major frames, there will be only one TM housekeeping data record for every 16.384 seconds of imagery data. Since one scene of TM imagery data occupies approximately 25 secs, either two or three TM housekeeping data ancillary records are required to span the full scene.

2.8.1.4 EPHEMERIS AND ATTITUDE ANCILLARY RECORD -

Each ephemeris and attitude ancillary record contains all the ephemeris data, attitude data, gyro data and gyro drift data from one major frame of PCD, which spans a time period of 4.096 secs. At least six ephemeris and attitude data ancillary records are required to span one full scene of TM imagery data, which occupies approximately 25 secs. (The gyro data comes from the attitude control inertial reference units, which have been designed to measure jitter in the nominal frequency range from 0.01 to 2.0 Hz).

2.8.1.5 RAW JITTER MEASUREMENTS ANCILLARY RECORD -

Each raw jitter measurements ancillary record contains all the information obtained from the three-axis Angular Displacement Sensor (ADS) from half of one major frame of PCD, where one PCD major frame occupies a time period of 4.096 secs. At least twelve raw jitter measurements ancillary records are required to span one full scene of TM imagery data, which occupies approximately 25 secs. (The ADS has been designed to measure the magnitude of the jitter in the nominal frequency range 2 to 125 Hz).

2.8.1.6 MISSION TELEMETRY ANCILLARY RECORD -

The contents of the mission telemetry ancillary record are taken directly from one major frame of mission telemetry data. It consists of ephemeris and attitude data and several temperature measurements.

2.8.1.7 GROUND CONTROL POINTS ANCILLARY RECORD -

This record contains information on the ground control points used to correct the precision Geocoded data products. This record is defined only for precision Geocoded products. There may be one or more of these records each containing a maximum of 10 GCPs.

CHAPTER 3

LANDSAT TM LOGICAL VOLUME DEFINITIONS

This chapter is devoted to the detailed file and record construction of the CCT, and is organized such that the detailed content of each record is shown in the order in which it appears on the tape. In addition, the detailed definition of the content of each field of every individual record type is given ONLY for the first time it appears on the tape. However, for subsequent references to that record type, the narrative supplies a reference to the table containing the detailed definition.

3.1 VOLUME DIRECTORY FILE - IMAGERY LOGICAL VOLUME

The Volume Directory File is the first file of every Landsat TM logical volume and consists of a Volume Descriptor Record, File Pointer Records and a Text Record. According to standard format family conventions, the volume directory file is repeated on each physical volume, with certain fields updated, whenever a logical volume spans more than one physical volume. Those fields which are modified when the volume directory is repeated at the start of a new physical volume are identified with notes in the detailed record layout tables.

3.1.1 VOLUME DESCRIPTOR RECORD - IMAGERY LOGICAL VOLUME

The Volume Descriptor Record is defined in Table 3.1.1.1. Its contents for the volume directory for the imagery logical volume are shown in Table 3.1.1.2. The Volume Descriptor Record is described in general terms in Section 4.3.1, and a detailed explanation of the content of each individual field is given in Table 4.3.1.

3.1.2 FILE POINTER RECORDS - IMAGERY LOGICAL VOLUME

There are three file classes in the imagery logical volume, and the File Pointer Records contain the names and codes of these file classes, as follows:

CLASS NAME	CLASS CODE	FILE CONTENT
LEADER FILE	LEAD	Scene header, scene-related ancillary records
IMAGERY FILE	IMGY	Image data records
TRAILER FILE	TRAI	Trailer records

The File Pointer Record is defined in Table 3.1.2.1. The File Pointer record contents for the imagery logical volume are shown in Tables 3.1.2.2, 3.1.2.3 and 3.1.2.4. The File Pointer Record is described in general terms in Section 4.3.2, and a detailed explanation of the content of each individual field is given in Table 4.3.2.

3.1.3 TEXT RECORD - IMAGERY VOLUME

For the imagery logical volume of the standard Landsat TM data product the Volume Directory File contains one Text record defined in Table 3.1.3.1. The contents, for the Landsat TM logical volume, are explained in Table 3.1.3.2.

The Text Record is described in general terms in Section 4.3.3, and a detailed explanation of the content of each individual field is given in Table 4.3.3.

TABLE 3.1.1.1
VOLUME DESCRIPTOR RECORD - DEFINITION

NO.	BYTE NOS.	DESCRIPTION
1	1-4	Record Sequence Number
2	5 ***	1st record sub-type code = 300(8)
3	6	Record type code = 300(8)
4	7	2nd record sub-type code = 022(8)
5	8	3rd record sub-type code = 022(8)
6	9-12	Length of this record
7	13-14	ASCII/EBCDIC Flag
8	15-16	2 Blanks
9	17-28	Superstructure control document number
10	29-30	Superstructure control document revision number
11	31-32	Superstructure record format revision letter
12	33-44	Software release number
13	45-60 **	Tape ID for physical volume containing this volume descriptor.
14	61-76 *	Logical Volume ID
15	77-92*	Volume Set ID
16	93-94	Number of Physical Volumes in the Set
17	95-96	Physical Volume Number, Start of Logical Volume
18	97-98	Physical Volume Number, End of Logical Volume
19	99-100 **	Physical Volume Number containing this Volume Descriptor
20	101-104 **	First Referenced File Number in this Physical Volume
21	105-108	Logical Volume Number within Volume Set
22	109-112 **	Logical Volume Number within Physical Volume
23	113-120 *	Logical Volume Creation Date
24	121-128 *	Logical Volume Creation Time
25	129-140 *	Logical Volume Generating Country
26	141-148 *	Logical Volume Generating Agency
27	149-160 *	Logical Volume Generating Facility
28	161-164 *	Number of Pointer Records in Volume Directory
29	165-168 *	Number of Records in Volume Directory
30	169-172	Number of Logical Volumes in the Set
31	173-260	Volume Descriptor Spare Segment
32	261-360	Local Use Segment

----

* Undefined in Null Volume Directory File
** Fields to be updated in a repeated Volume Directory File
*** Numbers followed by (8) are in OCTAL

TABLE 3.1.1.2

VOLUME DESCRIPTOR RECORD - IMAGERY VOLUME - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
B	1	1
B	2	300(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	360
A	7	A$
A	8	$$
A	9	CCB-CCT-0002
A	10	$E
A	11	$A
A	12	<MOSAIC>CVF01$
		<MQS$$$>CVF01$
A	13*	<CCNNNN>$$$$$$$$$$
A	14	<DDDDHHMMSSQQ>$$$$
A	15	LANDSAT$<A>$TM$$$$
N	16*	$1
N	17*	$1
N	18*	$1
N	19*	$1
N	20*	$$$1
N	21	$$$1
N	22	$$$1
A	23	<YYYYMMDD>
A	24	<HHMMSSXX>
A	25	CANADA$$$$$$
A	26	CCRS$$$$
A	27	MOSAICS$$$$$
		TMBPS$$$$$$$
		TMTS$$$$$$$$
		MQS$$$$$$$$$
N	28 **	3 for BIL; (3*n) for BSQ
N	29 **	5 for BIL; 2+(3*n) for BSQ
A	30	Blanks
A	31	Blanks
A	32	Blanks

----

* These values assume a single Physical Volume organization and will be updated for multiple physical volumes.

** n is the number of spectral bands in the product

$ denotes an ASCII blank (040(8))

Characters enclosed by angle brackets <> are defined at the time of logical volume creation

TABLE 3.1.2.1
FILE POINTER RECORD - DEFINITION

NO.	BYTE NOS.	DESCRIPTION
1	1-4	Record Sequence Number
2	5	1st record sub-type code = 333(8)
3	6	Record type code = 300(8)
4	7	2nd record sub-type code = 022(8)
5	8	3rd record sub-type code = 022(8)
6	9-12	Length of this record
7	13-14	ASCII/EBCDIC Flag
8	15-16	2 Blanks
9	17-20	Referenced File Number
10	21-36	Referenced File Name
11	37-64	Referenced File Class
12	65-68	Referenced File Class Code
13	69-96	Referenced File Data Type
14	97-100	Referenced File Data Type Code
15	101-108	Number of Records in Referenced File
16	109-116	Referenced File - Descriptor Record Length
17	117-124	Referenced File Maximum Record Length
18	125-136	Referenced File Record Length Type
19	137-140	Referenced File Record Length Type Code
20	141-142*	Referenced File Physical Volume Number, Start of File
21	143-144*	Referenced File Physical Volume Number, End of File
22	145-152 *	Referenced File Portion, 1st Record Number for this Physical Volume
23	153-160 *	Referenced file portion, last record number for this physical volume
24	161-260	Pointer Spare Segment
25	261-360	Local Use Segment

----

* Field to be updated in a repeated Volume Directory if Logical Volume split within a file

TABLE 3.1.2.2
FILE POINTER RECORD FOR LEADER FILE - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
B	1	2 for BIL; 2,5,8,11,14,17 or 20 for BSQ
B	2	333(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	360
A	7	A$
A	8	$$
N	9	1 for BIL; 1,4,7,10,13,16 or 19 for BSQ
A	10**	LS4$TM<LL>LEADBIL$
		5 BSQm
		6
A	11	LEADER$FILE
A	12	LEAD
A	13	MIXED$BINARY$AND$ASCII
A	14	MBAA
N	15 ***	3+n (or 3 + 2*n)
N	16	4320
N	17	4320
A	18	FIXED$LENGTH
A	19	FIXD
N	20*	1
N	21*	1
N	22*	1
N	23 ***	3+n (or 3 + 2*n)
A	24	Blanks
A	25	Blanks

----

* These values assume a single Physical Volume organization and will be updated for multiple physical volumes.

** This field can take as values many combinations, e.g. LS4TM2LEADBSQ5, where m is the band number to which the associated imagery belongs, and <LL> represents the level of corrections applied.

*** n is the number of spectral bands in the related imagery file

TABLE 3.1.2.3

FILE POINTER RECORD FOR IMAGERY FILE - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
----	------	-----
B	1	3 for BIL; 3,6,9,12,15,18 or 21 for BSQ
B	2	333(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	360
A	7	A$
A	8	$$
N	9	2 for BIL; 2,5,8,11,14,17 or 20 for BSQ
A	10**	LS4$TM<LL>IMGYBIL$ 5 BSQm 6
A	11	IMAGERY$FILE
A	12	IMGY
A	13	BINARY$ONLY
A	14	BINO
N	15***	n*P + 1 or n*m + 1
N	16	3600 (TM quad.); 7020 (TM full scene); 7020 (P quad.); 13500 (P full scene); 1200 (TM or P ql) or 3780 (TM geo) or 7389 (P geo)
N	17	3600 (TM quad.); 7020 (TM full scene); 7020 (P quad); 13500 (P full scene); 1200 (TM or P ql); 3780 (TM geo) or 7380 (P geo)
A	18	FIXED$LENGTH
A	19	FIXD
N	20*	$1
N	21*	$1
N	22*	$1
N	23***	n*P+1 or n*m+1
A	24	Blanks
A	25	Blanks

These values assume a single Physical Volume organization and will be updated for multiple physical volumes.

*** This field can take as value many combinations, e.g. LS4TM2IMGYBSQ5, where m is the band number to which the associated imagery belongs, and <LL> is the level of corrections applied.*

**** n is the number of spectral bands in the file.*

Geocoded products contain only the number of lines (m) required to define the product, which is always less than 2400 lines/band for products over Canadian territory.

P = 2944 (TM quad); 5888 (P quad); 5728 (TM full scene); 11456 (P full scene);
*716 (TM **or P** ql).*

TABLE 3.1.2.4
FILE POINTER RECORD FOR TRAILER FILE - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
B	1	4 for BIL; 4,7,10,13,16,19 or 22 for BSQ
B	2	333(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	360
A	7	A$
A	8	$$
N	9	3 for BIL; 3,6,9,12,15,18 or 21 for BSQ
A	10**	LS4$TM<LL>TRAIBIL$ 5 BSQm **6**
A	11	TRAILER$FILE
A	12	TRAI
A	13	MIXED$BINARY$AND$ASCII
A	14	MBAA
N	15 ***	(4*n)+1 or (2*4*n) + 1 <u>or (4*4*n)+1</u>
N	16	4320
N	17	4320
A	18	FIXED$LENGTH
A	19	FIXD
N	20*	1
N	21*	1
N	22*	1
N	23***	(4*n) + 1 or (2*4*n) + 1 <u>or (4*4*n)+1</u>
A	24	Blanks
A	25	Blanks

----

* These values assume a single Physical Volume organization and will be updated for multiple physical volumes

** This field can take as value many combinations, e.g. LS4TM2TRAIBSQ6, where m is the band number to which the associated imagery belongs, and <LL> is the level of corrections applied.

*** There are four records for EACH band in the associated imagery file, plus one file descriptor record.

<u>There are no trailer records for quicklook products.</u>

TABLE 3.1.3.1

TEXT RECORD - IMAGERY VOLUME - DEFINITION

```
NO.   BYTE NOS.         DESCRIPTION
--    -------           -----------

1     1-4      Record Number
2     5        1st record sub-type code = 022(8)
3     6        record type code, always = 077(8)
4     7        2nd record sub-type code = 022(8)
5     8        3rd record sub-type code = 022(8)
6     9-12     Length of this record = 360
7     13-14    ASCII/EBCDIC flag for this record = A$
8     15-16    Continuation flag
9 *   17-66    Product type
          PRODUCT:$$LANDSAT$4$TM$$BILn$QUADRANT-RAW$$$$$<LL>CRLF
                             5     BSQn$QUADRANT-SYSCOR$$
                             6ETM     $GEOCODED-SYSCOR$$
                                   $GEOCODED-PRECIS$$
                                   $FULSCENE-RAW$$$$$
                                   $FULSCENE-SYS$$$$$
                                   $FULSCENE-QL$$$$$$
                                   $FULLPASS-QL$$$$$$
10     67-124  Location and date/time of product creation
          PROCESSED:$$CANADA$CCRS$MOSAICS$$ON$<YYYYMMDD>
                         TMBPS$$$$
                         TMTS$$$$$
                         MQS$$$$$$
          $AT$<HHMMSSXX><CRLF>
11     125-173 Input Scene identification
          SCENE$$:$$$<LDDDDHHMMSSXX>$$$$$IMAGED$ON
          $<YYYYMMDD><CRLF>
12     174-216 Physical tape identification
          TAPE$ID:$$<XNNNNN>$$$$$$$$$$$$TAPE$<MM>$OF<JJ><CRLF>
13     217-244 WRS and product identification
          WRS$ID$:<DPPPRRR>$QUADRANT<QQ><CRLF>
                        $MAP$<QQQLDD>
                        $FULSCENE$$
                        $QUICKSCEN$
            WRS$ID$:<DPPPP>$$$$QUICKPASS$
14     245-267 Level of processing corrections applied
          LEVEL$OF$CORRECTION<LL><CRLF>
15     268-360 Blanks
                    --------------------
```

* This field can take on the following range of values :

- each product can be either BIL or BSQ;
- the number of bands can vary from 1 - 7;
- processing level RAW, for LL = 0, 1 or 2
- processing level SYSTEM CORRECTED, for LL = 3,4,5 or 8
- processing level PRECISION PROCESSED, for LL = 6,7,9 or 10

TABLE 3.1.3.2
TEXT RECORD - IMAGERY VOLUME - EXPLANATION

FIELD *EXPLANATION*
----- *------------*

7 *The ASCII/EBCDIC flag indicates if the alphanumeric data of this record is ASCII or EBCDIC.*

8 *This field contains two blanks unless the information of this record is continued on a following record, in which case, the field is coded C$.*

10 *The date of recording the Logical Volume is stored in the form <YYYYMMDD>, where YYYY is the year, MM is the month and DD is the day (e.g. 19830622 is June 22, 1983).*

11 *The input scene identification is made up in the following way:*
<LDDDDHHMMSSXX>
where:
L = Landsat ID
DDDD=Day number since launch
HHMMSSXX=Hours , minutes and seconds GMT at which the centre point was imaged.
In addition, the date of recording of the original Landsat TM image is stored in the form <YYYYMMDD>, where YYYY is the year, MM is the month, and DD is the day. (e.g. 19830622 is June 22, 1983).

