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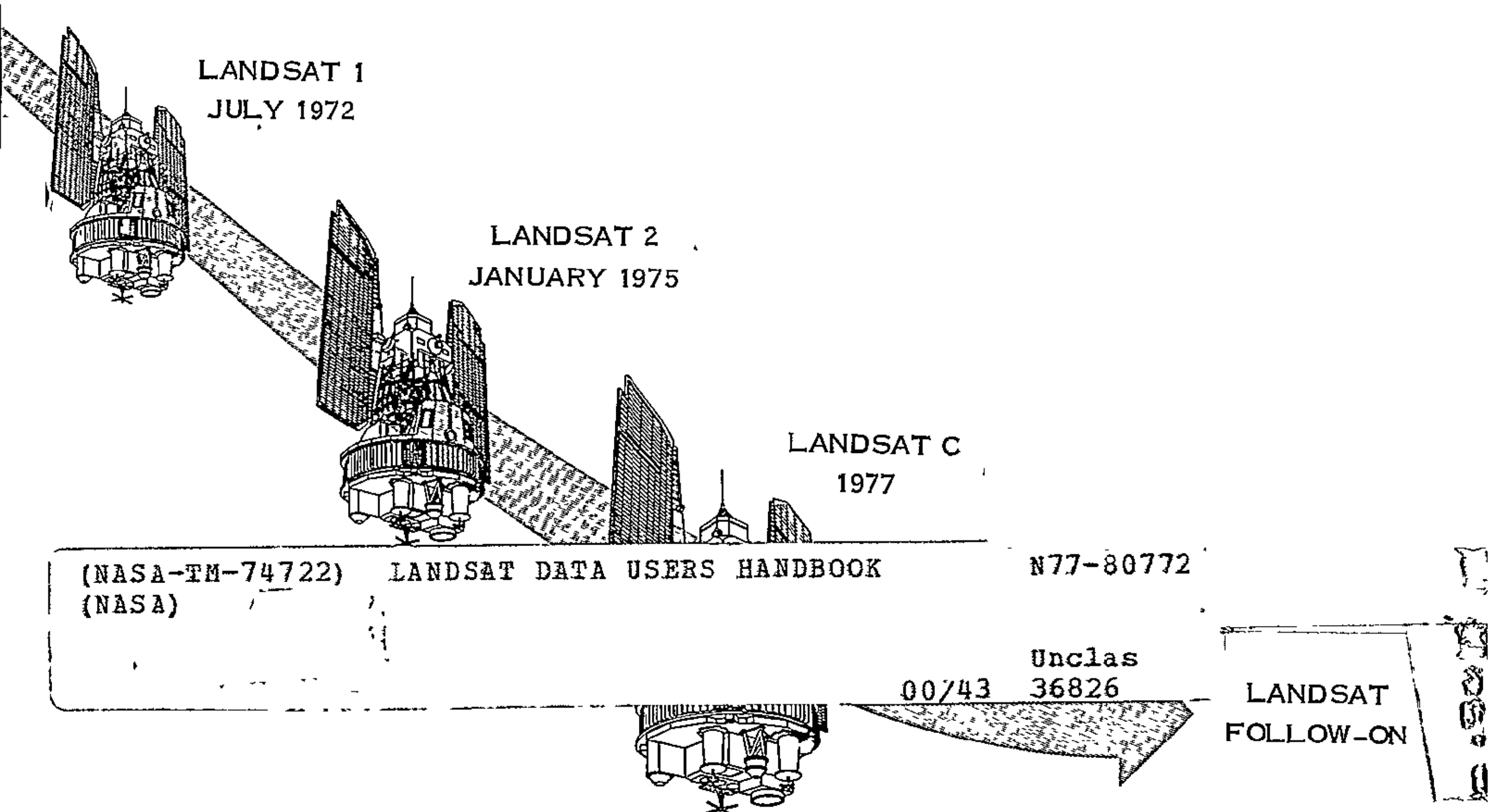
LANDSAT

DATA USERS HANDBOOK



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Landsat Data Users Handbook

Goddard Space Flight Center
Greenbelt, Maryland

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SECTION 1
INTRODUCTION

The first satellite in the Earth Resources Technology Satellite (ERTS) program was launched in July 1972 and designated ERTS 1. It was followed into space by a second satellite in January of 1975. At that time the program was redesignated as the Landsat program to emphasize its prime area of interest, the resources of land masses. The two in-orbit satellites were accordingly renamed Landsat 1 and Landsat 2.

