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TM DIGITAL IMAGE PRODUCTS FOR APPLICATIONS

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ABSTRACT

Landsat-4 Thematic Mapper (TM) images recorded on computer compatible tapes (CCTs) are currently available from the SCROUNGE image processing system of the Landsat-4 Assessment System (LAS) project of the National Aeronautics and Space Administration (NASA) at Goddard Space Flight Center (GSFC) in the following tape formats: 1) raw rectified data (CCT-BT); 2) calibrated data (CCT-AT); and 3) geometrically corrected data (CCT-PT). These formats represent different steps in the process of producing fully-corrected TM data. CCT-BT images are rectified from telemetry format to image format, but are uncorrected radiometrically and geometrically; they are generally used for internal transportation of data from one ground processing system to another. CCT-AT images have had data from faulty channels replaced and all data radiometrically calibrated to produce an archive image; they are available to researchers for radiometric characterization. The final products, the CCT-PT images, have been resampled by cubic convolution procedures to provide a geometrically corrected image using satellite ephemeris data. The CCT-PT image is the one to which all of the various radiometric and geometric corrections have been applied; this is the product that is available to all users.

Image files on the three tapes of the CCT-PT set are blocked four image lines per tape record, yielding a blocksize of 28672 bytes. The CCT-AT images also has a blocking factor of four but a blocksize of 26624 bytes; the equivalent values for the CCT-BT images are five and 32000 bytes.

Forward and reverse scans on all products are properly oriented east-west, but the CCT-BT and CCT-AT images have an alignment offset between scans. Original band-6 120m IFOV pixels have been replicated to four 30m IFOV pixels along a line in CCT-BT images, but the lines are not replicated to yield a full 4x4 block of 30m IFOV pixels that are array compatible with the other bands until the CCT-AT image is produced.

Saturated or very bright isolated pixels occurring in all bands result from apparent specular reflection of small objects on the ground. The pixels have proven to be useful in calculating interband registration coefficients for all CCT formats. The coefficients indicate that the bands are registered to each other within a small fraction of a pixel.

Author recommendations call for 1) better documentation, including that on tape files; 2) better calibration procedures and calibrated images; 3) nearest-neighbor resampling option in addition to cubic convolution; 4) computer processing using real-number formats for all intermediate products, to eliminate the effects of integer roundoff; and 5) the use of video laser disk media for recording archival and browse images. Areas for future research are indicated.

KEYWORDS: Remote Sensing, Landsat-4, Thematic Mapper, Digital Image Processing, Calibration, Geometric Correction, Interband Registration, Computer Compatible Tapes, Data Formats, CCT-BT, CCT-AT, CCT-PT.

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SECTION 1 -- INTRODUCTION

The Landsat Thematic Mapper (TM) remote sensing team includes people with varied fields of interest and experience. There are the engineers, the scientists, the managers and the users, to name a few of the major groups. From a different perspective, there are the people who designed the system, those who built it (Covault, 1982a), those who tested it to see who the hardware and software lived up to expectations, and those who want to use the resulting images (Covault, 1982b; 1983) and digital products to solve problems (Williams, 1983; Everett et al., 1983; Abrams et al., 1983; and Quattrochi, 1983). The first three groups talk common languages in engineering, mathematics and computer programming. The fourth group, the users, in many cases may not be acquainted with or understand the technical documentation produced by the engineers, scientists and computer professionals.

This document provides a transition. It is intended to provide a scientific characterization of the images, and information on the means by which the various images are being produced for the benefit of TM investigators, especially those who are concerned with radiometry. It assists users in information extraction by presenting some of the features and characteristics of the various digital image products used to produce the generally available final digitalimage product, the CCT-PT. It points to more detailed treatments of image characteristics or data formats in other documents.

Evaluation of TM image data will be the subject of another paper. Preliminary results by other investigators indicate that TM data have "... an image resolution and quality beyond expectations,..." (Covault, 1982b; 1983), due to performance at the optimum-expectation level of spacecraft and groundprocessing systems (Salomonson & Koffler, 1983). Others have concluded "...the TM data exhibits very good data quality and reliability, and can be used for accurate mensuration studies ..." (Bernstein & Lotspiech, 1983).

Other papers in this symposium cover technical details of the Landsat-4 system (Barker, 1983). Calibration procedures are presented in Barker, Abrams, et al. (1984a). Absolute calibration and engineering test results are in Barker, Abrams, et al. (1984b) while Barker, Ball, et al. (1984) describes post-launch calibration results for the TM reflective bands and studies improvements in the ground processing procedure. A discussion of sensor radiometry for the thermal band appears in Lansing & Barker (1984). Detailed discussion of results and recommendations is given in Barker (1984). This document will concentrate on the characterization of digital products.

SECTION 2 -- DIGITAL IMAGE PROCESSING

Thematic Mapper (TM) in-orbit data is now available for general use (Covault, 1982b; 1983; Williams, 1983). The SCROUNGE system, which comprised the Mission Management Facility (MMF), the Data Receive, Record, and Transmit Subsystem (DRRTS), the Applications Development Data System (ADDS), and the Landsat-D Assessment System (LAS) has processed TM images on a research and development basis at Goddard Space Flight Center (GSFC), of the National Aeronautics and Space Administration (NASA). SCROUNGE provided intermediate and/or final products directly to principal investigators (PIs) of TM assessment projects, and indirectly to the general public through the EROS Data Center (EDC) at Sioux Falls SD. SCROUNGE processing at NASA/GSFC provided images at the rate of one TM image per day. In July 1983, one year after launch, the TM Image Processing System (TIPS) took over image processing at a rate of 102 images per day.

SCROUNGE-era computer-assisted (digital) image processing resulted in photoproducts and computer-compatible tapes (CCTs) representing different levels of processing. Most people will work with the images and CCTs at the final-product stage, but intermediate products are available as an engineering tool. TM data in final-product form has geometric and radiometric corrections applied and is ready to be used in image analysis; the intermediate products have different levels of corrections applied (Table 2-1). This section discusses the characteristics of the different types of digital products.

In addition to the several high-density (HDT) tape formats used internally by NASA (Jai, 1982), SCROUNGE-era digital TM data exist in three formats (Table 2-1). The three formats are:

- Raw rectified data (CCT-BT)(Anon., 1982a) is generally used only for internal transportation of digital data from one ground processing system to another.
- Calibrated data (CCT-AT)(Baker & Gilson, 1982) should be used only by investigators doing radiometric characterization.
- Geometrically corrected data (CCT-PT) (Baker & Gilson, 1982) is the final product. The final product, the CCT-PT, is the one to which all of the various radiometric and geometric corrections have been applied; this is the product that is ideal for image analysis for applications.

General Comparisons among Landsat-4 Thematic Mapper Digital Products.

CCT SCROUNGE-ERA FORMATS (1982-1983) LANDSAT-4 TM DIGITAL DATA

	CCT-BT	CCT-AT	CCT-PT
TAPES	2	2	3
DENSITY	6250 bpi	6250 bpi	6250 bpi
BAND FORMAT	BSQ	BSQ	BSQ
IMAGE RECORDS/FILE	1197 (300—B6)	1497	1493
RECORD LENGTH	32000 BYTES	26624 BYTES	28672 BYTES
LINE LENGTH (FILLED)	6400 (6400)	6176 (6656)	6967 (7168)
BLOCKING FACTOR	5	4	4
PREPROCESSING			
RADIOMETRIC	NONE	YES	RESAMPLED
GEOMETRIC	FLIP REVERSE SCANS	NONE	RESAMPLED
EROS DATA CENTER AVAILABILITY	NO	YES	YES

Table 2-1. General Comparison among Landsat-4 Thematic Mapper Digital Products.

2.1 Raw Digital Image (CCT-BT)

SCROUNGE-era partially processed TM data was produced in a format (CCT-BT) used for data exchange between the ADDS and LAS (Anon., 1982a). CCT-BT tapes are not ready for general applications digital image processing. They are available through the NASA Science Office only to TM principal investigators (PIs). Radiometric correction and geometric registration procedures have not been applied to the image data. Start-line pulses and initial image pixels, not present in all channels of the telemetry data, have been trimmed before writing the image to the CCT-BT. Reverse scans have been flipped so that east and west ends of each scan are properly oriented. The interleaved minor-frame format used in the telemetry was sorted into band-sequential format (Figure 2-1).

The images were written as 8-bit byte data on two standard 6250 bpi CCTs in band sequential (BSQ) format. Four image files are on the first CCT-BT, and three image files are on the second (Figure 2-1). Tape identification files are also placed on both tapes. In addition, the first tape contains a special data file with housekeeping, ephemeris, attitude, and minor scan data plus data quality information (Section 2.1.5).

Each image line follows a particular format (Anon., 1982a). The first 10 bytes of each image line provide support data, including the scan number for that TM scene. The next 6176 pixels are image data, with the first pixel at the western edge of the scene. The image data are followed by 64 bytes of zero fill, by 64 bytes of support data containing channel gain and offset information, and by a final 64 bytes of zero fill (Figure 2-2). This yields an image line of 6400 bytes. Five such lines make a record on the tape (Section 2.1.1).

2.1.1 Blocking Factor

To save space on the tapes, image lines were not written as separate records to tape files, but were blocked five (5) lines per tape record. If an image is copied from the tape without taking into consideration the blocking factor, the image is compressed by having only one line out of five in the vertical direction and five lines across in the horizontal direction (Figure 2-3). The image has a line length (logical record length = LRECL in IBM terminology) of 6400 bytes; the physical record length (= BLKSIZE) on the tape is 32000 bytes. Some minicomputers are unable to read blocks of this size.

The image must be unblocked to be useful (Figure 2-2). The unblocking may be a preprocessing step on an auxillary computer where the image is copied from one tape to another by a utility program or unblocking may be performed automatically by the computer program that puts the image or a portion of it on a disk file for computer access.

2.1.2 Scan Shift

TM image data in B format is not aligned between forward scans and reverse scans (Engel, 1980). A linear feature is properly recorded within each scan, but between scans there is a large offset (Kieffer, Abrams, et al., 1983) (Figure 2-4).

The offset of the image in B format can be corrected to yield a nominal alignment of pixel columns, a B' format (Figures 2-5 and 2-6). To do this, an analyst makes repeated runs of a "mosaic" program; one run for each 16 image lines. The number of pixels offset is variable, dependent upon scene latitude. An offset that appears ideal for Mississippi does not appear to be appropriate for Maryland nor for New Mexico.

The offset applied to the B format image corrects the alignment between forescan and backscan, but does not take into account all factors. It is necessary to correct the B format image for the rotation of the earth. The correction for the rotation of the earth is applied by moving the start sample for each mosaic of 16 lines to the east (i.e., by increasing the value of the start sample by a constant). The value of the constant used is a function of angular distance from the equator. Operationally, it is easiest to produce an intermediate image, to determine the correction for the rotation of the earth, and then to apply that correction to the image to be studied. The application of both scan-offset and earth-rotation corrections produces a B'' format image.

The image in B format is available through the NASA Science Office to TM PIs only. The image in B' and B'' formats must be produced by the individual investigator doing his own digital image processing; the B' and B'' image formats are not standard Landsat-4 digital products.

Note that the B'' image format is close to being geometrically correct, without any resampling. It is not a precision-registered, geometrically-correct image. This format is useful for radiometric studies that require ground truth. It is also useful for other studies where lack of ancillary data prohibit the construction of a final-product image.

2.1.3 Defective Channels

Before launch, four channels were found to be defective. Because of construction difficulties, the sensor was launched with the known defects, and ground-processing software was adjusted to replace defective data. In the B format image, these corrections have not been applied.

Detector 3 of band 5 does not respond to radiance input (Barker, Ball, et al., 1984). Instead of valid data, the instrument counts or data numbers (DNs) in that data channel are at least one order of magnitude lower than that recorded in the previous channel and the following channel (Figure 2-7).

Channel 2 of band 2 and channel 7 of band 7 have twice as much noise as the average for all channels for the respective band (Barker, 1983 and Barker, Ball, et al., 1984). Channel 4 of band 2 has a smaller modular transfer function (MTF) than desired (Barker, 1983 and Barker, Ball, et al., 1984).

2.1.4 Band-6 Format

Band 6 is the thermal band, with a larger instantaneous field of view (IFOV) than the reflected-light bands (Engel, 1980; Covault, 1982a). The "footprint" for band 6 is 120m by 120m rather than 30m by 30m; this results in an array of numbers for the image that is 1/16 the size of the array for the other bands. For digital image processing purposes, the array size of each band should be the same. To accomplish this, processing software replicates each band-6 pixel to produce four pixels along a line and four identical lines.

In the B format image, the replication process is only half done. The pixel values are replicated in the scan direction, but the scan line has not been replicated (Figure 2-8). As a result, in the B format data, the band 6 image file has only 1/4 as many records as the other files (Figure 2-1). In the B' (Figure 2-9) image format, the scan lines have been duplicated by the user so that the band-6 file has the same number of records.

2.1.5 Ancillary Data

In addition to the image files that are characterized in the above sections, each tape produced in SCROUNGE-era B format contains data files that have useful ancillary data.

The first ancillary data file is the TAPE ID file (Anon., 1982a), found as the first file on both tapes. The ID file is one physical record, or five logical records (Section 2.1.1). A detailed description of the information and format of the ID file appears in Table 2-2.

The second ancillary data file is the Header Ancillary Annotation Trailer (HAAT) file, found as the second file on the first tape only (Anon., 1982a). The HAAT file is seven physical blocks in length; each logical record is 6400 bytes. HAAT file internal head and tail records contain general timing and location information; other records contain detailed housekeeping, ephemeris and attitude data. The general information is described below; characterization of the detailed information can be found in the "Interface Control Document" (Anon., 1982a).

Table 2-2. File Contents for the TAPE ID file.

Label	Location (bytes)	Example	Note
SYSTEM ID & DATE	1-12	L4TCC8230801	1
IMAGE FORMAT & VOLUME	15-22	CCT-BT 1	2
IMAGE SCENE ID.	23-38	0109 015-033	3
SOFTWARE VERSION	41-52	ADDS0 102.00	

Notes: 1. Landsat-4, Thematic Mapper, Computer Compatible Tape, created on day 308 (4 November) of 1982, tape #1.

2. First tape of data in B format.

3. Image taken on Launch Day + 109 days, for World Reference System (WRS) Path=015, Row=033.

The first record in the HAAT file contains general timing information as literal or alphanumeric fields. The times at which the first scan and the last scan lines for this scene were taken are given in bytes 21-36 and 37-52 in YYDDDHHMMSSTTTFF format. In this format "YY" is the year, ignoring the century numbers, "DDD" is the Julian day of the year, "HH" is the hour of the day and "MM" is the minute of the hour. The seconds are reported by "SS" and the thousandths of a second by "TTT"; "FF" values are the 16ths of a millisecond (Jai, 1982). The start and stop Payload Correction Data (PCD) times are given in bytes 53-68 and 69-84 in the same format.

The seventh or last record in the HAAT file contains general location information as literal fields. The date of acquisition is given in bytes 5-11. The latitude and longitude for the image center are given in bytes 13-28, and the same for the NW corner in bytes 39-54. The World Reference System (WRS) path-row coordinates are given in bytes 31-37. Bytes 66-78 contain solar elevation data. The full scene identification code may be found in bytes 92-117.

2.2 Radiometrically Calibrated Image (CCT-AT)

The intermediate digital-data product during the SCROUNGE-era was the CCT-AT. In producing the CCT-AT digital product, some of the imperfections of the CCT-BT images are removed, and the images are written on the tapes in a general user format (Anon., 1979). The images are not yet suitable for general applications analyses.

Radiometric correction procedures have been applied to the image data (Barker, Abrams, et al., 1984a), but not geometric registration procedures. CCT-AT tapes, which are generated by NASA-GSFC for archival purposes, are available through EDC to researchers interested in radiometry.

The images were written in band sequential format (BSQ) as 8-bit byte data on two standard 6250 bpi CCTs. Three image files are on the first CCT-AT, and four image files are on the second (Figure 2-10). Tape identification files and other data files are also placed on both tapes. Identification files, data files and image files are packaged in the manner recommended by the Landsat Ground Station Operators Working Group (LGSOWG) (Anon., 1979; Baker, et al., 1983).

The formats for the image file and for the image lines are different for a CCT-BT (Section 2.1) and a CCT-AT (Figure 2-11). The image file for a CCT-AT has prefixed one internal header record to the image data. In the A format image, the image lines do not have the initial 10 bytes of labeling information, but they do have an appendage of 480 bytes (Section 2.2.1); the first image pixel is at byte #1.

2.2.1 Blocking Factor

CCT-AT image data during the SCROUNGE-era were blocked 4 lines per tape record (Baker, et al., 1983). In addition, hardware efficiency demands in LAS require that the 6176 data pixels per line be padded so that the line length is an even multiple of 512. This results in an additional 480 bytes per line, for a total line length of 6656 bytes and a physical record length (= BLKSIZE) of 26624 bytes (Figure 2-11).

The one-line internal header record for the image file is in a separate record the same length as the image line. Most of that record is blank. When the internal header record is reblocked along with the true image lines, it produces one line with alphanumeric header data and three lines with "spaces" (ASCII code = 32) (Figure 2-12).

The resulting image array does not have its start line and start sample at location 1,1 but rather at line=5, sample=1.

2.2.2 Scan Shift

The scan shift is the same in both A format and B format images. Since the transformation from B to A does not involve geometric corrections (Figures 2-13 to 2-16), A' and A'' products are derived by the user from an A format image in the same way as B' and B'' images were derived from a B format image (Section 2.1.2).

2.2.3 Defective Detectors

In the A format image, a software "quick fix" was applied by SCROUNGE to two of the channels of data produced by defective detectors (Section 2.1.3). Data from band 5, channel 3, is replaced with data from channel 4, and data from band 2, channel 4, is replaced with data from channel 5. This results in two identical lines out of every 16, in both forward and reverse scans in images from bands 2 and 5 (Figures 2-14 and 2-15).

2.2.4 Band-6 Format

Unlike the band 6 image in B format, the band 6 image file in A format has the same structure as the other bands (Figures 2-10 and 2-16). The size of the image array was enlarged to provide array compatibility with that of the other bands.

2.2.5 Calibration

TM image data in A format is produced by radiometric calibration (Barker, Abrams, et al., 1984a) of images in B format.

Prior to launch, the channels were calibrated against a National Bureau of Standards integrating sphere (Engel, 1980; Anon., 1982b; Barker, Abrams, et al., 1984a; Barker, Ball, et al., 1984). The calibrated channels were used to calibrate the on-board Internal Calibration (IC) system (Barker, Abrams, et al., 1984a; Barker, Ball, et al., 1984). Since launch, data from the IC was used to determine gain and offset for each channel (Barker, Abrams, et al., 1984a; 1984b). The application of sensor-specific calibration factors provided by the IC to the reflectance data allows production of high-quality images containing accurate radiometric data (Barker, Abrams, et al., 1984a). The actual application of calibration data proceeds at high speed through the use of a radiometric look up table (RLUT).

A B-format image can be calibrated in several ways (Figure 2-17) to produce an A-format image. For example, the authors placed a special order for a particular image to be calibrated by using pre-launch nominal values, without use of the IC, plus histogram equalization procedures to produce one set (Figures 2-13 to 2-16) of A format images, and by the IC plus histogram equalization procedures to produce another set (Figures 2-18 to 2-21) of A format images. An investigator interested in radiometry can make special requests for image calibration in A format:

- An image that has received nominal calibration only; this requires special processing by the ADDS portion of the SCROUNGE system.
- An image that has received IC calibration only, without histogram normalization.
- An image that has received the nominal calibration, followed by histogram equalization; this requires special processing by the ADDS portion of the SCROUNGE system.
- An image that has received IC calibration, followed by histogram equalization. Under the SCROUNGE system, this is the option used if there is no special request.
- An image that has received histogram equalization processing only.

The authors found differences between the products of the two types of calibration, IC followed by histogram equalization and nominal followed by histogram equalization. These differences were investigated by producing difference images for corresponding bands between the IC calibration and nominal calibration A format images. Examples of the difference images (Figures 2-22 to 2-25) show that: 1) differences between the two calibration techniques are almost always less than 2 DN levels (see below); 2) changes in calibration tend to be autocorrelated along scan lines, since the corrections have the same calibration offset for all data produced by a given channel, and since the calibration gain for similar pixels is similar; 3) each scan line tends to have changes in calibration that are independent of what happens in neighboring lines; and 4) each TM band has its own pattern of changes in calibration.

Histograms have been produced for calibration difference images for all TM bands (Figure 2-26). These histograms show that for all TM bands except band 4, most pixel DNs are not changed by the change in calibration procedure. TM band 4 has a 1-DN change between the two calibration procedures for 86.5% of the sampled image pixels and a 2-DN change of 5.2%. This could arise from the unusual IC pulse shape for band 4 channels (Barker et al, 1983b). TM band 1 has a 1-DN change for 33.2% of the pixels. TM band 3 has a 1-DN change between the two calibration procedures for 16.4% of the image pixels. Band 2 has a 1-DN change for 15.4% and band 5 has a 1-DN change for 8.7% of the pixels. Band 7 has 2-DN changes for 0.1%. Other DN changes involve trivial percentages.

Histograms were also produced for each of the 16 channels for each spectral band (Figure 2-27). These show that the two types of calibration produce different results for each channel.

A word of caution. Instrument variability with time (Barker, Abrams, et al., 1984b) has placed constraints on the several calibration procedure options available (Figure 2-17). Radiometric image analysis (Barker, 1983; Barker, Abrams, et al., 1984b) has indicated that it is essential to apply IC radiometric correction before other calibration corrections to preserve the radiometric accuracy needed for applications analyses.

2.2.6 Ancillary Data

In addition to the image files that are characterized in the above sections, each tape in A format contains data files that are not in image format. These data files contain information that may be necessary or very useful to the individual interested in information extraction.

The first ancillary data file is the LGSOWG VOLUME DIRECTORY file (Anon., 1979; Baker & Gilson, 1982), found as the first file on both tapes. The file has 17 physical records, or 68 logical records (Section 2.2.1). The first logical record contains the LGSWOG Volume Descriptor Record. The next 16 records contain pointers to various files on that tape. Details of file contents may be obtained from Baker & Gilson (1982).

The second ancillary file is the LAS label file for HAAT data. This label file contains a record describing the HAAT data file and optional history records.

The third ancillary data file is the HAAT file, found as the third file on the first tape only (Baker & Gilson, 1982). HAAT file records contain detailed housekeeping, ephemeris and attitude data. The general information is found on records #2 and #32, which are copies of records #1 and #7 from the HAAT file of the CCT-BT tape (Section 2.1.5). Characterization of the detailed information may be obtained in Baker & Gilson (1982).

The fourth ancillary data file is the LAS label file for image data, band 1. The general contents of the label file are the same as that described above for the HAAT label file. Files with this same format and data are found as external labels in front of each image file on both tapes (Figure 2-10).