12 *The physical tape identification is a 16 character field e.g. P11234.........., followed by the tape sequence number, <MM>, within the Physical Volume set containing a total of <JJ> tapes.*

13 *The identification of the WRS scene and quadrant describing this product <DPPPRRRQQ>:*
D = D for descending passes, or A for ascending passes
PPP = path
RRR = row.
QQ = Quadrant product number 1 through 12 as defined in figure 2.2.1-1.

QQQLDD = NTS map identifier for 1:50000 scale map in top left corner of Geocoded product, where QQQ is the 3 digit quadrangle, L specifies the 1:250000 map and DD specifies the 1:50000 map.

14 *The level of corrections, <LL>, supplied in this field is described in Table 2.1.*

3.2 LEADER FILE

The Leader file is the first data file in the imagery logical volume, and is of the class LEADER FILE with the class code LEAD.

3.2.1 FILE DESCRIPTOR RECORD

The File Descriptor Record Fixed Segment is defined in Table 3.2.1.1. Its contents, for the Leader File, are shown in Table 3.2.1.2. The File Descriptor Record is described in general terms in Section 4.3.4, and a detailed explanation of the content of each individual field is given in Table 4.3.4. The File Descriptor Record Variable Segment of the Leader file is defined, with its contents, in Table 3.2.1.3.

3.2.2 SCENE HEADER RECORD

The scene header record is defined and explained in Tables 3.2.2.1 and 3.2.2.2 respectively.

3.2.3 ANCILLARY RECORDS

There are two types of scene-related ancillary record.

1. *Map projection record.*
2. *Radiometric transformation record.*

3.2.3.1 MAP PROJECTION ANCILLARY RECORD -

The map projection record is described in Table 3.2.3.1.1.

3.2.3.2 RADIOMETRIC ANCILLARY RECORD -

The radiometric ancillary record is defined in Table 3.2.3.2.1 and explained in Table 3.2.3.2.2. Since full scan lines of band 6 (thermal) data are replicated four times, to achieve the same pixel centre to pixel centre spacing for all bands, the transformation tables for each of the band 6 detectors are replicated four times.

TABLE 3.2.1.1
FILE DESCRIPTOR RECORD - DEFINITION

NO.	BYTE NOS.	DESCRIPTION
1	1-4	Record Sequence Number
2	5	1st record sub-type code = 077(8)
3	6	Record type code = 300(8)
4	7	2nd record sub-type code = 022(8)
5	8	3rd record sub-type code = 022(8)
6	9-12	Length of this record = 4320
7	13-14	ASCII/EBCDIC Flag
8	15-16	2 Blanks
9	17-28	Control Document Number for this Data File Format
10	29-30	Control Document Revision Number
11	31-32	File Design Descriptor Revision Letter
12	33-44	Software Release Number
13	45-48	File Number
14	49-64	File Name
15	65-68	Record Sequence and Location Type Flag
16	69-76	Sequence Number Location
17	77-80	Sequence Number Field Length
18	81-84	Record Code and Location Type Flag
19	85-92	Record Code Location
20	93-96	Record Code Field Length
21	97-100	Record Length and Location Type Flag
22	101-108	Record Length Location
23	109-112	Record Length Field Length
24	113	Flag indicating that data interpretation information is included within the file descriptor record.
25	114	Flag indicating that data interpretation information is included within the file in record(s) other than the descriptor
26	115	Flag indicating that data display information is included within the file descriptor record.
27	116	Flag indicating that data display information is included within the file in record(s) other than the file descriptor.
28	117-180	Reserved Segment
29	181-EOR	File Descriptor Variable Segment (EOR = End-of-Record)

TABLE 3.2.1.2

LEADER FILE - FILE DESCRIPTOR RECORD FIXED SEGMENT - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
B	1	1
B	2	077(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	4320
A	7	A$
A	8	$$
A	9	DPDTM$82-249
A	10	$E
A	11	$A
A	12	<PPPPPP>CVF01$
N	13	1 for BIL; 1,4,7,10,13,16 or 19 for BSQ
A	14**	LS4$TM<LL>LEADBIL$
		5 BSQm
		6
A	15	FSEQ
N	16	1
N	17	4
A	18	FTYP
N	19	5
N	20	4
A	21	FLGT
N	22	9
N	23	4
A	24	Y
A	25	N
A	26	N
A	27	N
A	28	Blanks

** This field can take as value many combinations e.g. LS4TM2LEADBSQ6, where m is the band number to which the associated imagery relates, and <LL> is the level of corrections applied.

TABLE 3.2.1.3
LEADER FILE DESCRIPTOR VARIABLE SEGMENT - DEFINITION

NO.	BYTE NOS.	VALUE	DEFINITION
1	1-6*	1	Number of header records
2	7-12	4320	Header record length
3	13-18	1	Number of map projection ancillary records
4	19-24	4320	Map projection ancillary record length
5	25-30**	2*n	Number of radiometric calibration ancillary records
6	31-36	4320	Radiometric Ancillary record length
7	37-52	000002000037016A	Scene identification field locator
8	53-68	000002000165016A	WRS identification field locator
9	69-84	000002000309016A	Mission identification field locator
10	85-100	000002000325016A	Sensor identification field locator
11	101-116	000002000117032A	Exposure date-time field locator
12	117-132	000002000213032A	Geographic reference field locator
13	133-148	000002001477096A	Image processing performed field locator
14	149-164	000002001717016A	Imagery format (interleaving) indicator locator
15	165-180	000002001653064A	Band indicator locator
16	181-196	000002000208002A	Quadrant indicator locator
17	197-212	000003000365032N	Inter-pixel and inter-line scale locator
18	213-228	000002000277016N	Quadrant product vertical overlap indicator
19	229-244	000002000293016N	Quadrant product horizontal overlap indicator
20	245-4140		Blanks

----
* Byte 1 of the variable segment is byte 181 of the record
** n is the number of spectral bands in the related imagery file.

TABLE 3.2.2.1
SCENE HEADER RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE	DESCRIPTION
B	1	1-4	Record Sequence Number
B	2	5	1st record sub-type code = 022(8)
B	3	6	Record type code = 022(8)
B	4	7	2nd record sub-type code = 022(8)
B	5	8	3rd record sub-type code = 011(8)
B	6	9-12	Length of this record = 4320
N	7	13-16	Header record sequence number = 1
A	8	17-20	Blanks

SCENE PARAMETERS

A	9	21-36	Product type identification - A16
A	10	37-52	Input scene identification - A16
N	11	53-68	Input scene centre latitude in degrees - F16.7
N	12	69-84	Input scene centre longitude in degrees - F16.7
N	13	85-100	Line number at input scene centre - F16.7
N	14	101-116	Pixel number at input scene centre - F16.7
A	15	117-148	Input scene centre time - A32
N	16	149-164	Reserved
A	17	165-180	WRS designator (path and row) - A16
N	18	181-196	WRS cycle - I16
A	19	197-212	Processed scene identification - A16
N	20	213-228	Processed scene centre latitude in degrees - F16.7
N	21	229-244	Processed scene centre longitude in degrees - F16.7
N	22	245-260	Line number at processed scene centre - F16.7
N	23	261-276	Pixel number at processed scene centre - F16.7
N	24	277-292	Count of overlap lines - I16
N	25	293-308	Count of overlap pixels - I16

MISSION PARAMETERS

A	26	309-324	Mission identification - A16
A	27	325-340	Sensor identification - A16
N	28	341-356	Orbit number - I16
A	29	357-372	Ascending/descending flag - A16

SENSOR PARAMETERS

A 30 373-388 Spare
N 31 389-1412 Upper and lower limits of wavelength range in nanometres, 8 bytes per limit, 16 bytes per spectral band - 64*2*I8. [LOCAL USE FIELD]
N 32 1413-1428 Number of active bands in the processed image - I16
N 33 1429-1444 Number of scene pixels per line in the processed image - I16
N 34 1445-1460 Number of scene lines in the processed image - I16
A 35 1461-1476 Spare

PROCESSING PARAMETERS

A 36 1477-1492 Radiometric calibration designator - 16A1
N 37 1493-1508 Radiometric resolution designator - I16
A 38 1509-1524 Scenic radiometric correction designator - 16A1
A 39 1525-1540 Geometric correction designator - 16A1
A 40 1541-1556 Resampling designator - 16A1
A 41 1557-1572 Map projection identifier - 16A1
A 42 1573-1588 Product processing level - A16
N 43 1589-1604 Number of Map Projection ancillary records - I16
A 44 1605-1620 Technique used to replace failed detectors [LOCAL USE FIELD] - 16A1
A 45 1621-1636 Kernel used for failed detector interpolation [LOCAL USE FIELD] - 16A1
N 46 1637-1652 Number of Radiometric ancillary records - I16
A 47 1653-1716 Active bands (one byte per band, maximum of 64 bands) - 64A1
A 48 1717-1732 Interleaving indicator - A16
N 49 1733-2132 Detector substitution array - 100I4
A 50 2133-2232 Detector smoothing array - 100A1
N 51 2233-2424 Mirror scan velocity profile coefficients - 12E16.9 [LOCAL USE]
N 52 2425-2680 Detector adjustments array - 4*16 I4 [LOCAL USE]
N 53 2681-2880 Unused
N 54 2881-2908 Reserved
A 55 2909-4320 Spare

TABLE 3.2.2.2
SCENE HEADER RECORD - EXPLANATION

FIELD EXPLANATION
----- -----------

NOTE: From field 9, all fields in the Header record are multiples of 4 bytes long, and are in either Numeric or Alphanumeric format. All Numeric fields are right-justified and the default format is F16.7 unless otherwise specified. All Alphanumeric fields are left-justified. All references to the input scene refer to the full raw WRS scene and all references to the processed scene refer to the Quadrant, Full-Scene or Geocoded product. (The raw scene has been corrected and truncated to account for detector offsets, and backward mirror sweeps have been reversed.)

1-6 The contents of fields 1 to 6 are defined by the LGSOWG Standard format. The use of 011(8) for the third record sub-type code means that the detailed record construction has been approved by the LTWG.

7 The scene header record sequence number is always 1.

9 Product identification:
CCRS$TMTS$QUARAW
CCRS$TMTS$QUASYS
CCRS$TMBP$QUASYS
CCRS$TMBP$FULRAW
CCRS$TMBP$FULSYS
CCRS$MOSA$GEOSYS
CCRS$MOSA$GEOPRE
CCRS$MSQ$$QLPASS
CCRS$MSQ$$QLSCEN
CCRS$MSQ$$FULRAW

10 The input scene identification is made up as follows <LDDDDHHMMSS>$$$$$, where:
L=Mission number
DDDD=Day number since launch
HHMMSS=Hours, minutes and seconds GMT at which the centre point was imaged.

11,20 Latitude is defined positive to the north, negative to the south.

12,21 Longitude is defined positive to the east, negative to the west.

14 The pixel number at input scene centre is measured relative to the first pixel of image data immediately following the last left fill pixel.

15 The centre time of the input data is made up as follows <YYYYNNDDHHMMSSFFF>, followed by 15 blanks, where
YYYY=year MM=minutes(00 to 59)

NN=month SS=seconds (00 to 59)
DD=day FFF=milliseconds (000 to 999)
HH=hours (00 to 23)

17 WRS designator, made up as follows
<MPPPRRR>$, followed by 8 blanks, where:
M=A (for ascending node)
or M=D (for descending node)
PPP=WRS nominal path number (001-233)
RRR=WRS nominal row number (001-248)

For non-standard framing, this refers to the Standard frame containing the input scene centre.

18 Number of orbital cycles since launch

19 The product identifier. For Full-scene and Quadrant products it takes the form <LDDDDHHMMSSQQ>$$$, where:
L=Mission number
DDDD=Day number since launch
HHMMSS=Hours, minutes and seconds GMT at which the WRS centre point was imaged
QQ = Quadrant product identifier 1 - 12 (see figure 2.2.1-1)
QQ=00 for Full-scene products

For Geocoded products it takes the form <QQQLDD>$$$$$$$$$$$, where:
QQQLDD = NTS map identifier for the 1:50000 scale map in the top left corner of the product (see field 13 in TEXT record)

23 This is the pixel number which is designated as the processed scene centre. For Quadrant and Full-scene products, any line length changes made for panoramic distortion and earth curvature effects are included. It is measured relative to the first pixel of image data immediately following the last left fill pixel. For Geocoded products this is the mid-point of the nominal product size which includes black-fill pixels which may have been added because of missing input data. (Note that Geocoded products have no left fill pixels.)

24 This is the number, L, of overlap lines, as shown in Table 2.2.1-1 defined as being the number of lines which belong to the Quadrant product immediately above and/or below the current product. CCRS supplies 80 overlap lines for Quadrant products. This field is zero for Geocoded *products and full scene products, and all quicklook products.*

*25 This is the number, P, of overlap pixels, as shown in Table 2.2.1-1 defined as being the number of pixels which belong to the adjacent Quadrant products. CCRS supplies 100 overlap pixels for Quadrant products. This field is zero for Geocoded products**, full scene products and all quicklook products.***

26 LANDSAT-4, LANDSAT-5 or LANDSAT-6, followed by 7 blanks, for Landsat D, D prime and 6 respectively.

*27 Sensor identification will be TM, followed by 14 blanks, for the Thematic Mapper **(or ETM followed by 13 blanks, for the Landsat 6 Enhanced Thematic Mapper.)***

29 The ascending/descending flag is set to A for ascending paths and to D for descending paths.

31 CCRS uses this LOCAL USE FIELD to specify the wavelength ranges of the spectral bands, in a format compatible with the CCRS MSS format.

32 The total number "n" of bands contained in the associated image file. All subsequent reference to band number is by "logical band number" where each of the bands is assigned, in ascending order, a "logical band number" in the range 1 to n.

33 This is the actual number of image pixels per line in the imagery file following this Leader file. It does not include left and right fill pixels. For raw Quadrant products this number is 3160 (line length variations ignored). For raw Full-scene products this number is 6120. For Quadrant and Full-Scene products this does not include left-fill or right-fill pixels. For Geocoded products this is the nominal product size including black-fill pixels, which have been used to replace missing imagery.

34 This is the actual number of scene lines in the imagery file following this Leader file.

36-41 Each processing option designator may be considered as a string of 16 1-byte codes, each specifying whether the identified correction has been applied (value = 'Y') or has not been applied (value = 'N').

36 Radiometric (sensor) calibration (sixteen bytes)

The first ten bytes indicate which of the following options have been applied:

BYTE	*OPTION*
1	*Internal calibration source*
2	*Pre-flight data*
3	*Histogram equalization*

4 Sun elevation correction
5 Film gamma correction
6 Scenic correction
7 Histogram mean and standard deviation
8 Reserved - set to "N"
9 Line dependent offset correction
10 CAL3 option

Note: If byte 10 is "N" the default calibration "CAL2" applies.

For CCRS radiometrically corrected CCT products, this field will normally contain either
YNNNNNYNYN-CAL2
OR YNNNNNYNYY-CAL3
OR N**Y**NNNNYNYY-if it was necessary to use preflight calibration data.

37 Radiometric resolution (sixteen bytes)

The number of bits required to store the maximum data range will always be 8. This value is right justified in the field.

38 Scenic radiometric corrections designator
The first fourteen bytes represent the following options

BYTE OPTION
1 Completely raw data
2 Linear representation
3 Logarithmic representation
4 Other non-linear representation
5 Reserved (set to 'N')
6 Sun illumination angle correction
7 Haze correction
8 Sun illumination angle and haze corrrection
9 Standard radiometric enhancement (CCRS)
10 Rangeland enhancement (CCRS)
11 Forestry enhancement (CCRS)
12 Custom enhancement
13 Mixedwood Forestry enhancement (CCRS)
14 Softwood Forestry enhancement (CCRS)

39 Geometric correction designator, the first 13 bytes describe the corrections which have been applied.

BYTE CORRECTION
1 Forward/reverse alignment, plus integral detector placement
2 Detector placement and delay
3 Mirror scan profile
4 Line length information
5 Gyro data
6 Angular displacement sensor (ADS) data
7 Attitude correction system (ACS) data
8 Ephemeris data
9 Scan gap
10 Ground control points

11 Earth rotation
12 Sensor altitude and panoramic distortion
13 Digital terrain model (DTM)

40 Resampling algorithm designator

The first 3 bytes represent the following options

BYTE	*OPTION*
1	*No resampling*
2	*Resampling along-scan line only*
3	*Two-dimensional resampling*

Bytes 4 - 12 take the value 'N'.

