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# LANDSAT-D

# DATA FORMAT CONTROL BOOK



# VOLUME VI

# (PRODUCTS)

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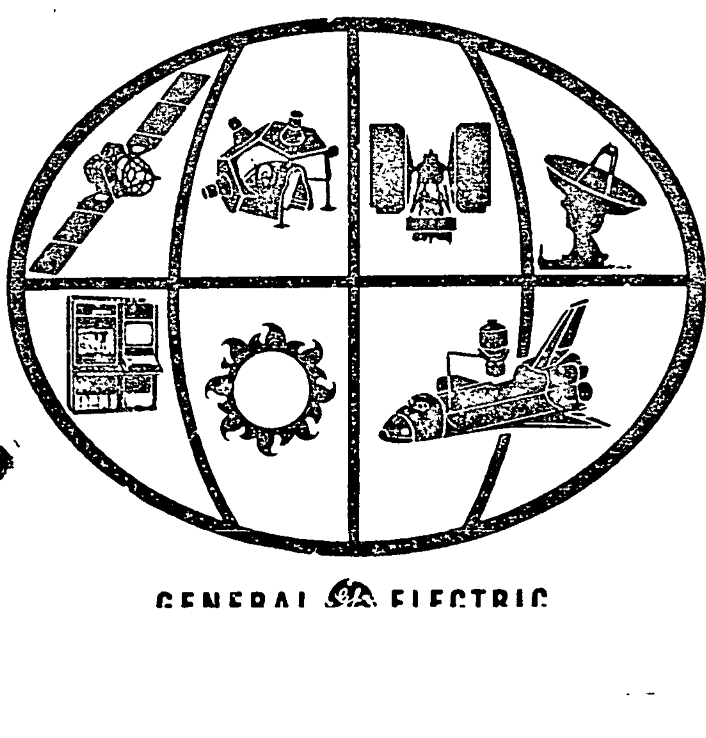

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LANDSAT-D

DATA FORMAT CONTROL BOOK

VOLUME VI (PRODUCTS)

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GODDARD SPACE FLIGHT CENTER

GREENBELT, MARYLAND

UNDER

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REVISION LOG

This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

| Revision | Page No. | Para. No. Affected | Rev. Date |
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|---|---|---|
| 3.2 | Radiometric Correction Using Internal Calibration Data | 10/81 |

# SECTION 1

# INTRODUCTION

## 1.1 PRODUCT OVERVIEW

The NASA GSFC Landsat-D Data Management System (DMS) generates a variety of standard image products from the raw thematic mapper (TM) and multispectral scanner (MSS) payload data. The image processing functions performed by the DMS include: screening imagery for quality, determining cloud cover, applying radiometric corrections, determining geometric correction information, and applying geometric corrections. Among the outputs from the DMS are HDT, CCT and 241 mm film media products. Detailed descriptions of the format of each product are given in Appendixes A through K of this document (published under separate covers).

This document derives its requirements from GSFC 430-D-100, GSFC Specification for the Landsat-D System.

## 1.2 PRODUCT TYPES

There are four basic product types:

a. Unprocessed data, which consists of raw sensor data

b. Partially processed data, which consists of radiometrically corrected sensor data with geometric correction information appended

c. Fully processed data, which consists of radiometrically and geometrically corrected sensor data

d. Inventory data, which consists of summary information about product types b. and c. (above).

Figure 1.2-1 shows all Landsat-D/D Prime products, in the form of a matrix of product type vs. media and sensor. Inventory data are always associated with

| MEDIA | SENSOR | PRODUCT TYPE | | |
|---|---|---|---|---|
| | | UNPROCESSED (RAW) | PARTIALLY PROCESSED | FULLY CORRECTED |
| HDT | MSS | HDT-RM/GM | HDT-AM (GHIT-AM)* | —— |
| | TM | HDT-RT | HDT-AT (GHIT-AT) | HDT-PT (GHIT-PT) |
| CCT | MSS | —— | —— | —— |
| | TM | —— | CCT-AT | CCT-PT |
| 241MM FILM | MSS | —— | —— | —— |
| | TM | —— | —— | F241-PT (GFIT) |

*INVENTORY PRODUCTS ARE INDICATED IN PARENTHESIS

Figure 1.2-1. Landsat D/D Prime Product Matrix one of the other product types, in particular partially processed and fully corrected HDTs and film

The following paragraphs discuss each of the four product types. Section 2 gives the details of HDT internal format; a discussion of the radiometric correction process is given in Section 3, and of the geometric correction information in Section 4.

### 1.2.1 UNPROCESSED DATA

The format of the MSS and TM sensor data is given in Data Format Control Book, Volume V: Payload. Unprocessed MSS data is recorded on 14- or 28-track high density tapes (HDT), and unprocessed TM data is recorded on 28-track HDTs. The MSS HDTs recorded within the DMS are called HDT-RM (always 28-track), while those MSS HDT recorded outside and transferred to the DMS are called HDT-GM (always 14-track) (reference Appendix K). The TM HDTs are all recorded within the DMS and are called HDT-RT (reference Appendix J).

### 1.2.2 PARTIALLY PROCESSED DATA

Partially processed products are generated on CCT and HDT for TM data and on HDT for MSS data. They are created by reformatting and radiometrically correcting the unprocessed sensor data and appending geometric correction information for two map projections (SOM and either UTM or Polar Stereographic). The MSS product, recorded on both 14- and 28-track HDTs, is called HDT-AM (reference Appendix C). The TM products are called HDT-AT (reference Appendix A), recorded on 28-track HDTs, and CCT-AT (reference Appendix D), recorded on 1600 or 6250 bpi CCTs. A product HDT normally contains many scenes; however, the CCT product is generated on an individual scene basis (requiring multiple tape reels).

### 1.2.3 FULLY CORRECTED DATA

A full range of fully corrected TM products (HDT, CCT, 241 mm film) are generated within the DMS. These products consist of sensor data in a selected map projection that has been both radiometrically and geometrically corrected. The geometric correction is performed by resampling (using 4 x 4 cubic convolution or nearest neighbor technique) the radiometrically corrected image data onto a predefined map grid using geometric correction information which has been appended to the partially processed product (HDT or CCT).

The fully corrected TM products are called HDT-PT (reference Appendix B), CCT-PT (reference Appendix D), and F241-PT (reference Appendix I). This HDT product is recorded on 28-track tape, the CCT product can be recorded on either 1600 or 6250 bpi 9-track tape. There are no fully corrected MSS products.

### 1.2.4 INVENTORY DATA

Inventory products consist of summary information on computer compatible tapes. Four of the previously discussed products have associated inventory products: the HDT-AM inventory tape is called a GHIT-AM (reference Appendix G), the HDT-AT inventory tape is called a GHIT-AT (reference Appendix F), the HDT-PT inventory tape is called a GHIT-PT (reference Appendix E), and the F241-PT inventory tape is called a GFIT (reference Appendix H).

# SECTION 2

# HDDR FORMATTING

## 2.1 GENERAL DISCUSSION

In this section the formatting performed by the Martin Marietta/Honeywell Model No. 2879-L 28 - track high density digital recorders (HDDR) and by the Model No. 1479-L 14 - track high density digital recorders when placing data onto high density tapes (HDT) is discussed. The major formatting functions, in the basic order of occurrence, are: demultiplexing, track assignment, framing, randomizing, bit inversion, error correction coding, digital coding, time coding, and packing. Each of these functions is described in the following paragraphs. The formatting is the same for all types of data (MSS, TM, uncorrected, partially processed, fully corrected. The only differences in the formatting performed by 14-track and 28-track recorders are in demultiplexing, track assignment, packing, and in the use of bit inversion.

Before reaching the HDDR the data has already been converted into a serial bit stream with sync words, etc., embedded. There is no synchronization between the contents of the serial bit stream and any of the HDDR formatting functions. The recording HDDR is not aware of the contents of the input bit stream, the reading HDDR only recognizes the information added by the recording HDDR.

## 2.2 DEMULTIPLEXING

The input serial bit stream is taken one bit at a time and allocated to one of 24 data channels for a 28-track HDDR or to one of ten data channels for a 14-track HDDR. The allocation for a 28-track HDDR is shown in Table 2.2-1. The allocation for a 14-track HDDR is shown in Table 2.2-2.