The *ERTS Data Users Handbook* was first published in December of 1971 and was revised periodically through December of 1972 Anticipating the widespread popularity of this first major step in space remote sensing of earth's resources, every effort was made to get the handbook into investigator's and potential user's hands as quickly as possible. Publication of the document before the launch of Landsat 1 and its revision after only six months of orbital operation has resulted in numerous errors and inaccuracies throughout the handbook. This total revision, the *Landsat Data Users Handbook*, corrects those defects, reflects current users needs more accurately (especially in the area of computer compatible tapes) and incorporates as much information as possible about the third spacecraft in the Landsat series, Landsat-C

The intent of this revised handbook is the same as the original to satisfy investigator's and user's needs for information about Landsat data products and how to acquire them Throughout the Landsat program's successful five-year history, both the data products themselves and the procedures for acquiring them have changed considerably These changes have also been included in this revision

As in the original document, the main body of the handbook provides information of interest to all users. Section 2 provides a concise description of the Landsat system. A new section providing a brief description of some of the applications of Landsat data has been included as Section 3 Detailed descriptions of data products are provided in Section 4, and the new sources and procedures for obtaining Landsat data are described in Section 5. Appendices provide more detailed treatment of topics of interest to most investigators and users to various degrees. Appendices C and D have been completely rewritten to provide extensive detail on the MSS and computer compatible tapes, respectively. They have been designed to satisfy an expressed need among users for detailed digital information that is vital to their use of Landsat data in computer environments. Appendix F has also been completely rewritten to reflect the latest orbital and image reference designation information Recent and planned hardware and procedural changes in the NASA Image Processing Facility (formerly the NASA Data Processing Facility) are described in Appendix H. The other appendices have been revised to reflect the most current information available

SECTION 2
LANDSAT SYSTEM DESCRIPTION

2.1 LANDSAT MISSION

The mission of Landsat is to provide for the repetitive acquisition of high resolution multispectral data of the earth's surface on a global basis. Two sensor systems have been selected for this purpose· A four-channel (five-channel on Landsat-C) multispectral scanner (MSS) system and a three-camera (two-camera on Landsat-C) return beam vidicon (RBV) system. In addition, the Observatory is utilized as a relay system to gather data from remote, widely distributed, earth-based sensor platforms equipped by individual investigators. The data acquired by the total Landsat System thus permits quantitative measurments to be made of earth-surface charcteristics on a spectral, spatial, and temporal basis

The overall Landsat 1 and 2 System and the planned Landsat-C System are illustrated in Figure 2-1 The Observatory carries a payload of imaging multispectral sensors (MSS and RBV except for the RBV on Landsat-C, which is panchromatic), wideband video tape recorders, and the spaceborne portion of a Data Collection System (DCS). The spacecraft "housekeeping" telemetry, tracking, and command subsystems are compatible with stations from NASA's Space Tracking and Data Network (STDN). Wideband payload video data are received at Fairbanks, Alaska; Goldstone, California, and the GSFC Network Test and