Bytes 13-16 take one of the following codes:
NONE - None (always applicable to raw products)
NN$$ - Nearest neighbour
(usually applicable to TMTS bulk corrected products)
CC$$ - Cubic convolution
S8$$ - 8-point (sin x)/x
DS8$ - 8-point damped (sin x)/x
S16$ - 16-point (sin x)/x
DS16 - 16-point damped (sin x)/x
BLI$ - bilinear interpolation
PSD$ - pixel stuff/delete
DDRK - Dead detector replacement kernel
QL8$ - Every 8th line and 6th pixel
KD16 - 16 point Kaiser damped (sin x)/x

41 Map projection four-byte designator

The first 4 bytes represent the following options

BYTE	*OPTION*
1	*No projection / SCMP - Superficial Conic Map Projection*
2	*UTM*
3	*Reserved*
4	*Geocoded product*

Bytes 5-16 take the value 'N'.

42 The product class is stored in the first two bytes of this field as two numeric characters representing the overall level of corrections applied, as shown in Table 2.1. The remainder of this field is blank.

44 This field specifies the technique used for replacement of failed detectors. One of the following codes will be in bytes 1-4 of this field:
NONE - No failed detector replacement was done
NN$$ - Nearest Neighbour
SPAT - Spatial Interpolation within the band
Bytes 5-16 are ASCII blanks.

45 This field specifies the type of kernel used for failed *detector replacement. It can take on the same values as bytes 13-16 of field 40 above. The description of the resampling kernel is in byte positions 1-4 and bytes 5-16 are ASCII blanks.*

47 This field may be considered as 64 bytes, where the n'th byte is set to 1 if the band is in the imagery file associated with this Leader file, and to 0 otherwise. Only the first seven bytes are defined for TM products. Bytes 8-64 are always zero filled. ***Byte 20 is used for the ETM PAN band.***

48 This field takes the value 'BIL', followed by 13 blank bytes, if the data is Band Interleaved by Line, or 'BSQ' followed by 13 blank bytes, if the organization is Band Sequential.

49,50 The detector numbering convention is as follows:

DETECTOR	*BAND, DETECTOR*	***PAN***
1 - 16	*1, detectors 1 - 16*	***detectors 1 - 16***
17 - 32	*2, detectors 1 - 16*	***detectors 17- 32***
33 - 48	*3, detectors 1 - 16*	***blanks***
49 - 64	*4, detectors 1 - 16*	***(same as TM mode)***
65 - 80	*5, detectors 1 - 16*	***(same as TM mode)***
81 - 84	*6, detectors 1 - 4*	***(same as TM mode)***
85 - 100	*7, detectors 1 - 16*	***(same as TM mode)***

For descending passes detector 1 is the southernmost detector of each band. For ascending passes detector 1 is the northernmost detector of each band.

49 This field may be considered as an array of size 100 4-byte ASCII elements in I4 format, one element for each of the 100 TM detectors. The n'th element contains the detector number, m, which actually recorded the imagery data which is supplied for detector n.

50 This field may be considered as an array of 100 1-byte ASCII elements, one for each of the 100 TM detectors. A 1-byte ASCII code is used to signify the smoothing technique used. A blank code indicates no smoothing has been applied. This field is blank-filled for all MOSAICS products.

51 Two sets of mirror velocity profile correction coefficients are supplied, one for the forward scan and one for the reverse scan. Each set contains 6 coefficients, each stored in an E16.9 format.

*52 The table of adjustments for detector alignments is given as a 4*16 element array of 4-byte ASCII characters. The order of the elements is 16 entries for each of Reverse scan - West end; Reverse scan - East end; Forward scan - West end; Forward scan - East end.*

53 Reserved

TABLE 3.2.3.1.1
MAP PROJECTION ANCILLARY RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE	DESCRIPTION
B	1	1-4	Record sequence number
B	2	5	1st record sub-type code = 044(8)
B	3	6	Record type code = 044(8)
B	4	7	2nd record sub-type code = 022(8)
B	5	8	3rd record sub-type code = 011(8)
B	6	9-12	Record length = 4320
			MAP PROJECTION DATA
			Note: all references to the input scene refer to the full WRS frame, after nominal detector alignment and truncation, and after scan line reversal, whereas all references to the processed scene refer to the Quadrant, Full-Scene or Geocoded product.
			INPUT SCENE RELATED DATA
N	7	13-28	Nominal number of scene data pixels - I16
N	8	29-44	Nominal number of scene data lines - I16
N	9	45-60	Nominal scale of input inter-pixel distance in metres at nadir - F16.7
N	10	61-76	Nominal scale of input inter-line distance in metres at nadir - F16.7
N	11	77-92	Image skew at scene centre due to earth rotation only in degrees (field "skew" in figure 3.2.3.1-1) - F16.7
			UTM/PS RELATED DATA FOR INPUT SCENE
N	12	93-108	UTM datum and zone number for input image WRS scene centre -A6,I10 where UTM datum = 'NAD 83' or 'NAD 27'
N	13	109-124	Actual northing of WRS centre in metres - F16.7
N	14	125-140	Actual easting of WRS centre in metres - F16.7
N	15	141-156	Northing of input image centre in metres - F16.7
N	16	157-172	Easting of input image centre in metres - F16.7
N	17	173-188	Vertical offset of scene centre to WRS nominal centre in metres - F16.7
N	18	189-204	Horizontal offset of scene centre to WRS nominal centre in metres - F16.7

N	*19*	*205-220 Orientation of input image centre in degrees relative to the UTM grid. This is defined as the real subsatellite track heading relative to the UTM coordinate system, measured from north through east (fields "TRKHDN" + "CON" in figure 3.2.3.1-1) - F16.7*
N	*20*	*221-332 Reserved (for SOM related data)*

PROCESSED SCENE RELATED DATA

N	*21*	*333-348 Number of pixels per line in product. For Quadrant and Full-scene products this does not include left-fill or right-fill pixels. For Geocoded products this is the nominal product size - F16.7*
N	*22*	*349-364 Number of lines per processed image - F16.7*
N	*23*	*365-380 Scale of processed inter-pixel distance in metres - F16.7*
N	*24*	*381-396 Scale of processed inter-line distance in metres - F16.7*
N	*25*	*397-412 UTM datum and zone number for processed image - A6,I10 where UTM datum = 'NAD 83' or 'NAD 27'*
N	*26*	*413-428 Line number in processed image at WRS scene centre - F16.7*
N	*27*	*429-444 Pixel number in processed scene at WRS scene centre (see field 21 above)- F16.7*
N	*28*	*445-460 Orientation of processed image centre in degrees, this is the convergence of the meridians (angle between geographic north and UTM grid north). In figure 3.2.3.1-1 this is field "CON" - F16.7*

SENSOR DATA

N	*29*	*461-476 Actual satellite orbital inclination away from a polar orbit (field SATHDN in figure 3.2.3.1-1) - F16.7*
N	*30*	*477-492 Actual spacecraft ascending node (longitude at equator) - F16.7*
N	*31*	*493-508 Actual altitude of satellite at WRS scene centre referenced to geoid in metres - F16.7*
N	*32*	*509-524 Actual ground speed of satellite at WRS scene centre in metres per second - F16.7*
N	*33*	*525-540 Satellite heading in degrees (real subsatellite track direction angle relative to true north), including the effects of orbital inclination and skew due to earth rotation (field "TRKHDN" in figure 3.2.3.1-1) - F16.7*
N	*34*	*541-556 Spare (zero-fill)*
N	*35*	*557-572 Cross-track field of view in degrees - F16.7*
N	*36*	*573-588 Sensor scan rate in scans per second - F16.7*
N	*37*	*589-604 Sensor active sampling rate in samples per second - F16.7*
N	*38*	*605-620 Sun elevation angle at WRS centre in degrees - F16.7 [LOCAL USE]*
N	*39*	*621-636 Sun azimuth angle at WRS centre in degrees -*

F16.7 [LOCAL USE]

N	40	637-764	Precise UTM coordinates (in metres) of the 4 corners of the Geocoded product. F16.7
N	41	764-892	Precise latitude and longitude (in degrees) of the 4 corners of the product. F16.7
N	42	893-1020	Precise coordinates of the 4 corners of the Geocoded product expressed in input pixels and lines. These are input pixels AFTER nominal alignment, truncation and scan line reversal, i.e. Level 0 product - F16.7
A	43	1021-1260	Reserved
N	44	1261-4320	Zero fill [LOCAL USE]

TABLE 3.2.3.1.2
MAP PROJECTION ANCILLARY RECORD - EXPLANATION

FIELD	EXPLANATION
7	Left fill and right fill pixels are not included in this count.
9,10,23,24	For band 6 data, this refers to the pixel size after replication of lines and pixels.
27	It is measured relative to the first pixel of image data immediately following the last left fill pixel. For geocoded products, black fill pixels which represent missing imagery are included in the count.
40,41,42	These fields are blank filled for raw and system-corrected products. The coordinates for these fields are given in the following order: - top left - top right - bottom right - bottom left
40	UTM coordinates of 4 corners, given in Northing - Easting order for each corner.
41	Latitude and Longitude of 4 corners, given in latitude - longitude order for each corner.
42	Pixel and line coordinates of 4 corners, given in pixel and line order for each corner.

Note: See Appendix A for scene centre definitions.

TABLE 3.2.3.2.1
RADIOMETRIC ANCILLARY RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE NUMBER	DESCRIPTION
-----	-----	----	-----------
B	1	1-4	Record sequence number
B	2	5	1st record sub-type code = 077(8)
B	3	6	Record type code = 044(8)
B	4	7	2nd record sub-type code = 022(8)
B	5	8	3rd record sub-type code = 011(8)
B	6	9-12	Record length = 4320
N	7	13-16	Band number = 1 to 7 **(or 20 for P band)** - I4
N	8	17-20	Lower reflectance limit - I4
N	9	21-24	Upper reflectance limit - I4
N	10	25-28	Equalizing reference detector - I4
N	11	29-48	Offset coefficient (A0) - E20.10
N	12	49-68	Gain coefficient (A1) - E20.10
Note: fields 13 thru 28 consist of 256 1-byte binary elements			
B	13	69-324	Detector 1 lookup table
B	14	325-580	Detector 2 lookup table
B	15	581-836	Detector 3 lookup table
B	16	837-1092	Detector 4 lookup table
B	17	1093-1348	Detector 5 lookup table
B	18	1349-1604	Detector 6 lookup table
B	19	1605-1860	Detector 7 lookup table
B	20	1861-2116	Detector 8 lookup table
B	21	2117-2372	Detector 9 lookup table
B	22	2373-2628	Detector 10 lookup table
B	23	2629-2884	Detector 11 lookup table
B	24	2885-3140	Detector 12 lookup table
B	25	3141-3396	Detector 13 lookup table
B	26	3397-3662	Detector 14 lookup table
B	27	3663-3908	Detector 15 lookup table
B	28	3909-4164	Detector 16 lookup table
N	**29**	**4165-4168**	**Multiplexor unit for this band (ETM)**
A	**30**	**4169-4172**	**Gain state for this band LOW$ or HIGH (ETM)**
A	**31**	**4173-4320**	**Blanks**

TABLE 3.2.3.2.2
RADIOMETRIC ANCILLARY RECORD - EXPLANATION

FIELD EXPLANATION
----- ------------

1-6 The contents of fields 1 to 6 are defined by the LGSOWG format, and field 5 takes the value (011)8 to indicate that it conforms to the LTWG recommendations.

8-9 Fields 8 and 9 indicate the lower and upper reflectance limits (percentages) respectively used in the contrast stretch, FORTRAN format I4, range 0 to 100.

10 In the radiometric calibration process, one detector in each band is defined as the equalizing reference detector, for which an absolute calibration is computed. The other detectors are matched to it using histogram analysis, to reduce the effects of radiometric striping.

11-12 The A0 and A1 coefficient may be used in conjunction with the expression

$$R' = A0 + V'*A1$$

to convert linear digital values , V', in the current band to scene radiance, R' (in watts /m2sr). Each coefficient is stored in 20 bytes corresponding to the FORTRAN format E20.10.

13-28 Fields 13 to 28 each contain 256 data items for one of the 16 detectors within the band where each data item can take a value between 0 and 255, and is stored as a binary value in 1 byte. Since full scan lines of band 6 data are replicated four times, the transformation tables for each of the four band 6 detectors are replicated four times. If the transformation tables are changed within the product, fields 13 through 28 will be zero-filled. For Quadrant and Full-scene products, the gains and offsets used to correct the data on a line by line basis, can be extracted from the suffix area of the image data record. ***Two records will be required for the PAN band, with the second record containing LUT's for detectors 17 thru 32 in place of detectors 1 thru 16.***

3.3 IMAGERY FILE

In the BSQ organization, there is one imagery file containing all the scan lines of imagery data for one spectral band. In the BIL organization, there is one imagery file containing all the scan lines of imagery data for ALL of the requested spectral bands. The imagery file is of class IMAGERY FILE, with the class code IMGY. The imagery file contains the following records:

1. *File descriptor Record,*

2. *Image Records.*

3.3.1 FILE DESCRIPTOR RECORD

The File Descriptor Record Fixed Segment is defined in Table 3.2.1.1, and its contents, for the Imagery File, are shown in Table 3.3.1.1. The File Descriptor Record is described in general terms in Section 4.3.4 and a detailed explanation of the content of each individual field is given in Table 4.3.4. The variable segment is defined in Table 3.3.1.2 and its contents are given in Table 3.3.1.3.

3.3.2 IMAGE RECORD

The image record for raw and georeferenced quadrant products is defined in Table 3.3.2.1 and explained in Table 3.3.2.3. The image record for raw and georeferenced and quicklook full-scene products and for quicklook pass products is defined in Table 3.3.2.2 and is explained in Table 3.3.2.3. The image record for Geocoded products is defined in Table 3.3.2.4 and is explained in Table 3.3.2.5.

TABLE 3.3.1.1

IMAGERY FILE - FILE DESCRIPTOR FIXED SEGMENT - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
B	1	1
B	2	077(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	1200 or 1860 or 3600 or 3780 or 7020 or 7380 or 13500
A	7	A$
A	8	$$
A	9	DPDTM$82-249
A	10	$E
A	11	$A
A	12	<PPPPPP>CVF01$
N	13	2 for BIL; 2,5,8,11,14,17 or 20 for BSQ
A	14 **	LS4$TM<LL>IMGYBIL$
		5 BSQm
		6
A	15	FSEQ
N	16	1
N	17	4
A	18	FTYP
N	19	5
N	20	4
N	21	FLGT
N	22	9
N	23	4
A	24	Y
A	25	N
A	26	Y
A	27	N
A	28	Blanks

** This field can take as value many combinations, e.g. LS5TM1IMGYBSQ6, where m is the band number to which the imagery relates, and <LL> is the level of corrections applied.