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Table 2.2-1. 28-Track HDDR Demultiplexing Scheme

| INPUT BIT STREAM BIT ORDER | ASSIGNED DATA CHANNEL | INPUT BIT STREAM BIT ORDER | ASSIGNED DATA CHANNEL |
|---|---|---|---|
| 1 | 10 | 17 | 17 |
| 2 | 9 | 18 | 18 |
| 3 | 8 | 19 | 19 |
| 4 | 7 | 20 | 20 |
| 5 | 6 | 21 | 21 |
| 6 | 5 | 22 | 22 |
| 7 | 4 | 23 | 23 |
| 8 | 3 | 24 | 24 |
| 9 | 2 | 25 | 10 |
| 10 | 1 | 26 | 9 |
| 11 | 11 | 27 | 8 |
| 12 | 12 | 28 | 7 |
| 13 | 13 | – | – |
| 14 | 14 | – | – |
| 15 | 15 | – | – |
| 16 | 16 | – | – |

Table 2.2-2. 14-Track HDDR Demultiplexing Scheme

| INPUT BIT STEAM BIT ORDER | ASSIGNED DATA CHANNEL |
|---|---|
| 1 | 10 |
| 2 | 9 |
| 3 | 8 |
| 4 | 7 |
| 5 | 6 |
| 6 | 5 |
| 7 | 4 |
| 8 | 3 |
| 9 | 2 |
| 10 | 1 |
| 11 | 10 |
| 12 | 9 |
| 13 | 8 |
| 14 | 7 |
| • | • |
| • | • |
| • | • |
| • | • |
| • | • |
| • | • |

## 2.3 TRACK ASSIGNMENT

Each data channel is assigned to a track on the HDDR.

Tables 2.3-1 and 2.3-2 give the track assignments for 14- and 28-track HDDRs, respectively. The outside tracks are reserved for IRIG-A time code and NASA 36-bit time code, discussed further in paragraph 2.10. The error correction channels are discussed in paragraph 2.7.

## 2.4 FRAMING

The digital data assigned to each data track is divided into frames. Each frame contains 504 bits as shown in Figure 2.4-1. There are 420 input data bits per frame plus parity information, error correction code and synchronization code. The 420 data bits are divided into 60 seven-bit words; each of these words has a parity bit appended. The error correction information and the synchronization word occupy the last 24 bits of the frame. The 12-bit synchronization word is used to align data from the various tracks when reading data from the tape. The synchronization word contains the binary pattern 001100010000 ($310_{16}$). The last 12 bits in a frame contain the synchronization word, and are preceded by 12 bits which contain the error correction information, discussed in paragraph 2.7.

## 2.5 RANDOMIZING

Pseudo random data modulation is added to the data stream to lower the bit error rate. Table 2.5-1 gives the precise pseudo random sequence that is used to

Table 2.3-1. 14-Track HDDR Track Assignments

| TRACK NO. | USE |
|---|---|
| 1 | ANALOG-IRIG-A TIME CODE |
| 2 | DIGITAL-ERROR CORRECTION CHANNEL A (DIGITAL-CHANNEL 12) |
| 3 | DIGITAL-CHANNEL 1 |
| 4 | DIGITAL-CHANNEL 2 |
| 5 | DIGITAL-CHANNEL 3 |
| 6 | DIGITAL-CHANNEL 4 |
| 7 | DIGITAL-CHANNEL 5 |
| 8 | DIGITAL-CHANNEL 6 |
| 9 | DIGITAL-CHANNEL 7 |
| 10 | DIGITAL-CHANNEL 8 |
| 11 | DIGITAL-CHANNEL 9 |
| 12 | DIGITAL-CHANNEL 10 |
| 13 | ANALOG-AUXILIARY TRACK |
| 14 | ANALOG-NASA 36 TIME CODE |

Table 2.3-2. 28-Track HDDR Track Assignments

| TRACK NO. | |
|---|---|
| 1 | ANALOG-IRIG A TIME CODE |
| 2 | DIGITAL-CHANNEL ERROR CORRECTION B (CH 26) |
| 3 | DIGITAL-CHANNEL 12 |
| 4 | DIGITAL-CHANNEL 24 |
| 5 | DIGITAL-CHANNEL 2 |
| 6 | DIGITAL-CHANNEL 22 |
| 7 | DIGITAL-CHANNEL 4 |
| 8 | DIGITAL-CHANNEL 20 |
| 9 | DIGITAL-CHANNEL 7 |
| 10 | DIGITAL-CHANNEL 18 |
| 11 | DIGITAL-CHANNEL 5 |
| 12 | DIGITAL-CHANNEL 16 |
| 13 | DIGITAL-CHANNEL 3 |
| 14 | DIGITAL-CHANNEL 14 |
| 15 | DIGITAL-CHANNEL 1 |
| 16 | DIGITAL-CHANNEL 15 |
| 17 | DIGITAL-CHANNEL 6 |
| 18 | DIGITAL-CHANNEL 17 |
| 19 | DIGITAL-CHANNEL 8 |
| 20 | DIGITAL-CHANNEL 19 |
| 21 | DIGITAL-CHANNEL 9 |
| 22 | DIGITAL-CHANNEL 21 |
| 23 | DIGITAL-CHANNEL 11 |
| 24 | DIGITAL-CHANNEL 23 |
| 25 | DIGITAL-CHANNEL 10 |
| 26 | DIGITAL-CHANNEL ERROR CORRECTION A (CH 25) |
| 27 | DIGITAL-CHANNEL 13 |
| 28 | ANALOG-NASA 36 TIME CODE |

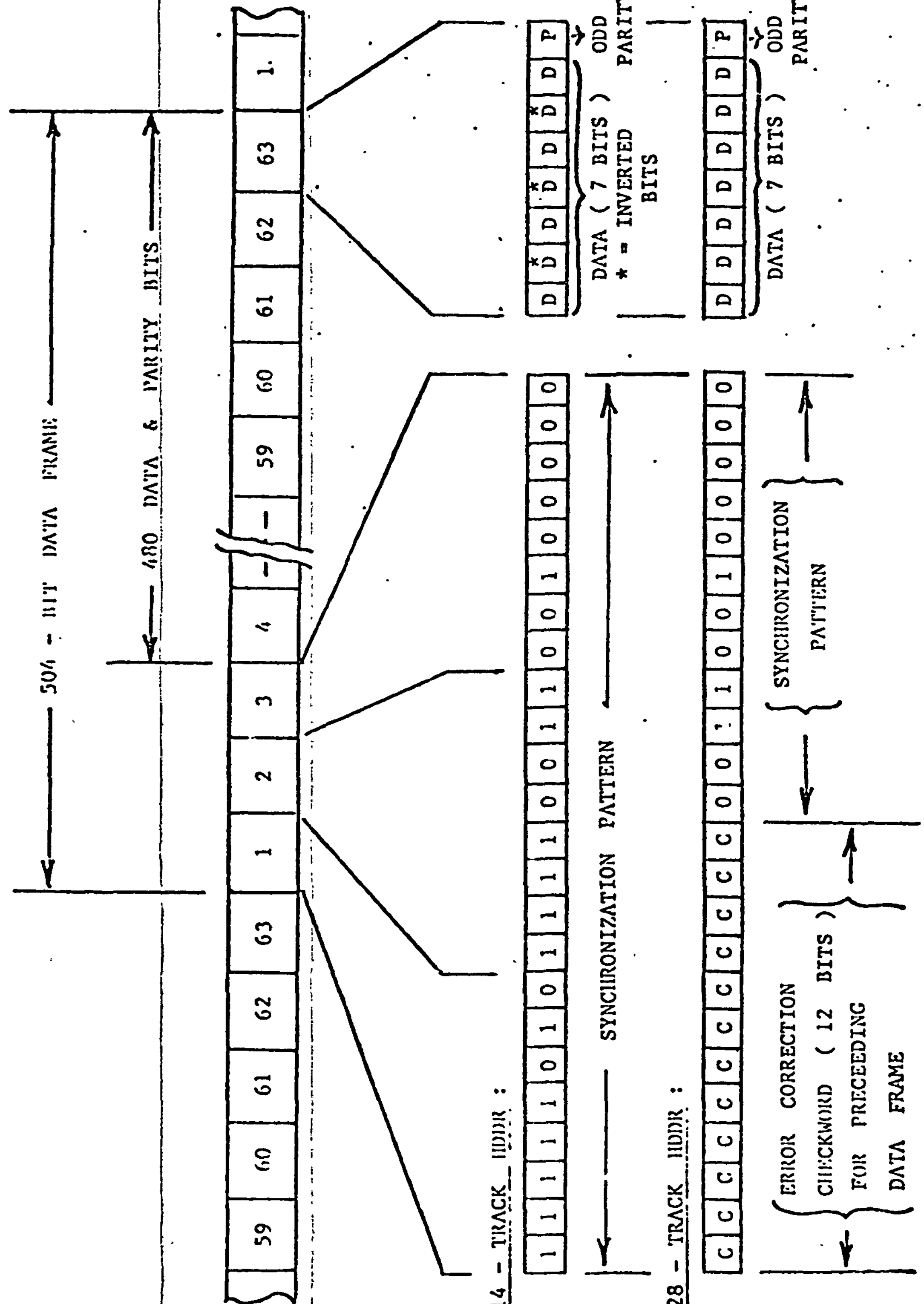


Figure 2.4-1. High Density Recording Frame Format

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Table 2.5-1. Randomization Code