2.3 Geocorrected Image (CCT-PT)

The final and finished digital-data product is the CCT-PT. The radiometrically fully-corrected images were written on the tapes in a user format (Anon., 1979) and are suitable for general applications analyses.

Completely processed TM data generated by SCROUNGE (Baker & Gilson, 1982) is available in the CCT-PT format used for product data. Radiometric and geometric correction procedures have been applied to the image data. This is the format for the image data on tape that NASA/GSFC supplied during the SCROUNGE era to the EROS Data Center (EDC).

The images were written as 8-bit byte data in BSQ format on three standard 6250 bpi CCTs (Figure 2-28). Two image files are on the first and second CCT-PT, and three image files are on the third. Tape identification files and other data files are also placed on the tapes. Identification files, data files and image files are packaged in the manner recommended by LGSOWG (see Baker & Gilson, 1982a).

2.3.1 Blocking Factor

To save space on the tapes, image lines were not written separately to tape files, but were blocked 4 lines per tape record (Baker & Gilson, 1982). In addition, hardware efficiency demands within the LAS computer required that the 6967 data pixels per line be padded so that the line length was an even multiple of 512. This padding resulted in an additional 201 bytes per line, for a total line length of 7168 bytes and a blocksize of 28672 bytes (Figure 2-29).

The one-line internal header record for the image file is in a separate record in front of the image data. The situation is nearly identical to that for A format images (Section 2.2.1).

The resulting image array does not have its start line and start sample at location 1,1 but rather at line=5, byte=1.

2.3.2 Geometric Corrections Applied

Geometric correction places TM image samples into a map coordinate system. This simplifies subsequent applications data processing (Beyer, MS), but does not affect the spectral response of ground cover types (Bartolucci et al., 1983).

During the SCROUNGE-era, ground processing produced geometrically corrected images using resampling based on systematic correction data (SCD), derived from payload correction data (PCD) (Anon., 1982b) and mirror scan correction data (MSCD). During this processing, flight segment telemetry was converted into a geometric projection of the scan pattern (Beyer, 1983). A transformation was generated between the geoid location of each pixel and the appropriate coordinates for any output grid system. The output grid was filled with data using a resampling technique. SCROUNGE used cubic convolution procedures rather than nearest neighbor or bilinear interpolation for resampling. The original 30 m IFOV of the pixels in the B and A format images was resampled to a grid interval of 28.5 m.

Precision geometric correction using the known locations of ground control points was not available during the SCROUNGE-era. The nominal corrections produced from satellite ephemeris data provide images that closely correspond to maps. Working with a CCT-PT image of Death Valley CA, registered to a topographic base, Abrams et al. (1983) found a registration error of less than two pixels, for terraine with 7000 feet of local relief. McDonald (1983), working with a CCT-PT image of flat farmland in Arkansas, reported an error in geometric accuracy of about 0.1 pixel. Goodenough (1983) found that ground registration errors along a scan were greater than across a scan (32m versus 40m). Bryant et al. (1983) calculated an average vector offset of 132.77m using 75 ground control points for a full scene.

Some apparent errors in geometric precision in film products result from imperfect geometric fidelity of filmwriters. Kiefer et al. (1983) found scale errors corresponding to 4 pixels and skew errors of 3 pixels. Large errors reported (68-72m) were attributed at least in part to "highly significant skewness" in the rotary-drum, film-writing device (Bender, et al., 1983).

2.3.3 Earth Rotation Correction

A consequence of applying geometric corrections is the correction for the rotation of the earth under the orbiting satellite. This correction results in the two black wedges found in full-scene or near-edge photoproducts and the corresponding fields of zero values found in the digital image files as "fill" pixels (Figure 2-29). These two fill fields have caused problems in image enhancement procedures that expand the dynamic range of raw or transformed data by thresholding selected percentages at the high and low ends of the frequency distribution.

Because the effects of the earth's rotation are corrected by using fill pixels, the first image pixel will be found in tape record line 5, but at a sample number some distance in from the start of the line. The distance is a variable depending upon latitude north or south. If it is necessary to locate the first image pixel on any line, the analyst or a computer program must search for the first non-zero pixel in that line, and then move three pixels to the right, to avoid edge effects caused by cubic convolution resampling of image data and fill data (Baker & Gilson, 1982).

SECTION 3 -- RESULTS

The authors employed a number of digital image analysis tools to examine particular features of Landsat-4 TM images. Preliminary results from these investigations are presented below.

3.1 Specular Reflectance

Statistically-based image evaluation procedures commonly show the presence of a few very high values, often reaching saturation levels (DN=255). Line and sample location data and printouts of pixel values show (Figure 3-1) that the same pixels are involved in each band. This indicates that the high DN values result from specular reflectance from some object within the scene and are not noise.

In a few cases, the source of specular reflectance was determined. In a Goddard Space Flight Center (GSFC) TM scene, curved surfaces (the inflated warehouse near Bldg. 20, the water tower at Bldg. 16, and the pressure dome for Bldg. 15) show specular reflectance. In the same scene, some flat roof areas also show specular reflectance. Specular reflectance could be obtained from silo tops, from covered stadiums, from cars parked in alignment in a parking lot, from pitched roofs, etc.

The specular-reflectance pixele provided an opportunity to look for instrument lag. It is important to know if the TM sensors are slow to recover from a bright reflectance reading. Examination of the DN values around several specular-reflectance pixels indicates that the next pixel in the scan line is at least 100 DN values lower. Any adjacent pixel with DN values above those of its neighboring pixels can easily be explained as a mixed pixel from a large bright source. Statistical studies of large numbers of specular-reflectance pixels are being considered, but at present there is no clear evidence for instrument lag.

3.2 Registration

Two aspects of registration can be considered: 1) the band-to-band registration that provides an accurate multispectral image array; and 2) the image to ground registration that allows the image to be used as a map. The latter aspect was not investigated by the authors; it is discussed in Section 2.3.2.

Investigation of specular radiometric responses (Section 3.1) has shown that there is close interband registration in both the B and A format images, which have the same image geometry, and in the P format images. Identification of specular reflectance pixels is complicated by the different sensitivities of the different spectral bands (see also Bryant et al., 1983a). In some bands, notably bands 1 and 4, the spectral reflectance pixels are saturated; saturated pixels record a maximum DN of 255. In other bands, notably 2 and 3, the spectral reflectance provides a peak DN value considerably above that of its neighbors, but not at saturation. The same peak can almost always be identified in all spectral bands (Figures 3-2 and 3-3).

3.2.1 Prime Focal Plane, Internal

The two early, 4-band TM scenes for Detroit, MI (scene ID = 40004-15401 and 40009-15413) in CCT-BT format, and one 7-band scene for Memphis, TN (ID = 40037-16033) in CCT-AT format have have been examined for interband registration as indicated by spectral reflectance. Each scene was treated separately. In some cases, specular reflectance pixels for large areas such as quarries occupy too large and diverse an area for registration evaluation. In most cases, specular reflectance involves only one or two pixels, and these locations are suitable for interband registration evaluation.

The authors have made center-of-gravity calculations for small image segments centered on isolated specular reflectance pixels. The assumption is that the weighted-average line and sample values for each band in the multispectral small image segment will have the same value if the bands are corrected. The data for each Detroit scene taken separately indicates that the bands on the primary focal plane (Engel, 1980) are registered to a fraction of a pixel in both line and sample directions (Figure 3-2). The Detroit-1 image had a registration error of up to 0.14 pixels in the scan direction and up to 0.28 pixels across scan; the equivalent values for the Detroit-2 image are 0.22 and 0.48. Errors of up to 0.45 pixels in scan and up to 0.15 pixels across scan were obtained for a comparison of bands 1-4 for the Memphis scene (Figure 3-3).

Other authors have reported similar results. Using a different procedure, that of line-to-line displacement, Fusco and Mehl (1983) found a misregistration that measured less than 0.1 pixel. The same value was determined by Bryant et al. (1983a; 1983b). Visual comparison of contrasting targets using an interactive video display on a part of the Washington D.C. scene (ID = 40109-15140) found that bands 1-4 were perfectly coregistered (Bender et al., 1983).

3.2.2 Cold Focal Plane, Internal

Center-of-gravity calculations for specular reflectance pixels for a subimage from the Memphis scene (ID = 40037-16033) in CCT-AT format indicates that bands 5 and 7 on the cold focal plane (Engel, 1980) are registered to 0.04 pixels in scan and

0.05 pixels across scan directions (Figure 3-3). Band 6 was not investigated at this time because it senses emitted rather than reflected light.

Band-to-band registration error of bands 5 and 7 was reported to be less than 0.1 pixel (Bryant et al., 1983a; 1983b).

3.2.3 Prime-Cold Comparisons

Most studies indicate that the reflected-light bands on the two focal planes are only slightly misregistered. The authors' center-of-gravity (Section 3.2.1) comparison between the two focal planes using a part of the Memphis scene (ID = 40037-16033) in CCT-AT format indicates that the error in registration of the reflected-light bands to each other is 0.2 pixels in the scan direction and 0.3 pixels across scan (Figure 3-3). Card et al. (1983), using a moving-block correlation method on the Arkansas scene (ID = 40037-16031), reported errors of 0.25 and 0.50 pixels along and across scan. Using the phase correlation image alignment method on the 2 November 1982 Washington D.C. scene (ID = 40109-15140), Bryant et al. (1983a; 1983b) found between 0.1 and 0.35 pixels error in registration.

Other authors, using different images and techniques, have reported larger registration errors. Fusco and Mehl (1983) reported a displacement of 0.5 pixels between focal planes for the Arkansas scene (ID = 40037-16031), as measured by correlation profile maxima. Bender et al. (1983) found a displacement of 1-2 pixels by interactive video display analysis of the Washington D.C. scene (ID = 40109-15140). Barker (1983) reported an apparent misregistration of about 0.75 pixels along scan and 0.2 pixels across scan. Using an analysis of linear features, Gurney & Eng (1983) reported error values of 0.75 pixels and 0.5 pixels along and across scans respectively.

3.3 Striping

Digital image processing for image segments that are very uniform shows the presence of light and dark stripes (Metzler & Malila, 1983). Some images have forward and reverse scans that are consistantly different by up to 4 DNs (Barker, 1983; Metzler & Malila, 1983). Other images show only minor differences between forward and reverse scans; Kiefer et al. (1983) reported a difference of about 0.1 DN in the mean for a CCT-AT image segment from the Washington D.C. scene (ID = 40109-15140), and Bender et al. (1983) reported DN differences with a range of 0.3-0.9 for a different part of the same scene.

Another type of striping is found within each scan. Some image lines have DNs that are consistantly higher or lower than those of neighboring lines for the same scan; Kiefer, Abrams, et al. (1983) found a typical 0.8 DN difference in the mean among the 16 channels in each band.

In photoproducts, the range in DN values results in line-parallel stripes by line and by scan, seen in water bodies, ice and snow fields, and other large uniform areas. Striping is present in 3-band color composite images, 1-band pseudocolor images, and black and white images.

The sensor pecularities that produce the striping are also present in data from heterogenous areas, but in these cases, the image signal variability overpowers the striping noise.

Striping is evident in B, A, and P format images. Because of the difficulties of making sensors exactly alike, it is not suprising that striping is found in B format images. Striping in A format images indicates that sensor calibration is not yet able to remove all of the differences in sensitivity of neighboring detectors. Striping in P format images indicates that cubic convolution resampling does not remove the effect.

Photointerpretation of the image data is only slightly hampered by the striping, but striping poses major problems for digital image processing. Image enhancement procedures will enhance the striping. Image classification mapping procedures will produce incorrect classifications; most classification procedures work one pixel at a time and are unable to compensate for the radiometric changes that produce light or dark stripes.

3.4 CCT-AT Radiometric Abnormalities

One consequence of applying radiometric corrections to byte data is the phenomenon of empty bins in frequency histograms (Bartolucci et al., 1983; Bender et al., 1983). A histogram of a large area in a TM scene (Figure 3-4) in A format has occasional DN values in the middle of a gradational sequence with no frequency counts. This is especially true if the histogram is otained for a single channel of data.

This is an effect of integer arithmetic. Calibration corrections are not integer numbers, but numbers with decimal fractions. Image DN numbers are integers, ranging from zero to to 255. When an integer is multiplied by a decimal value, and the result is stored as an integer value, there will be certain DN values in the resulting calibrated image that can not be generated. A histogram of the calibrated data will have a zero tally for these particular DNs.

The cubic convolution resampling procedure used to produce the final product image produces new DN values (Section 2.3.2), so that empty bins do not exist in P format images (Metzler & Malila, 1983).

In a histogram for any data channel, the empty bins occur with a constant periodicity (Figure 3-5). The period of occurrence is different for each channel and each spectral band. The difference in the reoccurrence period arises from the different calibration factors applied to data from each detector of each band. The periodicity results from the linear calibration correction procedures used.

The periodicity in the data for a given channel can be used to back-calculate one of the calibration factors used for that channel. For example, data channel 1 of band 7 for Memphis (scene ID = 40037-16033) has a period of 33 for the presence of empty bins. This means that a range of 32 DNs in the uncalibrated image is placed into a range of 33 DNs in the calibrated image. Thus

$$33/32 = 1.03125$$

is calculated to be the relative calibration gain factor, for original digital counts to calibrated digital counts. Neither the calibration offset factor nor the original radiance values can be determined in this manner.

3.5 CCT-PT Radiometric Abnormalities

An artifact is created by applying cubic convolution resampling methods to digital TM data. At each end of a scan of 16 lines, the CCT-PT image has fill pixels with zero DNs (Section 2.3.3). The resampling procedure operates in such a manner that the near-edge combination of zero DNs and real-data DNs produces intermediate DNs along a 3-pixel border zone (Baker & Gilson, 1982). These "fuzzy frame edges" (Kiefer et al., 1983) result in erroneous histograms and misclassified pixels when the image is processed for applications analyses.

3.6 Pseudocolor Pixel Prints

The authors have devised a new tool for the radiometric evaluation of TM images that takes advantage of color graphics and human response to changes in color. The pseudocolor pixel print (PsCPP) product is produced by applying a custom color look up table to an image. Standard pseudocolor (Ps) look up tables span the range of 0-255 in a gradient that allows gross structure to be easily detected but that masks fine structure. The PsCPP look up table was designed to show differences in DN values of one count as color differences, over a repeating cycle of 32 colors. PsCPP uses eight cycles of colors to span the entire range of 0-255; this masks coarse structure, but the combination of Ps and PsCPP processing permits analysis of both levels of structure.

PsCPP products show dramatically the fine structure in TM single-band images (Figures 2-6 and 2-9). Banding becomes very obvious, especially that caused by dead detectors (Section 2.1.3) rather than by minor variation in detector response and calibration (Section 3.2).

SECTION 4 -- DISCUSSION

4.1 Summary

Thematic mapper (TM) digital data has characteristics of tape files, image format and image radiometry that are important to the applications scientist. First of all, the data resides in different tape files at initial (Figure 2-1), intermediate (Figure 2-10), and final (Figure 2-28) stages of SCROUNGE processing at LAS. Within each image data file, the image lines are blocked by a factor of either 5 for a CCT-BT or 4 for a CCT-AT and CCT-PT (Sections 2.1.1, 2.2.1, and 2.3.1); access to a mainframe or large minicomputer is needed because of the large block sizes involved (i.e., up to 32,000 bytes). On each set of tapes, the image data files are in correct spectral sequence, but not in correct number sequence; band 7 is located before band 6 because band 7 was added to the sensor package late in the program, and is thus the 7th set of sensors (Covault, 1982a). Within each CCT format, the image file has a different format; support data are provided in the CCT-BT format (Section 2.1, Figure 2-2) and internal header records are provided in the CCT-AT and CCT-PT formats (Sections 2.2 and 2.3, Figure 2-12). Channels with defective data have been repaired in a manner that substitutes a minor image defect for a major one (Section 2.1.3). The cubic convolution resampling used to produce the CCT-PT images masks but does not eliminate the effects of duplicating lines. TM calibration on the intermediate CCT-AT product and the final CCT-PT product does not perfectly compensate for all problems, with the result that currently-available TM images show striping both by line and by scan (Section 2.2.5). Nominal geometric corrections which provide proper geodetic relationships between different parts of the image are available only for the final product image, the CCT-PT (Sections 2.3.2 and 2.3.3). Special user processing of the intermediate TM image formats can yield an image with approximate geometric alignment without resampling (Section 2.1.2); this special product, a CCT-B'' or a CCT-A'' image, is useful for radiometric studies, but does not otherwise take the place of the CCT-PT image.

4.2 Research Areas

During their investigation of TM image characteristics, the authors have noted many image or sensor characteristics that need to be determined and quantified. For this Early Results Symposium, not all could be done; many interesting characteristics of TM images remain to be explored.

4.2.1 Overshoot & Undershoot

The absence, or the presence and characterization, of undershoot and overshoot need to be determined for TM data. Kieffer et al. (1983) reported erratic overshoot and undershoot for a portion of the Washington D.C. scene (ID = 40109-15140). Since both cases represent the response lag of the sensors in crossing a sharp boundary in reflectivity, scenes featuring land-water or snow/ice-water boundaries need to be examined. Overshoot would exist if the scan, in passing from a uniform bright area to a uniform dark area, exhibits a gradational transition rather than a sharp transition. Undershoot would exist in the case of a gradational transition from a uniform dark area to a uniform bright area.

It is necessary to distinguish two cases. A gradational transition in the real world that is accurately recorded by TM sensors must be distinguished from a sharp transition in the real world that is inaccurately recorded by TM sensors as a gradational transition. For large areas, the boundary between bright and dark areas will be traversed by both forward and reverse TM scans. If the same gradational boundary is found in both scan directions, it should be a real-world event and not a sensor artifact.

Another consideration is the type of image product involved. Undershoot and overshoot on an image in B or A formats could be a characteristic of the sensor. The same effect on an image in P format could be a characteristic of the cubic convolution resampling procedure; this would be independent of forward and reverse scans, but should involve a narrow boundary zone.

4.2.2 Bright-Spot Recovery

Closely linked to the problem of overshoot and undershoot is the problem of bright-spot recovery. In the latter case, the item of concern is how quickly do TM detectors return to low reflectance conditions after sensing an individual pixel of high reflectivity.

The evaluation done to date using specular reflectance pixels (Section 3.1) evaluated by printouts of DNs for small areas within an image indicates that the recovery from bright spots is sufficiently rapid. However, statistical studies using large numbers of specular reflectance pixels are needed to determine how fast the TM detectors recover.

4.2.3 Light Leaks

The presence of internal reflections affecting the primary focal plane sensors was reported (Markham & Barker, 1984). Preliminary analysis indicates that the sensor receives light comming from two directions; from the front (towards the telescope) and from the back. Light that has passed through filters and sensors for band 1 has the greatest effect on other bands. In this case, there is a 15-pixel lag between sensing a bright spot in band 1 and the effect of internally reflected light producing a 1.2% increase in DN value in band 4 (e.g., a 255 DN pixel in band 1 adds 3 DNs to what is sensed in band 4. The lag results from the different physical locations of the sensor array within the TM. There appear to be interactions among other bands, but at much lower percentages.

The internal reflection will have to be completely characterized so that the effect can be eliminated before attempting to calculate the absolute radiometric data needed for a variety of research projects (Barker, Abrams, et al., 1984a).

4.2.4 Out-of-Band Spectral Response

Another possible phenomenon to be characterized is the response of the sensors to light with a wavelength outside the band width (Markham & Barker, 1983). In other words, the filters are not completely opaque outside of spectral window. Of concern is not only the light with wavelengths just outside the 50% shoulder that defines the spectral window for the filter, but also the light sensed that is at some wavelength distant from the filter window. How much light is sensed and at what wavelength location, both in absolute terms and relative to the filter window, are the questions for which answers need to be sought.

4.2.5 Specifications

How the TM system meets specifications (Anon., 1982b) will be discussed in a later document. This research is still ongoing.

4.2.6 Odd-Even Difference

Examination of image statistics has shown that there is an odd-even difference in detectors which is not removed by calibration. This results from a difference in physical location in the sensor array between even-numbered detectors and odd-numbered detectors (Anon., 1982b) and/or different electronics. This effect needs to be quantified and characterized using multiple images, so that it can be removed by improved radiometric calibrations.

4.2.7 Within-Scan Droop

A possible problem is a change in the electronically-induced offset (Barker, Abrams, et al., 1984b; Metzler & Malila, 1983) during a scan. If the offset changes between the start and end of the individual scan, the usefulness of TM data for radiometric and digital-image classification-mapping purposes could be reduced. It should be possible to detect the effects of this condition, if it takes place, by the analysis of uniform bright and dark scenes. The effect, if present, would follow the direction of scan, and therefore could be separated from atmospheric and illumination effects. It should be possible to remove the effects of this drift during radiometric calibration.

4.2.8 Spectral Calibration

It is necessary to test the assumption of homogeneity of filters. The filters were cut out of a single piece of "uniform" filter material (Markham & Barker, 1984), so that different filter chips came from different microlocations and small, detectable nonuniformities could be present. For characterization of the spectral calibration among data channels, it is necessary to look at the microscale heterogeneity of the filter material used. In addition, by comparing relative gains in each channel over several scenes, spectral differences between the channels can be characterized (Engel et al., 1983; Markham & Barker, 1984).

4.2.9 Autocorrelation

The examination of the differences between nominal and IC calibration procedures has shown (Section 2.2.5) that changes in DNs between the two calibration procedures applied often occur in scan lines. Printouts of the difference images give ample visual evidence of autocorrelation (Figures 2-22 to 2-25). This needs to be tested statistically, and characterized so that autocorrelation effects can be removed by those that consider it necessary to do so (Basu & Odell, 1974; Irons & Labovitz, 1982).

SECTION 5 -- CONCLUSIONS

5.1 Definitely True Conclusions

Without any reservations or qualifications, we can make the following conclusions at this time about the Landsat-4 TM sensor system and its digital-data products:

- Detector 3 of band 5 does not respond. In any image processing software system, this channel of data will need to be replaced (Section 2.1.3).
- The "empty-bin" phenomenon in CCT-AT images results from integer truncations of mixed-mode arithmetic operations (Section 3.4).

5.2 Probably True Conclusions

With only minor reservations or qualifications, we can conclude:

- TM final-product digital data (CCT-PT) is very useful data with high radiometric and geometric quality (Salomonson & Koffler, 1983; Bernstein et al., 1983) that will open new avenues of Earth-related research (Williams, 1983).
- Interband registration, calculated from apparent spectral-response pixels for small, reflective objects on the ground, is within 0.5 pixel accuracy in both line and sample directions (Section 3.2), both within and between each focal plane.
- Ancillary data files, residing on the same tapes as the image files, contain useful information in character format. This data can be printed in easy-to-read forms by utility "TAPEDUMP" programs that read and print character format.