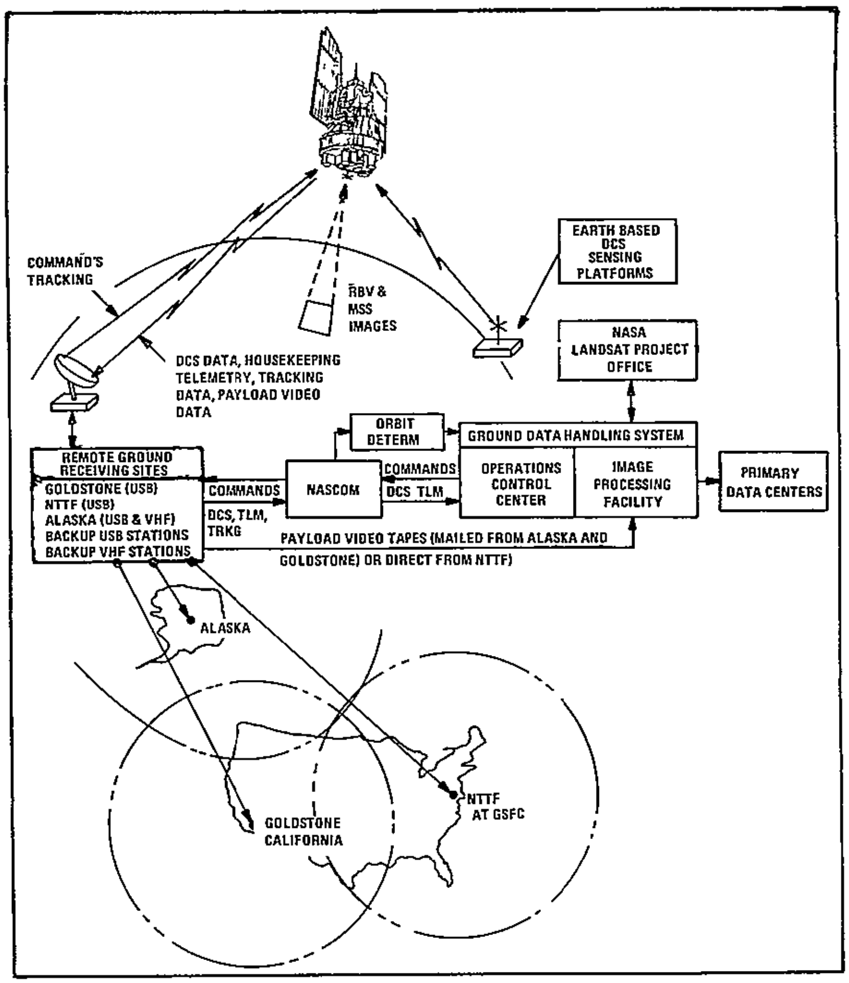


Figure 2-1 Overall Landsat System

Training Facility (NTTF) at Greenbelt, Maryland Payload data are also being received at non-U.S. ground stations in western Canada, Brazil and Italy. Additional non-U.S ground stations are planned for eastern Canada, Iran, Zaire and Chile.

The Operations Control Center (OCC) is the focal point of mission orbital operations. Here the overall system is scheduled, spacecraft commands are originated and orbital operations are executed and evaluated DCS, telemetry, and command data transfer between the OCC and remote ground sites is accomplished by NASA Communications (NASCOM) The NASA Image Processing Facility (IPF) accepts payload video data in the form of magnetic tapes received in real time at the NTTF Station via the OCC or by mail from Alaska and Goldstone. The IPF then performs the video-to-film conversion producing black and white images from individual spectral bands and color composites from several bands. The IPF includes a storage and retrieval system for all data acquired by the U.S. and provides for delivery of data products and services to the primary data centers and other government organizations. Together, the OCC and IPF comprise the Landsat Ground Data Handling System (GDHS).

2.2 OBSERVATORY SYSTEM

The elements of the Landsat Observatory System include the payload subsystems and the various support subsystems comprising the spacecraft vehicle. Their configuation is shown in Figure 2-2

Control of Observatory attitude to the local vertical and to the orbital velocity vector within 0 7 degree of each axis is achieved by a three-axis active Attitude Control Subsystem (ACS). It uses horizon scanners for pitch and roll control, and a gyrocompassing mode for yaw orientation An independent passive Attitude Measurement Sensor (AMS), operating over a narrow range of about ± 2 degrees, provides pitch and roll attitude data accurate to within 0.07 degree to aid in image location. Orbit adjustment capability is furnished by a monopropellant hydrazine subsystem employing one-pound force thrusters. This system is used to remove launch vehicle injection errors, and to provide periodic trim to maintain an orbit with an 18-day repetitive cycle

Payload video data are transmitted to ground stations over two wideband S-band data links. Traveling wave tube amplifiers with commandable power output and shaped beam antennas are used in this subsystem to provide maximum fidelity of the payload data at minimum power The two links are identical, though operating at different frequencies, and are interchangeable. Each link is compatible with data from either of the two imaging sensors (the RBV and the MSS). Cross-strapping and dual mode operation with a single amplifier is provided to assure system