TABLE 3.3.1.2
IMAGERY FILE - FILE DESCRIPTOR VARIABLE SEGMENT - DEFINITION

NO.	BYTE NOS.	DEFINITION
1	1-6*	Number of image records
2	7-12	Image record length
3	13-36	Reserved(blanks)
		PIXEL GROUP DATA
4	37-40	Number of bits per pixel
5	41-44	Number of pixels per data group
6	45-48	Number of bytes per data group
7	49-52	Justification and order of pixels within data group
		IMAGE DATA
8	53-56	Number of bands of imagery in this file
9	57-64	Number of lines per image(one band) excluding top and bottom border lines
10	65-68	Number of left border pixels
11	69-76	Number of image pixels per line
12	77-80	Number of right border pixels
13	81-84	Number of top border lines
14	85-88	Number of bottom border lines
15	89-92	Interleaving indicator
		RECORD DATA
16	93-94	Number of physical records per line
17	95-96	Number of physical records per multispectral line in this file
18	97-100	Number of bytes of prefix data per record
19	101-108	Number of bytes of image data per record
20	109-112	Number of bytes of suffix data per record
21	113-116	Prefix/suffix repeat flag
		PREFIX/SUFFIX DATA LOCATORS
22	117-124	Image line number locator
23	125-132	Image(band) number locator
24	133-140	Time of scan line locator
25	141-148	Actual number of left-fill pixels count locator
26	149-156	Actual number of right-fill pixels count locator
27	157-188	Blanks
28	189-196	Scan line quality code locator
29	197-204	Calibration information locator
30	205-212	Gain values field locator
31	213-220	Bias values field locator
32	221-252	Blanks
33	253-256	Number of left fill bits within pixel
34	257-260	Number of right fill bits within pixel
35	261-268	Maximum available data range of pixel (from zero)
36	269-EOR	Blanks

** Byte 1 of the variable segment is byte 181 of the File Descriptor record*

TABLE 3.3.1.3

IMAGERY FILE - FILE DESCRIPTOR VARIABLE SEGMENT - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
N	1 *	<NNNN> for BSQ; (n*NNNN) for BIL
N	2	3600 or 3780 or 7020 or 13500 or 1200 or 1860 or 7380
A	3	Blanks
N	4	8
N	5	1
N	6	1
N	7	$$$$
N	8 *	n for BIL; 1 for BSQ
N	9 *	<NNNN>
N	10	0
N	11	3500 or 3600 or 6920 or 13400 or 7200 or 1100
N	12	0
N	13	0
N	14	0
A	15	BIL$ - Band Interleaved by Line; or BSQ$ - Band Sequential
N	16	1
N	17 *	n for BIL; 1 for BSQ
N	18	20
N	19	3500 or 3600 or 6920 or 13400 or 1100 or 1760 or 7200
N	20	68 or 148 (Geocoded products)
N	21	$$$$
		LOCATORS
A	22	000104PB
A	23	000504PB
A	24	000904PB or $$$$$$$$ (Geocoded products)
A	25	001304PB
A	26	001704PB
A	27	$$$$$$$$
A	28	000108SB or $$$$$$$$ (Geocoded products)
A	29	003712SB
A	30	005704SB
A	31	006104SB
A	32	Blanks
N	33	0
N	34	0
N	35	255
A	36	Blanks

* n is the number of spectral bands in the product in this file

<NNNN> is the number of image lines (including overlap) in the file

<NNNN> has the value 2944 (or 5888) for Quadrant products, 5728 (or 11456) for Full-scene products and is less than 2400 for Geocoded products. It is 716 for quicklook scene products and variable for quicklook pass products.

TABLE 3.3.2.1
QUADRANT IMAGE DATA RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE NUMBER	DESCRIPTION
B	1	1-4	Record sequence number
B	2	5	1st record sub-type code = 355(8)
B	3	6	Record type code = 355(8)
B	4	7	2nd record sub-type code = 333(8)
B	5	8	3rd record sub-type code = 011(8)
B	6	9-12	Record length = 3600 or 7020
			PREFIX DATA
B	7	13-16	Scan line number
B	8	17-20	Logical Band Number
B	9	21-24	Time in GMT at start of scan in milliseconds
B	10	25-28	Count of left fill pixels
B	11	29-32	Count of right fill pixels
			IMAGE DATA
B	12	33-3532	Image pixels (or 33-6952)
			SUFFIX DATA **(starts at 6953 for PAN data)**
B	13	3533-3540	Scan line quality 3533 - sync loss indicator 3534 - local use quality code 3535 - detector substitution indicator 3536-3538 - local use quality codes 3539-3540 - calibration pulse width
B	14	3541-3544	Counted full-scan line length
B	15	3545-3548	Embedded line length
B	16	3549-3550	Time error from line start to midscan
B	17	3551-3552	Time error from midscan to line end
B	18	3553-3556	Scan line direction
B	19	3557-3560	Current half-scan line length
B	20	3561-3568	Satellite time code at start of scan
B	21	3569-3580	Calibration information
B	21a	3569	Detector identification
B	21b	3570	Calibration lamp value quality
B	21c	3571	Calibration lamp state
B	21d	3572	Calibration state sequence number
B	21e	3573-3576	Low level calibration value - before dc restore (thousandths of levels)
B	21f	3577-3580	High level calibration value (thousandths of levels)
B	21g	3581-3584	Cal. lamp computed gain value (millionths of units)
B	21h	3585-3588	Cal. lamp computed bias value (millionths of units)
B	21j	3589-3592	Applied gain value (millionths of units)
B	21k	3593-3596	Applied bias value (millionths of units)
B	21l	3597-3600	Low level calibration value - after dc restore (thousandths of levels)

TABLE 3.3.2.2
FULL-SCENE IMAGE DATA RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE NUMBER	DESCRIPTION
B	1	1-4	Record sequence number
B	2	5	1st record sub-type code = 355(8)
B	3	6	Record type code = 355(8)
B	4	7	2nd record sub-type code = 022(8)
B	5	8	3rd record sub-type code = 044(8)
B	6	9-12	Record length = 7020 or 13500 or 1200
			PREFIX DATA
B	7	13-16	Scan line number
B	8	17-20	Logical Band Number
B	9	21-24	Time in GMT at start of scan in milliseconds
B	10	25-28	Count of left fill pixels
B	11	29-32	Count of right fill pixels
			IMAGE DATA
B	12	33-6952	Image pixels **(or 33-1432 or 33-1132)**
			SUFFIX DATA **starts at 6953 1433 or 1133**
B	13	6953-6960	Scan line quality
			6953 - sync loss indicator
			6954 - local use quality code
			6955 - detector substitution indicator
			6956-6958 - local use quality codes
			6959-6960 - calibration pulse width
B	14	6961-6964	Counted full-scan line length
B	15	6965-6968	Embedded line length
B	16	6969-6970	Time error from line start to midscan
B	17	6971-6972	Time error from midscan to line end
B	18	6973-6976	Scan line direction
B	19	6977-6980	Current **full**-scan line length
B	20	6981-6988	Satellite time code at start of scan
B	21	6989-7000	Calibration information
B	21a		6989 - Detector identification
B	21b		6990 - Calibration lamp value quality
B	21c		6991 - Calibration lamp state
B	21d		6992 - Calibration state sequence no.
B	21e		6993-6996 - Low level calibration value - before dc restore
B	21f		6997-7000 - High level calibration value (thousandths of levels)
B	21g		7001-7004 - Cal. lamp computed gain value (millionths of units)
B	21h		7005-7008 - Cal. lamp computed bias value (millionths of units)
B	21j		7009-7012 - Applied gain value (millionths of units)

B	*21k*	*7013-7016 - Applied bias value* *(millionths of units)*
B	*21l*	*7017-7020 - Low level calibration value* *- after dc restore* *(thousandths of levels)*

TABLE 3.3.2.3
QUADRANT AND FULL SCENE IMAGE DATA RECORD - EXPLANATION

FIELD	EXPLANATION
1-6	The contents of fields 1 to 6 are defined by the LGSOWG Standard Format. Second record subtype code for image data on a Quadrant product basis is 333(8). Third record subtype code for quadrant products is 011(8) to indicate that the record construction conforms to LTWG recommendations. Second **and third** record subtype code**s** for image data on a full scene basis are **022(8)** 044(8).
8	Logical Band Number within the product. For example for a product containing TM bands 1, 4 and 7, the logical band numbers are 1, 2 and 3 respectively. The actual wavelength ranges can be established by accessing the "active bands" field 47 and the "wavelength range" field of the scene header record.
9	Each byte of this field will be set to 377(8) if GMT timing information is not available
10	The count of left fill pixels includes the pad pixels inserted for geometric corrections, such as earth rotation correction. For all quadrant raw products (from ascending and descending imagery) 250 left fill pixels will be inserted in each line. For quadrant bulk-corrected products from imagery recorded on descending passes 250 left fill pixels will be inserted in the first line of the first swath and the number of left fill pixels in subsequent swaths will be adjusted to compensate for geometric errors such as earth rotation. For quadrant bulk-corrected products from imagery recorded on ascending passes, 250 left fill pixels will be inserted in the last line of last swath of imagery in the product and the number of left fill pixels in swaths going upward in the imagery (northward) will be adjusted to compensate for geometric errors. For full scene products, the number of left fill pixels is increased to 500. For quadrant P band products the left fill count is 500, for full scene P band products the left fill count is 1000. For quicklook products, the left fill count is 80.
12	Image pixels occupy locations 33-3522(6952)**(13432)(1132)**
13	Byte 3533 (6953) is the sync loss indicator for the current line. It is set to 1 if sync was lost, and to 0 otherwise. Byte 3**53**5 (6955) is set to 1 if the imagery data for the line was substituted by that for another detector. Byte 3534 (6954) and bytes 3536 (6956) through 3538 (6958) are reserved for local use quality control flags, and are set to 0 under normal conditions and to 1 if the error condition occurs. Bytes 3539-3540 (6959 - 6960) are used to store the count of contiguous pixels in the calibration pulse used to

compute the calibration pulse value in field 21f. (TBD)

14 This is the number of pixels counted in the original geometrically uncorrected scan line. The band 6 count is after correction to 30 metre pixel size.

15 This is the number of pixels in the scan line determined from the line length information embedded in the imagery data stream.

16 The time error in clock counts from the nominal line start to midscan count of 161,164 can be converted to time error in microseconds, by multiplying by (1/(84.903/16)).

17 The time error in clock counts from the nominal midscan to line stop count of 161,165 can be converted to time error in microseconds, by multiplying by (1/(84.903/16)).

*NOTE: The active scan time is given by the expression ((161,165+161,164)+(Field 17 + Field 16) * (1/(84.903/16))) Since pixels for each detector within a line are sampled every 9.611 usecs, the line length is given by*

(active scan time/9.611).

18 Scan line direction code is 0 for the forward scan and 1 for the reverse scan.

19 This is the number of scene pixels following the left fill pixels. Field 10 + Field 11 + Field 19 = Field 11 of Table 3.3.1.2.

20 The satellite time code is stored as binary coded decimal digits in 8 bytes as follows:
Hundreds of days
Tens of days, days
Tens of hours, hours
Tens of minutes, minutes
Tens of seconds, seconds
Tenths of seconds, hundredths of seconds
Milliseconds, sixteenths of milliseconds
Zero filled

21a The detector numbering sequence within each spectral band is 1 thru 16 ***(or 32)****, where detector 16* ***(or 32)*** *is the most northerly.*

21b The calibration lamp value quality flag takes one of the following values:

0 - good
1 - not used
2 - not available.

21c The calibration lamp state identifies which of the eight possible states is being sampled in field 21f (zero fill for band 6).

21d Each calibration lamp state lasts for 40 scans, and this field *gives the sequence number in the range 1 to 40. (For radiometric calibration purposes, the first seven values at any one calibration state should not be used). This field is zero-filled for band 6.*

21e For bands 1 through 5 and 7, this is the zero-radiance calibration level (background reference level, BDC) which is output during the shutter-closed period, before dc restoration. For band 6, this is the detector-measured temperature (in digital counts) of the shutter surface during the dc-restore calibration period.

21f For bands 1 through 5 and 7, this is the average over the number of pixels specified in field 13 Pulse Calibration Width. For band 6, this is the detector-measured temperature (in digital counts) of the temperature-controlled blackbody.

NOTE: The calibration shutter and blackbody temperatures referenced in fields 21e and 21f can be found in the TM housekeeping data record with sequence number 1. For band 6 calibration, effective spectral radiances are calculated for the shutter (NS) and blackbody (NB) using temperature values from the housekeeping data. Digital counts for the shutter (CS) and blackbody (CB) are the values from the calibration area of the data stream and are stored in fields 21e and 21f. Gain and bias are determined from these four parameters, as in Appendix G of reference 1.

21g-21k The gain and bias values are stored as 2's complement binary values in millionths of units. Fields 21g and 21h are the computed gain and bias using either the onboard calibration device or default values. Fields 21j and 21k are the final gain and bias applied to the data from the specified detector.

21l This field is used to store the zero-radiance calibration level (background reference level, ADC) which is output during the shutter-closed period after dc restoration. For band 6, this is the detector-measured temperature of the shutter surface after the dc-restoration calibration period.

TABLE 3.3.2.4
GEOCODED IMAGE DATA RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE NUMBER	DESCRIPTION
B	1	1-4	Record sequence number
B	2	5	1st record sub-type code = 355(8)
B	3	6	Record type code = 355(8)
B	4	7	2nd record type code = 022(8)
B	5	8	3rd record sub-type code = 044(8)
B	6	9-12	Record length = 3780 or 7380
			PREFIX DATA
B	7	13-16	Image line number
B	8	17-20	Logical band number
B	9	21-24	Zeros
B	10	25-28	Actual number of left fill pixels
B	11	29-32	Actual number of right fill pixels
			IMAGE DATA
B	12	33-3632	Image pixels (or 33-7232)
			SUFFIX DATA **(starts at 3633 or 7233)**
B	13	3633-3636	Image line quality indicator Normally will be zero filled Byte 3634 will be set to 1 if data from lines with sync loss was used in accumulating scene statistics
B	14	3637-3656	Zeros
B	15	3657-3660	Number of pixels of image data
B	16	3661-3700	Spare
B	17	3701-3704	Sun azimuth angle at centre of image line (thousandths of degrees)
B	18	3705-3708	Sun elevation angle at centre of image line (thousandths of degrees)
B	19	3709-3712	Latitude at centre of image line (millionths of degrees)
B	20	3713-3716	Longitude at centre of image line (millionths of degrees)
B	21	3717-3720	Northing of first pixel of image line (metres)
B	22	3721-3724	Northing of last pixel of image line (metres)
B	23	3725-3728	Easting of first pixel of image line (metres)
B	24	3729-3732	Easting of last pixel of image line (metres)
B	25	3733-3736	Pixel width (metres)
B	26	3737-3740	Pixel length (metres)
B	27	3741-3780	Spare

TABLE 3.3.2.4
GEOCODED IMAGE DATA RECORD - EXPLANATION

FIELD	EXPLANATION
1-6	The contents of fields 1-6 are defined by the LGSOWG standard format.
10	Actual number of left-fill pixels, this field is non-zero only when a portion of the scan line is missing, i.e. outside the input image.
11	Actual number of right-fill pixels.
13	Bad data in this context occurs when data with known problems such as sync losses are used in the histograms when generating scene statistics.
15	This is the number of scene pixels excluding left and right fill pixels but including black fill pixels used to indicate missing imagery; where field 10 + field 11 + field 15 = total image line length.
17,18	Sun azimuth and sun elevation angles at the centre of the image data line are expressed in thousandths of degrees and represented as 32 bit integers. The centre of each image line is defined to be the centre of the Geocoded product in an East-West direction, including black-fill pixels. The Easting of the centre point of all lines is identical.
19,20	Latitude and longitude at the centre of the image line are provided in millionths of degrees and are represented as 32 bit integers.
21,22	The northing coordinate expressed in metres is represented as a 32 bit integer.
23	The easting coordinate expressed in metres is represented as a 32 bit integer. This corresponds to the first pixel of image data, whether or not it is black filled to indicate missing imagery.
24	The easting coordinate expressed in metres is represented as a 32 bit integer. This corresponds to the last pixel of image data, whether or not it is black filled to indicate missing imagery.
25,26	The pixel width and length expressed in metres are represented as 32 bit integers. For band 6, the pixel width and length relate to the resampled replicated pixels.

NOTE: Field 21 through 24, UTM coordinates are for the top left corner of the pixel.

Negative values are represented in 2's complement form.

3.4 TRAILER FILE

The trailer file is of the class TRAILER FILE with the class code TRAI. Each trailer file contains the following record types:

1. *File Descriptor Record,*

2. *Trailer Record.*

3.4.1 FILE DESCRIPTOR RECORD

The File Descriptor record fixed segment is defined in Table 3.2.1.1 and its contents, for the Trailer File, are shown in Table 3.4.1.1. The variable segment is defined in Table 3.4.1.2, and its contents are given in Table 3.4.1.3. The File Descriptor Record is described in general terms in Section 4.3.4 and a detailed explanation of the content of each individual field is given in Table 4.3.4.

3.4.2 TRAILER RECORD

In order to maintain a manageable record size, there are two sets of four trailer records for each of the bands accommodated in the accompanying image data file, where the first set refers to the forward mirror scan, and the second set refers to the reverse mirror scan. Each trailer record contains raw data histograms for 4 detectors for that band. In addition, it contains the parity error count and a quality summary. It is defined in Table 3.4.2.1, and explained in Table 3.4.2.2. There are no trailer records for quicklook products.

