General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

TM DIGITAL IMAGE PRODUCTS FOR APPLICATIONS
(SUMMARY)

JOHN L. BARKER
NASA/GODDARD SPACE FLIGHT CENTER

FRED J. GUNTHER
ROCHELLE B. ABRAMS
DAVE BALL
COMPUTER SCIENCES CORPORATION

KEYWORDS: Remote Sensing, Landsat-4, Thematic Mapper, Digital Image Processing, Radiometric Calibration, Geometric Resampling, Interband Registration, Computer Compatible Tapes (CCT), Formats of Tapes, CCT-BT, CCT-AT, CCT-PT, Channel-Correlated Shifts, SCROUNGE-era, TIPS, RLUT (Radiometric Look-Up Table)

Landsat-4 Thematic Mapper (TM) digital image products recorded onto computer compatible tapes (CCTs), which were available for internal research purposes during the SCROUNGE-era processing prior to August, 1983, are reviewed. They were generated by the SCROUNGE image processing system of the Landsat-4 Assessment System (LAS) facility of the National Aeronautics and Space Administration (NASA) at Goddard Space Flight Center (GSFC) in the tape formats: 1) Raw band-sequential data (CCT-BT), generally used for internal transportation of digital data from one ground processing system to another; 2) Calibrated data (CCT-AT), useful for researchers doing radiometric characterization; 3) Geometrically resampled data (CCT-PT), the final product. The formats represent different steps in the process of producing fully-corrected TM data (Table 1). CCT-BT images are re-sequenced from telemetry format to image format, but are uncorrected radiometrically and geometrically. CCT-AT images have had data from two faulty data channels replaced and all data radiometrically calibrated. CCT-PT images have been resampled by cubic convolution procedures to provide a geometrically corrected image using satellite ephemeris and altitude data and scan-mirror correction data. The final product, the CCT-PT, is the one to which all of the radiometric and geometric corrections have been

applied; this is the product that is available to users, who may purchase the set of tapes from NOAA at the EROS Data Center (EDC) in Sioux Falls, SD.

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 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. Some other characteristics of the tapes are summarized in Table 1.

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. Production of the CCT-PT involves two sequential steps of geometric resampling to produce 28.5m IFOV pixels.

Image processing artifacts are present in both CCT-AT and CCT-PT products. Application of Radiometric Look-Up Table (RLUT) during radiometric calibration produces discontinuities in the histograms as a result of skipping some gray levels or digital numbers (DN). RLUTs are chosen to cause expansion of original raw data so that it can be recovered by removing the interspersed "empty bins" in CCT-AT digital images. This empty-bin artifact is smoothed over by cubic convolution resampling. However, resampling produces a new artifact when image data and zero-fill data are convolved at the east and west edges of the geocorrected image to produce "fuzzy frame edges."

Channel and scan striping are evident in images in all three image formats. Channel striping in CCT-BT arises from the difficulties in making sensors exactly alike and in CCT-AT images from imperfect radiometric calibration. Scan striping apparently arises from random resetting of the offset to one of two reference states at the start of each scan. It is referred to here as a "channel-correlated shift" since all channels within a band shift at the same time even though the magnitude of their shifts differ. Channels 4, 8, 10 and 12 of Band 1 and Channel 7 of band 7 are the channels

with the largest shifts of between 1 and 2 digital numbers (DN). Cubic convolution resampling to produce the CCT-PT reduces the visual impact of all striping. If resampling was performed to a north oriented column, it would reduce the apparent striping even further, as well as provide a more map-compatible product.

Saturated or very bright isolated pixels in all bands result from apparent specular reflection of small objects on the ground. These 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. The higher spatial resolution of 30m TM imagery as compared to 80m Multispectral Scanner (MSS) imagery has resulted in a dramatic increase in pixels with apparent specular reflection. Higher resolution sensors can expect to see even more specular reflection, especially from man-made objects. New information extraction techniques are needed to utilize these new radiometrically discontinuous data.

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.

TABLE 1

General Comparisons among Landsat-4 Thematic Mapper Digital Products.

CCT SCROUNGE-ERA FORMATS (prior to August 1983)
LANDSAT-4 TM DIGITAL TAPES

	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