| INPUT DATA BIT # | PRN CODE BIT | INPUT DATA BIT # | PRN CODE BIT | INPUT DATA BIT # | PRN CODE BIT |
|---|---|---|---|---|---|
| 1 | 1 | 32 | 0 | 63 | 0 |
| 2 | 0 | 33 | 0 | 64 | 1 |
| 3 | 0 | 34 | 1 | 65 | 1 |
| 4 | 0 | 35 | 1 | 66 | 0 |
| 5 | 0 | 36 | 1 | 67 | 1 |
| 6 | 1 | 37 | 1 | 68 | 1 |
| 7 | 0 | 38 | 0 | 69 | 1 |
| 8 | 0 | 39 | 0 | 70 | 1 |
| 9 | 0 | 40 | 1 | 71 | 1 |
| 10 | 0 | 41 | 0 | 72 | 1 |
| 11 | 0 | 42 | 0 | 73 | 1 |
| 12 | 1 | 43 | 1 | 74 | 0 |
| 13 | 1 | 44 | 1 | 75 | 0 |
| 14 | 0 | 45 | 0 | 76 | 0 |
| 15 | 0 | 46 | 1 | 77 | 0 |
| 16 | 0 | 47 | 1 | 78 | 0 |
| 17 | 0 | 48 | 0 | 79 | 0 |
| 18 | 1 | 49 | 1 | 80 | 1 |
| 19 | 0 | 50 | 1 | 81 | 0 |
| 20 | 0 | 51 | 1 | 82 | 0 |
| 21 | 0 | 52 | 1 | 83 | 0 |
| 22 | 0 | 53 | 0 | 84 | 0 |
| 23 | 0 | 54 | 1 | 85 | 1 |
| 24 | 1 | 55 | 1 | 86 | 1 |
| 25 | 1 | 56 | 0 | 87 | 1 |
| 26 | 1 | 57 | 0 | 88 | 0 |
| 27 | 1 | 58 | 0 | 89 | 0 |
| 28 | 0 | 59 | 1 | 90 | 0 |
| 29 | 1 | 60 | 1 | 91 | 1 |
| 30 | 1 | 61 | 0 | 92 | 0 |
| 31 | 0 | 62 | 1 | 93 | 0 |

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Table 2.5-1. Randomization Code (cont'd)

| INPUT DATA BIT # | PRN CODE BIT | INPUT DATA BIT # | PRN CODE BIT | INPUT DATA BIT # | PRN CODE BIT |
|---|---|---|---|---|---|
| 94 | 1 | 125 | 1 | 156 | 0 |
| 95 | 0 | 126 | 0 | 157 | 0 |
| 96 | 0 | 127 | 1 | 158 | 0 |
| 97 | 1 | 128 | 1 | 159 | 1 |
| 98 | 1 | 129 | 1 | 160 | 1 |
| 99 | 1 | 130 | 0 | 161 | 0 |
| 100 | 1 | 131 | 0 | 162 | 0 |
| 101 | 1 | 132 | 1 | 163 | 0 |
| 102 | 0 | 133 | 1 | 164 | 0 |
| 103 | 1 | 134 | 0 | 165 | 1 |
| 104 | 0 | 135 | 0 | 166 | 0 |
| 105 | 0 | 136 | 1 | 167 | 1 |
| 106 | 0 | 137 | 0 | 168 | 0 |
| 107 | 0 | 138 | 1 | 169 | 0 |
| 108 | 1 | 139 | 0 | 170 | 0 |
| 109 | 1 | 140 | 1 | 171 | 1 |
| 110 | 1 | 141 | 1 | 172 | 1 |
| 111 | 0 | 142 | 1 | 173 | 1 |
| 112 | 0 | 143 | 1 | 174 | 1 |
| 113 | 1 | 144 | 1 | 175 | 0 |
| 114 | 1 | 145 | 1 | 176 | 1 |
| 115 | 0 | 146 | 1 | 177 | 1 |
| 116 | 0 | 147 | 0 | 178 | 0 |
| 117 | 1 | 148 | 0 | 179 | 0 |
| 118 | 0 | 149 | 0 | 180 | 0 |
| 119 | 1 | 150 | 0 | 181 | 1 |
| 120 | 1 | 151 | 0 | 182 | 1 |
| 121 | 1 | 152 | 0 | 183 | 1 |
| 122 | 0 | 153 | 1 | 184 | 1 |
| 123 | 1 | 154 | 0 | 185 | 0 |
| 124 | 1 | 155 | 0 | 186 | 0 |

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Table 2.5-1. Randomization Code (cont'd)

| INPUT DATA BIT # | PRN CODE BIT | INPUT DATA BIT # | PRN CODE BIT | INPUT DATA BIT # | PRN CODE BIT |
|---|---|---|---|---|---|
| 187 | 1 | 219 | 1 | 251 | 0 |
| 188 | 0 | 220 | 1 | 252 | 0 |
| 189 | 0 | 221 | 0 | 253 | 0 |
| 190 | 1 | 222 | 0 | 254 | 0 |
| 191 | 1 | 223 | 0 | 255 | 1 |
| 192 | 0 | 224 | 0 | 256 | 1 |
| 193 | 1 | 225 | 0 | 257 | 1 |
| 194 | 1 | 226 | 0 | 258 | 0 |
| 195 | 0 | 227 | 1 | 259 | 0 |
| 196 | 1 | 228 | 0 | 260 | 1 |
| 197 | 1 | 229 | 0 | 261 | 1 |
| 198 | 1 | 230 | 0 | 262 | 0 |
| 199 | 1 | 231 | 0 | 263 | 0 |
| 200 | 0 | 232 | 1 | 264 | 1 |
| 201 | 1 | 233 | 1 | 265 | 0 |
| 202 | 1 | 234 | 1 | 266 | 1 |
| 203 | 0 | 235 | 0 | 267 | 1 |
| 204 | 0 | 236 | 0 | 268 | 1 |
| 205 | 0 | 237 | 0 | 269 | 0 |
| 206 | 1 | 238 | 1 | 270 | 1 |
| 207 | 1 | 239 | 0 | 271 | 1 |
| 208 | 0 | 240 | 0 | 272 | 1 |
| 209 | 1 | 241 | 1 | 273 | 0 |
| 210 | 0 | 242 | 0 | 274 | 0 |
| 211 | 1 | 243 | 0 | 275 | 1 |
| 212 | 1 | 244 | 1 | 276 | 1 |
| 213 | 0 | 245 | 1 | 277 | 0 |
| 214 | 1 | 246 | 1 | 278 | 0 |
| 215 | 1 | 247 | 1 | 279 | 1 |
| 216 | 1 | 248 | 1 | 280 | 1 |
| 217 | 1 | 249 | 0 | 281 | 0 |
| 218 | 1 | 250 | 1 | 282 | 0 |