TABLE 3.4.1.1
TRAILER FILE - FILE DESCRIPTOR FIXED SEGMENT - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
-----	-----	-----
B	1	1
B	2	077(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	4320
A	7	A$
A	8	$$
A	9	DPDTM$82-249
A	10	$E
A	11	$A
A	12	<PPPPPP>CVF01$
A	13	3 for BIL; 3,6,9,12,15,18 or 21 for BSQ
A	14 **	LS4$TM<LL>TRAIBIL$
	5	BSQm
	6	
A	15	FSEQ
N	16	1
N	17	4
A	18	FTYP
N	19	5
N	20	4
A	21	FLGT
N	22	9
N	23	4
A	24	Y
A	25	N
A	26	N
A	27	N
A	28	Blanks

** This field can take as values many combinations, e.g. LS4TM2TRAIBSQ6, where m is the band number to which the associated imagery belongs, and <LL> is the level of corrections applied.

TABLE 3.4.1.2

TRAILER FILE - FILE DESCRIPTOR VARIABLE SEGMENT - DEFINITION

FIELD	BYTE NOS.	DEFINITION
1	1-6*	Number of trailer records
2	7-12	Trailer record length
3	13-36	Reserved (blanks)
4	37-52	Parity error count field locator
5	53-68	Quality code summary map field locator
6	69-4140	Blanks

TABLE 3.4.1.3

TRAILER FILE - FILE DESCRIPTOR RECORD VARIABLE SEGMENT - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
N	1	(2*4*n) where n is the number of bands
N	2	4320
A	3	Blanks
A	4	0000AA004117004N where AA = (2*4*n + 1)
a	5	0000AA004121200A where AA = (2*4*n + 1)
A	6	Blanks

---

* Byte 1 of the variable segment is byte 181 of the File Descriptor record

TABLE 3.4.2.1
TRAILER RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE NUMBER	DESCRIPTION
B	1	1-4	Record sequence number
B	2	5	1st record sub-type code = 022(8)
B	3	6	Record type code = 366(8)
B	4	7	2nd record sub-type code = 022(8)
B	5	8	3rd record sub-type code = 011(8)
B	6	9-12	Record length = 4320
N	7	13-16	Trailer record sequence number
N	8	17-20	Sequence number of trailer record within band
			TRAILER DATA
B	9	21-4116	Histograms for 4 detectors within the band
N	10	4117-4121	Parity error count
A	11	4120-4320	Quality summary, and [LOCAL USE]

TABLE 3.4.2.2
TRAILER RECORD - EXPLANATION

FIELD	EXPLANATION
1-6	The contents of fields 1 to 6 are defined by the LGSOWG format. The third record sub-type code is set to 011(8) to indicate that the format conforms to LTWG recommendations.
8	Since one record of 4320 bytes can hold the histograms of only 4 detectors, four trailer records are required for each mirror scan direction of each spectral band. For band 6, full scan lines are replicated four times. Hence, 16 histograms will be provided for each mirror scan direction of band 6. Histograms are generated for 30m band 6 pixels.
9	This field contains the histograms of the RAW data for 4 detectors for the band, and consists of 256 data items for each detector, where each data item occupies 4 bytes and contains the count, in binary, of the number of occurrences of that value (range 0 to 377(8)) in the RAW scene. This field is zero-filled for Geocoded products, since there is no "equivalent" detector.
11	This field may be used for a free format description of the quality of the data.

3.5 VOLUME DIRECTORY FILE - SUPPLEMENTAL LOGICAL VOLUME

The Volume Directory file is the first file of every TM logical volume and consists of a Volume Descriptor Record, File Pointer Records and a Text Record. According to standard format family conventions, the volume directory file is repeated, with certain fields updated, whenever a logical volume spans more than one physical volume. Those fields which are modified when the volume directory is repeated at the start of a new physical volume are identified with notes in the detailed record layout tables.

3.5.1 VOLUME DESCRIPTOR RECORD - SUPPLEMENTAL LOGICAL VOLUME

The Volume Descriptor Record is defined in Table 3.1.1.1. Its contents for the volume directory for the supplemental logical volume are shown in Table 3.5.1.1. The Volume Descriptor Record is described in general terms in Section 4.3.1, and a detailed explanation of the content of each individual field is given in Table 4.3.1.

3.5.2 FILE POINTER RECORD - SUPPLEMENTAL LOGICAL VOLUME

There is one file class in the supplemental logical volume, and the File Pointer Record contains the name and code of that file class, as follows:

CLASS NAME	CLASS CODE	FILE CONTENT
SUPPLEMENTALFILE	SUPP	Interval header, interval-related ancillary.

The File Pointer Record is defined in Table 3.1.2.1. The file pointer record content is shown in Table 3.5.2.1. The File Pointer Record is described in general terms in Section 4.3.2, and a detailed explanation of the content of each individual field is given in Table 4.3.2.

3.5.3 TEXT RECORD - SUPPLEMENTAL LOGICAL VOLUME

For the standard Landsat TM data product supplemental logical volume, the Volume Directory File contains one text record, defined in Table 3.5.3.1. Its English contents are shown in Table 3.5.3.2 and explained in Table 3.5.3.3. The Text Record is described in general terms in Section 4.3.3, and a detailed explanation of the content of each individual field is given in Table 4.3.3.

TABLE 3.5.1.1

VOLUME DESCRIPTOR RECORD - SUPPLEMENTAL VOLUME - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
B	1	1
B	2	300(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	360
A	7	A$
A	8	$$
A	9	CCB-CCT-0002
A	10	$**E**
A	11	$A
A	12	<MQS$$$>CVF01$
		<MOSAIC>CVF01$
A	13*	<CCNNNN>$$$$$$$$$$
A	14	<DDDDHHMMSSQQ>$$$$
A	15	LANDSAT$<A>$TM$$$$
N	16*	$1
N	17*	$1
N	18*	$1
N	19*	$1
N	20*	$$$1
N	21	$$$2 (or $$$1)
N	22*	$$$2 (or $$$1)
A	23	<YYYYMMDD>
A	24	<HHMMSSXX>
A	25	CANADA$$$$$$
A	26	CCRS$$$$
A	27	MOSAICS$$$$$
		TMBPS$$$$$$$
		TMTS$$$$$$$$
		MQS$$$$$$$$$
N	28	1
N	29	3
A	30	Blanks
A	31	Blanks

----

* These values assume a single Physical Volume organization and will be updated for multiple physical volumes.

$ denotes an ASCII blank (040(8))

Characters enclosed by angle brackets <> are defined at the time of logical volume creation.

TABLE 3.5.2.1
FILE POINTER RECORD FOR SUPPLEMENTAL FILE - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
B	1	2
B	2	333(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	360
A	7	A$
A	8	$$
N	9	1
A	10	LS4$TM$$SUPP$$$$ 5 **6**
A	11	SUPPLEMENTALFILE
A	12	SUPP
A	13	MIXED$BINARY$AND$ASCII
A	14	MBAA
N	15 ***	q
N	16	540
N	17	6300
A	18	VARIABLE$LEN
A	19	VARE
N	20*	1
N	21*	1
N	22*	1
N	23***	q
A	24	Blanks
A	25	Blanks

----

* These values assume a single Physical Volume organization and will be updated for multiple physical volumes.

*** This field is calculated according to the requested number of interval-related ancillary records

TABLE 3.5.3.1

TEXT RECORD - SUPPLEMENTAL VOLUME - DEFINITION

FIELD TYPE	FIELD NUMBER	VALUE
-----	-----	-----
1	1-4	Record Number
2	5	1st record sub-type code = 022(8)
3	6	record type code, always = 077(8)
4	7	2nd record sub-type code = 022(8)
5	8	3rd record sub-type code = 022(8)
6	9-12	Length of this record
7	13-14	ASCII/EBCDIC flag for this record
8	15-16	Continuation flag
9	17-66	Supplemental file description
10	67-124	Location and date/time of product creation
11	125-173	Orbit identification
12	174-216	Physical tape identification
13	217-360	Blanks

TABLE 3.5.3.2

TEXT RECORD - SUPPLEMENTAL VOLUME - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
----	-----	-----
B	1	3
B	2	022(8)
B	3	077(8)
B	4	022(8)
B	5	022(8)
B	6	360
A	7	A$
A	8	$$
A	9	Bytes 17 to 66:- PRODUCT:$$LANDSAT4TM$$SUPPLEMENTAL$DATA$$FILE$<CRLF> 5 **6ETM**
A	10	Bytes 67 to 124:- PROCESSED:$$CANADA$CCRS$MOSAICS$$$ON$<YYYYMMDD>$AT$<HHMMSSXX><CRLF> TMBPS$$$$$ TMTS$$$$$$ MQS$$$$$$$
A	11	Bytes 125 to 173:- ORBIT$$:$$$<BBBBBBBB>$$$$$$$$$$IMAGEDON<YYYYMMDD><CRLF>
A	12	Bytes 174 to 216:- TAPE$ID:$$<XXNNNN>$$$$$$$$$$$$TAPE$<MM>$OF$<LL><CRLF>
A	13	Blanks

TABLE 3.5.3.3
TEXT RECORD - SUPPLEMENTAL VOLUME - EXPLANATION

FIELD	EXPLANATION
1	A binary number containing the sequence number of this record within the file.
2	First record sub-type code for text records is 022(8)
3	The record type code for text records is 077(8)
4	Second record sub-type code for text records is 022(8)
5	Third record sub-type code for text records is 022(8)
6	This field contains a binary number giving the length of this record in bytes. This value is 360, for all records in the volume directory file.
7	The ASCII/EBCDIC flag indicates if the alphanumeric data of this record is ASCII or EBCDIC.
8	This field contains two blanks unless the information of this record is continued on a following record, in which case, the field is coded C$.
10	The date of recording the Logical Volume is stored in the form <YYYYMMDD>, where YYYY is the year, MM is the month and DD is the day (e.g. 19830622 is June 22, 1983).
11	The orbit is an 8-byte ASCII Numeric string, <BBBBBBBB>. In addition, the date of recording of the original Landsat TM image is stored in the form <YYYYMMDD>, where YYYY is the year, MM is the month, and DD is the day. (e.g. 19830622 is June 22, 1983).
12	The physical tape identification is a 16 character field e.g. IS1234.........., followed by the tape sequence number, <MM>, within the Physical Volume set containing a total of <LL> tapes.

3.6 SUPPLEMENTAL FILE

The Supplemental file is the only data file in the supplemental logical volume, and is of the class SUPPLEMENTAL FILE with the class code SUPP.

3.6.1 FILE DESCRIPTOR RECORD

The File Descriptor Record Fixed Segment is defined in Table 3.2.1.1. Its contents, for the Supplemental File, are shown in Table 3.6.1.1. The File Descriptor Record Variable Segment of the Supplemental file is defined, with its contents, in Table 3.6.1.2. The File Descriptor Record is described in general terms in Section 4.3.4, and a detailed explanation of the content of each individual field is given in Table 4.3.4.

3.6.2 INTERVAL HEADER RECORD

The interval header record is defined and explained in Tables 3.6.2.1 and 3.6.2.2 respectively.

3.6.3 TM HOUSEKEEPING DATA ANCILLARY RECORD

The TM housekeeping data ancillary record, relating to the interval, is defined and explained in Tables 3.6.3.1 and 3.6.3.2 respectively.

3.6.4 EPHEMERIS AND ATTITUDE ANCILLARY RECORD

The ephemeris and attitude ancillary record, relating to the interval, is defined and explained in Tables 3.6.4.1 and 3.6.4.2 respectively.

3.6.5 RAW JITTER MEASUREMENTS ANCILLARY RECORD

The raw jitter measurements (ADS) ancillary record, relating to the interval, is defined and explained in Tables 3.6.5.1 and 3.6.5.2 respectively.

3.6.6 MISSION TELEMETRY ANCILLARY RECORD

The mission telemetry record, relating to the interval, is defined and explained in Tables 3.6.6.1 and 3.6.6.2 respectively. Since all the telemetry data that is required for processing TM data is found within the PCD, this record is not required for TM products. However, it is defined here for compatibility with MSS products.

3.6.7 GROUND CONTROL POINT ANCILLARY RECORD

The Ground Control Point Ancillary record is defined and explained in tables 3.6.8.1 and 3.6.8.2 respectively. This record is defined only for precision Geocoded products. There may be one or more of these records, each containing a maximum of 10 GCPs. The GCP's in this record lie within the Geocoded product.

TABLE 3.6.1.1
SUPPLEMENTAL FILE - FILE DESCRIPTOR FIXED SEGMENT - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
B	1	1
B	2	077(8)
B	3	300(8)
B	4	022(8)
B	5	022(8)
B	6	540
A	7	A$
A	8	$$
A	9	D**M**DTM$82-249
A	10	$**E**
A	11	$A <MQS$$$>CVF01$
A	12	<MOSAIC>CVF01$
N	13	1
A	14**	LS<S>$TM$$SUPP$$$$
A	15	FSEQ
N	16	1
N	17	4
A	18	FTYP
N	19	5
N	20	4
A	21	FLGT
N	22	9
N	23	4
A	24	Y
A	25	N
A	26	N
A	27	N
A	28	Blanks

** <S> is the satellite number

TABLE 3.6.1.2
SUPPLEMENTAL FILE - FILE DESCRIPTOR VARIABLE SEGMENT - DEFINITION

NO.	BYTE NOS.	VALUE	DEFINITION
1	1-6*	1	Number of interval-related header records
2	7-12	1800	Interval-related header record length
3	13-18	t	Number of TM housekeeping data records
4	19-24	2880	TM housekeeping data record length
5	25-30	e	Number of processed ephemeris data records
6	31-36	4680	Processed ephemeris data record length
7	37-42	0	Number of scene definition (scene header) records
8	43-48	0	Scene definition record length
9	49-54	0	Number of scene quality data records
10	55-60	0	Scene quality data record length
11	61-66	0	Number of geometric modelling (map projection) data records
12	67-72	0	Geometric modelling data record length
13	73-78	0	Number of sparse matrices records
14	79-84	0	Sparse matrices record length
15	85-90	0	Number of GCD mirror scan start time records
16	91-96	0	GCD mirror scan start time record length
17	97-102	j	Number of high frequency across-scan line matrix records (raw jitter measurements)
18	103-108	6300	High frequency across-scan line matrix record length
19	109-114	0	Number of high frequency cross scan matrix records
20	115-120	0	High frequency cross scan matrix record length
21	121-126	0	Spare
22	127-132	0	Spare
23	133-138	m	Number of mission telemetry ancillary records
24	139-144	3600	Mission telemetry ancillary record length
25	145-150	g	Number or Ground Control point records
26	151-156	1800	Length of Ground Control Point record
27	157-172	000002000025016A	Interval data start time locator
28	173-188	000002000041016A	Interval data stop time locator
29	189-204	000002000093008A	Orbit field locator
30	205-360	Blanks	Spare

----

* Byte 1 of variable segment is byte 181 of record

TABLE 3.6.2.1
INTERVAL HEADER RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE	DESCRIPTION
-----	------	----	-----------
B	1	1-4	Sequence number
B	2	5	1st record sub-type code = 111(8)
B	3	6	Record type code = 022(8)
B	4	7	2nd record sub-type code = 111(8)
B	5	8	3rd record sub-type code = 044(8)
B	6	9-12	Length of this record = 1800
N	7	13-16	Interval header record sequence number
N	8	17-20	Blanks
			INTERVAL HEADER DATA
A	9	21-24	Blanks
A	10	25-40	Input scene start time
A	11	41-56	Input scene stop time
A	12	57-72	PCD telemetry start time
A	13	73-88	PCD telemetry stop time
A	14	89-92	Number of PCD major frames
A	15	93-100	Orbit number
A	16	101-1800	Spare

TABLE 3.6.2.2
INTERVAL HEADER RECORD - EXPLANATION

FIELD EXPLANATION
----- -----------

1-6 The contents of fields 1 through 6 are defined by the superstructure. The second record sub-type for interval related data is 111(8). The third record sub-type code for records defined by CCRS is 044(8).

7 Field 7 contains the sequence number of this interval header record.

10,11,12,13 All times are made up in the following way:
<DDDDMMMMMMMMTTT>$, where;
DDDD = day of year
MMMMMMMM = milliseconds of day
TTT = thousandths of milliseconds

10,11 Fields 10 and 11 may be blank-filled if there is no associated imagery logical volume.