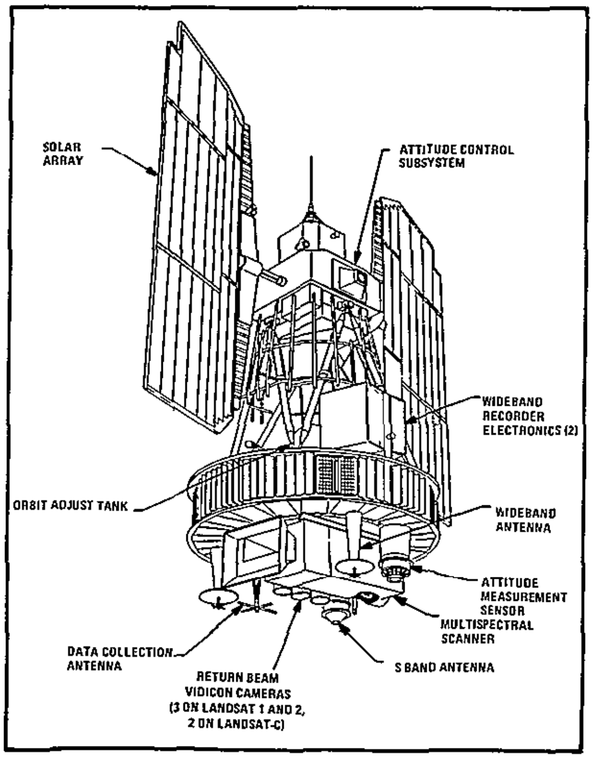


Figure 2-2. Landsat Observatory Configuration

operation even in the event of some hardware failures. Telemetry, tracking, and command capability are fully compatible with the STDN system. Electrical power is generated by two independently driven solar arrays, with storage provided by batteries for spacecraft eclipse periods and during launch.

The payload equipment is centrally packaged in a circular structure at the base of the spacecraft, providing close proximity between the payload sensors, their electronics, and wideband communications equipment. The RBV camera heads are mounted to a common baseplate to maintain accurate alignment. A superinsulation thermal blanket surrounds equipment on the circular structure, except for specified radiator areas, where heat is rejected from the center section. During minimum operating periods, heaters are used to maintain temperature levels.

2.3 PAYLOADS

2.3.1 Return Beam Vidicon Camera

On Landsat 1 and 2, the return beam vidicon (RBV) camera system operates by shuttering three independent cameras simultaneously, each sensing a different spectral band in the range of 0 48 to 0 83 micrometers Since these measure reflected solar radiation, the RBV is operated only in daylight The ground scene viewed (185 by 185 kilometers in area) is stored on the photosensitive surface of the camera tube and after shuttering, the image is scanned by an electron beam to produce a video signal output Each camera is read out sequentially, requiring about 3.5 seconds for each of the three spectral images To produce overlapping images along the direction of spacecraft motion, the cameras are reshuttered every 25 seconds The video bandwidth during readout is 3.2 MHz. Orientation of the three camera heads is shown in Figure 2-3.

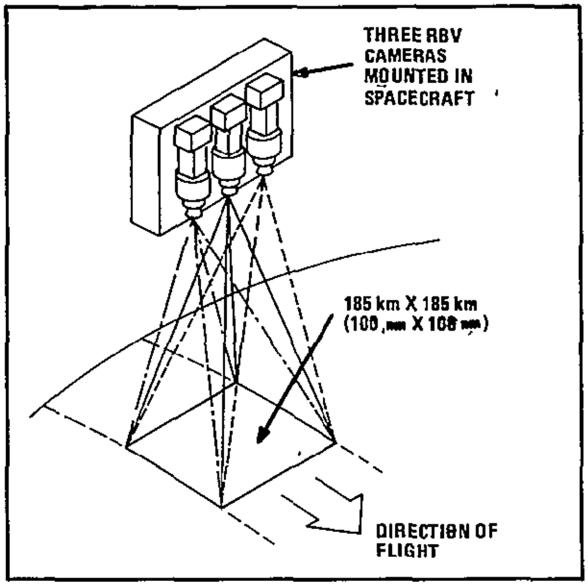


Figure 2-3 RBV Camera Head Operation on Landsat 1 and 2

On Landsat-C, to be launched late in 1977, the RBV camera system will be considerably different. Two panchromatic cameras will be used, producing two side-by-side images rather than three overlapping images of the same scene Effective resolution of the RBV will be increased by a factor of two. Each of the side-by-side images will portray a ground scene approximately 98 by 98 kilometers (53 x 53 nautical miles) in area. Four RBV images will approximately coincide with one MSS frame.