5.3 Possibly True Conclusions

With reservations and qualifications, we can make the following conclusions at this time:

- The SCROUNGE-era fixup employed for the various defective data channels (Section 2.1.3), that of replacing the defective line with a duplicate of the previous good line, is acceptable. This conclusion should be tested by a study that compares accuracy against computer processing cost for these alternate methods: 1) complete line replacement using the previous line; 2) alternate pixel replacement from previous and following lines; 3) replacement with the average of neighboring lines; and 4) calculation of missing scan lines from data in the same and neighboring lines in the different bands once band adjustments are made for differing spectral responses.

SECION 6 -- RECOMMENDATIONS

6.1 Landsat-4 Spacecraft Management

As part of the continuing improvements and changes to the operational procedures for spacecraft control, maintenance, and sensor operation, we recommend that:

- o repeated lamp turn-ons be avoided when using manual-mode internal calibration in order to extend the life of the lamp (Barker, Abrams, et al., 1984b).

6.2 Landsat-4 SCROUNGE

As part of the continuing improvements and changes to the SCROUNGE system, we recommend that:

- o Better documentation accompany the digital products. This includes not only documentation on paper but also internal documentation on magnetic tape files. More parameter values should be recorded in literal (character) fields so that a simple tape dump can provide the user with the data.

- o Better calibration be applied to remove channel and scan differences that result in striping (see also Bernstein & Lotspeich, 1983). This would involve treating forward and reverse scans separately rather than averaging pulse heights from forward and reverse scans (Barker, Abrams, et al., 1984b) and using drive-specific background average data rather than scene-wide averages to determine offset (Barker, Ball, et al., 1984).

- o Data from bad channels be handled better. For channel 4 of band 2, the "bad" data should be used, not replaced. For channel 3 of band 5, a more appropriate substitution should be used (see also Bernstein & Lotspeich, 1983).

6.3 Landsat-4 TIPS

In the development of the TM Image Processing System (TIPS), we recommend that:

- o In addition to the SCROUNGE-era resampling by cubic convolution procedures to produce the CCT-PT image

(Section 2.3.2), the optional capability be developed to produce a CCT-PT product using the nearest neighbor resampling procedure. The latter procedure has the advantage of not changing the DNs of the pixels. Pixel values that are unchanged after radiometric calibration are needed to allow radiometric characterization and evaluation of TM scenes.

- In addition to the SCROUNGE-era geodetic correction to produce a CCT-PT product, TIPS apply corrections based upon known locations of ground-control points. Research into registration requirements for accuracy (Boyd et al., 1981) has shown that an even distribution of ground-control points is more important than the total number.

6.4 Landsat-4 NOAA

We recommend that:

- Ground processing computer programs have the ability to go directly to CCT-PT geocorrected images. This would eliminate integer arithmetic problems with intermediate products, thus providing higher radiometric accuracy.

- Images be made available to the user community both on a full scene basis and on a partial scene basis. Such a partial scene basis could produce images that correspond to 1x2-degree topographic quadrangles, or to 15-minute quadrangles. Partial scene images could be made available on CCTs or on 8-inch floppy disks.

- Archival, browse, and product images be recorded on video laser disk media. Low cost, random access, multiple scene storage, and ease of distribution are the obvious advantages (Goldstein, 1982; Mobery & Laefsky, 1982; Moussy, 1983). Remote sensing has been described as a "write-once, read often" process.

6.4 Landsat-D'

In preparing the TM sensor system before the launch of Landsat-D', we recommend that:

- The dynamic range be expanded. Alternately, high-gain / normal-gain options should be added to the analog-digital converter to permit a normal scene to more nearly fill the available DN range of 0-255. TM bands 2 and 3 do not reach saturation levels, even when recording light reflected from snow.

- An opaque light-trap be placed behind the sensors to eliminate internally reflected light which is affecting the TM sensors of Landsat-4.

- An opaque light-mask be placed around filter mounts on the prime focal plane to eliminate light passing between the detector assemblies (Barker, Abrams, et al., 1984b).

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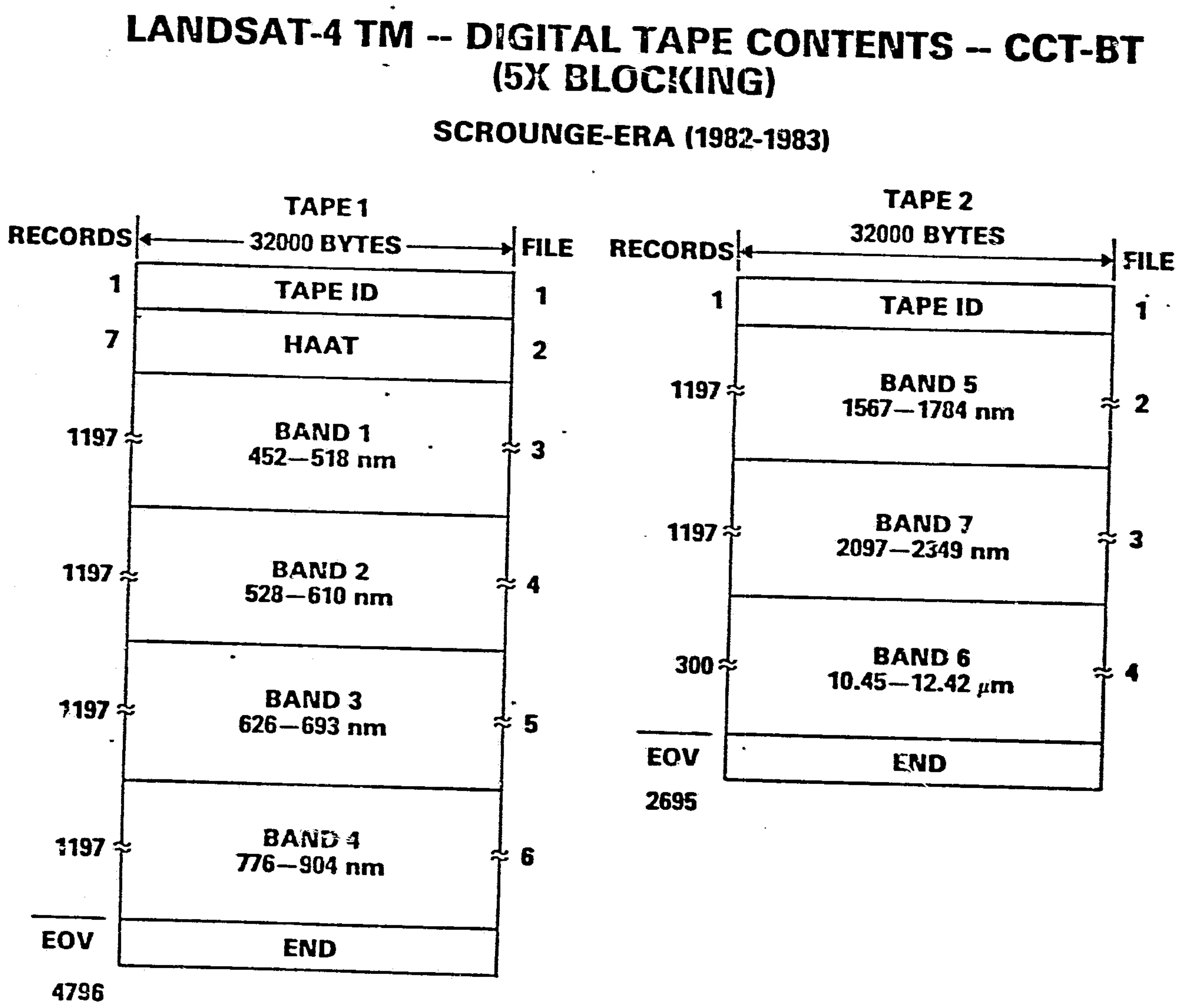

Figure 2-1. File organization of TM data and images on the two CCT-BT tapes used for data exchange between ADDS and LAS. Note that TM band 6 follows band 7 in correct spectral sequence.

LANDSAT-4 TM — CCT-BT — INITIAL PORTION OF DATA MATRIX (UNBLOCKED)

WASHINGTON DC (ID = 40109-15140) 2 NOV 1982

BYTE NUMBERS

	LINE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	CHANNEL 1 (DETECTOR) NUMBER
FORWARD SCAN 3	1	0	0	0	237	1	0	1	0	124	0	61	58	54	46	31	32	43	38	42	44	43	42	45	30	37	16
	2	0	0	0	237	1	0	1	0	116	0	58	55	51	47	37	42	46	42	44	44	44	30	55	57	58	15
	3	0	0	0	237	1	0	1	0	108	0	58	55	53	49	41	41	46	43	49	33	55	54	58	59	61	14
	4	0	0	0	237	1	0	1	0	100	0	61	53	51	45	34	41	52	57	61	54	53	57	62	59	57	13
	5	0	0	0	237	1	0	1	0	92	0	58	58	46	34	29	42	58	58	59	56	57	39	53	54	57	12
	6	0	0	0	237	1	0	1	0	84	0	53	48	43	27	33	48	61	59	60	54	53	53	50	55	58	11
	7	0	0	0	237	1	0	1	0	76	0	55	50	43	34	44	54	62	59	56	53	37	68	65	49	42	10
	8	0	0	0	237	1	0	1	0	68	0	47	48	43	40	45	50	54	54	59	52	59	51	40	33	32	9
	9	0	0	0	237	1	0	1	0	60	0	49	47	47	48	43	47	60	62	53	43	37	32	32	32	33	8
	10	0	0	0	237	1	0	1	0	52	0	50	55	44	41	38	44	53	40	34	33	32	33	32	32	34	7
	11	0	0	0	237	1	0	1	0	44	0	44	45	43	36	35	34	34	33	32	33	34	36	36	36	57	6
	12	0	0	0	237	1	0	1	0	36	0	35	34	37	36	32	32	32	32	33	39	32	53	37	34	59	5
	13	0	0	0	237	1	0	1	0	28	0	57	34	38	42	37	37	35	34	32	41	51	52	35	36	61	4
	14	0	0	0	237	1	0	1	0	20	0	52	46	55	53	38	34	33	32	31	43	55	49	33	41	72	3
	15	0	0	0	237	1	0	1	0	12	0	56	61	64	58	34	30	30	30	30	45	35	47	31	41	72	2
	16	0	0	0	237	1	0	1	0	4	0	58	62	61	53	34	33	33	31	32	44	51	14	37	45	62	1
REVERSE SCAN 2	17	0	0	0	237	1	0	2	0	252	0	34	41	46	37	36	45	50	50	50	38	57	50	52	54	51	16
	18	0	0	0	237	1	0	2	0	244	0	39	39	45	37	47	43	43	50	49	54	54	52	52	51	50	15
	19	0	0	0	237	1	0	2	0	236	0	42	43	45	42	57	46	40	49	52	53	53	50	55	53	51	14
	20	0	0	0	237	1	0	2	0	228	0	38	45	45	41	50	57	38	36	49	50	50	53	57	57	55	13
	21	0	0	0	237	1	0	2	0	220	0	45	49	42	42	45	55	46	38	46	49	58	56	55	58	53	12
	22	0	0	0	237	1	0	2	0	212	0	50	48	40	43	42	51	54	43	55	50	53	54	53	56	50	11
	23	0	0	0	237	1	0	2	0	204	0	50	45	42	45	45	50	58	49	51	45	53	57	59	58	52	10
	24	0	0	0	237	1	0	2	0	196	0	50	41	43	44	45	46	55	47	49	36	42	46	41	31	51	9
	25	0	0	0	237	1	0	2	0	188	0	48	38	44	43	45	45	58	47	44	48	36	37	40	43	39	8
	26	0	0	0	237	1	0	2	0	180	0	44	41	45	45	45	45	53	51	40	48	42	37	40	39	42	7
	27	0	0	0	237	1	0	2	0	172	0	42	43	45	46	45	44	50	48	38	46	44	42	37	37	43	6
	28	0	0	0	237	1	0	2	0	164	0	42	47	44	44	42	45	41	40	38	43	48	49	46	36	41	5
	29	0	0	0	237	1	0	2	0	156	0	45	53	47	45	43	39	39	35	38	45	46	47	31	45	41	4
	30	0	0	0	237	1	0	2	0	148	0	50	54	54	46	41	34	37	42	37	36	41	40	39	46	45	3
	31	0	0	0	237	1	0	2	0	140	0	53	53	52	49	41	34	32	33	27	37	42	46	47	48	58	2
	32	0	0	0	237	1	0	2	0	132	0	55	54	52	50	48	44	38	39	33	42	53	57	54	46	58	1
FORWARD SCAN 1	33	0	0	0	237	1	0	3	0	124	0	49	49	57	58	58	59	54	44	50	55	47	43	51	55	58	16
	34	0	0	0	237	1	0	3	0	116	0	47	41	43	55	61	58	54	37	58	58	53	52	62	58	55	15
	35	0	0	0	237	1	0	3	0	108	0	53	50	49	56	61	55	56	54	53	56	59	61	53	50	50	14
	36	0	0	0	237	1	0	3	0	100	0	54	58	65	62	61	58	57	54	57	62	65	62	56	50	49	13
	37	0	0	0	237	1	0	3	0	92	0	57	62	67	59	57	57	58	60	60	66	64	57	52	31	52	12
	38	0	0	0	237	1	0	3	0	84	0	59	63	63	56	59	61	63	62	62	61	59	52	45	43	50	11
	39	0	0	0	237	1	0	3	0	76	0	60	61	62	57	62	62	60	57	57	58	61	59	50	37	60	10
	40	0	0	0	237	1	0	3	0	68	0	56	57	49	43	53	59	60	60	62	62	58	53	53	66	78	9
	41	0	0	0	237	1	0	3	0	60	0	66	69	68	51	62	60	38	58	38	51	53	56	63	74	86	8
	42	0	0	0	237	1	0	3	0	52	0	73	70	64	54	57	59	55	55	52	57	64	66	68	68	80	7
	43	0	0	0	237	1	0	3	0	44	0	55	53	43	43	50	53	57	57	43	57	67	66	68	70	81	6
	44	0	0	0	237	1	0	3	0	36	0	48	47	31	29	44	58	63	68	58	52	59	62	66	69	65	5
	45	0	0	0	237	1	0	3	0	28	0	61	58	35	35	43	60	69	69	60	46	55	66	66	66	64	4
	46	0	0	0	237	1	0	3	0	20	0	61	52	34	36	44	56	68	60	62	49	57	57	57	53	54	3
	47	0	0	0	237	1	0	3	0	12	0	50	47	42	46	52	51	55	57	57	39	61	62	62	65	66	2
		SUPPORT DATA										IMAGE DATA (30m IFOV)															

Figure 2-2. An example of data and organization of TM images in CCT-BT format, as unblocked when written onto a copy tape or a disk file. The example shows the initial portion of each image line, which is now also a data record. Note the scan number in Column 7. Compare with Figure 2-4. Note that the grey wedge in column 9 is complete for a reverse scan (even numbered line) followed by a forward scan (odd numbered line).

LANDSAT-4 TM — CCT-BT (ORIGINAL 5X BLOCKING)

WASHINGTON DC (ID = 40103-15140) 2 NOV 1982

BYTE NUMBERS

SAMPLE LINE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	0	0	237	1	0	1	0	124	0	61	58	54	46	31	32	43	38	42	44	45	42	45	50	57
2	0	0	0	237	1	0	1	0	84	0	53	48	43	27	33	48	61	59	60	54	53	53	50	55	58
3	0	0	0	237	1	0	1	0	44	0	44	45	43	36	35	34	34	35	32	33	34	36	36	36	57
4	0	0	0	237	1	0	1	0	4	0	58	62	61	53	34	33	33	31	32	44	51	44	37	45	62
5	0	0	0	237	1	0	2	0	220	0	45	49	42	42	45	55	46	38	46	49	50	56	55	58	53
6	0	0	0	237	1	0	2	0	180	0	44	41	45	45	45	45	53	51	40	48	42	37	40	39	42
7	0	0	0	237	1	0	2	0	140	0	53	53	52	49	41	34	32	33	27	37	42	46	47	48	58
8	0	0	0	237	1	0	3	0	100	0	54	58	65	62	61	58	57	54	57	62	65	62	56	50	49
9	0	0	0	237	1	0	3	0	60	0	66	69	68	51	62	60	58	58	58	51	53	56	65	74	86
10	0	0	0	237	1	0	3	0	20	0	61	52	34	36	44	56	68	68	62	49	57	57	57	53	54
11	0	0	0	237	1	0	4	0	236	0	54	56	56	52	56	58	57	55	59	60	61	45	49	44	40
12	0	0	0	237	1	0	4	0	196	0	61	54	52	57	57	58	59	61	64	54	49	55	50	55	60
13	0	0	0	237	1	0	4	0	156	0	52	57	59	56	55	59	61	59	48	46	45	48	51	58	62
14	0	0	0	237	1	0	5	0	116	0	53	50	47	46	47	49	48	45	45	46	47	49	49	50	54
15	0	0	0	237	1	0	5	0	76	0	52	63	75	83	80	70	61	55	48	38	26	23	27	33	38
16	0	0	0	237	1	0	5	0	36	0	61	55	45	39	30	33	36	36	39	43	52	59	52	40	37
17	0	0	0	237	1	0	6	0	252	0	68	73	69	57	51	53	52	52	55	60	55	53	57	51	57
18	0	0	0	237	1	0	6	0	212	0	56	54	50	55	54	62	68	69	70	70	57	46	49	49	52
19	0	0	0	237	1	0	6	0	172	0	54	65	69	69	76	73	77	75	53	32	39	33	45	51	46
20	0	0	0	237	1	0	6	0	132	0	72	69	74	74	72	68	57	49	61	69	65	61	62	62	63

SUPPORT DATA (bytes 1–10) | IMAGE DATA (30m IFOV) (bytes 11–25)

Figure 2-3. An example of data and organization of TM images in CCT-BT format, as blocked on the tape. The example shows the initial portion of each tape record. Because of the blocking factor, five (5) image lines make up one record on the tape. Note the scan number in column 7. Compare with Figure 2-3.

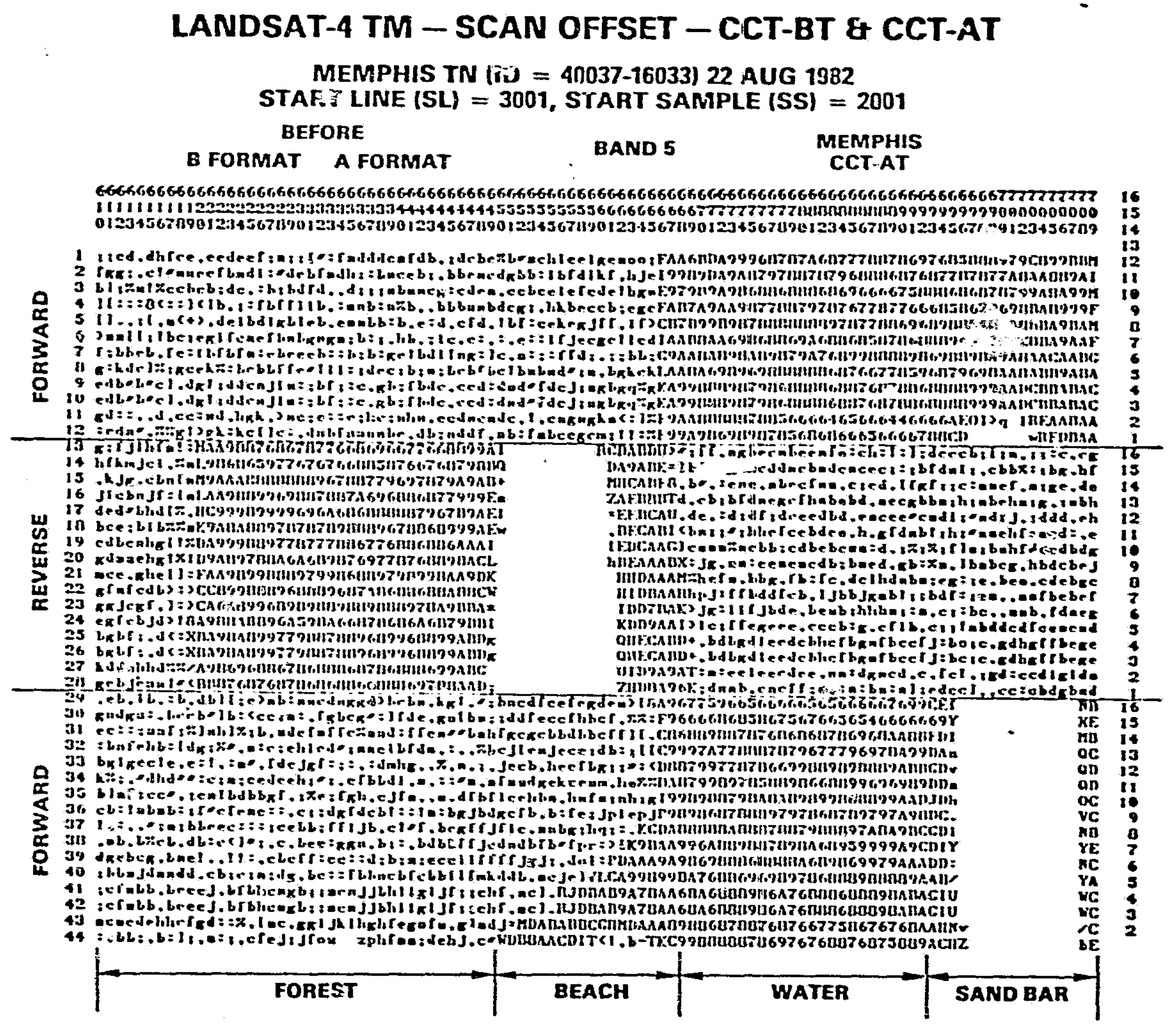

Figure 2-4. An example of a Band 5 image in CCT-AT format. The "before" image demonstrates the existing scan shift between forward and reverse scans (See Figure 2-5).