NOTE: For Geocoded data this is is the WRS scene(s) in which product occurs.

TABLE 3.6.3.1
TM HOUSEKEEPING DATA ANCILLARY RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE	DESCRIPTION
B	1	1-4	Sequence number
B	2	5	1st record sub-type code = 177(8)
B	3	6	Record type code = 044(8)
B	4	7	2nd record sub-type code = 111(8)
B	5	8	3rd record sub-type code = 044(8)
B	6	9-12	Record length = 2880
N	7	13-16	TM housekeeping data record sequence number
N	8	17-20	PCD major frame identifier
			PCD MAJOR FRAME START TIME
N	9	21-24	Day of year at start of PCD frame (STC) Fortran I4
N	10	25-32	Milliseconds of day at start of PCD frame (STC) Fortran I8
N	11	33-35	Microseconds at start of PCD frame (STC) Fortran I3
N	12	36	Tenths of microseconds at start of PCD frame I1
			TM HOUSEKEEPING DATA
N	13	37-122	Blackbody temperature sample and conversion to Degrees C
N	13.1	37-46	TM housekeeping sample time offset (microseconds) I10
N	13.2	47-50	TM housekeeping sample I4
(Fields 13.3 thru 13.8 contain coefficients to convert to engineering units)			
N	13.3	51-62	A0 coefficient E12.6
N	13.4	63-74	A1 coefficient E12.6
N	13.5	75-86	A2 coefficient E12.6
N	13.6	87-98	A3 coefficient E12.6
N	13.7	99-110	A4 coefficient E12.6
N	13.8	111-122	A5 coefficient E12.6
Note: data fields 14 thru 44 are constructed from 86 bytes in an identical fashion to field 13.			
N	14	123-208	Silicon focal plane assembly temperature (FPA) Degrees C
N	15	209-294	Calibration shutter temperature Degrees C
N	16	295-380	Unused
N	17	381-466	Baffle temperature Degrees C
N	18	467-552	Cold stage FPA temperature Degrees K
N	19	553-638	Unused
N	20	639-724	Unused
N	21	725-810	Scan line corrector temperature Degrees C
N	22	811-896	Calibration shutter hub temperature Degrees C
N	23	897-982	Unused
N	24	983-1068	Unused

N	25	1069-1154 Relay optics temperature Degrees C
N	26	1155-1240 Unused
N	27	1241-1326 Unused
N	28	1327-1412 Unused
N	29	1413-1498 Unused (Unpacked as serial word B)
N	30	1499-1584 Unused
N	31	1585-1670 Unused (Unpacked as serial word D)
N	32	1671-1756 Unused (Unpacked as serial word E)
N	33	1757-1842 Unused (Unpacked as serial word F)
N	34	1843-1928 Unused (Unpacked as serial word G)
N	35	1929-2014 Unused
N	36	2015-2100 Unused (Unpacked as serial word L)
N	37	2101-2186 Primary mirror temperature Degrees C
N	38	2187-2272 Unused
N	39	2273-2358 Secondary mirror temperature Degrees C
N	40	2359-2444 Unused
N	41	2445-2530 Unused
N	42	2531-2616 Unused
N	43	2617-2702 Unused
N	44	2703-2788 Unused
A	45	2789-2836 Serial words B,D,E,F,G,L
N	46	2837-2880 Spare

TABLE 3.6.3.2
TM HOUSEKEEPING DATA ANCILLARY RECORD - EXPLANATION

The construction of the TM housekeeping data ancillary record follows that of all interval related ancillary record types.

FIELD	EXPLANATION
1-6	The contents of fields 1 through 6 are defined by the superstructure. Field 5 takes the value 044 (8) for records defined by CCRS.
7	Field 7 contains the sequence number of this ancillary record within the set of interval related ancillary records of this type, starting from 1.
8	Field 8 of PCD related records is defined to contain EITHER flags to indicate which elements within this record have been updated within the current PCD major frame, OR the sequence number of this interval related ancillary record WITHIN the PCD major frame. This TM housekeeping ancillary record has been defined for the telemetry data which is stored in the third PCD major frame after the telemetry major frame pulse, and will be identified by a sequence number of 1. If telemetry data from the first major frame after the telemetry major frame pulse is required, then it will be stored in a record with an identical format but with the sequence number 2.
9-12	Fields 9 through 12 give the satellite time code at the START of the relevant PCD major frame, in days, milliseconds of day and microseconds and tenths of microseconds.
13-44	In common with other interval related ancillary records, the TM housekeeping data fields supply the time offset from the start of the PCD major frame, the observation itself, and sufficient auxiliary information to convert the observation to engineering units.
13.1	Field 13.1 gives the time offset of the observation since the start of the PCD major frame, in microseconds.
13.2	Field 13.2 contains the TM housekeeping sample.
13.3-13.8	Fields 13.3 through 13.8 contain coefficients A0, A1, A2, A3, A4 and A5 respectively, which are required to convert the telemetry function from counts (C) to engineering units by using the following equation: $EU = A0 + A1*C + A2*C**3 + A4*C**4 + A5*C**5$

TABLE 3.6.3.2
TM HOUSEKEEPING DATA ANCILLARY RECORD - EXPLANATION

FIELD	*EXPLANATION*
45	*The content of serial words B, D, E, F, G and L extracted from minor frames 32, 34, 35, 36, 37 and 39 is reproduced here in an expanded form, with 1 byte being used to store the data from each bit of the serial word. Each byte can take the ASCII Numeric value of 0 - OFF or 1 - ON.*

TABLE 3.6.4.1
EPHEMERIS AND ATTITUDE ANCILLARY RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE	DESCRIPTION
B	1	1-4	Sequence number
B	2	5	1st record sub-type code = 366(8)
B	3	6	Record type code = 044(8)
B	4	7	2nd record sub-type code = 111(8)
B	5	8	3rd record sub-type code = 044(8)
B	6	9-12	Record length = 4680
N	7	13-16	Ephemeris and attitude data record sequence number
A	8	17-20	Four flags indicating whether the component was updated in the current PCD major frame. Values are 0/1 representing NO/YES Byte 17 - ephemeris flag Byte 18 - attitude flag Byte 19 - gyro flag Byte 20 - gyro drift flag
			PCD MAJOR FRAME START TIME
N	9	21-24	Day of year at start of PCD frame (STC) Fortran I4
N	10	25-32	Milliseconds of day at start of PCD frame (STC) Fortran I8
N	11	33-35	Microseconds at start of PCD frame (STC) Fortran I3
N	12	36	Tenths of microseconds at start of PCD frame I1
			EPHEMERIS DATA
N	13	37-46	Ephemeris measurement time offset (microseconds) I10
N	14	47-68	Spacecraft position component X Fortran D22.15
N	15	69-90	Spacecraft position component Y Fortran D22.15
N	16	91-112	Spacecraft position component Z Fortran D22.15
N	17	113-134	Spacecraft velocity component X Fortran D22.15
N	18	135-156	Spacecraft velocity component Y Fortran D22.15
N	19	157-178	Spacecraft velocity component Z Fortran D22.15
			ATTITUDE DATA
N	20	179-188	Attitude measurement time offset (microseconds) I10
N	21	189-210	EPA1 D22.15
N	22	211-232	EPA2 D22.15
N	23	233-254	EPA3 D22.15
N	24	255-276	EPA4 D22.15
			GYRO DATA
N	25	277-286	Gyro measurement (first measurement) time

offset (microseconds) I10

N 26 287-4510 64 sets of gyro measurements, where each set consists of measurements for each of 3 axes, Fortran (64 (3D22.15))

GYRO DRIFT DATA

N 27 4511-4520 Gyro drift measurement time offset (microseconds) I10
N 28 4521-4542 Gyro drift - x axis D22.15
N 29 4543-4564 Gyro drift - y axis D22.15
N 30 4565-4586 Gyro drift - z axis D22.15
N 31 4587-4680 Spare

TABLE 3.6.4.2
EPHEMERIS AND ATTITUDE ANCILLARY RECORD - EXPLANATION

FIELD	EXPLANATION
1-6	*The contents of fields 1 through 6 are defined by the superstructure. Field 5 takes the value 044(8) for records defined by CCRS.*
7	*Field 7 contains the sequence number of the ancillary record within the set of interval related ancillary records of this type.*
8	*Field 8 of PCD related records is defined to contain EITHER flags to indicate which elements within this record have been updated within the current PCD major frame, OR the sequence number of this interval related ancillary record WITHIN the PCD major frame. For the ephemeris and attitude ancillary record, this field contains update flags, as follows:* *Ephemeris data is updated in alternate major frames,* *Attitude data is updated in every major frame,* *Gyro data is updated 64 times in every major frame at equal time intervals,* *Gyro drift data is updated once in (approximately) every sixteenth major frame.*
9-12	*Fields 9 through 12 give the satellite time code at the START of the relevant PCD major frame, in days, milliseconds of day, microseconds and tenths of microseconds of day.*
13	*In common with other interval related ancillary records, the ephemeris and attitude data fields supply the time offset for the observation. The time since the start of the PCD major frame is given in microseconds.* *UNITS AND FRAME OF REFERENCE* *All components are stored with reference to the earth-centred inertial (ECI) frame. In the ECITOD system, the Z-axis is along a line from the centre of the earth coincident with the true earth spin axis, positive north. The X-axis is along a line from the centre of the earth toward the intersection of the true equator and true ecliptic of date. The Y-axis completes the right-handed set.* *The ECITOD system varies slowly with respect to a truly inertial system due to precession and nutation of the earth's axis and precession of the plane of the ecliptic. These variations occur sufficiently slowly that the ECITOD system can be considered to be inertial over a span of a few days for attitude control purposes.*
14,15,16	*Spacecraft position components are given in ECITOD coordinates in metres.*
17,18,19	*Spacecraft velocity components are given in metres/millisecond.*

21-24 Attitude is Euler parameters EPA1, EPA2, EPA3 and EPA4 that specify vehicle attitude relative to the ECI frame. The parameters are components of the reference quaternion (as propagated from gyro data) which defines spacecraft attitude. Components 1 through 3 define the Eigen axis of rotation in ECI coordinates, and component 4 defines rotation about that axis, as follows;

$EPA1 = AX * \sin(O/2)$
$EPA2 = AY * \sin(O/2)$
$EPA3 = AZ * \sin(O/2)$
$EPA4 = \cos(O/2)$

where A = Eigenaxis of rotation, and O = magnitude of rotation.

25 Time of measurement of gyro drift is indeterminate.

26 Gyro output units are arc-seconds of angle.

28-30 Gyro drift output units are radians/512 msecs.

TABLE 3.6.5.1

RAW JITTER MEASUREMENTS ANCILLARY RECORD - DEFINITION

FIELD	FIELD	BYTE	DESCRIPTION
B	1	1-4	Sequence number
B	2	5	1st record sub-type code = 345(8)
B	3	6	Record type code = 044(8)
B	4	7	2nd record sub-type code = 222(8)
B	5	8	3rd record sub-type code = 044(8)
B	6	9-12	Record length = 6300
N	7	13-16	Raw jitter measurements record sequence number
N	8	17-20	Sequence number within PCD major frame
			PCD MAJOR FRAME START TIME
N	9	21-24	Day of year at start of PCD frame (STC) Fortran I4
N	10	25-32	Milliseconds of day at start of PCD frame (STC) Fortran I8
N	11	33-35	Microseconds at start of PCD frame (STC) Fortran I3
A	12	36	Tenths of microseconds at start of PCD frame - I1
			ADS TEMPERATURE DATA
N	13	37-46	ADS temperature (1) time offset (microseconds) I10
N	14	47-58	ADS temperature (1) Degrees C E12.5
N	15	59-68	ADS temperature (2) time offset (microseconds) I10
N	16	69-80	ADS temperature (2) Degrees C E12.5
N	17	81-90	ADS temperature (3) time offset (microseconds) I10
N	18	91-102	ADS temperature (3) Degrees C E12.5
N	19	103-112	ADS temperature (4) time offset (microseconds) I10
N	20	113-124	ADS temperature (4) Degrees C E12.5
			ADS MEASURMENTS
N	21	125-134	ADS measurement (1), axis 1, time offset (microseconds) I10
N	22	135-144	ADS measurement (1), axis 2, time offset (microseconds) I10
N	23	145-154	ADS measurement (1), axis 3, time offset (microseconds) I10
B	24	155-6298	1024 ADS measurements, each measurement consisting of 1 sample of each of 3 axes, 2 bytes each sample.
N	25	6299-6300	Spare

TABLE 3.6.5.2

RAW JITTER MEASUREMENTS ANCILLARY RECORD - EXPLANATION

FIELD	EXPLANATION
1-6	The contents of fields 1 through 6 are defined by the superstructure. Field 5 takes the value 044(8) for records defined by CCRS.
7	Field 7 contains the sequence number of this ancillary record within the set of interval related ancillary records of this type.
8	Field 8 of PCD related records is defined to contain EITHER flags to indicate which elements within this record have been updated within the current PCD major frame, OR the sequence number of this interval related ancillary record WITHIN the PCD major frame. For the raw jitter measurements ancillary record, field 8 contains the sequence number of this record type within the PCD major frame.
9-12	Fields 9 through 12 give the Satellite Time Code at the START of the relevant major frame, in days, milliseconds, microseconds and tenths of microseconds.
13,15,17,19	Fields 13, 15, 17 and 19 give the time offsets of the four ADS temperature measurements in microseconds.
14,16,18,20	Fields 14, 16, 18 and 20 contain the four ADS temperature measurements.
21-23	Fields 21, 22 and 23 give the time offset of the observation since the start of the major frame, in microseconds. Since there are measurements for 3 ADS axes, the time offset is provided for the first measurement of EACH of the three axes. The time interval between successive measurements is 2 msecs.
24	Since each axis of the ADS is sampled every 2 msecs, there will be a total of 2048 ADS measurements per PCD major frame. Each jitter measurements ancillary record therefore contains 1024 samples from EACH of the three axes, which are roll, pitch and yaw respectively. Each sample is stored as a 2-byte binary integer, where the most significant bit of the first byte is the sign, and the least significant bit represents (250/2**11) microradians. Total requirements for one PCD major frame are 2 records, each of length 6300 bytes.

TABLE 3.6.6.1

MISSION TELEMETRY ANCILLARY RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE	DESCRIPTION
B	1	1-4	Sequence number
B	2	5	1st record sub-type code = 355(8)
B	3	6	Record type code = 044(8)
B	4	7	2nd record sub-type code = 111(8)
B	5	8	3rd record sub-type code = 044(8)
B	6	9-12	Record length = 3600
N	7	13-16	Mission telemetry ancillary record sequence number
N	8	17-20	Blank
			TELEMETRY MAJOR FRAME START TIME
N	9	21-24	Day of year at stat of telemetry frame (STC) Fortran I4
N	10	25-32	Milliseconds of day at start of telemetry frame (STC) Fortran I8
N	11	33-35	Microseconds at start of telemetry frame (STC) I3
A	12	36	Tenths of microseconds at start of PCD frame - I1
			EPHEMERIS DATA
N	13	37-46	Flight software time offset (I10)
N	14	47-68	Spacecraft position component X Fortran D22.15
N	15	69-90	Spacecraft position component Y Fortran D22.15
N	16	91-112	Spacecraft position component Z Fortran D22.15
N	17	113-134	Spacecraft velocity component X Fortran D22.15
N	18	135-156	Spacecraft velocity component Y Fortran D22.15
N	19	157-178	Spacecraft velocity component Z Fortran D22.15
			ATTITUDE DATA
N	20	179-188	Flight software time offset (I10)
N	21	189-210	EPA1 D22.15
N	22	211-232	EPA2 D22.15
N	23	233-254	EPA3 D22.15
N	24	255-276	EPA4 D22.15
			ROLL, PITCH, YAW AXIS ANGULAR INCREMENTS
N	25	277-286	Flight software time offset (I10)
N	26	287-308	Roll axis angular increment D22.15
N	27	309-330	Pitch axis angular increment D22.15
N	28	331-352	Yaw axis angular increment D22.15
			ROLL, PITCH, YAW ANGULAR RATE
N	29	353-362	Flight software time offset (I10)
N	30	363-384	Roll axis angular rate D22.15
N	31	385-406	Pitch axis angular rate D22.15

N	*32*	*407-428 Yaw axis angular rate D22.15*

ROLL, PITCH, YAW ATTITUDE ERROR

N	*33*	*429-438 Flight software time offset (I10)*
N	*34*	*439-460 Roll attitude error D22.15*
N	*35*	*461-482 Pitch attitude error D22.15*
N	*36*	*483-504 Yaw attitude error D22.15*
N	*37*	*505-516 Reserved (Zero fill)*
N	*38*	*517-526 Zero fill*

HOUSEKEEPING DATA SAMPLES

N	*39*	*527-538 A0 coefficient E12.6 for item 1*
N	*40*	*539-550 A1 coefficient E12.6 for item 1*
N	*41*	*551-562 A2 coefficient E12.6 for item 1*
N	*42*	*563-574 A3 coefficient E12.6 for item 1*
N	*43*	*575-586 A4 coefficient E12.6 for item 1*
N	*44*	*587-598 A5 coefficient E12.6 for item 1*
N	*45*	*599-670 A0 through A5 for item 2*
N	*46*	*671-742 A0 through A5 for item 3*
N	*47*	*743-814 A0 through A5 for item 4*
N	*48*	*815-886 A0 through A5 for item 5*
N	*49*	*887-958 A0 through A5 for item 6*
N	*50*	*959-1030 A0 through A5 for item 7*
N	*51*	*1031-1102 A0 through A5 for item 8*
N	*52*	*1103-1174 A0 through A5 for item 9*
N	*53*	*1175-1246 A0 through A5 for item 10*
N	*54*	*1247-1318 A0 through A5 for item 11*
N	*55*	*1319-1390 A0 through A5 for item 12*
B	*56*	*1391-2926 128 samples for each of 12 data items*
B	*57*	*2927-2950 Zero fill (Reserved)*
N	*58*	*2951-3600 Spare*

TABLE 3.6.6.2
MISSION TELEMETRY ANCILLARY RECORD - EXPLANATION

FIELD EXPLANATION
----- -----------

1-6 The contents of fields 1 through 6 are defined by the superstructure. Field 5 takes the value 044(8) for records defined by CCRS.