2 3.2 Multispectral Scanner

The Landsat 1 and 2 multispectral scanner (MSS) is a line scanning device that uses an oscillating mirror to continuously scan perpendicular to the spacecraft velocity as shown in Figure 2-4. Six lines are scanned simultaneously in each of the four spectral bands for each mirror sweep. Spacecraft motion provides the along-track progression of the scan lines. Radiation is sensed simultaneously by an array of six detectors in each of four spectral bands from 0 5 to 1 1 micrometers. The detectors' outputs are sampled, encoded to

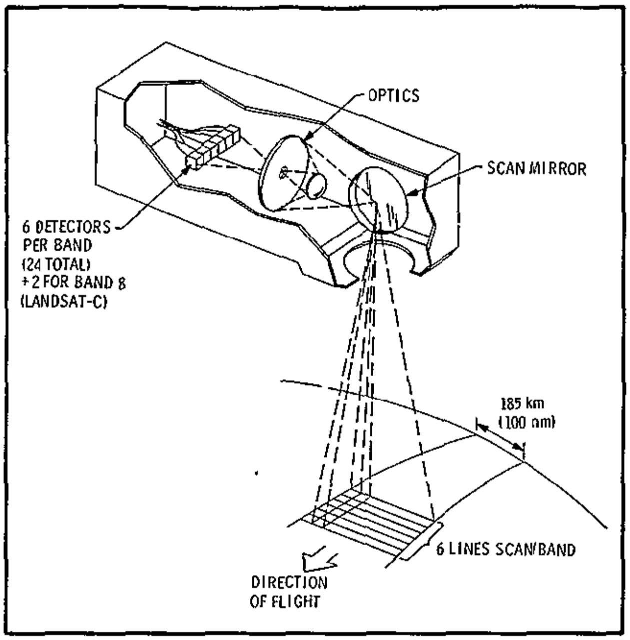


Figure 2-4 MSS Scanning Arrangement

six bits and formatted into a continuous data stream of 15 megabits per second During image data processing in the GDHS facility, the continuous strip imagery is transformed to framed images with a 10 percent overlap of consecutive frames and an area coverage approximately equal to that of the RBV images (185 by 185 kilometers).

On Landsat-C, the MSS will be modified to include a fifth spectral band operating in the thermal infrared region from 10 4 to 12.6 micrometers. This band will have only two detectors, thus the spatial resolution of this band will be one-third that of the other four bands.

2.3.3 Wideband Video Tape Recorders

The uses of data from the RBV and MSS sensors are complementary in several respects and both sensors can be operated simultaneously over the same terrain during daylight hours. When operated over a ground receiving station, their data are transmitted in real time to the ground receiving site and recorded there on magnetic tape

When the RBV and MSS sensors are operated at locations remote from a ground receiving station two wideband video tape recorders (WBVTR), included as part of the Observatory payload, are used to record the video data Each WBVTR records and reproduces either RBV or MSS data upon command and each has a recording capacity of 30 minutes.

2.3.4 Data Collection System

The Data Collection System (DCS) obtains data from remote, automatic data collection platforms, which are equipped by specific investigators, and relays the data to ground stations whenever the Landsat spacecraft can mutually view any platform and any one of the ground stations, as shown in Figure 2-5 Each DCS platform collects data from as many as eight sensors, supplied by the cognizant investigator, sampling such local environmental conditions as temperature, stream flow, snow depth, or soil moisture Data from any platform are available to investigators within 24 hours from the time the sensor measurements are relayed by the spacecraft