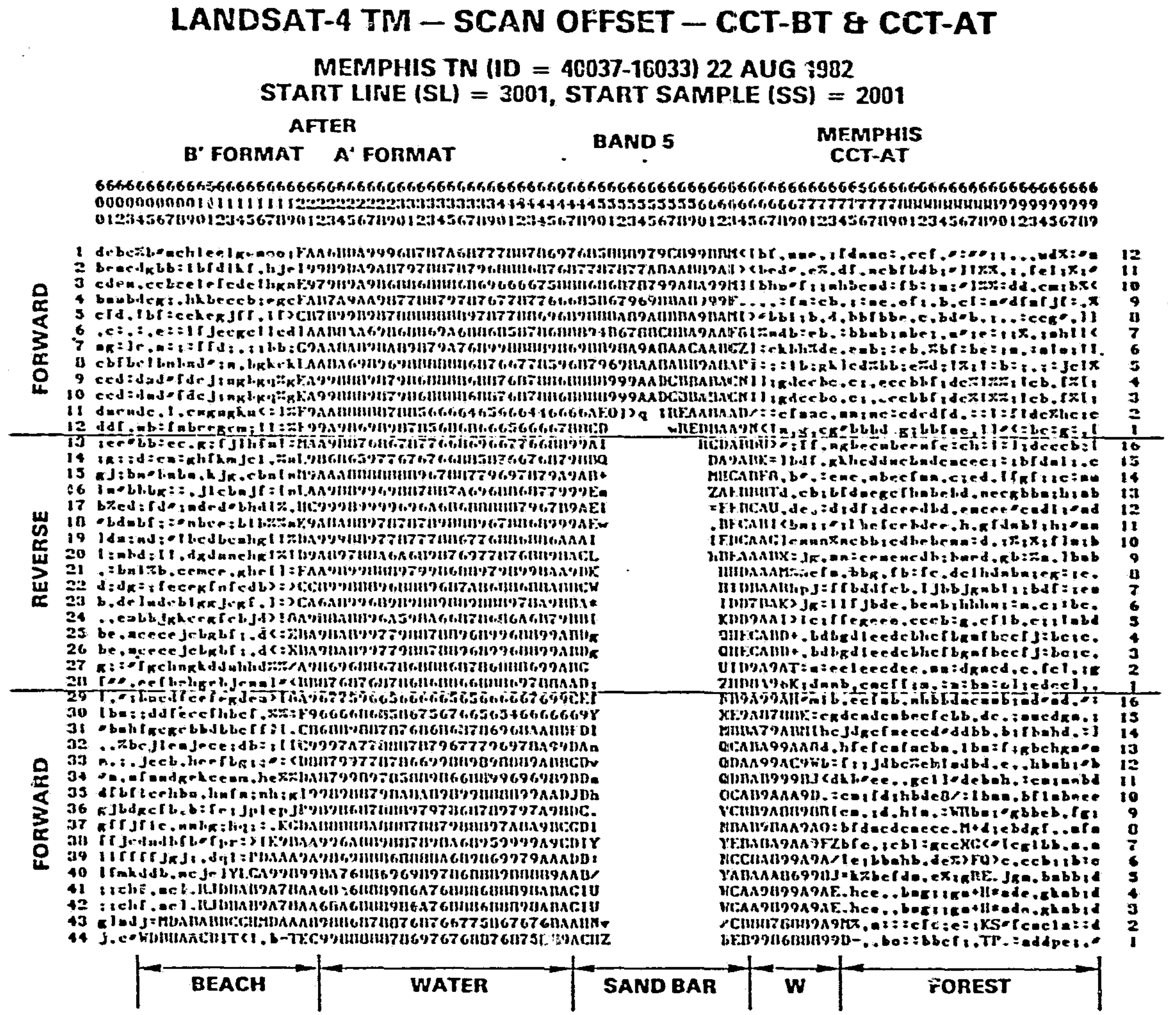

Figure 2-5. An example of a Band 5 image in A' format. The "after" image demonstrates the results of digital image processing to remove alignment offset and to produce an A' or B' format image. The area demonstrated is a 3.0 km wide by 1.32 km high portion of the Mississippi River near Memphis TN; DNs are represented by an alphanumeric code allowing evaluation of both gross and fine structure. Compare with Figure 2-4.

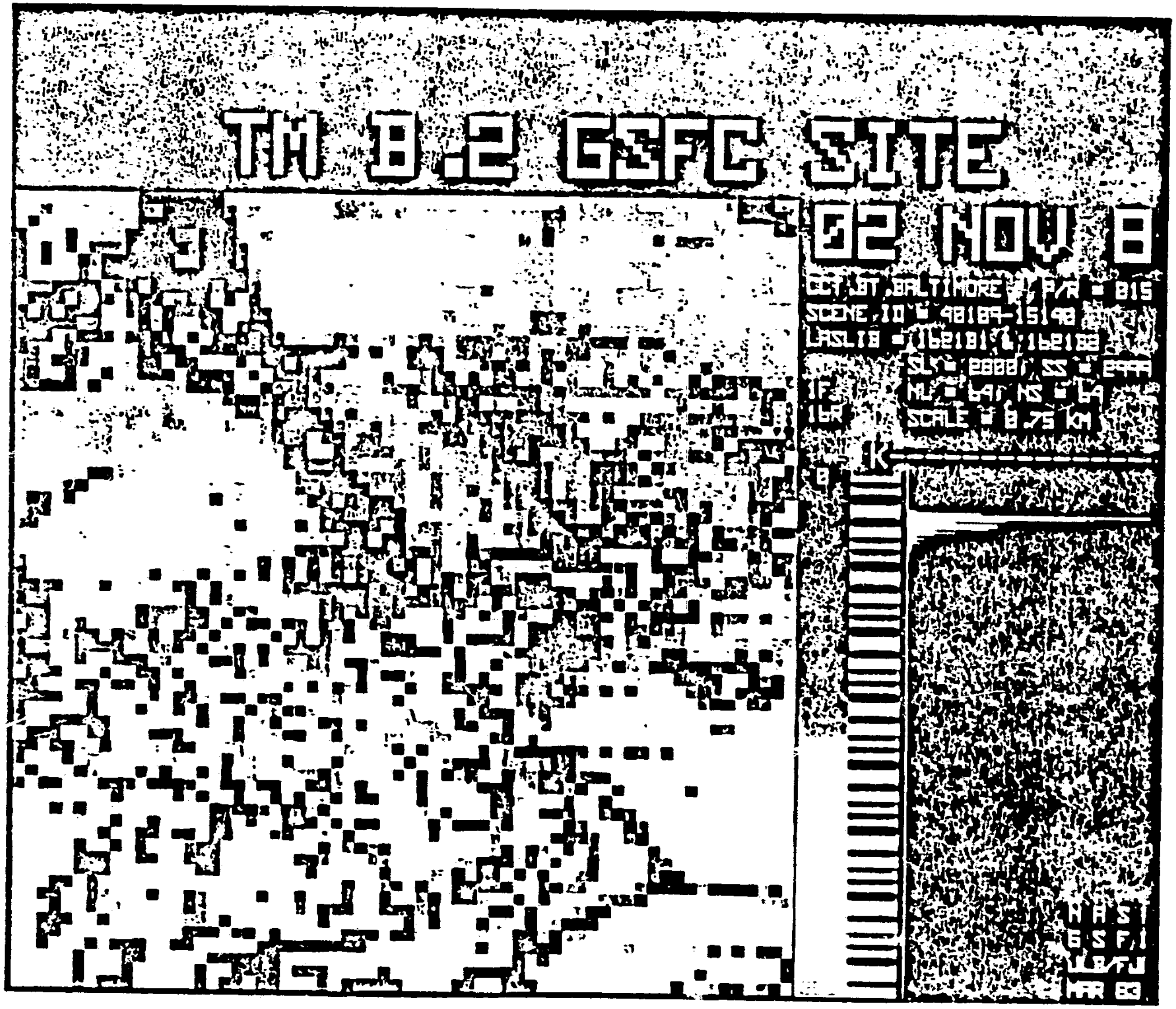

Figure 2-6. An example of a Pseudocolor Pixel Print image for TM data in B' format. The sensor scans have been adjusted right and left to produce a nominally geometrically correct alignment. The area demonstrated is an image segment centered on NASA-GSFC. The ragged histogram is due to unequal bin size in the Analog-Digital (A-D) Converter in the sensor system.

LANDSAT-4 TM — CCT-AT — BAND 5 (UNBLOCKED)

WASHINGTON DC (ID = 40109-15140) 2 NOV 1982
BYTE NUMBERS

	SAMPLE / LINE	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	CHANNEL (DETECTOR) NUMBER
FORWARD SCAN 1	1	100	110	119	115	110	92	78	86	78	53	63	82	94	90	77	50	56	58	58	57	71	68	65	54	54	16
	2	92	104	108	110	102	83	77	89	75	56	56	73	93	89	73	38	48	56	62	62	64	62	63	56	54	15
	3	97	109	111	109	100	79	79	82	81	65	58	68	92	83	61	46	42	47	61	61	66	60	61	57	69	14
	4	101	112	104	93	86	77	76	77	69	71	67	66	78	73	61	56	51	49	53	50	51	59	69	76	78	13
	5	74	78	76	72	70	76	86	84	82	76	73	70	76	78	68	65	57	57	54	61	65	72	73	90	102	12
	6	83	81	77	74	74	84	98	98	93	90	78	73	78	81	77	66	69	66	61	70	78	78	83	91	106	11
	7	77	77	73	72	78	86	92	90	87	87	77	68	79	82	77	53	64	70	61	69	74	81	73	79	97	10
	8	77	75	76	86	85	84	[illegible]	92	90	85	82	71	73	79	73	54	69	71	60	57	68	79	79	74	76	9
	9	84	86	93	94	95	95	93	91	91	91	84	74	73	78	70	54	61	66	66	55	58	73	76	82	82	8
	10	97	94	98	94	98	92	93	93	90	92	83	68	70	80	71	58	70	77	67	55	61	74	80	89	91	7
	11	82	83	77	73	74	75	72	71	68	68	67	66	62	74	74	60	70	72	62	57	59	69	83	91	87	6
	12	67	65	61	66	67	69	66	66	62	62	58	65	58	63	74	65	72	66	57	55	50	55	81	91	84	5
	13	67	66	66	74	70	67	67	68	66	64	58	57	61	66	62	62	72	66	64	54	46	46	77	88	84	4
	14	2	3	3	2	4	2	2	3	3	3	3	3	2	3	4	2	3	3	3	3	2	3	3	2	3	3 ←
	15	70	71	72	72	69	64	65	66	65	64	61	65	48	66	68	60	65	64	58	52	44	43	68	85	85	2
	16	76	70	72	74	70	68	67	69	65	63	67	73	66	63	70	68	70	60	57	47	50	38	42	66	70	1
REVERSE SCAN 2	17	94	93	82	70	68	61	66	62	53	56	54	63	63	68	69	73	74	75	76	78	72	68	69	73	84	16
	18	94	90	87	79	80	78	73	80	65	59	58	68	72	74	77	76	79	76	76	73	66	65	67	68	82	15
	19	91	90	90	82	77	74	79	78	64	57	57	69	75	80	83	85	88	83	76	74	70	70	70	72	87	14
	20	90	92	90	85	79	74	77	79	65	58	57	68	83	83	85	84	86	88	85	85	70	76	78	90	100	13
	21	94	93	91	87	81	77	77	79	66	61	64	70	85	84	82	82	77	77	74	82	90	94	102	105	110	12
	22	93	92	90	89	84	78	77	81	73	63	64	67	69	68	68	66	68	67	69	71	92	104	109	109	109	11
	23	85	84	86	85	84	76	73	81	74	63	63	65	65	64	64	62	64	64	65	66	84	101	105	101	104	10
	24	82	82	83	85	36	80	76	82	80	65	68	66	68	63	61	65	62	66	66	65	72	99	106	105	100	9
	25	67	76	83	84	88	82	78	79	79	66	67	66	68	65	66	66	69	72	70	73	76	93	99	94	90	8
	26	53	67	73	75	74	73	73	69	65	66	62	60	76	78	77	76	78	83	82	83	82	85	85	88	83	7
	27	57	66	62	59	61	59	60	61	59	57	53	59	74	74	74	70	78	75	76	77	76	78	82	85	89	6
	28	59	65	59	56	57	58	58	58	59	57	58	58	66	72	72	70	72	71	72	72	72	67	73	81	82	5
	29	61	68	76	75	73	77	75	76	80	80	79	76	74	62	57	58	59	60	61	59	61	59	62	76	73	4
	30	2	4	3	3	3	2	3	2	3	3	3	3	3	3	3	3	3	3	2	3	2	4	3	3	3	3 ←
	31	56	74	77	74	77	77	77	76	75	76	72	72	74	66	60	61	60	53	51	46	42	34	20	32	28	2
	32	55	73	80	74	68	61	54	57	73	74	66	64	58	53	51	50	54	49	34	20	24	27	26	43	37	1
FORWARD SCAN 3	33	70	69	78	95	100	104	101	98	100	100	100	98	87	70	65	70	72	65	51	48	50	41	37	59	75	16
	34	79	81	83	99	102	104	101	98	96	94	92	90	82	77	62	65	68	56	39	46	51	47	40	38	57	15
	35	89	88	89	96	95	96	95	92	90	93	93	89	85	72	59	67	68	59	47	43	44	41	52	56	55	14
	36	85	87	91	96	94	96	96	97	91	93	91	89	82	78	62	67	66	66	69	59	44	45	59	53	61	13
	37	69	75	76	78	77	82	90	96	92	90	82	78	82	88	68	72	71	75	73	62	69	70	68	68	68	12
	38	69	70	71	69	73	76	78	86	81	79	77	81	80	74	74	83	82	85	74	58	70	69	67	67	70	11
	39	68	74	80	78	81	74	75	85	84	82	71	81	75	66	68	70	70	73	59	52	65	67	70	70	73	10
	40	78	73	66	59	60	63	67	73	77	78	71	82	85	84	65	72	72	72	64	57	69	77	77	82	73	9
	41	87	85	79	77	68	63	61	58	54	66	60	61	62	92	67	67	72	67	60	50	59	57	52	70	74	8
	42	82	81	82	83	79	83	81	79	76	78	100	62	62	76	70	60	70	66	51	51	68	68	62	79	70	7
	43	74	76	76	78	75	77	75	78	78	82	89	78	66	73	68	61	68	62	47	49	64	71	74	78	67	6
	44	72	70	69	66	66	68	71	71	73	77	76	70	60	71	69	60	62	62	44	52	53	58	66	54	50	5
	45	85	87	91	87	82	72	56	60	64	68	66	68	66	71	67	64	59	64	61	46	46	62	53	56	58	4
	46	3	3	3	3	4	3	3	3	2	3	3	4	4	3	3	3	3	3	3	2	3	4	4	2	3	3 ←
	47	89	89	92	86	87	81	76	76	73	72	73	73	74	73	73	64	62	53	38	36	39	42	58	68	74	2

Figure 2-7. An example of data for TM band 5, showing the defective channel 3. The scan organization is the same shown in Figure 2-3.

BAND 6
LANDSAT-4 TM — CCT-BT — INITIAL PORTION OF DATA MATRIX (UNBLOCKED)

WASHINGTON DC (ID = 40109-15140) 2 NOV 1982
BYTE NUMBERS

SAMPLE / LINE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
1	0	0	0	237	1	0	1	0	30	0	117	117	117	117	116	116	116	116	117	117	117	117	118	118	118	4
2	0	0	0	237	1	0	1	0	22	0	114	114	114	114	114	114	114	114	116	116	116	116	116	116	116	3
3	0	0	0	237	1	0	1	0	14	0	117	117	117	117	119	119	119	119	118	118	118	118	117	117	117	2
4	0	0	0	237	1	0	1	0	6	0	115	115	115	115	116	115	116	116	115	115	115	115	114	114	114	1
5	0	0	0	237	1	0	2	0	158	0	118	118	118	118	117	117	117	117	117	117	117	117	118	118	118	4
6	0	0	0	237	1	0	2	0	150	0	116	116	116	116	114	114	114	114	114	114	114	114	115	115	115	3
7	0	0	0	237	1	0	2	0	142	0	119	119	119	119	118	118	118	118	119	119	119	119	119	119	119	2
8	0	0	0	237	1	0	2	0	134	0	116	116	116	116	115	115	115	115	115	115	115	115	116	116	116	1
9	0	0	0	237	1	0	3	0	30	0	118	118	118	118	118	118	118	118	118	118	118	118	118	118	118	4
10	0	0	0	237	1	0	3	0	22	0	115	115	115	115	114	114	114	114	115	115	115	115	114	114	114	3
11	0	0	0	237	1	0	3	0	14	0	118	118	118	118	117	117	117	117	117	117	117	117	118	118	118	2
12	0	0	0	237	1	0	3	0	6	0	114	114	114	114	114	114	114	114	116	116	116	116	116	116	116	1

SUPPORT DATA (bytes 1–10) | IMAGE DATA (120m IFOV ÷ 4) (bytes 11–25)

Figure 2-8. An example of data and organization for TM band 6, in unblocked CCT-BT format. Note that raw 120m IFOV pixels from the sensor were repeated four (4) times along a line by the ADDS preprocessing to produce the B format image. Compare with Figures 2-3 and 2-16.

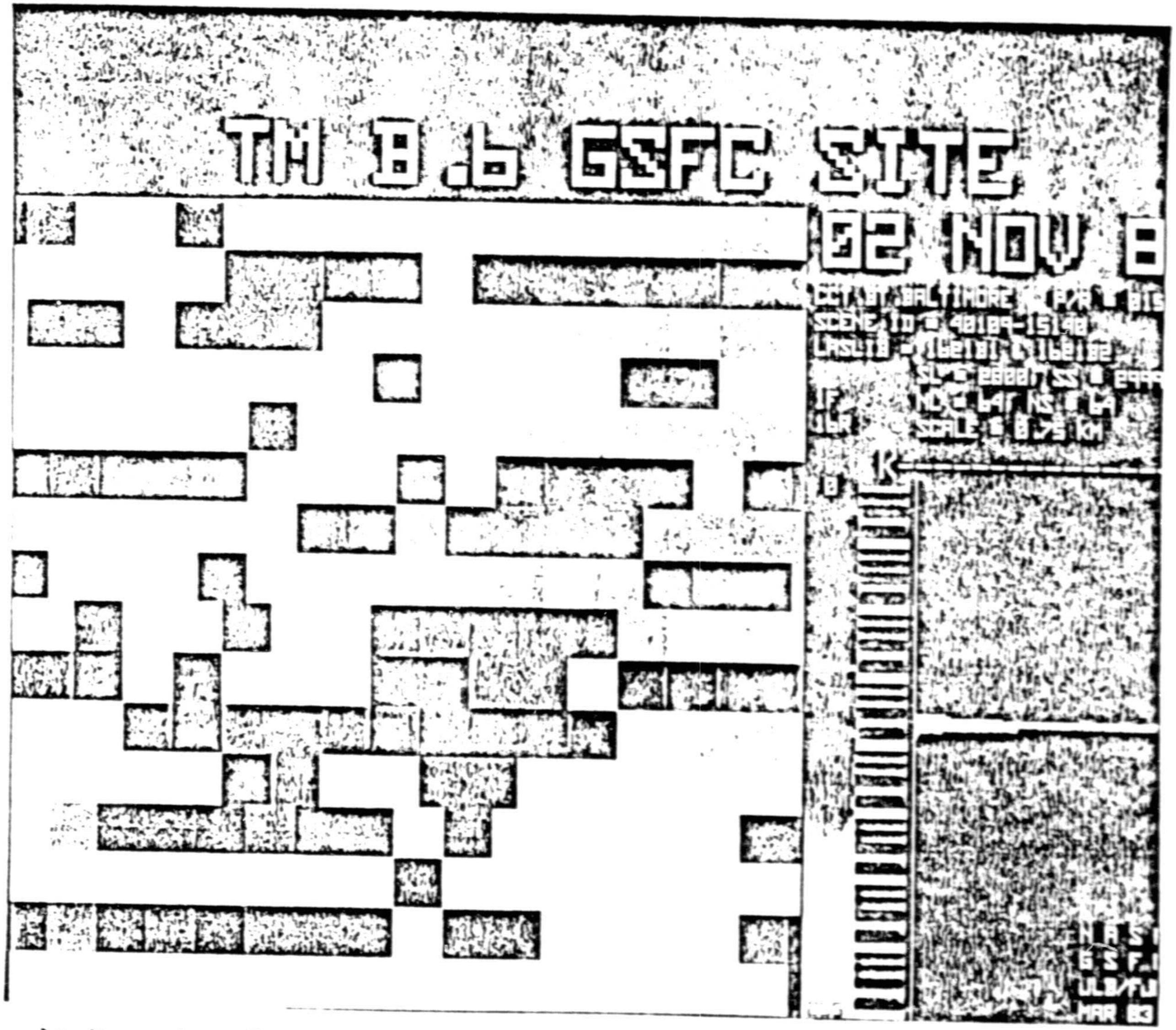

Figure 2-9. An Example of a Pseudocolor Pixel Print image for TM Band 6 in B' format. Compare with Figure 2-6; notice the 120 m IFOV pixel size. In the histogram, the unequal bin size resulting in a minimum between two modes is a result of the A-D converter in the sensor system.

LANDSAT-4 TM — DIGITAL TAPE CONTENTS — CCT-AT (4X BLOCKING)

SCROUNGE-ERA (1982-1983)

RECORDS	TAPE 1	FILE
17	LGSOWG DIRECTORY ←360→	1
3	HAAT LABEL ←512→	2
33	HAAT DIRECTORY ←6656→	3
4	BAND 1 LABEL ←512→	4
1497	BAND 1 DATA 452—518 nm (6656 x 4) = ←26624→	5
4	BAND 2 LABEL ←512→	6
1497	BAND 2 DATA 528—610 nm ←26624→	7
4	BAND 3 LABEL ←512→	8
1497	BAND 3 DATA 626—693 nm ←26624→	9
EOV	END	
1562		

RECORDS	TAPE 2	FILE
17	LGSOWG DIRECTORY	1
4	BAND 4 LABEL ←512→	2
1497	BAND 4 LABEL 776—904 nm ←26624→	3
4	BAND 5 LABEL ←512→	4
1497	BAND 5 DATA 1567—1784 nm ←26624→	5
4	BAND 7 LABEL ←512→	6
1497	BAND 7 DATA 2097—2349 nm ←26624→	7
4	BAND 6 LABEL ←512→	8
1497	BAND 6 DATA 10.45—12.42 μm ←26624→	9
1	LCSWOG NULL	
	END	
6022		

Figure 2-10. File organization of TM data and images on the two CCT-AT tapes used by LAS for data archive.