Table 2.5-1. Randomization Code (cont'd)

| INPUT DATA BIT # | PRN CODE BIT | INPUT DATA BIT # | PRN CODE BIT | INPUT DATA BIT # | PRN CODE BIT |
|---|---|---|---|---|---|
| 283 | 1 | 316 | 0 | 349 | 1 |
| 284 | 0 | 317 | 0 | 350 | 0 |
| 285 | 1 | 318 | 1 | 351 | 0 |
| 286 | 0 | 319 | 1 | 352 | 0 |
| 287 | 1 | 320 | 1 | 353 | 1 |
| 288 | 1 | 321 | 1 | 354 | 1 |
| 289 | 1 | 322 | 0 | 355 | 0 |
| 290 | 1 | 323 | 1 | 356 | 1 |
| 291 | 1 | 324 | 1 | 357 | 0 |
| 292 | 1 | 325 | 0 | 358 | 1 |
| 293 | 1 | 326 | 0 | 359 | 1 |
| 294 | 0 | 327 | 0 | 360 | 0 |
| 295 | 0 | 328 | 1 | 361 | 1 |
| 296 | 0 | 329 | 1 | 362 | 1 |
| 297 | 0 | 330 | 1 | 363 | 1 |
| 298 | 0 | 331 | 1 | 364 | 1 |
| 299 | 0 | 332 | 0 | 365 | 1 |
| 300 | 1 | 333 | 0 | 366 | 1 |
| 301 | 0 | 334 | 1 | 367 | 1 |
| 302 | 0 | 335 | 0 | 368 | 0 |
| 303 | 0 | 336 | 0 | 368 | 0 |
| 304 | 0 | 337 | 1 | 370 | 0 |
| 305 | 0 | 338 | 1 | 371 | 0 |
| 306 | 1 | 339 | 0 | 372 | 0 |
| 307 | 1 | 340 | 1 | 373 | 0 |
| 308 | 0 | 341 | 1 | 374 | 1 |
| 309 | 0 | 342 | 0 | 375 | 0 |
| 310 | 0 | 343 | 1 | 376 | 0 |
| 311 | 0 | 344 | 1 | 377 | 0 |
| 312 | 1 | 345 | 1 | 378 | 0 |
| 313 | 0 | 346 | 1 | 379 | 1 |
| 314 | 1 | 347 | 0 | 380 | 1 |
| 315 | 0 | 348 | 1 | 381 | 1 |

Table 2.5-1. Randomization Code (cont'd)

| INPUT DATA BIT # | PRN CODE BIT | INPUT DATA BIT # | PRN CODE BIT |
|---|---|---|---|
| 382 | 0 | 413 | 1 |
| 383 | 0 | 414 | 1 |
| 384 | 0 | 415 | 1 |
| 385 | 1 | 416 | 0 |
| 386 | 0 | 417 | 1 |
| 387 | 0 | 418 | 1 |
| 388 | 1 | 419 | 1 |
| 389 | 0 | 420 | 0 |
| 390 | 0 | | |
| 391 | 1 | | |
| 392 | 1 | | |
| 393 | 1 | | |
| 394 | 1 | | |
| 395 | 1 | | |
| 396 | 0 | | |
| 397 | 1 | | |
| 398 | 0 | | |
| 399 | 0 | | |
| 400 | 0 | | |
| 401 | 0 | | |
| 402 | 1 | | |
| 403 | 1 | | |
| 404 | 1 | | |
| 405 | 0 | | |
| 406 | 0 | | |
| 407 | 1 | | |
| 408 | 1 | | |
| 409 | 0 | | |
| 410 | 0 | | |
| 411 | 1 | | |
| 412 | 0 | | |

modulate every data bit in every 504 bit frame. Parity bits, synchronization words, and error correction information are not modulated. Parity is added after data modulation and bit inversion. The modulation is an Exclusive OR function given by:

| DATA BIT | PSEUDO RANDOM BIT | ENCODED BIT BEFORE INVERSION |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

## 2.6 BIT INVERSION AND BYTE PARITY

In the 14-track format, bits 2, 4 and 6 within each seven-bit data word are inverted after modulation. This inversion is not included in the 28-track format. In both formats, odd parity is calculated for each data word and the parity bit is inserted immediately following the data word (see Figure 2.4-1).

## 2.7 ERROR CORRECTION CODING

In addition to the parity bits embedded in the data channels, two other error correction capabilities are inserted onto the tape: the 12-bit checkword at the end of each data frame, and the separate error correction tracks on the tape. As shown in Tables 2.3-1 and 2.3-2, there is one such track on a 14-track recorder and two tracks on the 28-track recorders. Each of these tracks contains longitudinal parity bits for a set of data tracks; the groupings for the 28-track recorders are given in Table 2.7-1; all ten data tracks on a 14-track recorder are covered by the one error correction track. These parity tracks are encoded the same as data tracks, with synchronization words, checkwords, bit inversion (in the 14-track format), randomizing, and odd parity inserted after each seven-bit longitudinal parity word. This longitudinal parity information is odd parity.

Table 2.7-1. Error Correction Track Groups for 28-Track HDDR

| | GROUP A | GROUP B |
|---|---|---|
| INCLUDES | | |
| DATA CHANNELS: | 2 | 1 |
| | 3 | 4 |
| | 5 | 6 |
| | 8 | 7 |
| | 9 | 13 |
| | 10 | 14 |
| | 11 | 15 |
| | 12 | 16 |
| | 17 | 22 |
| | 18 | 23 |
| | 19 | 24 |
| | 20 | |
| | 21 | |
| LONGITUDINAL PARITY CHANNEL: | 25 | 26 |

The checkword computed for each frame is used when reading the tape to detect the vast majority of errors, including error bursts. The checkword is also utilized, along with the embedded parity bits and the longitudinal parity information, to correct most of the detected errors. The basic principle is:

Each group of bits to be protected against errors is passed through a Modulo-2 divide network, which utilizes as a divisor the polynomial:

$$X^{12} + X^{11} + X^3 + X^2 + X + 1$$

and the 12-bit remainder which results is appended to the original group of bits. Thereafter, the complete data set (including the remainder bits) is again passed through the same divide network; any error condition will be indicated by a non-zero remainder at the completion of this process.

When an error condition is detected, the longitudinal parity information can be used to establish a check matrix across all recorded channels included in the error protection group. If more than one channel is in error, the byte parity information imbedded within the data frame can be used to identify the error. When the use of byte parity cannot isolate the error, the error condition is declared to be uncorrectable.

## 2.8 DIGITAL CODING

The serial digital data str for each track constructed in the above formatting steps is recorded on the tape in non-return to zero level (NRZ-L) format, illustrated in Figure 2.8-1. NRZ-L transitions occur only when there is a change in the logic value; i.e., 1 to a 0 or 0 to a 1.

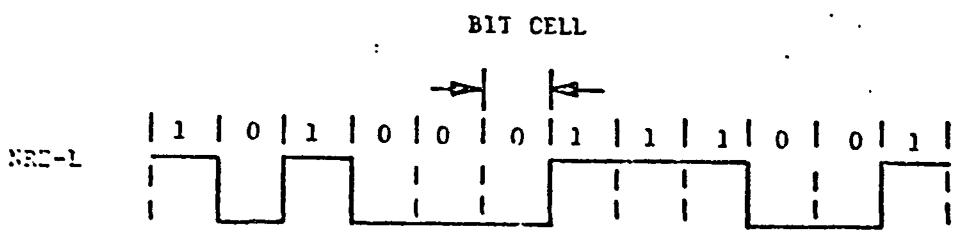


Figure 2.8-1. Non-Return-to-Zero-Level Digital Code

## 2.9 TIME CODING

The two outside tracks on the recorder are reserved for time code. The NASA 36-bit time code is recorded only on HDT-GM tapes. The 36-bit time code from these tapes is not used in the DMS. The format of the NASA 36-bit time code is given in Data Format Control Book, Volume V (Payload). The other timecode, IRIG-A is recorded on all all HDT's generated by the Landsat-D Ground Segment for use as a tape index. It is used to locate the desired data on a tape, especially when searching the tape at high speed in either the forward or reverse direction. The IRIG-A is Universal Time - Coordinated, monotonically increasing, and has a time resolution of a tenth of a second. IRIG-A is recorded on the tape whenever the tape is moving, even if data is not being recorded. Table 2.9-1 and Figure 2.9-1 describe and illustrate key features of this time code format.

## 2.10 PACKING

The electronics in the 14-track HDDRs pack data on each digital track at a density of 20 Kbits/inch. The electronics in the 28-track HDDRs pack data on each digital track at a density of 33.3 Kbits/inch.