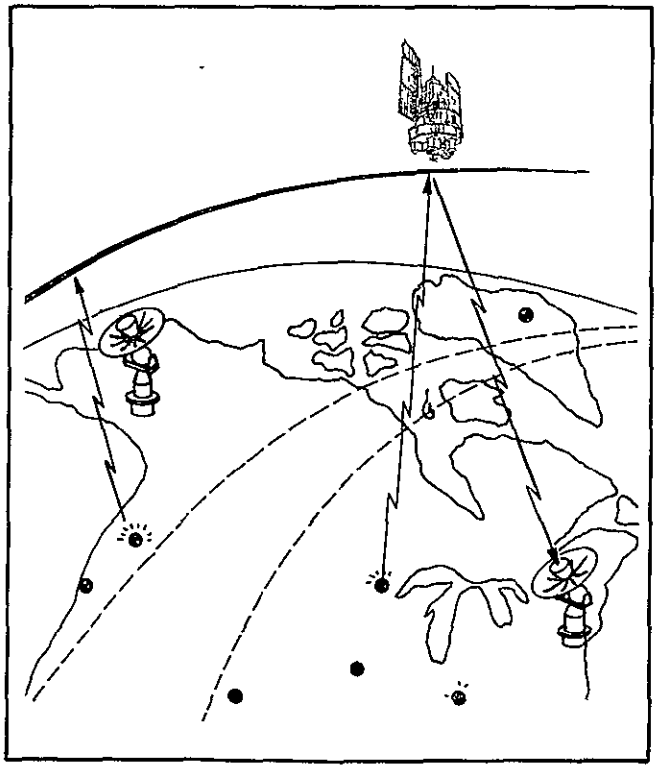


Figure 2-5 Data Collection System

2.4 ORBIT AND COVERAGE

Systematic, repetitive earth coverage under nearly constant observation conditions is provided for maximum utility of the RBV and MSS images collected by Landsat Each Observatory operates in a circular, sun-synchronous, near-polar orbit at an altitude of approximately 920 kilometers (570 miles). They circle the earth every 103 minutes, completing 14 orbits per day and viewing the entire earth every 18 days. The launch of Landsat 2 was timed so that its orbit follows the orbital track of Landsat 1 with a delay of 9 days The two Observatories together thus pass over and provide coverage of ground points every nine days. The orbit is selected and trimmed so that each satellite ground trace repeats its earth coverage at the same local time every day. Repetitive image centers are maintained to within 37 km (20 nm). A typical one-day ground coverage trace for one Observatory is shown in Figure 2-6 for the daylight portion of each orbital revolution.

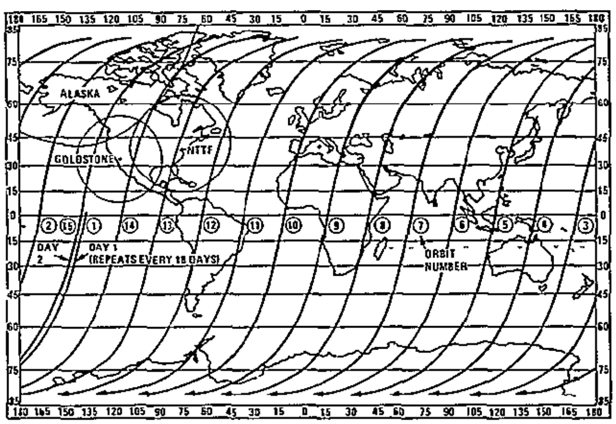


Figure 2-6. Typical Landsat Daily Ground Trace (Daylight Passes Only)

2.5 OPERATIONS CONTROL CENTER

The OCC is the hub of all Landsat mission activities, it provides control of the spacecraft and payload orbital operations required to satisfy the mission and flight objectives. The OCC operates 24 hours per day, and its activities are geared to the operations timeline dictated by the 103-minute spacecraft orbit and the network coverage capability. The primary receiving stations in Fairbanks, Alaska; Goldstone, California; and the NTTF at Greenbelt, Maryland, provide contact with the spacecraft on 12 or 13 of the 14 orbits each day.

The OCC system is shown in Figure 2-7. The OCC computer performs spacecraft and sensor "housekeeping" telemetry processing, command generation, display processing, system scheduling, and processing of DCS information. Interacting with the computer and its software are the OCC operations consoles, each console has a cathode ray tube display and other station and alarm indicators The consoles provide the operations personnel with all the information required to assess the health of the spacecraft and payloads, and to make and implement rapid command and control decisions. Each cathode ray tube is under control of the computer, and an operator can display any data in the computer system library, by immediate keyboard request, to evaluate the performance of any subystem or payload on board the spacecraft

The OCC also provides quick look–image displays for video data acquired locally by the NTTF station during orbits that pass over the eastern part of the United States. DCS data are received from Goldstone and the NTTF and preprocessed in the OCC for subsequent formatting and cataloging in the IPF

2.6 NASA IMAGE PROCESSING FACILITY

The IPF is a job-oriented facility that produces high quality data for distribution to primary data centers and other government organizations. Figure 2-8 shows a simplified system functional configuration. Spacecraft ephemeris, derived from tracking data, is provided to the IPF from the OCC. These data, along with telemetry, are used to produce an Image Annotation Tape for identification, location, and annotation of all imagery during image processing.