7 Field 7 contains the sequence number of this ancillary record within the set of interval related ancillary records of this type.

9-12 Fields 9 through 12 give the Satellite Time Code at the start of the relevant telemetry major frame, in days, milliseconds, microseconds and tenths of microseconds.

14-24 All ephemeris and attitude data fields are explained in the ephemeris and attitude data ancillary record, Table 3.6.4.2.

26-28 Roll, pitch and yaw axis angular increments are given in radians.

30-32 Roll, pitch and yaw axis angular rates are given in radians/sec.

34-36 Roll, pitch and yaw attitude error are given in radians.

39-55 Coefficients required to express 12 binary-encoded data items in engineering units are supplied.

56 There are 128 samples, S, of each of a maximum of 12 data items, D, where the samples are stored in the order S1D1, S1D2, ... S1D12, S2D1,... S128D12.
The data items are defined as follows:
- *D1 - calibration lamp 1 current*
- *D2 - calibration lamp 2 current*
- *D3 - calibration lamp 3 current*
- *D4 - blackbody temperature*
- *D5 - silicon FPA temperature*
- *D6 - calibration shutter temeperature*
- *D7 - backup shutter temperature*
- *D8 - cold stage FPA temperature*
- *D9 - SLC temperature*
- *D10 - baffle temperature*
- *D11 - spare*
- *D12 - spare*

TABLE 3.6.8.1
GROUND CONTROL POINT ANCILLARY RECORD - DEFINITION

FIELD TYPE	FIELD NUMBER	BYTE	DESCRIPTION
----	------	----	-----------
B	1	1-4	Record sequence number
B	2	5	1st record sub-type code = 011(8)
B	3	6	Record type code 044(8)
B	4	7	2nd record sub-type code = 022(8)
B	5	8	3rd record sub-type code = 022(8)
B	6	9-12	Record length = 1800
N	7	13-16	GCP record sequence number
N	8	17-20	Number of GCPs/RCPs in this record
			GCP/RCP DATA
A	9	21-80	Spare
A	10	81-252	First GCP/RCP this record
A	10.1	81-88	Topographic map type
A	10.2	89-96	Topographic map identification
A	10.3	97-100	UTM zone of GCP/RCP
A	10.4	101-112	Northing of GCP/RCP
A	10.5	113-124	Easting of GCP/RCP
A	10.6	125-136	Northing location error of GCP/RCP
N	10.7	137-148	Easting location error of GCP/RCP
N	10.8	149-152	Elevation of GCP as shown on map
A	10.9	153-184	GCP/RCP Data Base Pointer
A	10.10	185-216	GCP description
N	10.11	217-224	GCP pixel coordinate
N	10.12	225-232	GCP line coordinate
A	10.13	233-236	GCP flags
A	10.14	237-252	Spare
A	11	253-424	Definition of 2nd GCP/RCP
A	12	425-596	Definition of 3rd GCP/RCP
A	13	597-768	Definition of 4th GCP/RCP
A	14	768-940	Definition of 5th GCP/RCP
A	15	941-1112	Definition of 6th GCP/RCP
A	16	1113-1284	Definition of 7th GCP/RCP
A	17	1285-1456	Definition of 8th GCP/RCP
A	18	1457-1628	Definition of 9th GCP/RCP
A	19	1629-1800	Definition of 10th GCP/RCP

TABLE 3.6.8.2
GROUND CONTROL POINT ANCILLARY RECORD - EXPLANATION

FIELD EXPLANATION
----- -----------

1-6 Contents of these fields are defined by the LGSOWG format.

7 GCP ancillary record sequence number - I4

8 Number of GCPs/RCPs in this record

10.1 Topographic map type, takes the following values:
CNUTM050 - 1:50000 NTS maps
CNUTM250 - 1:250000 NTS maps

10.2 The NTS maps in Canada are identified by
<QQQLDD>
where QQQ is the 3 digit quadrangle, L specifies the 1:250000 map and DD specifies the 1:50000 map, when 1:250000 scale maps are used DD is blank.

10.3 The UTM zone number, ranges from 7 to 22 for Canada - I4

10.4,10.5 Northing and easting of GCP/RCP centres in metres - F12.2

10.6,10.7 The difference between the measured GCP/RCP and the modeled GCP/RCP location in metres - F12.2

10.8 Elevation of the GCP as given on the map in metres - I4

10.9 This field is the link to the GCP/RCP Database. This is the actual identifier used to retrieve a GCP/RCP from the database.

10.13 Free format description of GCP

10.11,10.12 Pixel and line coordinates of GCP/RCP in image file

10.16 This is a 4 byte flag. Byte 1 is blank. Byte 2 indicates the modeling technique used to estimate residual error, it takes the following values:
N - none
A - Attitude and orbital polynomial model
Byte 3 indicates the order of the least squares model. It takes the following values:
0 - none
1 - affine
2 - quadratic
3 - cubic
Byte 4 is blank.

3.7 NULL VOLUME DIRECTORY FILE

The logical volume set is terminated with a null volume directory file. The null volume directory contains only one record, namely, the null volume descriptor record.

3.7.1 NULL VOLUME DESCRIPTOR RECORD

The null volume descriptor record is defined in Table 3.1.1.1 and its contents are shown in Table 3.7.1.1. The Volume Descriptor Record is defined in general terms in Section 4.3.1, and a detailed explanation of the content of each individual field is given in Table 4.3.1.

TABLE 3.7.1.1
NULL VOLUME DIRECTORY - VOLUME DESCRIPTOR RECORD - CONTENTS

FIELD TYPE	FIELD NUMBER	VALUE
-----	-----	-----
B	1	1
B	2	300(8)
B	3	300(8)
B	4	077(8)
B	5	022(8)
B	6	360
A	7	A$
A	8	$$
A	9	CCB-CCT-0002
A	10	$**E**
A	11	$A
A	12	<PPPPPP>CVF01$
A	13	<CCNNNN>$$$$$$$$$$
A	14	Blanks
A	15	Blanks
N	16	1
N	17	1
N	18	1
N	19	1
N	20	Blanks
N	21	3
N	22	3
A	23	Blanks
A	24	Blanks
A	25	Blanks
A	26	Blanks
A	27	Blanks
A	28	Blanks
A	29	Blanks
A	30	Blanks

CHAPTER 4

STANDARD FORMAT FAMILY OVERVIEW

This chapter has been designed to acquaint the user with the philosophy behind the CCRS standard Landsat TM Computer Compatible Tape (CCT) format design, showing its relationship to other implementations of the standard format, and giving an overview of the type of data contained within each record.

4.1 STANDARD FORMAT INTRODUCTION

The standard format used by CCRS for Landsat TM data is a member of the standard CCT family of tape formats, as defined by the Landsat Ground Station Operators' Working Group (LGSOWG) Technical Working Group (LTWG), and as maintained by the LGSOWG Change Control Board (CCB).

The standard format family incorporates the concept of a superstructure at four distinct levels, namely, volume, file, record and data field level, which permits the precise structure of the CCT to be defined within the tape itself. A major advantage emanating from this constraint is that CCT's incorporating the superstructure and containing data from the same remote sensing source (for example, Landsat TM), but generated by many different agencies, can be read with identical software. In addition, imagery data from other remote sensing sources, such as Landsat MSS data, airborne MSS data, and Seasat SAR data, when recorded in the standard format, can also be read with the same software.

The specific details of the standard format family of tape formats are defined by Buhler (1979), while the remainder of this section gives an overview of the most important features.

4.2 SUPERSTRUCTURE OVERVIEW

The general superstructure concepts are shown in Figures 5 and 6. Within the standard format family, data files are logically grouped on a tape or set of tapes, and this group is referred to as a logical volume. The individual tapes are the physical volumes. The family is sufficiently general to permit the storage of many logical volumes within one physical volume, or to split one logical volume across several different physical volumes. In addition, volume sets, consisting of more than one logical volume, each of which may span more than one physical volume, are also accommodated within the family.

At the highest level of organization, a logical volume written in the standard format may be seen to consist of an introductory file (the volume directory, which defines the logical and physical construction of the volume), the set of data files, and finally, a terminating file (the null volume directory). This null volume directory is only present after the last logical volume of a volume set.

Within the volume directory file, the first record is a volume descriptor record. This is followed by one file pointer record, for EACH data file within the logical volume, which is used to define the logical construction of that data file. This is optionally followed by a text record, which serves only as a descriptive record stored in alphanumeric form.

Within each data file, the first record is a file descriptor record containing detailed information on how to interpret the contents of its constituent records. In addition, each file has associated with it a file class, to identify the broad category to which the data belongs.

Finally, within each data record, the first six fields (twelve bytes) are normally used to specify that record's sequence number within the file, some record type coding information, and the length of the record.

It is therefore possible for two agencies to record Landsat TM imagery in records of differing lengths, storing, for example, the scan line number in quite different locations. Since the file classes and record *type codes are uniquely maintained by the LGSOWG CCB, it is possible to generate software which is driven by these two parameters alone to select the desired information from the records in the data files.*

4.3 SUPERSTRUCTURE RECORDS

There are only four superstructure records required to specify any standard family format. They are briefly described in the following four subsections, paying particular attention to the fields which are required to interpret the data files included within the volume. The precise location, format and content of these fields are given in Figure 7, and may represent all the information required by some users to interpret their tapes.

All superstructure records start with the record introductory information, consisting of record sequence number, record type and record length, stored in binary. All other fields are stored in ASCII, and are multiples of two bytes.

4.3.1 VOLUME DESCRIPTOR RECORD

The volume descriptor record contains all the information which applies to the logical volume as a whole, such as data source information, physical volume identification, and the physical relationship of the logical volume to other logical volumes within the tape or tape set. Of equal importance, is the specification of the number of file pointer records (and hence, of data files), and the number of text records. The contents of the volume descriptor record are explained in detail in Table 4.3.1.

The last file following the last logical volume within a volume set is the null volume directory file, consisting of one record only, the null volume descriptor record. Its purpose is two-fold: firstly, it marks the end of the volume set, and secondly it facilitates the addition of data to a tape which already contains data. In the latter case, the null volume directory file would be converted to a volume directory file by overwriting the null volume descriptor record with a volume descriptor record and appending the appropriate file pointer records.

4.3.2 FILE POINTER RECORD

There is one file pointer record for each of the data files on the tape, and it supplies the number and name of the associated data file, the maximum record length and an indication of the content of the file in terms of the type and format of the data. (The use of file pointer records therefore gives the user sufficient information to skip files, if desired). The contents of the file pointer record are explained in detail in Table 4.3.2.

4.3.3 TEXT RECORD

The text record is simply an extra record stored in the volume directory file to provide any type of information in human readable form. CCRS uses the text record to specify the product type and processing performed, the location, date and time of product creation, the specific scene identification and the physical tape identification. It is therefore a convenient means of confirming that the correct CCT is being processed. The contents of the text record are explained in detail in Table 4.3.3. An example of its contents is provided in Figure 8.

4.3.4 FILE DESCRIPTOR RECORD

The file descriptor record is separated into two segments, a fixed segment and a variable segment. The format of the first segment, as its name implies, is predetermined and it contains the file number and name, and specifies the format and location within each data record of the record introductory information, namely, the sequence number, type code and record length. The contents of the fixed segment of the file descriptor record are explained in detail in Table 4.3.4.

The format of the variable segment is unique to each individual file class, but several general rules are usually followed. For example, the number and length of up to three different record types may be specified. "Locators", giving the precise location and format of data considered to be important, are widely used. In addition, for files containing imagery data, valuable information concerning, for example, how pixels are packed within bytes, and the exact location of imagery data within the record, are also specified.

It is these last two components, namely, the field locators and the detailed pixel location specifications, which provide so much of the flexibility for processing similar data products from other sources.

FIGURE 8
SAMPLE TEXT RECORD - TM PRODUCT

PRODUCT: LANDSAT 5 TM BIL3 GEOCODED-PRECIS$$ 09
PROCESSED: CANADA CCRS MOSAICS ON 19860722 AT 14092335
SCENE : 0043152420 IMAGED ON 19850828
TAPE ID: RS1456 TAPE 1 OF 1
WRS ID :D017030 MAP 063D01
LEVEL OF CORRECTION 09

TABLE 4.1
LANDSAT TM RECORD TYPE CODES

BYTE 5 OCTAL	BYTE 6 OCTAL	BYTE 7 OCTAL	BYTE 8* OCTAL	DESCRIPTION
300	300	022	022	Volume Descriptor
300	300	077	022	Null Volume Descriptor
333	300	022	022	File Pointer
077	300	022	022	File Descriptor
022	077	022	022	Text Record
022	022	022	011	Scene Header
044	044	022	011	Ancillary (Map Projection)
077	044	022	011	Ancillary (Radiometric Calibration)
111	022	111	044	Interval Header
177	044	111	044	TM Housekeeping Ancillary
366	044	111	044	Ephemeris and Attitude Ancillary
544	044	222	044	Raw Jitter Measurements Ancillary
555	044	111	044	Mission Telemetry Ancillary
022	333	022	022	Annotation Ancillary
011	044	022	022	Ground Control Point Ancilliary
355	355	333	011	Quadrant imagery
355	355	022	044	Full-scene imagery
355	355	022	044	Geocoded imagery
022	366	333	011	Trailer

** Byte 8 takes the value 011(8) for record constructions defined by the LTWG, or the value 044(8) for record constructions defined by CCRS. The default value for byte 8 is 022(8).*

TABLE 4.3.1
VOLUME DESCRIPTOR RECORD - DETAILED EXPLANATION

Fields 1 to 6 are binary encoded fields. All other fields are in ASCII. Alphanumeric character strings are left-justified and numeric character strings are right-justified. Any fields not used are filled with ASCII blanks. Numbers which do not fill the field should be padded with leading blanks.

FIELD	EXPLANATION
1	A binary number containing the sequence number of this record within the file.
2	The first record sub-type code for the volume descriptor record is 300(8).
3	The record type code for superstructure records is 300(8).
4	The second record sub-type code for the volume descriptor record is 022(8). For the null volume descriptor record, it is 077(8).
5	The third record sub-type code for all superstructure records is 022(8).
6	This field contains a binary number giving the length of this record in bytes.
7	The ASCII/EBCDIC flag indicates if the alphanumeric information in the Volume Directory File is in ASCII or EBCDIC. For the Landsat TM format, ASCII only will be used, so this field will contain A$, where $ denotes an ASCII blank (i.e. 040(8)). Unless otherwise specified, $ represents a blank character.
8	Two blanks.