Table 2.9-1. Key Features of IRIG-A Time Code

1. TIME: Universal Time - Coordinated

2. TIME FRAME: 0.1 second

3. CODE DIGIT WEIGHTING

   Binary Coded Decimal time-of-year Code Word - 34 binary digits
   a. Seconds, minutes, hours, days and 0.1 seconds
   b. Recycles yearly

4. Code Word Structure:

   BCD: Word begins at Index Count 1. Binary coded Elements occur between Position Identifier Elements (7 for seconds, 7 for minutes, 6 for hours, 8 and 2 for days) until the Code Word is complete. An Index Marker occurs between decimal digits in each group to provide separation for visual resolution.

5. Least significant digit occurs first, except for fractional seconds information which occurs following the day-of-year information.

6. ELEMENT RATE: 1000 per second

7. ELEMENT IDENTIFICATION:

   a. "On time" reference point for all Elements is the leading edge
   b. Index Marker — 0.2 millisecond
      (Binary Zero or uncoded Element)
   c. Code Digit — 0.5 millisecond
   d. Position Identifier - 100 per second — 0.8 millisecond
      (Refers to the leading edge of the succeeding Element)
   e. Reference Marker - 10 per second — Two consecutive Position Identifiers
      (The "on time" point, to which the Code Word refers, is the leading edge of the second Position Identifier).

8. RESOLUTION: 1 millisecond (unmodulated)
   0.1 millisecond (modulated)

9. CARRIER FREQUENCY: 10 kHz

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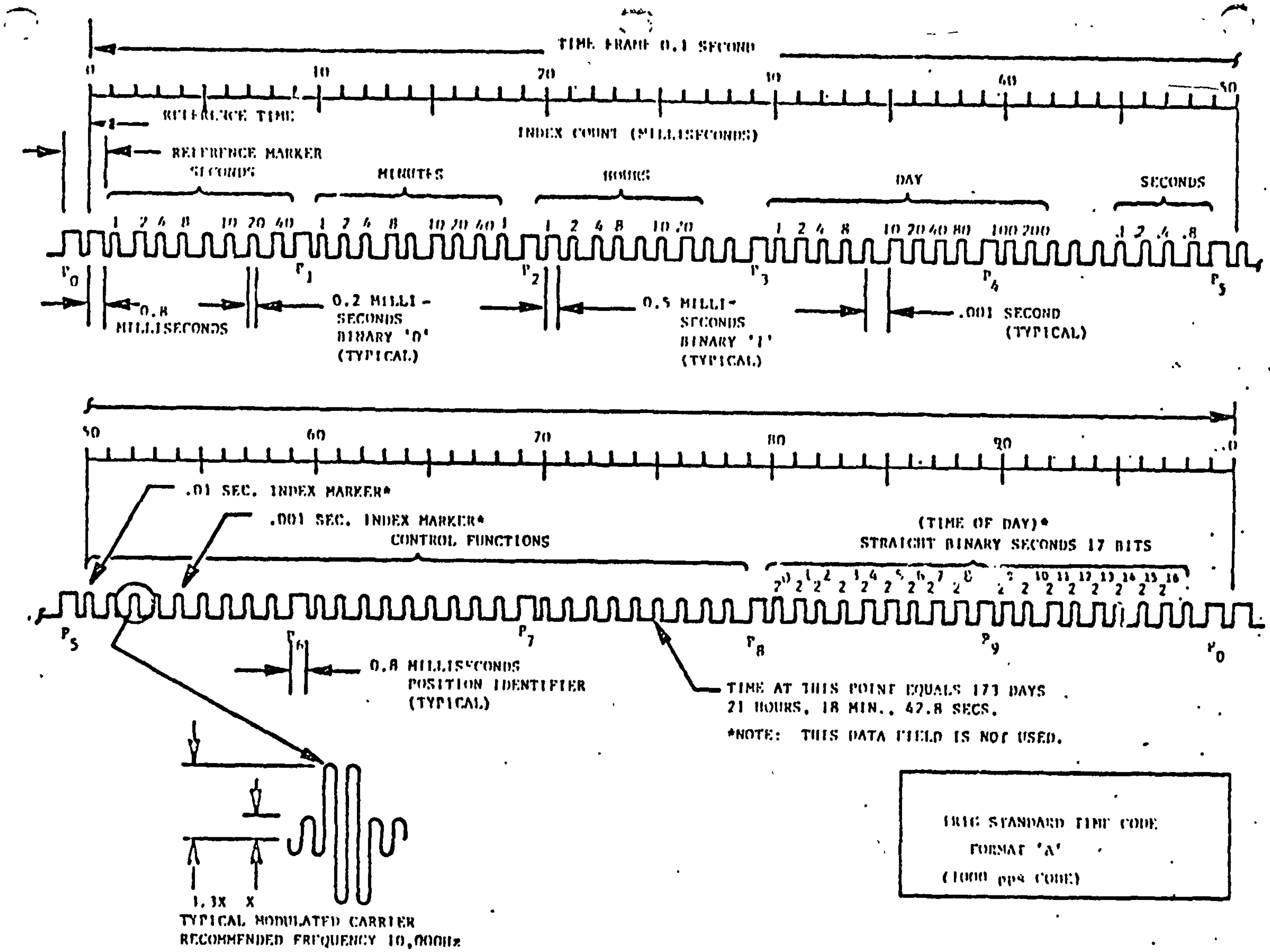


Figure 2.9-1. Inter-Range Instrumentation Group (IRIG) Format A

# SECTION 3

# RADIOMETRIC CORRECTION PROCESS

## 3.1 GENERAL DISCUSSION

The radiometric correction process converts output voltage samples from the MSS and TM photo detectors into values which represent the input radiance into the instruments. Output voltage samples are transmitted from the spacecraft as six-bit data for MSS and eight-bit data for TM. MSS corrected data is seven-bit for data transmitted in compressed mode (normally bands 1, 2 and 3) and six-bit for data transmitted in linear mode (band 4 always). Decompression tables determined during preflight testing are used to convert six-bit compressed data into seven-bit data, which is then radiometrically corrected. TM corrected data is always eight-bit for all bands.

To perform radiometric correction, voltage-radiance characteristics of each detector, determined before launch, and internal calibration data measured in orbit, are utilized, along with scene content information. The conversion of raw spacecraft data into the radiometrically corrected output is implemented using look-up tables, determined from gain and bias values, as described in the following paragraphs.

## 3.2 RADIOMETRIC CORRECTION USING INTERNAL CALIBRATION DATA

The fundamental detector calibration is made using gain and bias values computed from the internal calibration data and predefined calibration constants. Each scene is divided into several segments, for which gain and bias values are calculated for each detector from the averaged internal calibration values for that segment. The radiometric correction is of the form: $y = mx + b$, where m is the gain adjustment, b is the bias adjustment, and x is the uncorrected (decompressed if necessary) detector voltage sample.

Although the same basic method is used for both MSS and TM calibration, there is a difference between them since the calibration values are generated differently in the spacecraft instruments. Six calibration values are used for each MSS detector; these six values are generated after every second mirror sweep. Figure 3.2-1 shows a representation of the MSS calibration data acquired by each detector. The necessary six calibration values are selected by counting from the first sample to exceed the midpoint level of the rising edge of the calibration curve. The counts are fixed and are initially selected prior to spacecraft launch.

There are eight calibration values for each TM detector, except for band 6 (thermal IR band) detectors, which have only two internal calibration values. Each TM calibration value is constant over a 40 mirror scan period, so it takes 320 scans to generate the eight separate values. The first 5 scans of each 40-scan period are discarded, and the remaining 35 scans are averaged. Figure 3.2-2 shows a representation of the TM calibration data acquired by each detector in bands 1 - 5 and 7. Band 6 calibration details are TBD.