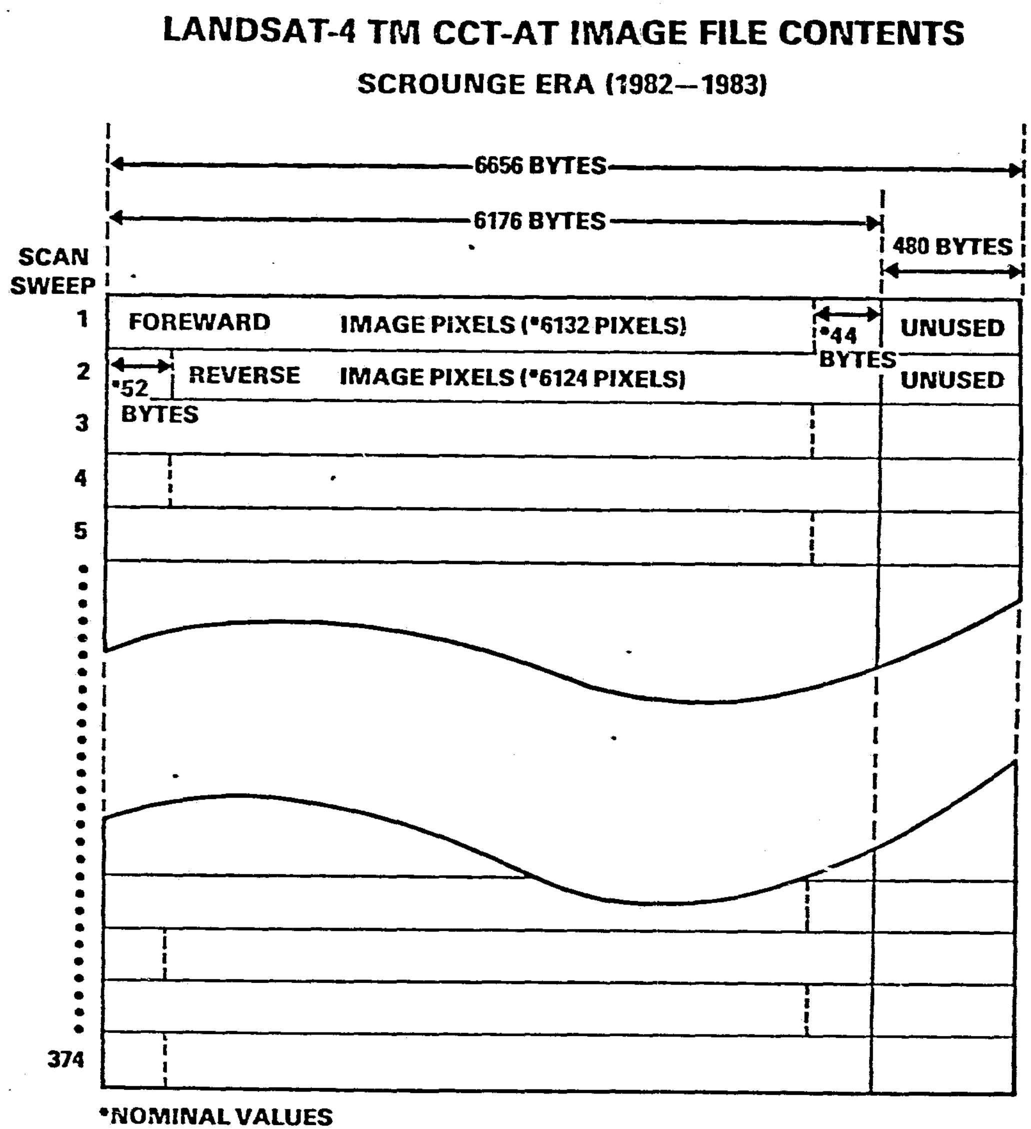

Figure 2-11. Image file contents for the CCT-AT.

LANDSAT-4 TM — CCT—AT — INITIAL PORTION OF DATA MATRIX (UNBLOCKED)

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
SCROUNGE ERA (1982-1983)

	SAMPLE LINE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	CHANNEL NUMBER
HEADER	1	0	0	0	1	63	192	18	18	0	0	104	0	65	32	32	32	67	67	66	45	67	67	84	45	48	
	2	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	
	3	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	
	4	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	
IMAGE DATA	5	96	87	86	88	77	77	75	75	74	74	75	71	69	67	70	71	71	65	61	62	61	55	55	57	59	16
	6	91	85	84	87	74	72	71	70	70	72	71	71	68	64	67	68	72	66	64	66	66	60	60	60	57	15
	7	88	89	82	88	79	74	71	69	73	75	75	76	76	72	77	72	67	66	65	67	71	67	62	57	58	14
	8	90	105	86	88	89	83	83	74	78	80	79	79	79	74	75	77	71	67	66	65	67	67	68	69	67	13
	9	79	84	87	100	100	97	100	89	82	80	74	75	74	76	75	77	74	70	68	70	76	84	90	90	90	12
	10	76	87	85	87	95	94	90	84	84	86	81	74	70	72	72	75	74	85	92	89	88	87	98	89	98	11
	11	79	97	93	88	85	31	85	84	85	84	84	80	77	75	75	75	77	89	88	88	88	89	88	91	87	10
	12	76	88	99	93	92	86	84	84	85	84	83	84	80	79	79	76	78	86	89	90	90	92	90	88	88	9
	13	76	83	93	101	95	89	86	85	84	86	81	85	83	81	79	80	82	79	36	86	91	91	89	90	96	8
	14	73	77	99	118	95	86	87	87	85	85	84	83	83	79	81	80	80	82	86	87	87	90	90	99	110	7
	15	72	76	95	127	105	86	84	85	85	80	84	78	78	81	84	81	80	82	88	91	88	91	89	93	96	6
	16	71	77	86	114	94	86	76	78	78	82	78	78	79	80	80	82	83	83	94	92	89	90	89	93	95	5
	17	72	77	80	103	101	86	78	78	83	80	78	80	76	81	82	80	83	83	96	96	88	90	89	89	96	4
	18	72	77	80	103	101	86	78	78	83	80	78	80	76	81	82	80	83	83	96	96	88	90	89	89	96	3
	19	70	71	78	99	102	77	76	81	87	84	83	80	77	78	78	79	78	81	81	89	90	90	89	91	90	2
	20	71	70	75	88	104	82	84	82	87	85	84	84	83	80	80	80	79	80	80	87	92	90	90	92	92	1

ORIGINAL PAGE IS OF POOR QUALITY

Figure 2-12. An example of data and ogranization for TM images in CCT-AT format, as unblocked when written to a copy tape or a disk file. The three lines of "32" values represent blanks padding the internal header record before the data is unblocked.

LANDSAT-4 TM — CCT-AT—NOMINAL CALIBRATION — BAND 4

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SWEEP	SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	
FORWARD	13	29	29	29	29	28	29	29	30	31	49	88	89	90	92	91	89	87	75	47	30	30	30	29	30	39	16
	14	28	29	28	28	28	29	28	29	30	57	89	89	90	92	92	89	90	88	81	43	28	30	28	29	32	15
	15	28	29	29	29	29	29	30	30	34	68	89	91	93	93	93	93	92	90	85	50	30	31	28	29	30	14
	16	29	29	30	28	29	30	29	30	35	74	89	91	92	93	93	92	92	92	88	59	30	32	30	30	30	13
	17	29	28	28	28	29	29	30	30	38	80	92	93	93	94	93	93	93	92	88	63	27	30	29	30	29	12
	18	28	29	29	28	29	29	30	30	43	83	89	90	93	93	93	93	93	93	90	64	30	31	30	30	28	11
	19	29	29	29	29	29	29	29	31	48	88	90	93	93	93	92	93	92	92	90	64	29	29	29	28	29	10
	20	28	29	28	29	29	30	29	30	52	87	89	92	92	92	93	91	92	92	88	68	30	30	29	28	28	9
	21	29	28	29	28	28	30	30	31	54	94	90	94	94	94	94	92	91	94	94	76	28	28	27	28	29	8
	22	29	30	29	29	29	30	30	32	63	95	91	92	92	92	93	93	93	92	92	82	35	30	30	29	29	7
	23	30	29	30	30	29	30	30	34	71	93	93	93	93	93	94	94	93	93	92	85	37	27	30	28	29	6
	24	28	29	29	28	29	29	29	34	72	92	93	93	93	94	94	94	94	93	92	88	44	28	29	28	28	5
	25	28	28	28	28	29	30	30	36	78	93	93	94	93	95	94	95	93	94	93	87	48	25	28	28	28	4
	26	28	29	28	28	29	29	29	39	82	91	92	93	93	93	94	93	95	93	91	87	50	26	29	29	29	3
	27	29	28	29	29	29	30	30	39	85	95	93	93	94	94	94	94	94	95	93	89	49	24	27	28	29	2
	28	29	29	29	29	30	30	30	37	78	92	92	93	93	93	94	95	95	95	93	90	45	27	30	29	29	1
REVERSE	29	75	72	78	83	76	68	73	71	68	75	73	77	77	73	73	78	80	77	77	77	84	78	72	89	53	16
	30	80	76	80	78	66	67	73	72	75	79	74	78	79	75	75	76	85	79	76	73	75	73	73	93	56	15
	31	78	74	77	68	71	70	71	77	85	78	77	76	78	74	75	80	81	79	78	79	78	81	77	89	53	14
	32	76	76	72	69	74	75	74	77	79	80	94	84	74	78	79	83	78	76	76	81	72	78	71	91	51	13
	33	75	71	71	68	80	83	78	77	84	88	83	78	76	76	78	81	76	71	78	84	77	88	81	89	51	12
	34	71	72	70	73	76	86	76	78	81	80	77	76	86	76	78	80	77	73	84	86	81	91	78	88	54	11
	35	75	71	74	73	79	86	85	84	88	85	76	86	85	74	70	76	78	78	80	78	86	100	89	90	66	10
	36	71	75	73	84	88	94	87	84	89	77	77	80	76	77	71	77	82	78	84	104	97	89	75	60	54	9
	37	79	77	73	79	86	83	84	85	81	80	82	72	76	78	74	77	86	84	104	99	85	83	48	31	38	8
	38	74	77	80	73	82	79	83	80	79	75	77	78	80	80	71	80	96	105	93	80	82	46	31	29	28	7
	39	73	78	79	81	87	83	81	85	79	83	77	79	83	86	72	82	93	108	94	67	38	30	29	28	28	6
	40	79	73	76	84	91	82	86	90	84	75	77	73	80	80	88	93	73	62	44	31	29	29	28	29	28	5
	41	89	83	86	84	73	71	74	81	80	79	78	83	82	70	55	36	32	30	29	30	28	28	30	28	28	4
	42	73	79	75	70	73	82	76	76	79	91	85	72	44	31	30	29	28	27	29	29	29	29	29	29	28	3
	43	72	79	80	79	80	69	76	89	93	84	48	34	30	29	28	28	28	28	33	43	43	43	34	30	29	2
	44	70	79	83	77	80	66	83	81	69	39	29	28	28	28	29	32	33	47	63	81	75	72	65	53	42	1
FORWARD	45	29	30	30	29	30	29	29	29	30	30	31	43	85	93	93	93	93	95	93	92	95	92	78	33	29	16
	46	28	29	28	28	29	28	29	29	29	29	30	35	71	94	92	93	94	93	93	93	93	92	82	37	29	15
	47	28	30	29	29	30	29	29	29	30	30	30	32	59	92	92	93	94	94	94	93	93	93	86	43	30	14
	48	29	29	29	30	30	28	30	30	29	30	30	30	48	89	92	93	95	94	92	92	93	92	88	50	30	13
	49	30	29	28	29	29	28	29	29	29	30	30	30	41	85	94	94	94	93	92	92	92	91	90	56	27	12
	50	28	30	29	30	29	28	28	29	29	29	29	29	34	71	92	92	93	94	93	91	93	93	92	68	21	11
	51	29	29	29	29	29	29	29	29	29	29	29	30	32	58	92	93	94	94	93	91	91	92	90	77	33	10
	52	29	29	28	28	28	28	28	28	29	29	29	29	30	42	85	92	93	93	92	92	90	90	92	83	37	9
	53	29	30	30	29	29	30	29	29	30	28	29	30	30	33	69	96	92	95	93	91	92	92	91	88	47	8
	54	28	30	29	29	29	29	28	29	29	29	30	30	29	31	54	91	93	92	92	92	91	93	93	92	60	7
	55	29	30	30	29	29	29	28	29	29	29	29	30	30	31	39	80	94	94	94	92	92	92	93	93	75	6
	56	29	30	29	28	29	28	28	28	28	28	29	29	29	30	32	62	92	93	94	93	93	93	93	93	86	5
	57	28	29	29	28	29	29	28	29	29	28	28	30	28	30	31	39	80	97	94	93	93	94	93	93	91	4
	58	28	29	28	28	28	28	27	28	29	28	29	29	28	29	29	33	60	92	92	92	93	92	92	92	92	3
	59	29	30	29	28	30	28	28	29	29	28	28	29	29	29	30	31	44	86	96	94	94	93	93	94	93	2

Figure 2-13: An example of TM data in CCT-AT format, unblocked. Note the changes in DNs between forward and reverse scans. Compare with Figures 2-14 to 2-16 to see the same pattern in other multispectral bands for this same image segment.

LANDSAT-4 TM — CCT-AT — NOMINAL CALIBRATION — BAND 2

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SWEEP	SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	CHANNEL
FORWARD	13	38	38	38	38	38	39	39	39	39	49	71	71	72	72	72	70	68	61	44	38	39	37	37	37	33	16
	14	38	38	38	38	38	38	39	39	40	53	72	72	74	74	73	72	73	70	66	46	38	40	38	37	35	15
	15	39	39	39	38	39	39	39	39	42	60	76	75	74	75	74	75	74	72	67	49	38	39	38	37	36	14
	16	39	38	39	39	39	39	39	39	43	63	76	75	74	76	76	75	74	72	71	55	38	40	39	38	37	13
	17	38	38	38	39	38	38	39	39	43	66	72	75	74	75	73	74	74	72	71	56	38	38	37	38	35	12
	18	38	38	38	38	38	39	38	39	43	67	72	72	75	74	74	73	75	74	72	58	38	39	39	37	38	11
	19	38	38	39	39	38	39	41	41	51	73	74	75	76	75	74	75	75	73	72	58	37	39	38	37	37	10
	20	39	39	39	39	39	39	39	41	51	72	74	74	74	73	74	74	74	74	71	60	40	39	39	38	38	9
	21	39	39	39	39	39	39	39	41	55	72	73	75	76	75	73	75	75	75	72	64	40	40	39	38	37	8
	22	38	37	37	37	38	38	38	41	56	73	72	73	74	72	73	73	73	71	71	69	42	37	40	37	37	7
	23	38	39	38	38	39	38	41	42	61	72	74	74	73	74	74	74	74	74	72	67	45	39	38	38	37	6
	24	38	38	38	39	39	39	39	41	61	73	73	73	74	74	74	73	74	73	72	70	50	37	39	39	38	5 ←
	25	38	38	38	35	39	39	39	41	61	73	73	73	74	74	74	73	74	73	72	70	50	37	39	39	38	4
	26	39	39	39	39	39	39	39	45	67	72	73	72	74	74	73	74	75	73	73	70	50	36	39	39	36	3
	27	39	38	41	38	40	41	42	42	60	69	72	75	74	75	77	76	75	75	74	75	61	46	41	42	39	2
	28	40	39	39	40	40	39	41	43	66	75	74	75	76	76	77	77	77	77	76	74	52	39	42	40	39	1
REVERSE	29	27	27	28	26	27	27	27	27	27	28	28	28	28	28	27	28	28	29	28	28	29	31	30	30	38	16
	30	27	27	26	27	27	26	27	27	27	27	27	27	28	27	28	27	29	29	28	28	29	29	29	30	38	15
	31	28	29	28	27	27	27	28	28	30	28	28	28	28	28	28	29	30	28	29	29	30	32	31	31	39	14
	32	27	30	27	27	27	27	27	28	30	30	31	28	28	28	28	28	28	28	28	30	30	31	31	31	38	13
	33	28	28	27	27	27	27	27	27	27	28	28	27	27	28	28	29	28	28	29	30	28	30	30	32	38	12
	34	27	28	27	27	27	28	28	27	28	29	28	28	29	26	28	30	30	28	30	30	28	30	30	31	38	11
	35	28	28	28	28	27	28	28	28	30	28	28	28	28	29	27	28	29	30	30	28	29	31	32	31	41	10
	36	27	28	28	27	28	30	30	28	28	28	28	29	30	28	28	28	30	28	28	31	31	31	35	42	43	9
	37	28	28	28	28	28	30	29	29	29	30	30	28	28	28	28	29	30	29	30	33	30	34	40	45	45	8
	38	26	27	27	27	27	28	28	27	28	27	27	27	28	28	27	28	29	31	30	27	34	43	45	46	45	7
	39	27	28	29	27	28	30	29	28	27	29	27	29	28	29	27	29	30	33	33	37	43	47	45	46	47	6
	40	28	27	27	29	29	30	29	30	29	29	28	28	29	29	30	33	35	38	42	45	45	45	42	41	44	5 ←
	41	28	27	27	29	29	30	29	30	29	29	28	28	29	29	30	33	35	38	42	45	45	45	42	41	44	4
	42	27	27	27	28	27	28	27	27	28	29	29	35	42	44	45	45	44	44	46	45	46	43	41	39	40	3
	43	28	30	28	30	28	29	30	31	33	39	39	43	46	45	45	46	43	44	40	39	40	41	39	39	40	2
	44	27	27	29	28	30	29	30	30	33	42	45	45	45	45	45	42	38	34	31	30	33	34	35	38	41	1
FORWARD	45	38	39	37	39	39	38	39	39	39	39	42	46	71	75	76	76	76	78	76	76	75	72	66	42	39	16
	46	39	38	38	39	40	39	41	39	39	41	41	42	61	75	74	75	77	77	76	73	75	74	70	45	40	15
	47	39	39	39	39	39	39	40	40	39	39	42	42	58	76	75	77	77	79	78	76	73	75	71	47	39	14
	48	39	39	39	39	39	39	39	39	39	41	40	41	50	75	76	76	79	79	77	78	76	76	74	52	40	13
	49	38	38	39	39	39	39	39	38	39	40	40	40	46	70	75	75	76	77	76	77	75	74	72	54	38	12
	50	39	39	39	38	39	38	39	38	39	39	41	39	42	62	76	76	76	76	77	76	75	73	74	62	39	11
	51	38	38	39	39	39	38	39	39	39	41	42	41	41	56	77	77	77	78	79	76	75	74	75	66	42	10
	52	39	39	39	39	39	39	39	39	39	40	40	40	43	47	72	77	75	77	78	77	75	73	74	71	46	9
	53	38	39	39	39	39	39	39	39	38	39	39	40	40	43	63	78	76	77	78	77	76	75	75	72	50	8
	54	37	38	38	33	38	40	37	38	38	38	38	40	40	42	52	75	75	75	75	74	74	74	72	74	58	7
	55	39	38	38	38	38	38	38	38	39	39	40	40	40	41	45	67	77	77	76	76	73	75	75	74	65	6
	56	38	39	39	38	37	38	39	38	38	40	40	39	40	41	40	54	77	76	76	76	75	74	73	75	72	5 ←
	57	33	39	39	38	37	38	39	38	38	40	40	39	40	41	40	54	77	76	76	76	75	74	73	75	72	4
	58	40	38	39	39	39	38	38	39	40	39	39	39	39	39	41	41	53	76	75	76	74	75	74	75	73	3
	59	39	40	38	38	38	40	39	40	39	38	39	40	38	41	40	41	45	63	70	72	77	75	76	77	75	2

Figure 2-14. An example of TM data for spectral band 2 in CCT-AT format, unblocked. Note the duplication of DNs for channel 5 to replace defective data in channel 4. Note also the difference in DNs between forward and reverse scans resulting from the scan offset.

LANDSAT-4 TM — CCT-AT — NOMINAL CALIBRATION — BAND 5

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

	SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	
FORWARD	13	7	7	6	6	8	8	9	9	10	18	105	157	160	165	164	163	159	145	83	27	16	13	10	11	13	16
	14	6	6	7	6	8	7	9	8	11	26	130	162	165	167	167	166	162	161	152	101	13	10	9	10	11	15
	15	9	7	8	7	9	10	9	10	11	40	141	160	165	169	167	168	168	165	161	125	22	17	12	10	11	14
	16	8	6	8	7	7	9	9	9	14	54	152	163	165	168	169	168	167	168	164	143	35	10	14	11	11	13
	17	8	7	9	6	7	11	9	10	14	65	153	159	166	169	168	168	166	170	166	147	42	14	14	11	12	12
	18	8	8	6	8	9	9	9	10	14	76	160	160	168	169	170	169	169	169	166	134	53	11	14	12	10	11
	19	8	6	6	8	6	10	10	10	18	100	162	160	165	167	169	169	168	169	167	154	46	14	13	12	10	10
	20	7	6	8	8	9	8	10	12	21	105	164	165	169	167	169	169	168	170	170	158	61	11	14	10	10	9
	21	8	9	9	8	10	10	9	13	20	104	159	161	168	170	171	171	168	172	174	174	86	17	17	13	10	8
	22	8	6	8	8	10	8	8	12	32	140	157	163	167	169	168	170	171	169	174	172	92	17	18	13	11	7
	23	9	7	8	10	9	11	11	10	39	139	165	166	169	168	169	170	171	168	172	174	116	18	13	13	7	6
	24	6	10	6	11	7	9	11	11	46	146	164	162	165	165	171	170	170	169	171	169	132	20	13	13	9	5
	25	6	8	8	9	9	10	11	13	60	149	161	163	167	168	172	171	172	171	169	170	134	26	17	14	12	4
	26	6	8	8	9	9	10	11	13	60	149	161	163	167	168	172	171	172	171	169	170	134	26	17	14	12	3 ←
	27	8	8	6	9	9	10	11	16	82	158	163	167	171	168	173	173	174	173	171	166	132	30	18	13	9	2
	28	6	9	7	8	8	10	10	13	52	149	162	166	169	171	172	174	174	174	173	171	142	35	17	13	8	1
REVERSE	29	55	54	53	64	60	48	53	50	52	55	54	56	57	59	56	58	59	58	60	57	58	54	45	46	41	16
	30	57	58	53	60	54	46	55	54	52	52	57	57	59	58	56	56	59	61	55	56	59	53	49	49	51	15
	31	59	59	58	54	50	50	55	54	61	59	60	56	60	56	55	55	57	55	55	56	59	59	47	46	43	14
	32	59	57	54	53	51	53	53	49	55	56	63	65	58	54	63	58	56	58	52	57	55	51	52	46	46	13
	33	60	53	53	49	53	54	53	52	53	63	58	56	55	53	61	58	58	59	55	60	52	52	50	51	44	12
	34	53	54	53	51	51	50	54	53	54	59	54	54	57	60	58	64	56	58	54	66	53	61	58	49	49	11
	35	54	53	53	54	43	57	59	55	59	62	56	58	61	55	54	53	61	54	59	54	52	67	61	52	60	10
	36	51	48	54	51	55	60	63	55	57	60	56	59	55	53	55	51	59	58	52	63	69	62	58	69	63	9
	37	50	59	53	55	56	60	59	59	63	59	62	56	53	54	54	55	60	52	61	70	52	51	43	20	16	8
	38	53	55	57	55	55	59	59	63	56	57	54	57	55	59	55	50	59	69	71	51	45	46	20	9	11	7
	39	54	52	58	56	56	62	62	59	59	59	59	63	60	63	52	53	57	70	65	51	25	13	10	10	10	6
	40	59	56	55	55	65	65	59	66	64	57	57	55	53	54	56	63	58	47	34	21	12	10	9	9	8	5
	41	62	60	62	63	59	52	52	56	61	59	53	54	56	47	43	27	19	13	11	10	11	9	10	7	8	4
	42	62	60	62	63	59	52	52	56	61	59	53	54	56	47	43	27	29	13	11	10	11	9	10	7	8	3 ←
	43	60	54	59	54	53	60	47	54	57	63	42	22	13	10	11	10	11	11	12	16	17	22	13	10	10	2
	44	54	52	57	58	61	63	53	56	50	52	13	11	8	10	10	12	13	18	29	44	48	53	55	38	29	1
FORWARD	45	9	9	7	8	8	9	8	9	10	10	14	24	92	167	171	170	171	171	169	167	171	172	163	75	14	16
	46	8	8	9	6	9	7	10	8	10	9	12	14	55	161	177	174	175	172	172	169	171	174	171	88	13	15
	47	8	8	9	9	7	9	8	11	7	11	11	14	32	139	168	169	169	168	170	167	165	171	169	107	17	14
	48	7	9	6	8	9	8	9	9	9	10	11	12	20	111	173	168	169	169	167	167	169	170	172	126	21	13
	49	8	6	9	7	10	8	9	9	9	10	10	12	14	86	163	166	167	169	167	164	166	166	172	138	29	12
	50	8	8	7	9	8	8	8	9	10	8	10	11	12	45	152	170	171	168	167	165	166	168	172	156	55	11
	51	8	8	8	8	8	8	8	8	7	10	10	10	11	27	132	164	168	168	164	167	164	169	173	163	67	10
	52	8	8	6	9	7	9	8	8	9	6	[illegible]	9	11	18	91	166	164	168	169	167	166	169	174	169	94	9
	53	8	8	9	10	8	8	10	7	9	9	9	10	11	14	37	139	165	169	169	169	167	169	172	171	120	8
	54	9	8	8	7	6	10	8	6	8	10	8	9	12	10	25	123	165	165	168	163	165	170	175	173	143	7
	55	9	8	8	9	8	8	9	6	9	9	9	10	9	13	14	66	159	166	168	166	166	170	173	171	164	6
	56	8	9	9	9	7	6	9	8	9	6	10	11	7	12	13	33	136	168	168	165	164	169	173	169	168	5
	57	9	8	8	7	7	6	9	8	6	11	8	9	11	10	13	19	79	158	163	168	168	168	175	169	171	4
	58	9	8	8	7	7	6	9	8	6	11	8	9	11	10	13	19	79	158	163	168	168	168	175	169	171	3 ←
	59	5	8	8	6	6	7	8	7	7	9	8	10	8	10	10	13	19	93	163	166	170	171	173	174	172	2

Figure 2-15. An example of TM data for spectral band 5 in CCT-AT format, unblocked. Note the duplication of DNs for channel 4 to replace defective data in channel 3. Note also the difference in DNs between forward and reverse scans resulting from the scan offset.