TABLE 4.3.1
VOLUME DESCRIPTOR RECORD - DETAILED EXPLANATION

FIELD	EXPLANATION
9	12 characters giving the Superstructure Format Control Document identifying number
10	2 characters indicating the revision number or letter of the Superstructure Format Control Document. Coded $A, for the original draft
11	2 characters indicating the revision letter of the Superstructure Record formats. Coded $A for the original draft . This code updates one letter character, alphabetically, each time there is a change to the format of a Superstucture Record (as opposed to a change to the control document which may not have been a change in the actual record format). The 26th revision is coded AA, the 27th AB, and so on.
12	12 characters identifying the software version used to write this Logical Volume. (i.e. the program name and version number).
13	This is a 16 character code also written or printed externally on the Physical Volume and used to uniquely reference a particular CCT. Also called the Tape Identifier. When a Logical Volume spans more than one Physical Volume, this code is updated for the continuation Physical Volumes. For CCRS CCTs this consists of two characters followed by four digits: <CCNNNN>, e.g. IS1234.
14	This is a 16 character code which uniquely identifies the Logical Volume. The logical volume identification will be made up in the following way: <DDDDHHMMSSQQ>$$$$ where: DDDD=Day number since launch HHMMSS=hours, minutes and seconds GMT at which the centre point of the full scene was imaged. QQ = Quadrant product number 1 - 12 (see figure 2.2.1-1).
15	A second 16 character field for identifying the Volume Set. The volume set identifier is composed of the satellite identification, and sensor description, LANDSAT$<A>$TM$$$$
16	An integer which indicates the total number of Physical Volumes in a Volume Set. A blank field indicates that the information was not available at the time the Logical Volume was recorded.

17 *This indicates the sequence number of the Physical Volume within a Volume Set, which contains the 1st record of the Logical Volume. For this format, this will always be 1. (2 characters)*

18 *This field indicates the sequence number of the last Physical Volume of a Volume Set. It should be coded blank if unknown at the time of recording. If the Logical Volume is contained on one Physical Volume, this field will have the same value as field 17. (2 characters)*

19 *This is the sequence number within the Volume Set of the Physical Volume that contains this Volume Directory File. If a Logical Volume is contained on one Physical Volume, then this value is the same as that for field 17. The value in this field must lie within the values for fields 17 and 18, inclusively. (e.g., if field 17 has a 1 and field 18 has a 3, then the value in field 19 can be 1,2 or 3, only). (2 characters)*

20 *This field gives the file number within the Logical Volume which follows this Volume Directory. If this is not the first Volume Directory of a Logical Volume, then this value may be greater than one. Volume Directory Files are not included in the file sequence number count. (4 characters)*

21 *This indicates the sequence number of the present Logical Volume within a Volume Set. The Null Volume directory is included in this count. The first logical volume is denoted as 1.*

22 *This is the sequence number of the present Logical Volume within a Physical Volume.*

23 *8 characters for the date the Logical Volume was recorded. The code is of the form: <YYYYMMDD>, where YYYY is year, MM is month, and DD is day (e.g. 19830622 is June 22, 1983)*

24 *8 characters for the time when the Logical Volume was recorded. The code is of the form: <HHMMSSXX>, where HH is hours, MM is minutes, SS is seconds, and XX is hundredths of seconds*

25 *12 characters for the name of the country generating this Logical Volume*

26 *8 characters for the laboratory or centre generating this Logical Volume.*

27 *12 characters identifying the computer facility on which the Logical Volume was recorded*

28 *The number of File Pointer Records in this Directory File. This gives the number of data files in the Logical Volume, (4 characters)*

29 *Total number of records in this Volume Directory. This will be the number of File Pointer Records plus one (for this record) plus the number of Text Records. (4 characters)*

30 This indicates the total number of logical volumes in the set. A blank field indicates that the information is not available at the time the Logical Volume was recorded.

31 92 bytes reserved by LGSOWG CCB for future revisions of this record format.

32 100 bytes available for local use. This format does not use this field, so it is filled with blanks.

TABLE 4.3.2
FILE POINTER RECORD - DETAILED EXPLANATION

Fields 1 to 6 are binary encoded fields. All other fields are in ASCII. Alphanumeric character strings are left-justified and numeric character strings are right-justified. Any fields not used are filled with blanks. Numbers which do not fill the field should be padded with leading blanks. The File Pointer Record occupies 360 bytes.

FIELD	EXPLANATION
1	A binary number containing the sequence number of this record within the file. This number will be between 2 and the number specified in field 29 of the Volume Descriptor Record.
2	The first record sub-type code for file pointer records is 333(8).
3	The record type code for superstructure records is 300(8).
4	The second record sub-type code for file pointer records is 022(8).
5	The third record sub-type code for all superstructure reocrds is 022(8).
6	This field contains a binary number giving the length of this record in bytes. This value is 360 for this record.
7	The ASCII/EBCDIC flag indicates if the alphanumeric information in the referenced file is in ASCII or EBCDIC. For the AVHRR format, ASCII only will be used, so this field will contain A$.
8	Two blanks.
9	Sequence number within the Logical Volume of the file referenced by this pointer. This is also the sequence number of the File Pointer Record within the Volume Directory. The first file following the first Volume Directory (2nd file of the Logical Volume) is file number 1. (4 characters)
10	A 16 character name which is the unique identification provided when the volume directory is created in order to specify the file referenced by this pointer.
11	This is a 28 character description of the class to which the referenced file belongs. The class of a file is based on the nature of its content.

12 The 4-byte code for the class described in field 11.

13 This 28-character field indicates the data type contained in the referenced file.

14 The 4-byte code for the data type described in field 13.

15 This 8 character field indicates the number of records in the referenced file. If this number is not known at the creation time, then this field is blank.

16 8 characters for the length, in bytes, of the File Descriptor Record in the referenced file. A blank field indicates that the information was not available at the time the Logical Volume was recorded.

17 8 character field for the length, in bytes, of the longest record in the referenced file other than the File Descriptor Record.

18 12 characters for the record length type. For this format, fixed length records are used, so this field will contain 'FIXED LENGTH'. The record length is given in field 17.

19 4-byte code for the record length type in field 18. For this format, this is 'FIXD'.

20 2 characters for the Physical Volume sequence number which contains the first record of the referenced file. May be left blank if information unknown at time of recording.

21 2 characters for the Physical Volume sequence number which contains the last record of the referenced file. May be left blank if information unknown at time of recording.

22 When a portion of the referenced file is on the PREVIOUS Physical Volume, this 8 character number is the record number of the first record of the referenced file to be recorded on THIS Physical Volume. In all other conditions, this number is 1. This, and the following field, are the only fields in a File Pointer Record to be changed on a repeated Volume Directory and are only changed in the File Pointer Record that refers to the split file.

23 When a portion of the referenced file is on the NEXT physical volume, this 8 character number is the record number of the last record of the referenced file to be recorded on THIS phyiscal volume.

24 100 bytes reserved for subsequent revisions. This is reserved by the LGSOWG-CCB.

25 100 bytes available for local use. This format does not use this field.

TABLE 4.3.4
FILE DESCRIPTOR RECORD - DETAILED EXPLANATION

Fields 1 to 6 are binary encoded fields. All other fields are in ASCII. Alphanumeric character strings are left-justified and numeric character strings are right-justified. Any fields not used are filled with blanks. Numbers which do not fill the field are padded with leading blanks.

FIELD	EXPLANATION
1	A binary number containing the record number of this record within the file. For the File Descriptor Record, this number is always 1.
2	The first record sub-type code for file descriptor records is 077(8).
3	The record type code for superstructure records is 300(8).
4	The second record sub-type code for file descriptor records is 022(8).
5	TThe third record sub-type code for all superstructure records is 022(8).
6	This field contains a binary number giving the length of this record in bytes.
7	The ASCII/EBCDIC flag indicates if the alphanumeric information in the Referenced File is in ASCII or EBCDIC. For the Landsat TM format, ASCII only will be used, so this field will contain A$.
8	Two blanks.
9	12 characters containing the number for the document that controls this file format.
10	2-bytes giving the revision number of the control document defining the current file format.
11	2-bytes giving the revision letter of the file format (as opposed to revisions which affect the control document without affecting the file format).
12	12 characters identifying the software version used to write this file.
13	4-byte sequence number of this file within the Logical Volume, excluding the volume directory.
14	This is the unique 16 character identification of the present file as stated in field 10 of the File Pointer

Record of the Volume Directory File.

15 This 4-byte field indicates if the other records in the file have sequence numbers.

16 These eight bytes give the location of the start of the sequence number field. They give the record byte number of the first byte of the field.

17 Four bytes indicating the length, in bytes, of the record sequence number field.

18 4-byte flag to indicate if the other records in the file have a record type code, and if the location of the code is fixed or variable.

19 These eight bytes give the location of the start of the record type code field. They give the record byte number of the first byte of the field.

20 Four bytes, indicating the length, in bytes, of the record type code field

21 4-byte flag to indicate if the other records in the file contain their record lengths.

22 These eight bytes give the location of the start of the record length field. They give the record byte number of the first byte of the field.

23 Four bytes, indicating the length, in bytes, of the record length field.

28 64 bytes for future expansion. Reserved by the LGSOWG-CCB.

29 File descriptor variable segment (see Tables 3.2.1.3, 3.3.1.2 and 3.4.1.2).

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APPENDIX A
DEFINITIONS

This appendix contains definitions of selected terms which appear in this document.

Input Image Centre:

The "centre" of the WRS scene from which the processed image was generated. The "centre" is specified by time (input scene centre time) and viewing vector (optical centreline of the sensor at the scene centre time.

Input Image Centre - Geographic Position:

The coordinates of the ground point (latitude and longitude) viewed by the optical centreline of the sensor at the input scene centre time.

Input Image Centre - Input Position:

The coordinates of the input image point (line and pixel in the reference band) which most closely viewed the geographic input image centre. This is generated by assuming that a raw CCT product had been generated from the HDDT before making the product. It is the same as the "Processed Image Centre - Image Centre" for a raw product.

Input Scene Centre Time:

Each orbit of the spacecraft is divided into a fixed number of scenes (equal to the number of rows in the WRS for the spacecraft). Each scene is assigned a scene centre time. A reference scene (WRS row 60 for Landsats 1-5) is assigned the decending node time. All remaining scenes are assigned scene centre times spaced equally about the reference scene centre time.

Processed Image Centre:

The geometric centre of the processed image. For raw Quadrant products it is the centre of the rectangle (ignoring line length variations on the right) bounding the nominally aligned image. For system-corrected Quadrant products, it is the centre of the parallelogram bounding the map projected image. For Geocoded products, it is the centre of the rectangle bounding the Geocoded map area.

Processed Image Centre - Geographic Position:

The ground coordinates (latitude and longitude) of the geometric centre of the processed image.

Processed Image Centre - Image Position:

The image coordinates (line and pixel) of the processed image centre. The coordinate system is defined such that line 1 is the first (topmost in image) image record on the CCT, and pixel 1 is the first (left most in image) pixel in any image record. For Quadrant products this definition does not include left-fill pixels; whereas, for Geocoded products it does include left-fill pixels.

APPENDIX B

Radiometric Calibration and Correction of the LANDSAT Thematic Mapper Sensors

INTRODUCTION

An internal calibration system is provided within the TM instrument to assistin performing radiometric calibration of the image data. The system consists of two major components, namely, an obscuration shutter which provides the zero-radiance surface for setting the dc (background) reference level, and a set of three calibration source lamps. At the completion of each imaging scan, the zero-radiance surfaces and the calibration lamps pass through the fields of view of all detectors. The zero-radiance reference level is intended to develop a zero-clamp level for the analog-to-digital circuitry, and it is fractionally updated to a nominal level of 3 digital counts during the calibration period. An internal sequencer automatically switches betweenthe eight possible lamp combinations, (by switching one of the three lamps on or off), with each calibration level being held for approximately 40 consecutive scans. The full sequence is therefore completed in 320 scans, which is roughly equivalent to a full WRS scene. Linear regression analysis can then be used to relate the average digital values recorded for each of the eight lamp states to the equivalent prelaunch digital values and to the radiance values measured using a standard reference 122-centimetre diameter integrating sphere. Assuming a linear response for each detector, a gain and offset, applicable to the full scene, can therefore be computed.

CHARACTERISTICS OF THE BACKGROUND REFERENCE LEVEL

It has been observed that the background level varies significantly as a result of dc restoration and therefore measurements should be taken from one of two windows, either before dc restore (BDC) or after dc restore (ADC). More significantly, however, there is a much more dramatic change in background level occurring at the start of each scan line. The variations are random with respect to both scan line number and scan direction, with magnitudes as large as 3 digital numbers. These observations have significantly affected the procedure required for the radiometric correction of TM data.

ABSOLUTE CALIBRATION OF TM DETECTORS

The procedure chosen by CCRS for the radiometric calibration of TM data is based on the method used by CCRS for LANDSAT Multispectral Scanner (MSS) data, and may be divided into three stages.

Firstly, a reference detector is chosen for each spectral band, and the corrections required to place the data from this detector on an absolute scale are calculated, using in-flight calibration data, pre-launch calibration data and the maximum and minimum radiance values asociated with the response of the band.
Secondly, the relative differences between all other detectors in each band and the reference detector are calculated, using the means and standard deviations of the raw data values as calculated from the sums and the sums of the squares of the scene data values. These, in turn, are usually calculated from the histograms of the raw data values. In order to ensure that the histograms correspond only to pixels with radiance values for which the response of each detector is linear, all those pixels which saturate any one detector within a band are removed from the histogram of each detector within that band. The procedure is repeated for each band in turn.

Finally, the absolute calibration of the reference detector for each band is combined with the relative calibration of the other detectors within the same band to provide an absolute calibration of all one hundred detectors.

OPERATIONAL PROCEDURE

Changes to the absolute calibration technique to account for background levels which vary randomly as a function of line number but which are constant within a line can be quite simply incorporated into the procedure.

Firstly, the calibration pulse average for each line must have the relevant background level measurement subtracted from it. The sequence of events during the calibration period is such that dc restoration precedes exposure to the calibration lamps on forward scans, but follows it for reverse scans. Therefore, for forward scans, ADC is used, but for reverse scans, BDC is the appropriate value. The modified calibration samples can then be included in the state average, in the usual way.

Secondly, the histograms for each detector of each band must be accumulated one line at a time for each direction independently, and must be truncated to remove all those pixels which saturate any one detector within the band. The line-dependent background level must then be subtracted from the truncated histogram, and must also be saved for later use when correcting the raw data. These histograms, which have been truncated to remove saturation effects and which have been shifted to account for background level variations, can then be incorporated into the accumulation of the sums and sums of squares of the raw data for the entire scene. The scene-dependent relative gains and offsets can then be computed. (Any systematic variations which are a function of pixel position within the scan line are assumed to have a negligible effect on the overall scene statistics, in comparison to the line-dependent background variations. Therefore, when accumulating histograms as required to derive the scene-dependent gains and offsets, no correction for pixel location effects will be included, other than the separate accumulation of forward and reverse histograms to account for the fundamental difference due to the dependency on direction.) The final phase of calculating absolute scene-dependent gains and offsets is to combine the absolute calibration of the reference detector with the relative calibration of the remaining detectors within the same band.

APPLICATION OF RADIOMETRIC CORRECTION

The raw data is corrected, taking account of corrections which are a function of scene, of scan direction, of line and of pixel position within the line. This is conveniently effected by first subtracting an offset from each raw data value and then dividing it by the scene-dependent gain. The offset includes a scene-dependent component derived from the absolute and relative calibrations, and a line-dependent component (BDC) extracted from the background data. It also includes a pixel-dependent component, which is calculated using linear interpolation between background values at five non-uniformly spaced breakpoints. For bulk-corrected products, the radiometric correction is performed in floating-point notation before the along-scan line resampling for geometric correction, and conversion to the final 8-bit form. For geocoded products, the radiometric correction is again performed before the first pass along-scan line resampling. Between resampling passes, the data is stored in 16-bit form to retain the maximum accuracy.