## 3.3 SCENE CONTENT RADIOMETRIC CORRECTION

Residual striping in imagery corrected using internal calibration data can result from slight errors in calibration due to non-linearities, quantization, hysteresis, calibration source variation, etc. To reduce this residual striping the look-up tables can be adjusted slightly using scene content on the basis of the following assumption: over a "large enough" segment of imagery each

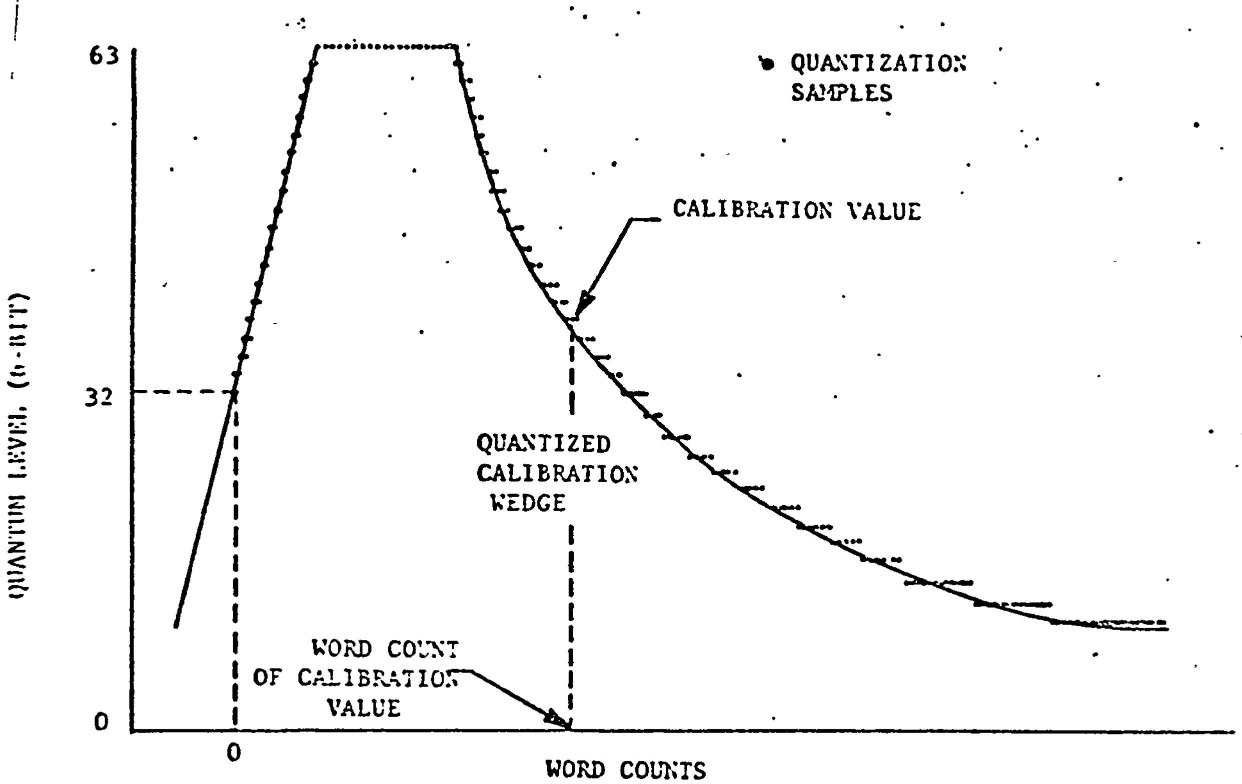


Figure 3.2-1. MSS Internal Calibration

detector in a band sees the same statistical distribution of radiances. This distribution is generated by collecting subsamples of data from each detector to create histograms of scene data. The histogram mean and standard deviation for each detector in a band are then equalized. The gain and bias values needed to accomplish this equalization process are used to generate the final look-up tables.

### 3.4 IMAGE SEGMENT BLENDING

To reduce radiance level discontinuities between adjacent segments, each segment is subdivided into subsegments and the gain and bias values for adjacent subsegments are blended together. This blending is performed for both radiometric methods, and is implemented by linearly interpolating the gain and bias values between subsegments.

# SECTION 4

# GEOMETRIC CORRECTION INFORMATION

## 4.1 GENERAL DISCUSSION

There are two types of geometric correction information found on the partially processed products: standard constants and scene dependent information. The standard constants include band and detector offsets, mirror velocity profile, nominal instrument and spacecraft parameter values, etc. The scene dependent information includes data about the nominal WRS image location, the actual image center, the spacecraft heading, Earth rotation, etc., plus detailed correction information which describes the manipulation required to transform the geometrically uncorrected array of image pixels received from the instruments and reformatted on the partially processed product into an array of pixels that are placed onto a map projection. These details are contained in matrices which are described in the following paragraphs. The first paragraph discusses the HRS and VRS coordinates generated to correct MSS data; the second paragraph discusses the matrices needed for the more complex TM correction process.

## 4.2 MSS GEOMETRIC CORRECTION DATA

Horizontal resampling (HRS) and vertical resampling (VRS) pixel and line coordinates needed for the geometric correction process are determined using space-to-space mapping and geometric interpolation. The relationships between input, hybrid, and output space associated with the space-to-space mapping process are illustrated in Figure 4.2-1.

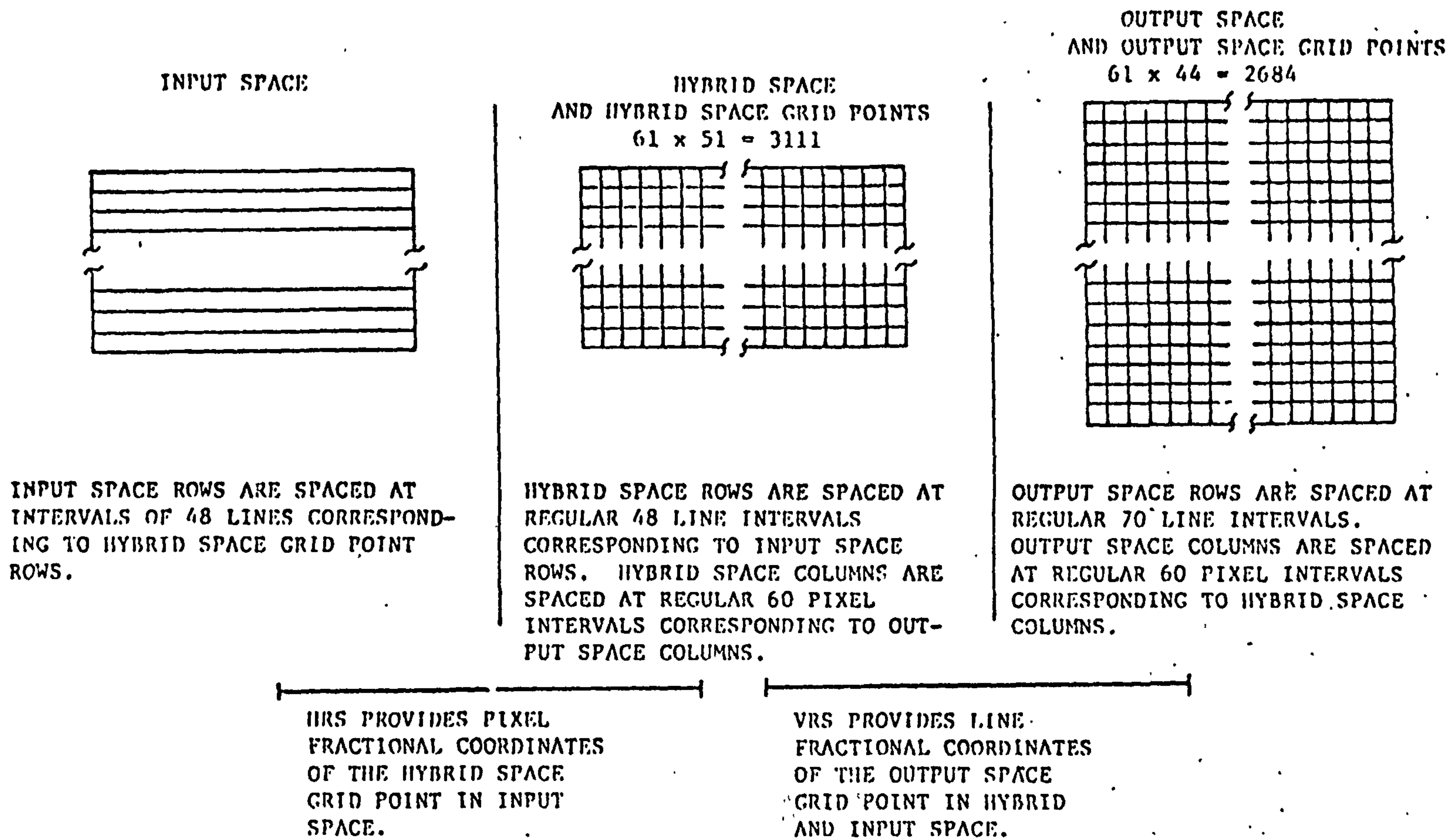


Figure 4.2-1. Input, Hybrid and Output Space Relationships for Multispectral Scanner Data

Figure 4.2-2 illustrates the input and hybrid spaces utilized in determining HRS pixel coordinates.