LANDSAT-4 TM — CCT-AT — NOMINAL CALIBRATION — BAND 6

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SWEEP	SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	CHANNEL
FORWARD	13	135	135	135	135	136	136	136	136	137	137	137	137	157	157	157	157	166	166	166	166	155	155	155	155	137	4
	14	135	135	135	135	136	136	136	136	137	137	137	137	157	157	157	157	166	166	166	166	155	155	155	155	137	
	15	135	135	135	135	136	136	136	136	137	137	137	137	157	157	157	157	166	166	166	166	155	155	155	155	137	
	16	135	135	135	135	136	136	136	136	137	137	137	137	157	157	157	157	166	166	166	166	155	155	155	155	137	
	17	134	134	134	134	135	135	135	135	138	138	138	138	159	159	159	159	168	168	168	168	159	159	159	159	137	3
	18	134	134	134	134	135	135	135	135	138	138	138	138	159	159	159	159	168	168	168	168	159	159	159	159	137	
	19	134	134	134	134	135	135	135	135	138	138	138	138	159	159	159	159	168	168	168	168	159	159	159	159	137	
	20	134	134	134	134	135	135	135	135	138	138	138	138	159	159	159	159	168	168	168	168	159	159	159	159	137	
	21	136	136	136	136	136	136	136	136	140	140	140	140	163	163	163	163	168	168	168	168	161	161	161	161	139	2
	22	136	136	136	136	136	136	136	136	140	140	140	140	163	163	163	163	168	168	168	168	161	161	161	161	139	
	23	136	136	136	136	136	136	136	136	140	140	140	140	163	163	163	163	168	168	168	168	161	161	161	161	139	
	24	136	136	136	136	136	136	136	136	140	140	140	140	163	163	163	[illegible]	168	168	168	168	161	161	161	161	139	
	25	134	134	134	134	134	134	134	134	140	140	140	140	162	162	162	162	168	168	168	168	164	164	164	164	141	1
	26	134	134	134	134	134	134	134	134	140	140	140	140	162	162	162	162	168	168	168	168	164	164	164	164	141	
	27	134	134	134	134	134	134	134	134	140	140	140	140	162	162	162	162	168	168	168	168	164	164	164	164	141	
	28	134	134	134	134	134	134	134	134	140	140	140	140	162	162	162	162	168	168	168	168	164	164	154	164	141	
REVERSE	29	136	136	136	136	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	136	136	136	136	136	4
	30	136	136	136	136	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	136	136	136	136	136	
	31	136	136	136	136	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	136	136	136	136	136	
	32	136	136	136	136	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	135	136	136	136	136	136	
	33	135	135	135	135	135	135	135	135	135	135	135	135	136	136	136	136	136	136	136	136	136	136	136	136	135	3
	34	135	135	135	135	135	135	135	135	135	135	135	135	136	136	136	136	136	136	136	136	136	136	136	136	135	
	35	135	135	135	135	135	135	135	135	135	135	133	135	136	136	136	136	136	136	136	136	136	136	136	136	135	
	36	135	135	133	135	135	135	135	135	135	133	133	135	136	136	136	136	136	136	136	136	136	136	136	136	135	
	37	137	137	137	137	137	137	137	137	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	135	2
	38	137	137	137	137	137	137	137	137	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	135	
	39	137	137	137	137	137	137	137	137	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	133	
	40	137	137	137	137	137	137	137	137	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	135	
	41	136	136	136	136	136	136	136	136	137	137	137	137	155	136	136	136	135	135	135	135	135	135	135	135	134	1
	42	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	135	135	135	135	135	135	133	135	134	
	43	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	135	135	135	135	135	135	133	133	134	
	44	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	135	135	135	135	135	135	135	135	134	
FORWARD	45	136	136	136	136	136	136	136	136	136	136	136	136	140	140	140	140	161	161	161	161	166	166	166	166	155	4
	46	136	136	136	136	136	136	136	136	136	136	136	136	140	140	140	140	161	161	161	161	166	166	166	166	155	
	47	136	136	136	136	136	136	136	136	136	136	136	136	140	140	140	140	161	161	161	161	166	166	166	166	155	
	48	136	136	136	136	136	136	136	136	136	136	136	136	140	140	140	145	161	161	161	161	166	166	166	166	155	
	49	134	134	134	134	135	135	135	135	135	133	135	135	137	137	137	137	154	154	154	154	166	166	166	166	160	3
	50	134	134	134	134	135	135	135	135	135	135	135	135	137	137	137	137	154	154	154	154	166	166	166	166	160	
	51	134	134	134	154	135	135	135	135	135	135	135	135	137	137	137	137	154	154	154	154	166	166	166	166	160	
	52	134	134	134	134	135	135	135	135	135	135	135	135	137	137	137	137	154	154	154	154	166	166	166	166	160	
	53	135	135	135	135	136	136	136	136	136	136	136	136	137	137	137	137	147	147	147	147	166	166	166	166	163	2
	54	135	135	135	135	136	136	136	136	136	136	136	136	137	137	137	137	147	147	147	147	166	166	166	166	163	
	55	135	135	135	135	136	136	136	136	136	136	136	136	137	137	137	137	147	147	147	147	166	166	166	166	163	
	56	135	135	135	135	136	136	136	136	136	136	136	136	137	137	137	137	147	147	147	147	166	166	156	166	163	
	57	134	134	134	134	134	134	134	134	135	135	135	135	135	135	135	135	138	138	138	138	158	158	158	158	165	1
	58	134	134	134	134	134	134	134	134	135	135	135	135	135	135	135	135	138	138	138	138	158	158	158	158	165	
	59	134	134	134	134	134	134	134	134	135	135	135	135	135	135	135	135	138	138	138	138	158	158	158	158	165	

Figure 2-16. An example of TM data for spectral band 6 in CCT-AT format, unblocked. Note the blocks of 16 pixels representing the 120-meter IFOV of the band-6 detectors. Note also the effects of the scan offset as seen previously in Figures 2-13 to 2-15.

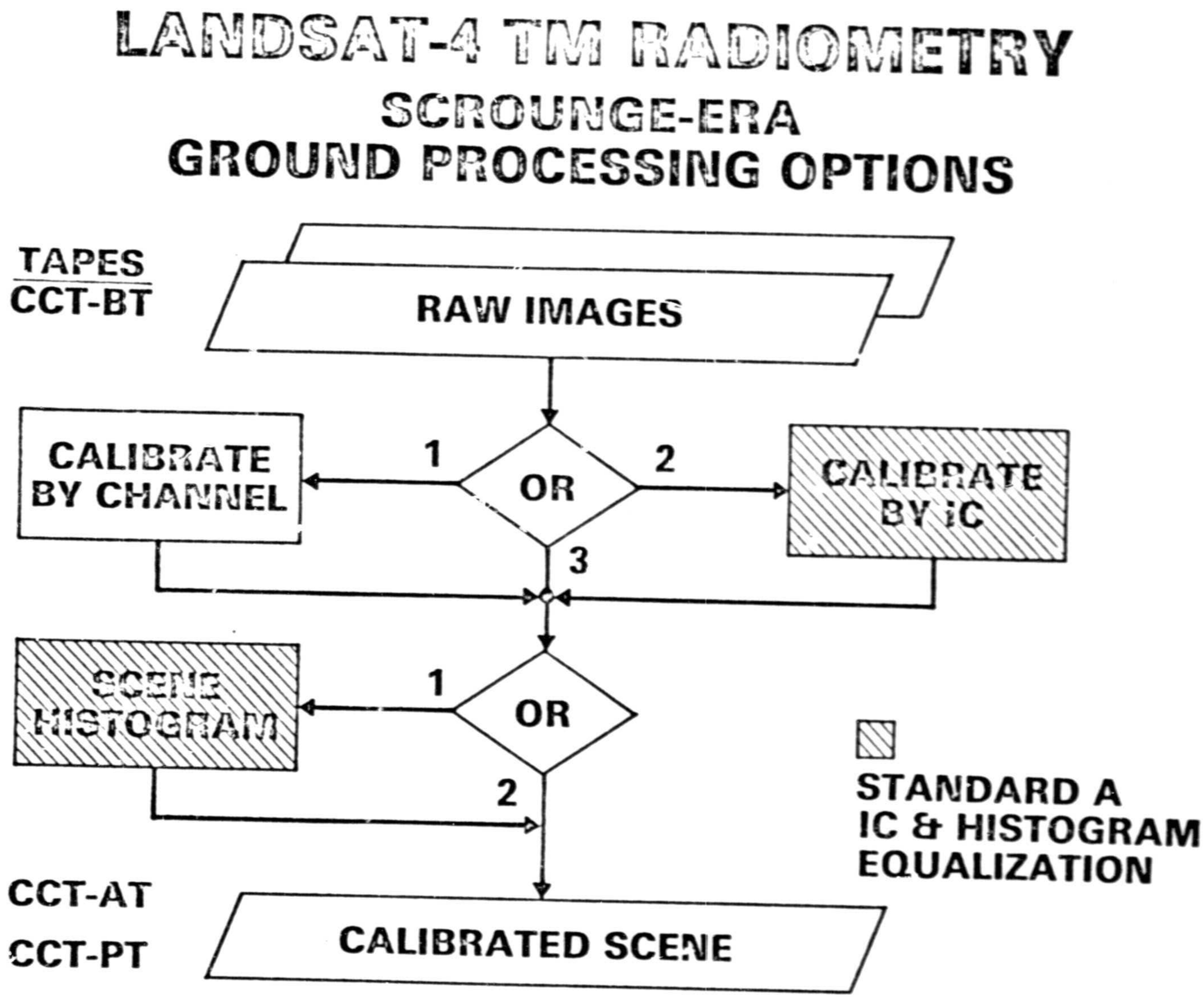

Figure 2-17. Diagram of LAS calibration options for TM data.

LANDSAT-4 TM — CCT-AT— IC BAND 2

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665
13	38	38	38	38	38	39	39	39	39	50	72	72	73	73	73	71	69	61	45	38	39	37	37	37	33
14	38	38	38	38	38	38	39	39	40	53	72	72	74	74	73	72	73	70	66	46	38	40	38	37	35
15	39	39	39	38	39	39	39	39	42	61	76	75	74	75	74	75	74	72	68	49	38	39	38	37	36
16	39	38	39	39	39	39	39	39	43	63	76	75	73	76	76	75	73	72	71	55	38	40	39	38	37
17	38	38	38	39	38	38	39	39	44	66	73	76	75	76	74	75	75	73	72	56	38	38	37	38	35
18	38	38	38	38	38	39	38	39	45	68	72	72	75	74	74	73	75	74	72	59	38	39	39	37	38
19	39	39	40	40	39	40	41	41	51	73	74	75	76	75	74	75	75	73	72	58	38	40	39	38	38
20	39	39	39	39	39	39	39	41	52	72	74	74	74	73	74	74	74	74	71	60	40	39	39	38	38
21	40	40	40	40	40	40	40	42	55	73	74	75	76	75	74	75	75	75	73	65	41	41	40	38	37
22	39	38	38	38	39	39	39	41	57	74	73	74	75	73	74	74	74	72	72	70	42	38	40	38	38
23	38	39	38	38	39	38	41	42	61	72	74	74	73	74	74	74	74	74	72	67	45	39	38	38	37
24	38	38	38	39	39	39	39	41	61	73	73	73	74	74	74	73	74	73	72	70	50	37	39	39	38
25	38	38	38	39	39	39	39	41	61	73	73	73	74	74	74	73	74	73	72	70	50	37	39	39	38
26	39	39	39	39	39	39	39	45	68	73	74	73	75	75	74	75	76	74	74	71	51	37	39	39	37
27	39	38	41	38	40	41	42	42	60	69	72	76	74	76	78	77	76	76	74	76	61	46	41	42	39
28	40	38	39	40	40	39	41	43	65	75	74	75	76	76	77	77	77	77	76	74	52	39	42	40	39
29	27	27	28	28	27	27	27	27	27	28	28	28	28	28	27	28	28	29	28	28	29	31	30	30	38
30	27	27	26	27	27	26	27	27	27	27	27	27	28	27	28	27	29	29	29	28	29	29	29	30	38
31	27	28	27	26	26	26	27	27	30	27	27	27	27	27	27	28	39	27	28	28	30	32	31	31	39
32	26	30	26	26	26	26	26	27	30	30	31	27	27	27	27	27	27	27	27	30	30	31	31	31	38
33	28	28	27	27	27	27	27	27	[illegible]	28	28	27	27	28	28	29	28	28	29	30	28	30	30	32	38
34	27	28	27	27	27	28	28	27	26	29	28	28	29	28	28	30	30	28	30	30	28	30	30	31	38
35	28	28	28	28	27	28	28	28	30	28	28	28	28	29	27	28	29	30	30	28	29	31	32	31	41
36	27	28	28	27	28	30	30	28	28	28	28	29	30	28	28	28	30	28	28	31	31	31	35	42	43
37	28	28	28	28	28	30	29	29	29	30	30	28	28	28	28	29	30	29	30	33	30	34	41	46	46
38	27	28	28	28	28	29	29	28	29	28	28	28	29	29	28	29	30	32	31	28	35	43	45	46	46
39	27	28	29	27	28	30	29	28	27	29	27	29	28	29	27	29	30	33	33	37	43	47	45	46	47
40	28	27	27	29	29	30	29	30	29	29	28	28	29	29	30	33	35	38	42	45	43	45	42	41	44
41	28	27	27	29	29	30	29	30	29	29	28	28	29	29	30	33	35	38	42	45	45	45	42	41	44
42	28	26	28	29	28	29	28	28	29	30	30	36	42	44	45	45	44	44	46	45	46	43	41	39	40
43	28	30	28	30	28	29	30	31	33	39	39	43	45	46	45	46	43	44	40	39	40	41	39	39	40
44	27	27	29	28	30	29	30	30	33	42	45	45	45	45	45	42	38	34	31	30	33	34	35	38	41
45	38	39	37	39	39	38	39	39	29	39	43	47	72	76	77	77	77	79	77	77	76	73	67	43	39
46	39	38	38	39	40	39	41	39	39	41	41	42	61	75	74	75	77	77	76	75	75	74	70	45	40
47	39	39	39	39	39	39	40	40	39	39	42	42	58	76	75	77	77	79	78	76	75	75	71	47	39
48	39	39	39	39	39	39	39	39	39	41	40	41	50	75	76	76	79	79	77	78	76	76	73	52	40
49	38	38	39	39	39	39	39	38	39	40	40	40	47	71	76	76	77	78	77	78	76	75	73	55	38
50	39	39	39	38	39	38	39	38	39	39	41	39	42	63	76	76	76	76	78	76	75	73	74	63	39
51	39	39	40	40	40	39	40	40	40	41	42	41	41	56	77	77	77	78	79	76	75	74	75	67	42
52	39	39	39	39	39	39	39	39	39	40	40	40	40	47	72	77	75	77	78	77	75	73	74	71	46
53	38	40	40	40	40	40	40	40	38	40	40	41	41	44	64	78	76	77	78	77	76	75	75	73	50
54	38	39	39	39	39	40	38	39	39	39	39	40	40	42	53	76	76	76	76	75	75	75	73	75	59
55	39	38	38	38	38	38	38	38	39	39	40	40	40	41	45	67	78	78	76	76	75	75	75	74	65
56	38	39	39	38	37	38	39	38	38	40	40	39	40	41	40	54	77	76	76	76	75	74	73	75	72
57	38	39	39	38	37	38	39	38	38	40	40	39	40	41	40	34	77	76	76	76	75	74	73	75	72
58	40	38	39	39	39	38	38	39	40	39	39	39	39	39	41	41	56	77	76	77	75	76	75	76	74
59	39	40	38	38	38	40	39	40	39	38	39	40	38	41	40	41	45	63	70	72	78	76	77	78	76

Figure 2-18. An example of TM data for spectral band 2 in CCT-AT format, unblocked, internal calibration. Note the duplication of DNs for channel 5 to replace defective data in channel 4. Note also the difference in DNs between forward and reverse scans resulting from the scan offset. Compare with Figures 2-14 and 2-22.

LANDSAT-4 TM — CCT-AT — IC — BAND 4

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665
13	28	28	28	28	27	28	28	29	30	48	87	88	89	92	91	88	86	74	46	29	29	29	28	29	39
14	28	29	28	28	28	29	28	29	30	56	88	88	89	91	91	88	89	87	80	43	28	30	28	29	32
15	27	28	28	28	28	28	29	29	33	67	88	90	92	92	92	92	91	89	84	49	29	30	27	28	29
16	28	28	29	27	28	29	28	29	34	73	88	90	91	92	92	91	91	91	87	59	29	31	29	29	29
17	28	27	27	27	29	26	29	29	38	79	91	92	92	93	92	92	92	91	87	62	26	29	28	29	28
18	28	29	29	28	29	29	30	30	42	82	88	89	92	92	92	92	92	92	89	63	30	31	30	39	28
19	28	28	28	23	28	28	28	30	47	87	89	92	92	92	91	92	91	91	89	63	28	28	28	27	28
20	27	28	27	28	28	30	28	30	51	86	88	91	91	91	93	90	91	91	87	68	30	30	28	27	27
21	28	27	28	27	27	29	29	30	53	93	90	93	93	93	93	92	91	93	93	75	27	27	26	27	28
22	28	29	28	28	28	29	29	31	62	90	90	91	91	91	92	92	[illegible]	91	91	81	34	29	29	28	28
23	29	28	29	29	28	29	29	33	70	92	92	92	92	92	93	93	92	92	91	84	36	26	29	27	28
24	28	29	29	28	29	29	29	34	71	91	92	92	92	93	93	93	93	92	91	87	43	28	29	28	28
25	27	27	27	27	28	29	29	36	77	92	92	93	92	94	93	94	94	93	92	87	47	24	27	27	27
26	28	29	28	28	29	29	29	38	81	90	91	92	92	92	93	92	94	92	90	86	49	26	29	29	29
27	28	27	28	28	28	29	29	39	83	94	92	92	93	93	93	93	93	94	92	88	48	23	26	27	28
28	28	28	28	28	30	30	30	37	77	91	91	92	92	92	93	94	94	94	92	89	45	26	30	28	28
29	74	71	77	82	75	66	72	70	68	74	72	76	76	72	72	77	79	76	76	76	83	77	71	88	52
30	79	76	79	77	65	66	73	72	75	78	74	77	78	75	75	76	84	78	76	75	75	73	73	92	55
31	77	73	76	67	71	70	71	76	84	77	76	75	77	73	74	79	80	78	77	78	77	80	76	88	52
32	75	75	71	68	73	74	73	76	78	79	93	83	73	77	78	82	77	75	75	80	71	77	70	90	[illegible]
33	74	71	71	68	79	82	77	76	83	87	82	77	75	75	77	80	75	71	77	83	76	87	80	88	50
34	70	71	69	72	75	85	75	78	81	80	76	75	85	75	78	80	76	72	83	83	81	90	78	87	54
35	74	70	73	72	78	85	84	83	87	84	75	85	84	73	69	75	77	77	79	77	85	99	88	89	65
36	70	74	72	83	87	94	86	83	79	76	76	79	75	76	70	76	81	77	83	103	96	88	74	59	53
37	78	76	72	78	85	82	83	84	80	79	81	71	75	77	73	76	85	83	103	98	84	82	47	30	29
38	74	76	79	73	81	78	82	79	78	75	76	77	79	79	71	79	95	104	94	79	81	46	30	28	27
39	72	77	78	81	86	83	81	84	78	63	76	78	83	83	71	82	92	107	93	66	37	29	28	27	27
40	78	72	75	84	90	82	85	89	84	74	76	72	79	79	87	92	72	61	43	31	29	29	28	29	28
41	79	82	86	84	72	70	73	80	79	78	77	82	81	69	54	36	32	29	28	29	27	27	29	27	27
42	75	78	75	76	73	81	76	74	78	90	84	72	43	31	30	29	28	27	29	29	29	29	29	29	28
43	71	78	79	78	79	68	75	88	92	84	47	34	29	28	27	27	27	27	33	42	42	42	34	29	28
44	69	78	83	76	80	65	83	81	68	39	28	27	27	27	28	32	33	47	62	81	74	71	64	52	42
45	28	29	29	28	29	28	28	28	29	29	30	43	84	93	93	93	93	94	93	92	94	92	77	32	28
46	28	29	28	28	29	28	29	29	29	29	30	34	71	93	91	92	93	92	92	92	92	91	81	36	29
47	27	29	28	28	29	28	28	28	29	29	29	31	58	91	91	92	93	93	93	92	92	92	85	43	29
48	28	28	28	29	29	27	29	29	28	29	29	29	48	88	91	92	94	93	91	91	92	91	87	50	29
49	29	28	27	28	28	27	28	28	28	29	29	29	41	84	93	93	93	92	91	91	91	90	89	55	26
50	28	30	29	30	29	28	28	29	29	29	29	29	34	70	91	91	92	93	92	90	92	92	91	67	31
51	28	28	28	28	28	28	28	28	28	28	28	29	31	57	91	92	93	93	92	90	90	91	89	76	32
52	28	28	27	27	27	27	27	27	28	28	28	28	30	43	84	91	93	93	91	91	89	89	91	82	37
53	28	29	29	28	28	29	28	28	29	27	28	29	29	32	68	95	92	94	93	91	92	92	91	87	46
54	27	29	28	28	28	28	27	28	28	28	29	29	28	30	53	90	92	91	91	91	90	92	92	91	59
55	28	29	29	28	28	28	27	28	28	28	28	29	29	30	38	79	93	93	93	91	[illegible]	91	92	92	74
56	29	30	29	28	29	28	28	28	28	28	29	29	29	30	32	61	91	92	93	92	92	92	92	92	85
57	27	28	28	27	28	28	27	28	28	27	27	29	27	29	31	39	79	96	93	92	92	93	92	92	90
58	28	29	28	28	28	28	27	28	29	28	29	29	28	29	29	33	59	91	91	91	92	91	91	91	91
59	28	29	28	27	29	27	27	28	28	27	27	28	28	28	29	31	43	86	95	93	93	92	92	93	92

Figure 2-19. An example of TM data in CCT-AT format, unblocked, internal calibration. Note the changes in DNs between forward and reverse scans. Compare with Figures 2-14 to 2-16 to see the same pattern in other multispectral bands for this same image segment. Compare with Figures 2-13 and 2-23.