Figure 4.2-3 illustrates the hybrid and output spaces utilized in determining VRS line coordinates.

The HRS determining process precedes the VRS process. The hybrid space is defined as part of the HRS determining process and it is the same hybrid space as utilized in the VRS process.

Grid line fill counts are determined for the image in hybrid space for each of the 51 hybrid space lines. The left and right grid line fill counts are determined as a part of the HRS grid point determination process. The grid line fill counts of the image in hybrid space are needed during completion processing to determine the amount of scan line fill required for each line of the fully processed image.

### 4.2.1 HYBRID SPACE

The hybrid space defined for the HRS process has grid points that are regularly spaced in 51 rows and 61 columns. The 51 rows of hybrid grid points correspond to 51 integer input space lines (as shown in Figure 4.2-2). The rows in both the input and hybrid spaces are spaced at intervals of 48 lines. For each hybrid grid point, the HRS process defines the pixel fractional coordinate in the input space. The line integer coordinate of the hybrid grid point is the same as the corresponding input space line. The pixel fractional coordinates are provided one row at a time, left to right, top row to bottom row. A total of 61 x 51, or 3111, pixel coordinates are provided.

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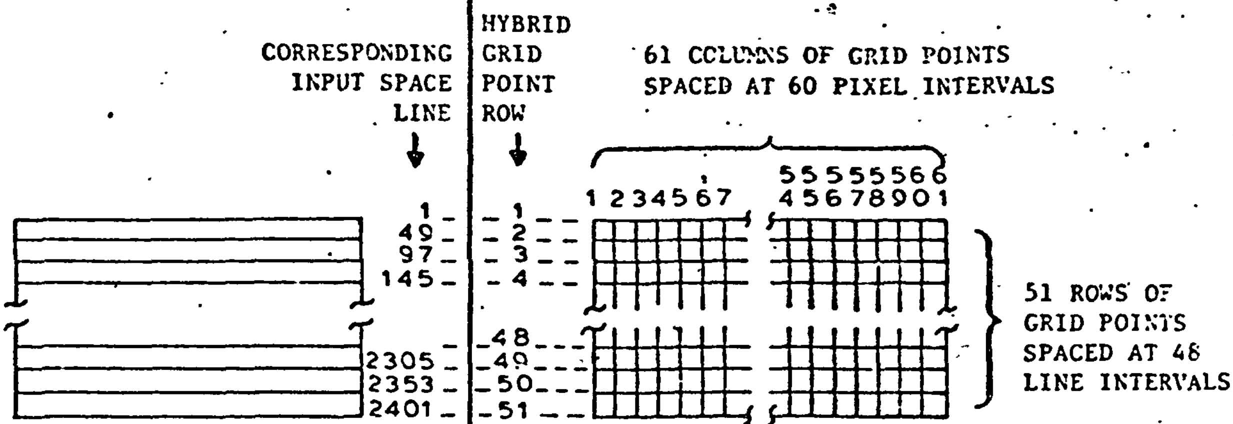



INPUT SPACE

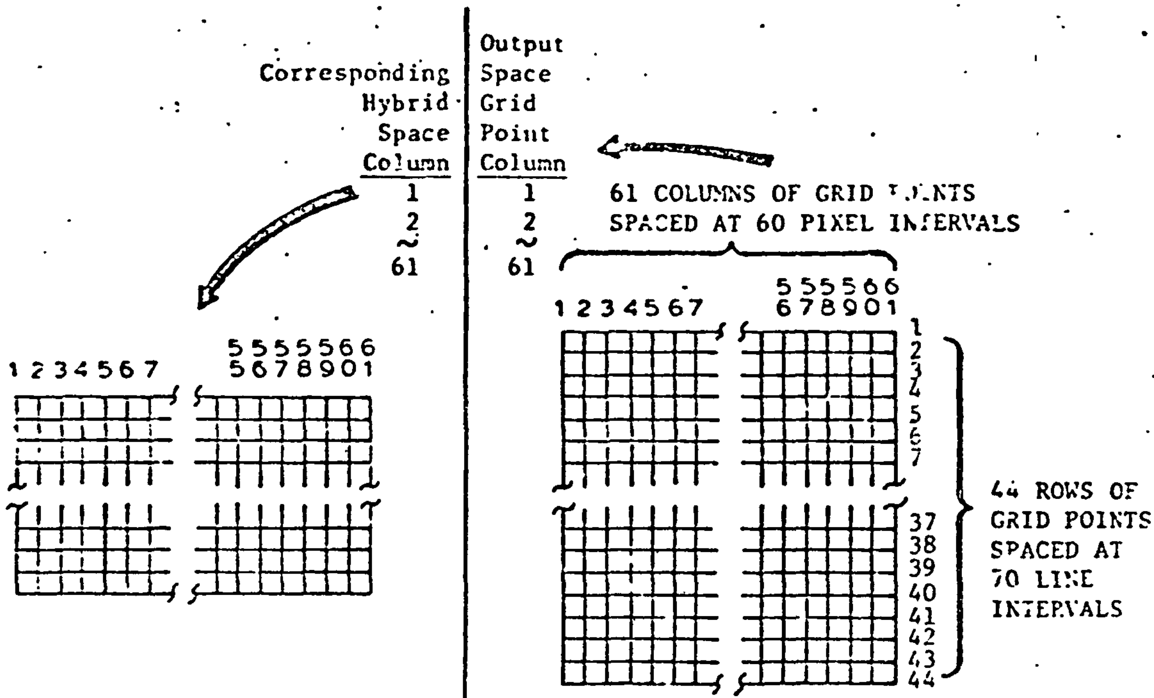
INPUT SPACE ROWS ARE SPACED AT INTERVALS OF 48 LINES AND CORRESPOND TO HYBRID SPACE GRID POINT ROWS.

HYBRID SPACE

HYBRID GRID POINTS ARE REGULAR IN HYBRID SPACE. FOR EACH HYBRID GRID POINT THE HRS PROCESS DEFINES:

- PIXEL FRACTIONAL COORDINATE OF THE HYBRID GRID POINT IN INPUT SPACE
- LINE INTEGER COORDINATE OF HYBRID GRID POINT SAME AS CORRESPONDING INPUT SPACE LINE

Figure 4.2-2. Illustration of Input and Hybrid Space for Determining HRS Sample Coordinates




HYBRID SPACE

HYBRID SPACE COLUMNS ARE SPACED AT INTERVALS OF 60 PIXEL AND CORRESPOND TO OUTPUT SPACE GRID POINT COLUMNS.

OUTPUT SPACE

OUTPUT SPACE GRID POINTS ARE REGULAR IN OUTPUT SPACE. FOR EACH OUTPUT SPACE GRID POINT THE VRS PROCESS DEFINES:

- LINE FRACTIONAL COORDINATE OF THE OUTPUT SPACE GRID POINT IN HYBRID AND INPUT SPACES

Figure 4.2-3. Illustration of Hybrid and Output Spaces for Determining VRS Line Coordinates

The left and right grid line fill counts are provided with the HRS grid point data for each of the 51 hybrid space rows. A total of 2 x 51, or 102, grid line fill counts are provided.

#### 4.2.2 OUTPUT SPACE

The output space defined for the VRS process has grid points regularly spaced in 44 rows and 61 columns. The 61 columns of output space grid points correspond to 61 columns in hybrid space (as shown in Figure 4.2-3). The columns in both hybrid and output space are spaced at intervals of 60 pixels. For each output space grid point the VRS process defines the line fractional coordinate in hybrid space, and by correspondence from the HRS process, in input space. The line fractional coordinates are provided one row at a time, left to right, top row to bottom row. A total of 61 x 44, or 2684, line coordinates are provided.

### 4.3 TM GEOMETRIC CORRECTION

The Thematic Mapper is a more complex and precise imaging instrument than the Multispectral Scanner, and the data required to define geometric corrections is also more complex. The correction data is provided in a series of matrices which are combined to develop a full correction matrix as the first step in generating fully-corrected imagery from partially-corrected products. In the space - to - space conversion process this correction data is defined in hybrid space, with the relationships shown in Figure 4.3 - 1.

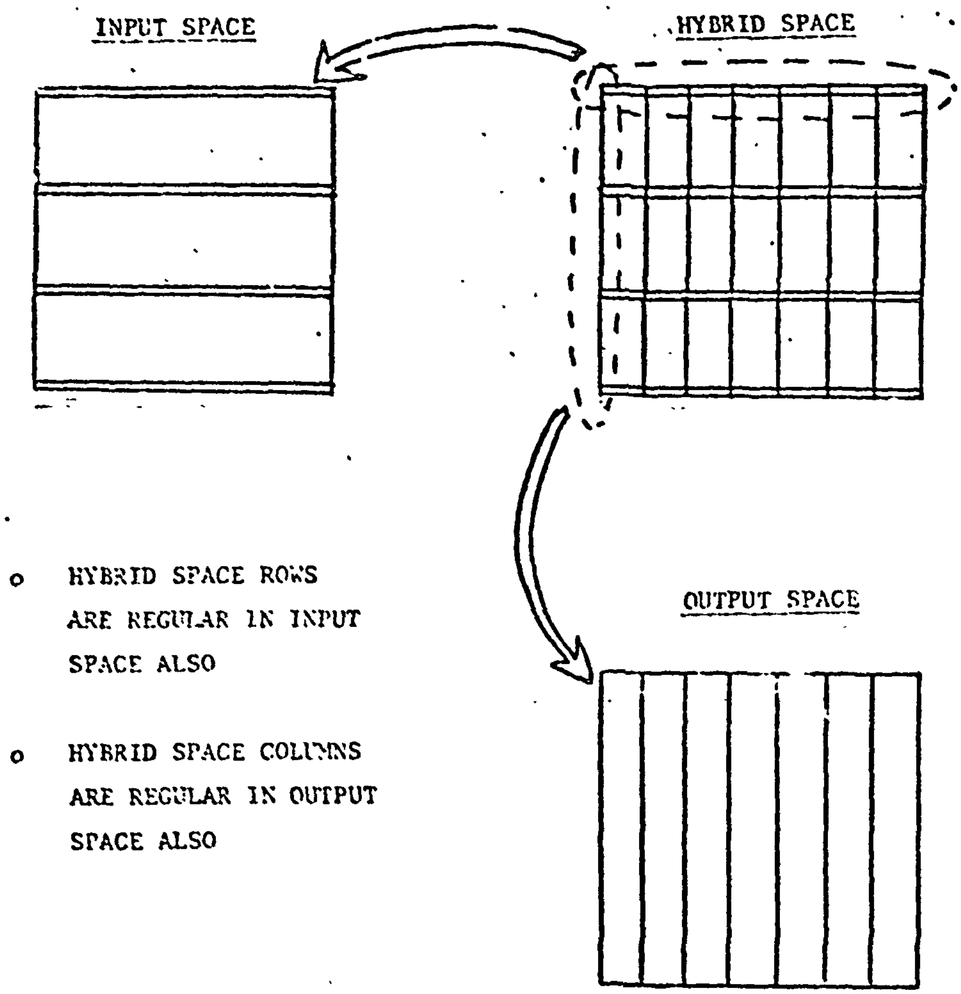



Figure 4.3 - 1. Input, Hybrid, and Output Space Relationships for Thematic Mapper Data.

4.3.1 BENCHMARK MATRIX

Basic correction data is provided in a benchmark matrix set which provides correction values at eight points along each of four pairs of grid rows across the image area. One row of each pair represents the sensor mirror scans in one direction, and the other row corresponds to scans in the reverse direction. At each grid point, four values are provided :

- The along - scan location within input space of the hybrid space grid - point, expressed as a fractional pixel number.
- The across - scan location within output space of the hybrid space grid - point, expressed in kilometers on the output map projection.
- The along - scan location within input space of a point displaced one pixel length (42.5 microradians) in the along - scan direction, expressed as a fractional pixel number.
- The across - scan location within output space of a point displaced one line width (42.5 microradians) in the across - scan direction, expressed in kilometers on the output map projection.

The benchmark values are computed using actual ephemeris data, and assuming linear mirror profiles, perfect optical axis pointing, and no high - frequency jitter for each of the two map projections into which the image data is to be correctible. Variances from these assumptions are provided in the form of additional correction data. The displaced - point values are used in applying these additional corrections to the basic grid point locations defined in the benchmark matrix.

### 4.3.2 HIGH FREQUENCY MATRICES

Additional high frequency correction data is provided in two high - frequency matrices, each consisting of 374 rows (one per mirror scan ; 187 in each scan direction) containing 35 grid points which are spaced at 2 msec intervals along each row. The along - scan matrix contains values which correct for scan mirror profile deviations from linearity, and for jitter motion about the spacecraft roll axis. The across - scan matrix values correct for scan line corrector mirror profile deviations from linearity, for scan mirror across - scan deviations, and for jitter motion about the spacecraft pitch and yaw axes. Values within both correction matrices are expressed in microradians, and are therefore useable to update the benchmark matrix values for either map projection.

### 4.3.3 ADDITIONAL CORRECTION DATA

In addition to the benchmark and high frequency correction matrices, additional data is provided to fully define the corrections required. These include :

(1) Mirror scan data - The mirror scan start time for each primary mirror scan is provided for use as the interpolation control parameter for expanding the benchmark matrix, and for precise time - positioning of the high - frequency correction data. The scan line length for each scan is also provided to define the useable image data available from each scan.

(2) Nominal pointing vector scan rate - The angular rate of motion of the optical axis across the earth which was used in calculating the correction data is provided for use in applying the additional correction values to the expanded benchmark matrix.

(3) Detector location data - The offsets of the detector array for each spectral band, and of each individual detector within each band relative to the optical axis to which the correction data applies are provided for use in developing the individual full correction matrix for each spectral band. These offsets include adjustments for detector response-time delays, which are unique for each detector and scan direction.

(4) Data alignment adjustments - The adjustments which have already been made to align the data from separate detectors within each spectral band is indicated. These adjustments do not include alignment of data from scans of opposite direction.

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# SECTION 5

## ABBREVIATIONS, ACRONYMS, SYMBOLS AND TERMS

| | |
|---|---|
| Band | A collection of pixels representing a spectral portion of a scene |
| BCD | Binary Coded Decimal |
| Bit | The smallest element of binary, computer-intelligible data |
| Byte | A unit of data consisting of eight bits |
| CCT | Computer Compatible Tape |
| CCT-AT | Computer Compatible Tape containing partially processed TM data |
| CCT-PT | Computer Compatible Tape containing fully corrected TM data |
| Detector | A component of a sensor that is able to sense incident energy in a region of the electromagnetic spectrum |
| DMS | Data Management System |
| ECC | Error Correction Code |
| F241-PT | 241 mm film containing fully corrected TM data |
| GFIT | Goddard Film Inventory Tape |
| GHIT | Goddard HDT Inventory Tape |
| GHIT-AM | Goddard HDT Inventory Tape for HDT-AM |
| GHIT-AT | Goddard HDT Inventory Tape for HDT-AT |
| GHIT-PT | Goddard HDT Inventory Tape for HDT-PT |
| HDDR | High Density Digital Tape Recorder |
| HDT | High Density Digital Tape |
| HDT-AM | High Density Tape containing partially processed MSS data |

| | |
|---|---|
| HDT-AT | High Density Tape containing partially processed TM data |
| HDT-GM | High Density Tape containing uncorrected MS data (generated externally) |
| HDT-PT | High Density Tape containing fully corrected TM data |
| HDT-RM | High Density Tape containing uncorrected MSS data (generated internally) |
| HDT-RT | High Density Tape containing uncorrected TM data |
| HRS | Horizontal Resampling |
| IR | Infrared |
| IRIG-A | Inter-range Instrumentation Group standard time, format A |
| Landsat | Land Satellite (formerly ERTS - Earth Resources Technology Satellite) |
| MSS | Multispectral Scanner |
| NRZ-L | Non-Return to Zero Level digital coding |
| Pixel | One image detector sample |
| PRN | Pseudo Random Noise |
| Scan Line | The data produced by one cross track motion of an active detector (a full scene width) |
| Scene | One or more spectral bands of data representing a 185km X 170km ground area |
| Sensor | An imaging instrument (a sensor may consist of one or more detectors) |
| SOM | Space Oblique Mercator Projection |

| | |
|---|---|
| Sweep | One back and forth cycle of mirror movement |
| TDRSS | Tracking and Data Relay Satellite System |
| TM | Thematic Mapper |
| UTM | Universal Transverse Mercator Projection |
| VRS | Vertical Resampling |

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