LANDSAT-4 TM — CCT-AT— IC BAND 5

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665
13	7	7	6	6	8	8	9	9	10	18	105	157	160	165	164	163	159	145	85	27	16	13	19	11	13
14	6	6	7	6	8	7	9	8	11	26	129	161	165	167	167	166	161	160	152	101	13	10	9	10	11
15	9	7	8	7	9	10	9	10	11	40	141	160	164	168	166	167	167	164	161	124	22	17	12	10	11
16	8	6	8	7	7	9	9	9	14	54	153	163	165	168	169	168	167	168	164	143	35	10	14	11	11
17	8	7	9	6	7	11	9	10	14	65	153	159	166	169	168	168	166	170	166	147	42	14	14	11	12
18	8	8	6	8	9	9	9	10	14	76	160	160	167	168	169	166	168	168	165	154	53	11	14	12	10
19	8	6	8	8	6	10	10	10	17	101	162	160	165	167	169	169	168	169	167	155	46	14	13	12	10
20	7	6	8	8	9	8	10	12	21	105	164	165	169	167	169	169	168	170	170	159	61	11	14	10	10
21	8	9	9	8	10	10	9	13	20	103	158	160	168	170	171	171	168	172	174	174	86	17	17	13	10
22	8	6	8	8	10	8	8	12	32	140	158	163	167	169	168	170	171	169	174	172	92	17	18	13	11
23	9	7	8	10	9	11	11	10	39	139	165	166	169	168	169	170	171	168	172	174	116	18	13	13	7
24	6	10	6	11	7	9	11	11	46	147	164	162	166	166	172	171	171	170	172	170	132	20	13	13	9
25	6	8	8	9	9	10	11	13	60	149	161	163	166	167	172	171	172	171	168	170	134	26	16	14	12
26	6	8	8	9	9	10	11	13	60	149	161	163	166	167	172	171	172	171	168	170	134	26	16	14	12
27	8	8	6	9	9	10	11	16	82	158	163	167	171	168	173	173	174	173	171	166	132	30	18	13	9
28	6	9	7	8	8	10	10	13	52	149	162	166	169	171	172	174	174	174	173	171	142	35	17	13	8
29	55	54	53	64	60	49	53	50	52	55	54	56	57	59	56	58	59	58	60	57	58	54	46	47	41
30	57	58	53	60	54	46	55	54	52	52	57	57	59	58	56	56	59	61	55	56	59	53	48	48	50
31	59	59	58	54	50	50	55	54	61	59	60	56	60	56	55	55	57	55	55	56	59	59	47	46	43
32	59	57	54	53	51	53	53	49	55	56	63	65	58	54	63	58	56	58	52	57	55	51	52	45	45
33	60	53	53	49	53	54	53	52	53	63	58	56	55	53	61	58	58	59	55	60	52	52	50	51	44
34	53	54	53	51	51	50	54	53	54	59	54	54	57	60	58	64	56	58	54	66	53	61	58	49	49
35	54	53	53	54	43	57	59	55	59	62	56	58	61	55	54	53	61	54	59	54	52	67	61	52	60
36	51	48	54	51	55	60	63	55	57	60	56	59	55	53	55	51	59	58	52	63	69	62	58	69	63
37	49	59	53	55	56	60	59	59	63	59	62	56	53	54	54	55	60	52	61	70	52	50	42	20	16
38	53	55	57	55	55	59	59	63	56	57	54	57	55	59	53	50	59	69	71	51	44	45	20	9	11
39	54	52	58	56	56	62	62	59	59	59	59	63	60	63	52	53	57	70	65	51	25	13	10	10	10
40	59	56	55	55	65	65	59	66	64	57	57	55	53	54	56	63	58	47	34	21	12	10	9	9	8
41	62	60	62	63	59	52	52	56	61	59	53	54	56	46	43	27	18	13	11	10	11	9	10	7	8
42	62	60	62	63	59	52	52	56	61	59	53	54	56	46	43	27	18	13	11	10	11	9	10	7	8
43	60	55	59	55	54	60	47	55	57	63	42	22	13	10	11	10	11	11	12	16	17	22	13	10	10
44	54	52	57	58	62	63	53	56	50	32	13	11	8	10	10	12	13	18	29	44	48	53	55	38	29
45	9	9	7	8	8	9	8	9	10	10	14	24	92	167	171	170	171	171	169	167	171	172	163	75	14
46	8	8	9	6	9	7	10	8	10	9	12	14	55	160	177	174	175	172	172	169	171	174	171	88	13
47	8	8	9	9	7	9	8	11	7	11	11	14	31	139	167	168	168	167	169	166	164	170	168	107	17
48	7	9	6	8	9	8	9	9	9	10	11	12	20	111	173	168	169	169	167	167	169	170	172	126	21
49	8	6	9	7	10	8	9	9	9	10	10	12	14	86	163	166	167	169	167	164	166	166	172	138	29
50	8	8	7	9	8	8	8	9	10	8	10	11	12	45	152	169	170	167	166	164	165	167	171	156	55
51	8	8	8	8	8	8	8	8	7	10	16	10	11	27	132	164	168	168	164	167	164	169	174	163	67
52	8	8	6	9	7	9	8	8	9	6	11	9	11	18	91	166	164	168	169	167	166	169	174	169	94
53	8	8	9	10	8	8	10	7	9	9	9	10	11	14	37	139	164	169	169	169	167	169	172	171	128
54	9	8	8	7	6	10	9	6	8	10	8	9	12	10	25	123	165	165	168	163	165	170	175	173	143
55	9	8	8	9	8	8	9	6	9	9	9	10	9	13	14	66	159	166	168	166	166	170	173	171	164
56	8	9	9	9	7	6	9	8	9	6	10	11	7	12	13	33	136	169	169	166	164	170	174	170	169
57	9	8	8	7	7	6	9	8	6	11	8	9	11	10	13	18	78	158	163	167	167	167	175	168	171
58	9	8	8	7	7	6	9	8	6	11	8	9	11	10	13	18	78	158	163	167	167	167	175	168	171
59	5	8	8	6	6	7	8	7	7	9	8	10	8	10	10	13	19	93	163	166	170	171	173	174	172

Figure 2-20. An example of TM data for spectral band 5 in CCT-AT format, unblocked, internal calibration. Note the duplication of DNs for channel 4 to replace defective data in channel 3. Note also the difference in DNs between forward and reverse scans resulting from the scan offset. Compare with Figures 2-15 and 2-24.

LANDSAT-4 TM — CCT-AT— IC BAND 6

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	65'	652	633	654	655	656	657	658	659	660	661	662	663	664	665
13	135	135	135	135	136	136	136	136	137	137	137	137	157	157	157	157	166	166	166	166	155	155	155	155	137
14	135	135	135	135	136	136	136	136	137	137	137	137	157	157	157	157	166	166	166	166	155	155	155	155	137
15	135	135	135	135	136	136	136	136	137	137	137	137	157	157	157	157	166	166	166	166	155	155	155	155	137
16	135	135	135	135	136	136	136	136	137	137	137	137	157	157	157	157	166	166	166	166	155	155	155	155	127
17	134	134	134	134	135	135	135	135	138	138	138	138	159	159	159	159	168	168	168	168	159	159	159	159	137
18	134	134	134	134	135	135	135	135	138	138	138	138	159	159	159	159	168	168	168	168	159	159	159	159	137
19	134	134	134	134	135	135	135	135	138	138	138	138	159	159	159	159	168	168	168	168	159	159	159	159	137
20	134	134	134	134	135	135	135	135	138	138	138	138	159	159	159	159	168	168	168	168	159	159	159	159	137
21	136	136	136	136	136	136	136	136	140	140	140	140	163	163	163	163	168	168	168	168	161	161	161	161	139
22	136	136	136	136	136	136	136	136	140	140	140	140	163	163	163	163	168	168	168	168	161	161	161	161	139
23	136	136	136	136	136	136	136	136	140	140	140	140	163	163	163	163	168	168	168	168	161	161	161	161	139
24	136	136	136	136	136	136	136	136	140	140	140	140	163	163	163	163	168	168	168	168	161	161	161	161	139
25	134	134	134	134	134	134	134	134	140	140	140	140	162	162	162	162	168	168	168	168	164	164	164	164	141
26	134	134	134	134	134	134	134	134	140	140	140	140	162	162	162	162	168	168	168	168	164	164	164	164	141
27	134	134	134	134	134	134	134	134	140	140	140	140	162	162	162	162	168	168	168	168	164	164	164	164	141
28	134	134	134	134	134	134	134	134	140	140	140	140	162	162	162	162	168	168	168	168	164	164	164	164	141
29	136	136	136	136	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	136	136	136	136	136
30	136	136	136	136	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	136	136	136	136	136
31	136	136	136	136	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	136	136	136	136	136
32	136	136	136	136	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	136	136	136	136	136
33	135	135	135	135	135	135	135	135	135	135	135	135	136	136	136	136	136	136	136	136	136	136	136	136	136
34	135	135	135	135	135	135	135	135	135	135	133	133	136	136	136	136	136	136	136	136	136	136	136	136	135
35	135	135	135	135	135	135	135	135	135	135	135	135	136	136	136	136	136	136	136	136	136	136	136	136	135
36	135	135	135	135	135	135	135	135	135	135	135	135	136	136	136	136	136	136	136	136	136	136	136	136	135
37	137	137	137	137	137	137	137	137	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	135
38	137	137	137	137	137	137	137	137	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	135
39	137	137	137	137	137	137	137	137	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	135	135
40	137	137	137	137	137	137	137	137	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	135
41	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	135	135	135	135	133	135	135	135	134
42	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	135	135	135	135	135	135	133	135	134
43	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	135	135	135	135	133	135	133	135	134
44	136	136	136	136	136	136	136	136	137	137	137	137	136	136	136	136	135	135	135	135	133	135	135	135	134
45	136	136	136	136	136	136	136	136	136	136	136	136	140	140	140	140	161	161	161	161	166	166	166	166	155
46	136	136	136	136	136	136	136	136	136	136	136	136	140	140	140	140	161	161	161	161	166	166	166	166	155
47	136	136	136	136	136	136	136	136	136	136	136	136	140	140	140	140	161	161	161	161	166	166	166	166	155
48	136	136	136	136	136	136	136	136	136	136	136	136	140	140	140	140	161	161	161	161	166	166	166	166	155
49	134	134	134	134	135	135	135	135	135	135	135	135	137	137	137	137	154	154	154	154	166	166	166	166	160
50	134	134	134	134	135	135	135	135	135	135	135	135	137	137	137	137	154	154	154	154	166	166	166	166	160
51	134	134	134	134	135	135	135	135	133	135	135	135	137	137	137	137	154	154	154	154	166	166	166	166	160
52	134	134	134	134	135	135	135	135	135	135	135	135	137	137	137	137	154	154	154	154	166	166	166	166	160
53	135	135	135	135	136	136	136	136	136	136	136	136	137	137	137	137	147	147	147	147	166	166	166	166	163
54	135	135	135	135	136	136	136	136	136	136	136	136	137	137	137	137	147	147	147	147	166	166	166	166	163
55	135	135	135	135	136	136	136	136	136	136	136	136	137	137	137	137	147	147	147	147	166	166	166	166	163
56	135	135	135	135	136	136	136	136	136	136	136	136	137	137	137	137	147	147	147	147	166	166	166	166	163
57	134	134	134	134	134	134	134	134	135	135	135	135	135	135	135	135	138	138	138	138	158	158	158	158	163
58	134	134	134	134	134	134	134	134	135	135	135	135	135	135	135	135	138	138	138	138	158	158	158	158	165
59	134	134	134	134	134	134	134	134	135	135	135	135	135	135	133	135	138	138	138	138	158	158	158	158	165

Figure 2-21. An example of TM data for spectral band 6 in CCT-AT format, unblocked, internal calibration. Note the blocks of 16 pixels representing the 120-meter IFOV of the band-6 detectors. Note also the effects of the scan offset as seen previously in Figures 2-13 to 2-15. Compare with Figure 2-16.

LANDSAT-4 TM — CCT-AT — NOMINAL MINUS IC — BAND 2

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665
13	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	0	-1	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0
19	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1
20	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	-1	-1	-1	-1	-1	-1	-1	-1	0	-1	-1	0	0	0	-1	0	0	0	-1	-1	-1	-1	-1	0	0
22	-1	-1	-1	-1	-1	-1	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	-1	0	-1	-1
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	-1
27	0	0	0	0	0	0	0	0	0	0	0	-1	0	-1	-1	-1	-1	-1	0	-1	0	0	0	0	0
28	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0
32	1	0	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1
38	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	-1	0	0	0	0	-1	0
51	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	-1	-1	-1	-1	-1	-1	-1	0	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	-1	0
54	-1	-1	-1	-1	-1	0	-1	-1	-1	-1	-1	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1

Figure 2-22. An example of the difference image between TM data processed using two different calibration options. Compare with Figures 2-14 and 2-18.

LANDSAT-4 TM – CCT-AT – NOMINAL MINUS IC – BAND 4

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

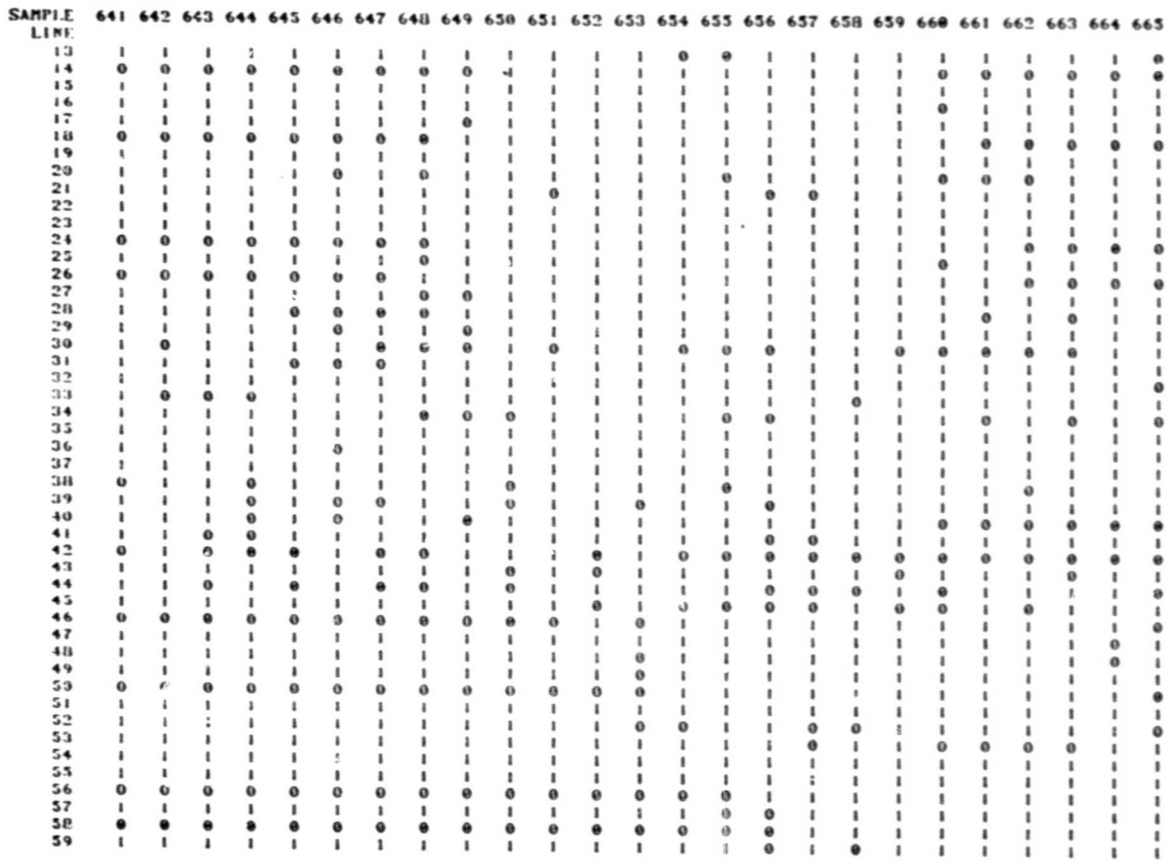

Figure 2-23. An example of the difference image between TM data processed using two different calibration options. Compare with Figures 2-13 and 2-23.

LANDSAT-4 TM — CCT-AT — NOMINAL MINUS IC — BAND 7

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665
13	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
15	0	0	0	0	0	0	0	0	0	-1	-2	-2	-1	-1	-1	-2	-1	-2	-2	-1	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	-1	0	0	-1	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0
23	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	-1	0	-1	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	-1	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0
26	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-2	-2	-2	-2	-1	-1	-1	0	0	0	0
27	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0
28	0	0	0	0	0	0	0	0	1	2	2	2	2	2	2	2	2	2	2	2	2	1	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	-1	-1	0	-1	0	0	0	0	0	-1	-1	-1	-1	0	-1	0	-1	-1	0	-1	-1	-1	-1	0	-1
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	-1	-1	-1	-1	0	0	0	-1	-1	0
36	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
45	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	-1	-2	-1	-1	-1	-1	-1	-1	-2	-2	-1	-1	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	0	-1	-1	-1	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	-1	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	0	0	-1	-1	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-2	-2	-2	-2	-2	-2	-1
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1

Figure 2-24. An example of the difference image between TM data processed using two different calibration options. Compare with Figures 2-15 and 2-24.

LANDSAT-4 TM — CCT-AT — NOMINAL MINUS IC — BAND 5

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3002, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	1	-1	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	-1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
43	0	-1	0	-1	-1	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	0	-1	-1	-1	-1
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	1	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	1	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 2-25. An example of the difference image between TM data processed using two different calibration options.

BAND-AVERAGE COMPARISON OF DIFFERENT CALIBRATION METHODS

LANDSAT-4 TM — CCT-AT — NOMINAL MINUS IC HISTOGRAMS
MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001 NL = 1024
NS = 1024
SCROUNGE ERA (1982-1983)

LEAST VALUE	FRACTION	BAND
−3	.000001	
−2	.000564	
−1	.331877	1
0	.666902	
1	.000657	
−3	.000001	
−2	.000025	
−1	.140252	2
0	.845494	
1	.014228	
−2	.000001	
−1	.159622	
0	.834955	3
1	.005421	
2	.000657	
0	.083167	
1	.864659	4
2	.052174	
1	.037438	
0	.912251	5
1	.050310	
0	1.000000	6
−2	.000899	
−1	.231982	
0	.702545	
1	.063312	7
2	.001261	
3	.000000	
4	.000000	
5	.000000	
6	.000001	

HISTOGRAM

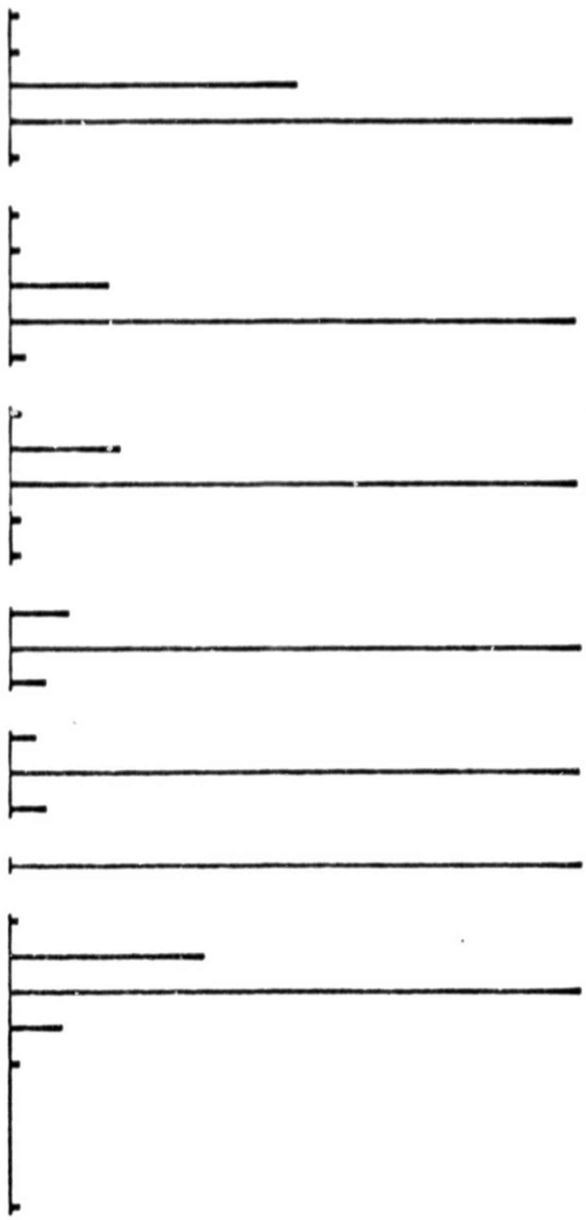

Figure 2-26. Histograms showing the frequency of differences between images produced by two different TM calibration options. Compare with Figures 2-22 to 2-25.

CHANNEL SPECIFIC COMPARISON OF DIFFERENT CALIBRATION METHODS
LANDSAT-4 TM — CCT-AT

BAND 7 NOMINAL — BAND 7 IC
MEMPHIS (ID = 40037-16033) 22 AUG 1982
SL = 3001, SS = 2001, NL = 64, NS = 1024

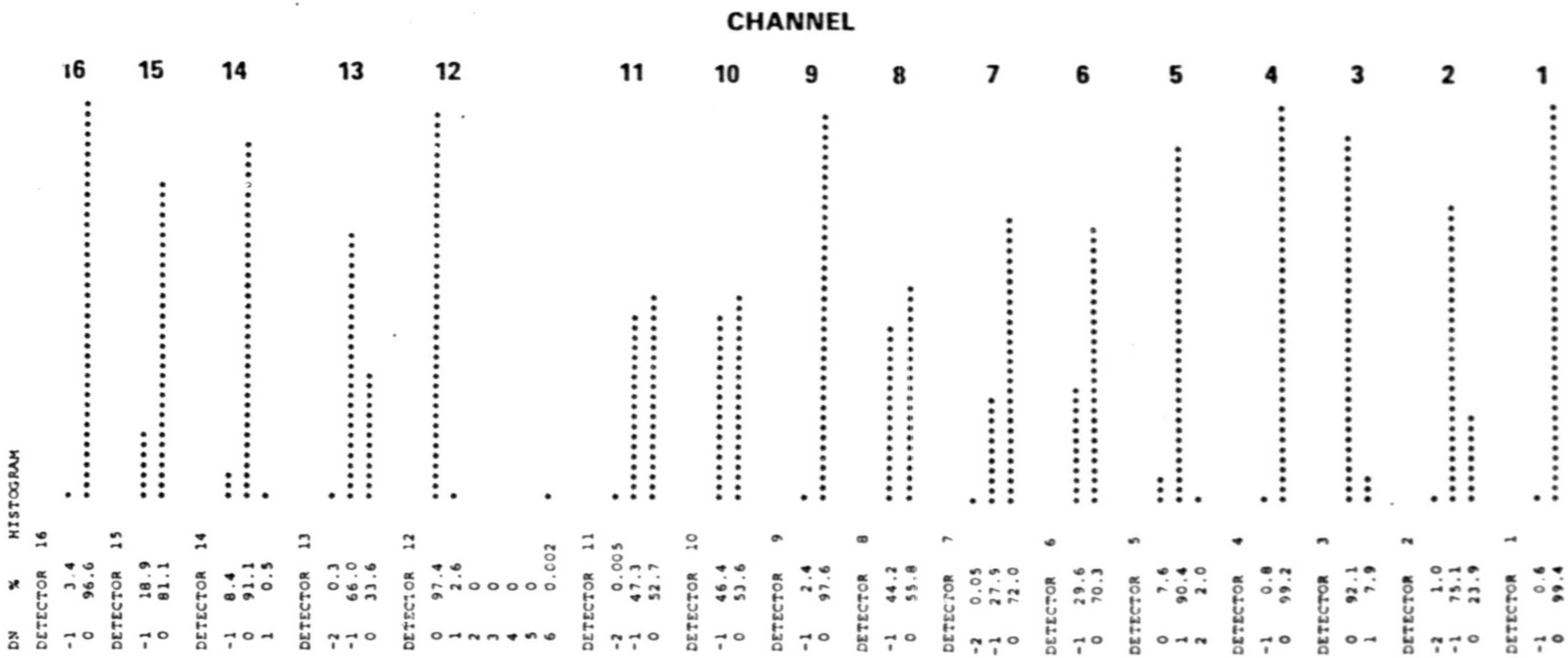

Figure 2-27. Histograms for each channel showing the different frequency of differences between band-7 images produced by two different calibration options. Compare with Figure 2-26.

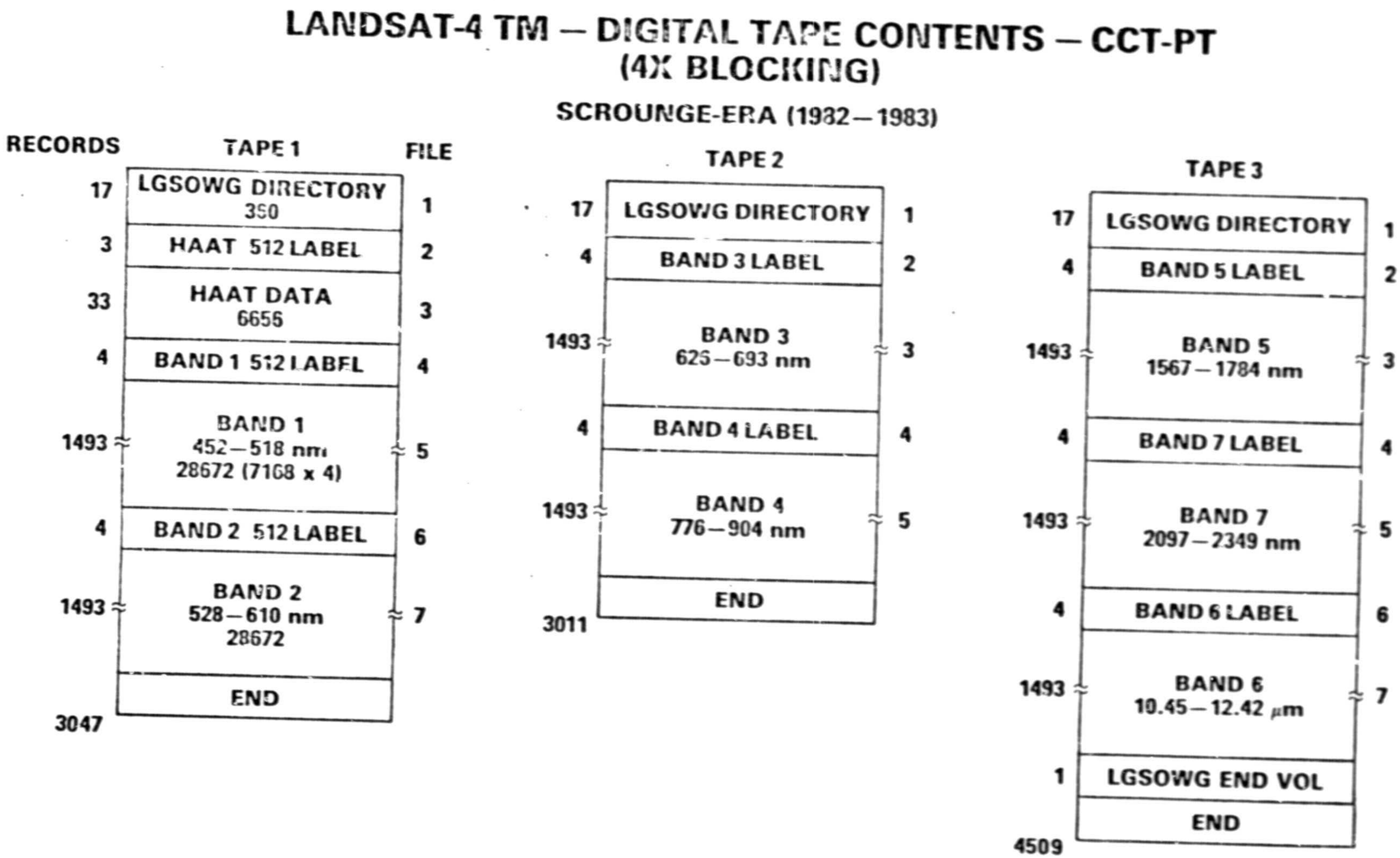

Figure 2-28. File organization of TM data and images on the three CCT-PT tapes produced by LAS as final products.

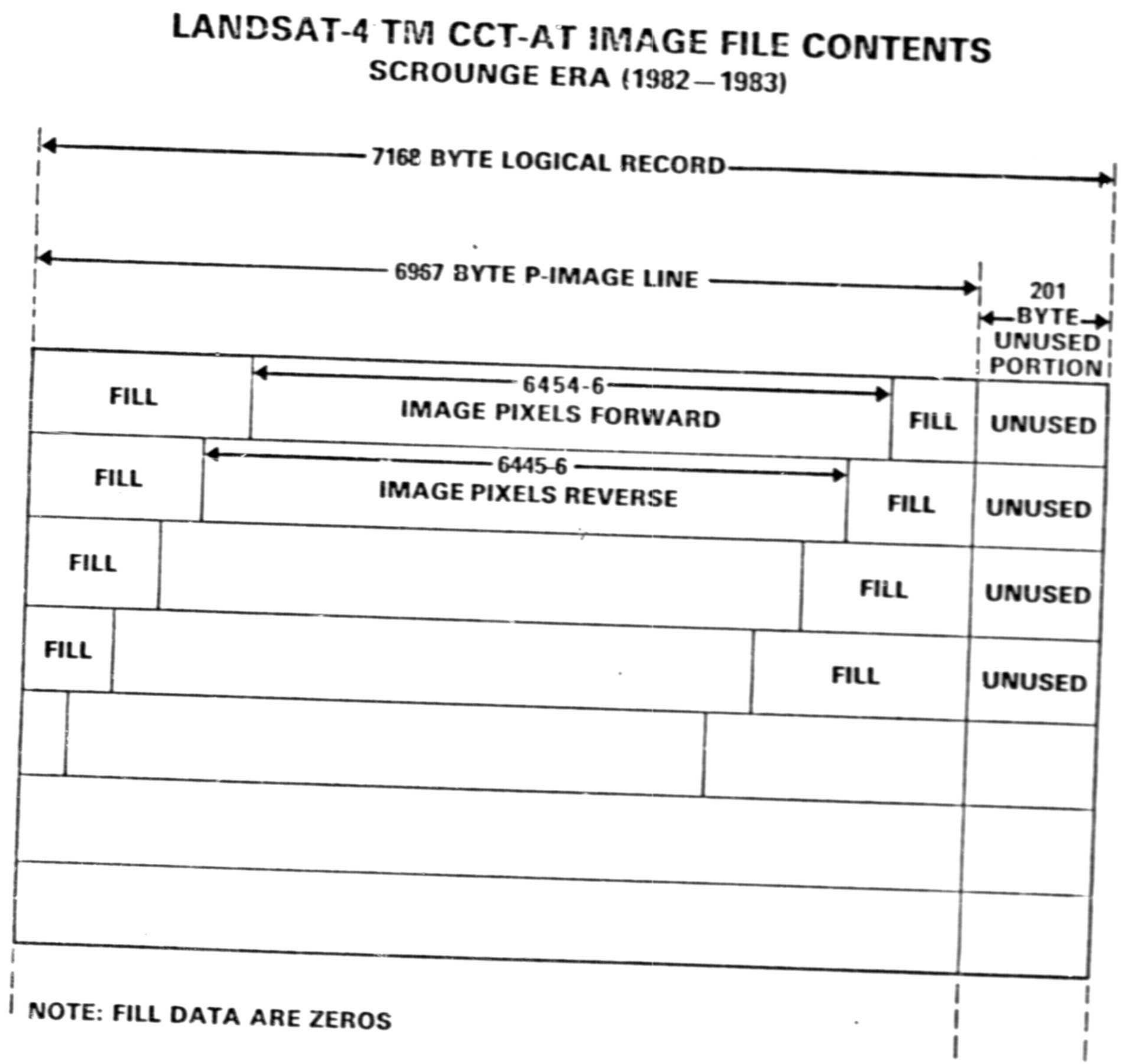

Figure 2-29. Image file contents of Landsat-4 TM data in CCT-AT format.

LANDSAT-4 TM APPARENT SPECULAR REFLECTANCE

DETROIT 2 (ID = 40009 -15413) 25 JULY 1982
SL = 1   SS = 1601

CCT.BT.DETROIT2.40009.15413.MK
SL = 1059 SS = 661 NL = 15 NS = 15 BAND = 1

VALUES OF IMAGE FROM FUNCTION PICPRINT

SAMPLE LINE	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675
1059	83	87	85	87	88	91	91	82	80	81	79	79	78	81	78
1060	83	83	86	87	87	93	90	82	80	81	80	78	81	80	81
1061	82	80	86	89	86	92	91	81	86	80	80	80	78	78	78
1062	81	82	87	88	90	99	103	102	89	84	81	80	81	81	77
1063	82	80	80	89	93	104	137	197	197	138	83	81	82	78	78
1064	80	81	85	90	94	114	143	218	134	96	82	80	78	79	80
1065	82	81	82	91	99	123	137	234	142	78	84	79	80	77	78
1066	82	83	90	103	113	136	157	173	119	77	82	79	76	81	79
1067	81	86	90	98	117	123	123	118	103	79	81	78	80	81	77
1068	81	81	82	77	83	88	94	102	193	172	113	86	81	82	84
1069	81	82	81	82	86	95	92	101	107	115	90	80	81	79	80
1070	82	81	79	83	89	87	90	96	101	104	82	81	83	80	78
1071	83	85	87	88	89	89	90	86	86	87	82	83	83	81	83
1072	84	87	88	86	85	85	90	98	95	94	93	93	94	91	89
1073	87	91	90	87	81	87	94	95	93	90	93	93	89	90	90

CCT.BT.DETROIT2.40009.15413.MK
SL = 1059 SS = 661 NL = 15 NS = 15 BAND = 3

VALUES OF IMAGE FROM FUNCTION PICPRINT

SAMPLE LINE	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675
1059	37	40	42	44	43	44	42	29	29	29	29	27	27	27	27
1060	33	36	43	44	43	45	42	30	29	28	27	27	27	27	27
1061	29	33	45	45	44	46	41	30	29	29	27	28	27	28	27
1062	29	33	45	49	46	49	53	33	36	31	28	28	27	27	27
1063	29	29	41	46	49	55	84	110	117	88	32	29	27	28	35
1064	29	29	38	46	49	60	86	179	98	40	30	27	27	26	26
1065	29	29	33	44	31	72	83	211	80	29	30	28	28	27	27
1066	29	31	39	39	63	76	91	103	63	32	30	27	28	27	26
1067	32	34	43	30	60	77	73	63	46	29	29	27	27	29	28
1068	29	29	29	29	31	39	43	33	132	106	61	32	29	26	27
1069	29	30	31	31	34	41	47	49	39	63	39	29	28	27	37
1070	31	31	33	33	43	44	43	36	32	39	33	29	29	28	29
1071	31	34	38	43	43	43	43	38	38	37	33	33	32	32	33
1072	38	41	41	40	38	37	41	31	31	31	30	49	49	46	44
1073	41	46	43	37	34	37	46	30	45	45	47	43	43	43	45

CCT.BT.DETROIT2.40009.15413.MK
SL = 1059 SS = 661 NL = 15 NS = 15 BAND = 2

VALUES OF IMAGE FROM FUNCTION PICPRINT

SAMPLE LINE	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675
1059	38	37	39	39	40	41	42	34	33	34	33	32	33	33	32
1060	37	36	39	40	40	41	41	33	34	32	32	32	33	32	32
1061	34	34	40	40	40	41	40	34	34	34	33	33	33	32	33
1062	33	35	41	42	42	44	47	48	38	36	36	34	33	33	31
1063	34	34	39	41	42	48	66	100	101	79	37	33	33	32	32
1064	33	34	37	38	40	45	54	83	73	55	48	47	42	38	6
1065	33	33	35	40	44	58	68	131	73	33	33	30	32	30	32
1066	32	36	40	44	51	59	67	86	66	42	37	34	31	32	30
1067	35	36	40	45	55	68	59	57	46	34	34	34	33	34	34
1068	34	33	34	33	34	37	40	42	97	89	57	34	33	32	30
1069	35	34	35	35	37	41	42	46	51	56	41	38	33	33	33
1070	39	35	36	37	40	40	40	37	44	56	36	33	33	32	33
1071	36	36	38	41	42	40	41	37	38	38	36	34	35	35	35
1072	38	38	38	[illegible]	37	37	38	41	41	42	42	42	41	40	38
1073	40	41	42	37	36	37	42	43	41	41	42	41	41	40	40

CCT.BT.DETROIT2.40009.15413.MK
SL = 1059 SS = 661 NL = 15 NS = 15 BAND = 4

VALUES OF IMAGE FROM FUNCTION PICPRINT

SAMPLE LINE	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675
1059	108	93	83	84	86	84	86	113	117	118	125	130	130	121	118
1060	106	93	83	84	83	86	90	114	116	119	127	126	122	117	116
1061	107	104	83	81	83	82	94	111	116	122	125	126	121	119	117
1062	114	109	90	81	84	86	91	108	122	125	121	120	119	116	117
1063	116	114	93	82	82	77	90	112	117	119	109	119	116	117	117
1064	116	117	100	81	81	74	82	192	121	101	108	119	117	117	117
1065	117	119	108	86	83	82	97	224	124	112	126	124	118	119	116
1066	113	116	102	96	81	75	82	99	118	112	124	121	113	114	113
1067	111	105	86	92	83	84	82	86	116	115	124	119	115	118	113
1068	113	113	110	110	110	93	91	76	138	102	91	109	114	119	117
1069	109	109	112	103	98	94	88	70	74	83	103	109	114	121	116
1070	110	109	106	101	90	89	89	82	86	87	108	116	112	110	107
1071	106	99	94	98	86	85	90	86	102	102	101	101	100	101	100
1072	95	89	91	97	100	102	87	72	74	77	72	71	78	69	73
1073	98	91	97	107	114	100	76	69	68	77	72	74	77	73	69

Figure 3-1. An example of spectral reflectivity. The bright pixel is located at relative line number 1065 and sample number 668.

LANDSAT-4 TM-INTERBAND REGISTRATION

PFP

5 x 5 CELL

CCT-BT DETROIT 1

BAND	CENTER	
	l = 2870	s = 1788
1	3.092	2.958
2	3.123	2.933
3	3.155	2.911
4	3.016	3.191
B1—B4	−0.076	0.233

CCT-BT DETROIT 2

BAND	CENTER	
	l = 1065	s = 1768
1	3.088	2.901
2	3.096	2.887
3	3.163	2.767
4	2.946	3.250
B1—B4	0.142	−0.349

Figure 3-2. Interband registration for the primary focal plane.

LANDSAT-4 TM — INTERBAND REGISTRATION — CCT-AT

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
APPARENT SPECULAR-REFLECTANCE PIXEL
LINE = 3342, SAMPLE = 2519

7 x 7 CELL

PRIMARY FOCAL PLANE

BAND	CENTER	
	LINE	SAMPLE
1	3.898	3.887
2	3.999	3.954
3	3.821	3.946
4	4.272	4.034
1—4	—0.374	—0.147

COLD FOCAL PLANE

BAND	CENTER	
	LINE	SAMPLE
5	4.077	4.166
7	3.939	4.215
5—7	0.138	—0.049
1—5	—0.179	—0.279

Figure 3-3. Interband registration for a 7-band TM image.

ORIGINAL PAGE IS
OF POOR QUALITY

LANDSAT-4 TM—CCT-AT—EMPTY BINS CHANNEL 1 HISTOGRAM

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982

SL = 3001 NL = 63
SS = 2001 NS = 1024

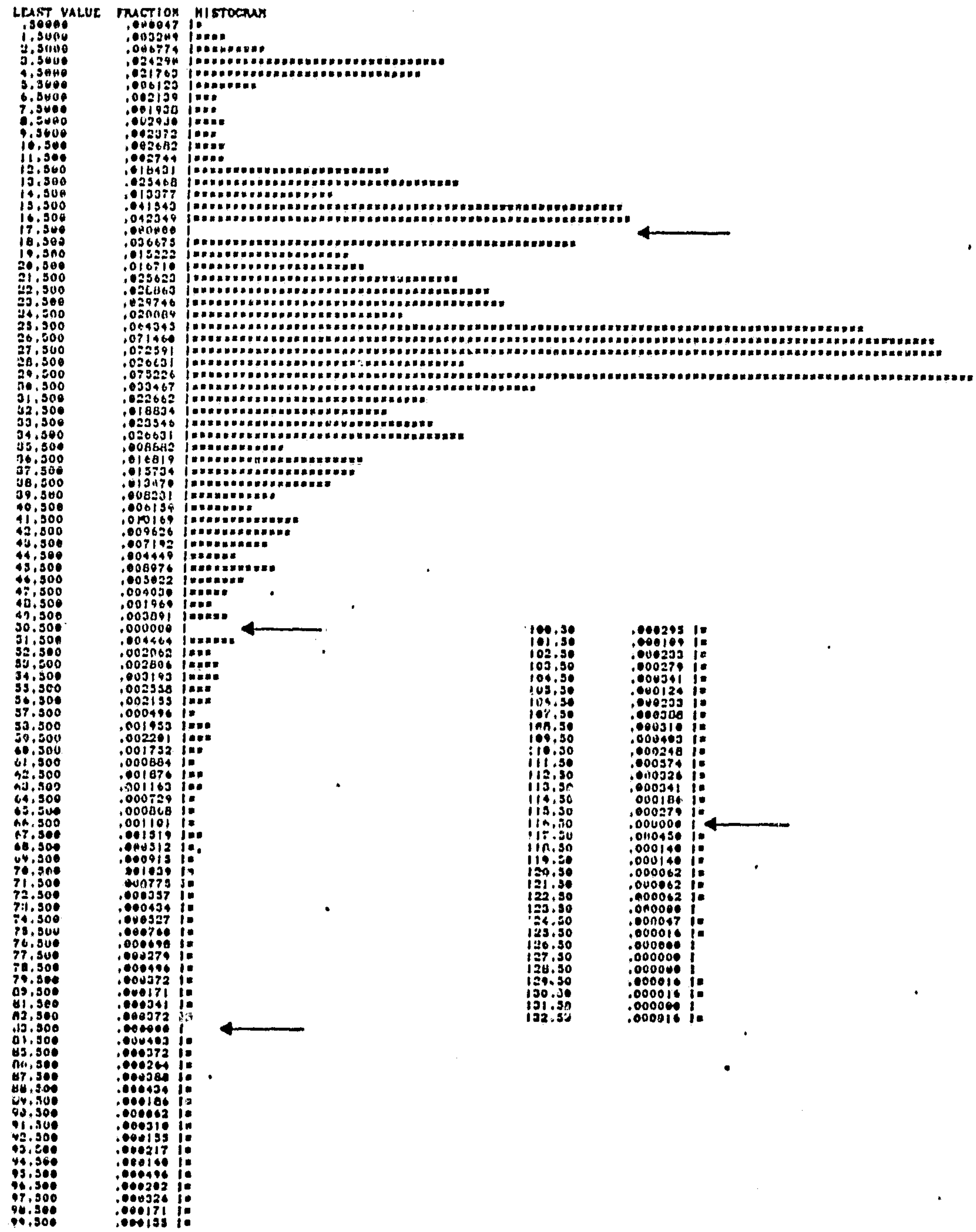

Figure 3-4. An example of a histogram for one data channel showing empty bins at DN values of 18, 51, 84, & 117.

LANDSAT-4 THEMATIC MAPPER
CCT-AT EMPLY BINS

MEMPHIS TN (ID = 40037—16033) 22 AUG 1982
EXAMPLE USING DETECTOR1

BAND	OBSERVED EMPTY BINS	PERIOD
1	79, 132	53
2	29, 74	45
3	39, 94	55
4	39, 117	78
5	47, 99, 151	52
6	—	—
7	18, 51, 84, 117	33

Figure 3-5. An example of empty bin locations and periodicity for data from detector 1, all 7 TM spectral bands.