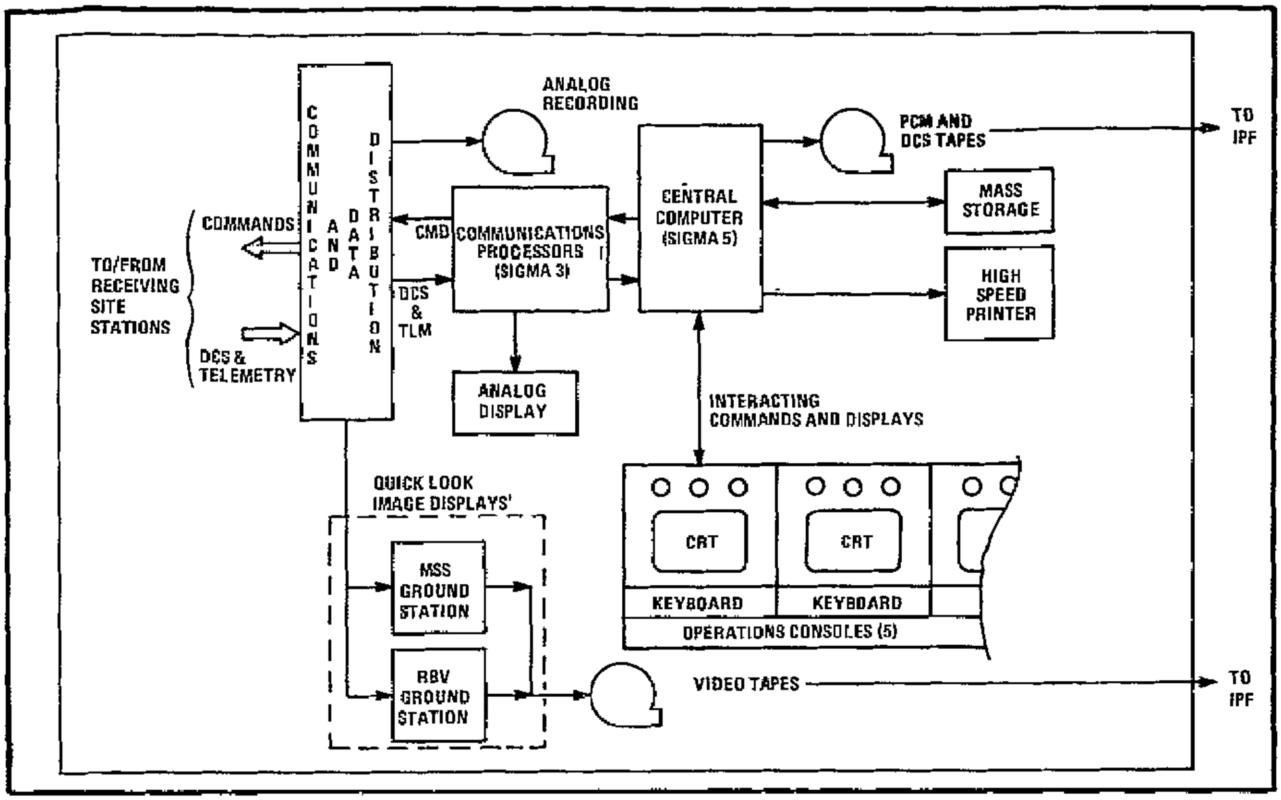


Figure 2-7. OCC System

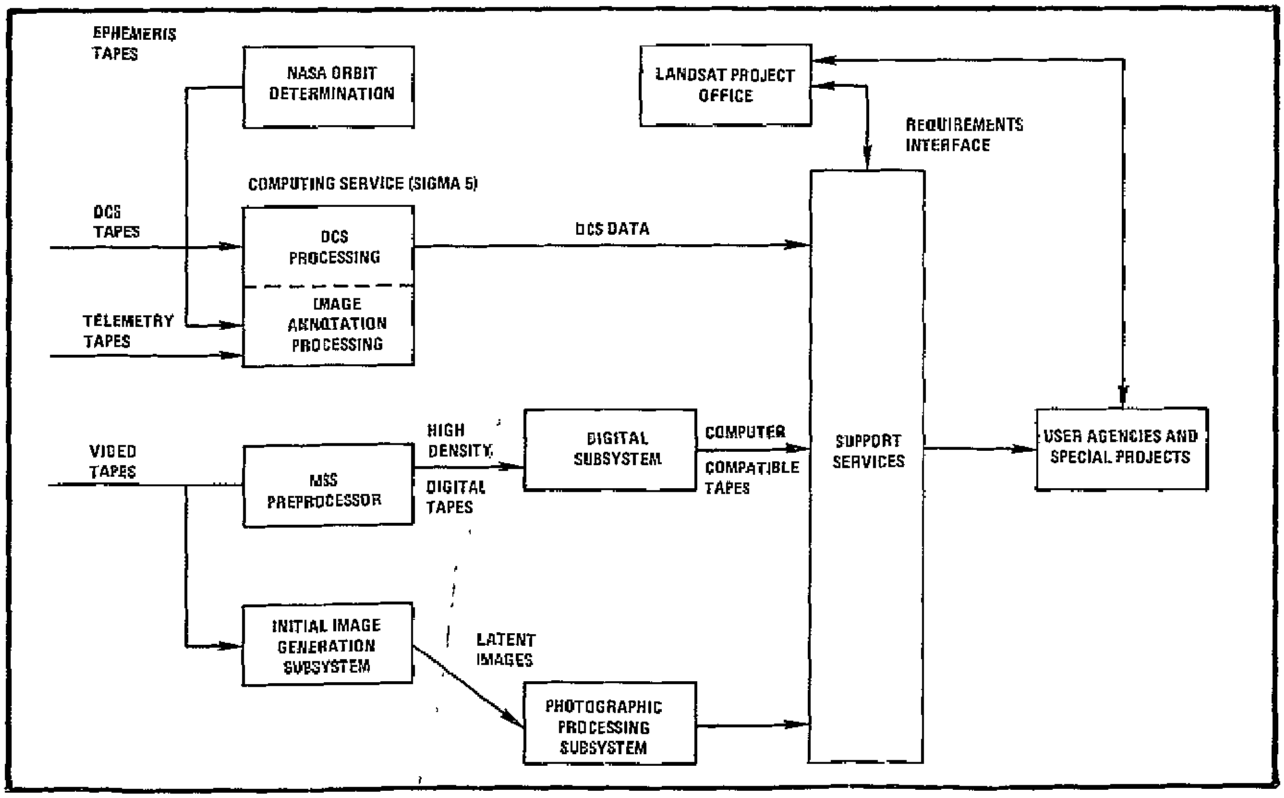


Figure 2-8. NASA Image Processing Facility (IPF)

There are two types of image processing performed in the IPF Initial Image Generation and Digital Tape Generation. All data are processed by the Initial Image Generation Subsystem while only selected data are converted to digital tapes

2.6.1 Initial Image Generation

Payload video data tapes are the principal input to the Initial Image Generation Subsystem (IIGS). Here an electron beam recorder (EBR) produces corrected images on 70 mm film of data from all video tapes. During video-to-film conversion, alphanumeric annotation data, image location, and a gray scale for calibration are recorded Initial radiometric corrections are also made to the image. The 70 mm film images produced by the IIGS are developed in the Photographic Processing Subsystem and inspected for quality and cloud cover. Archival copies of the 70 mm images are then prepared and forwarded to the primary data centers operated by USGS, USDA, and NOAA. These data centers are described in Section 5.

2.6.2 Digital Processing

Digtial processing is performed on selected image data when requested by users. Digital processing edits, calibrates, and formats digital data produced from the MSS preprocessing system and outputs this data on a computer compatible digital tape for distribution.

2.6.3 DCS Data Processing

Data collection system data are processed, formatted, and distributed to users on magnetic tape, computer listing, or punched cards within 24 hours from the time data collection platform sensor measurements are relayed by the spacecraft to ground receiving sites

2 6.4 Support Services

All of the IPF equipment and processes are scheduled by work orders that are generated to match user requests against received data through the IPF information system. The information system also serves as a data base to generate catalogs of image coverage, microfilm, and DCS data for distribution to users.

Close to one-quarter million master images are processed and stored at the IPF each year. The storage and retrieval system aids in the selection of only those images that are of interest to the user Users have access to all IPF data through several files to provide efficiency in searching areas of interest. These aids include:

- Browse Files - Complete microfilm file of all available images arranged by date and location, with a data base query and search system and image viewing equipment

- Coverage Catalogs - Listings in two separate catalogs of all U.S. and non-U.S. images that are returned to U S. ground stations over each 18-day coverage cycle. These catalogs are updated and distributed on a regular schedule.

Imagery requirements of user agencies and special projects are processed in either black and white or color from archival images stored in the master file. Sample of black/white imagery and color composites are avilable to permit the user to select the material most useful Other data (such as DCS tapes and listings, digital image tapes, catalogs, and calibration data) are provided to users either to fill a standing order or by specific data request.

2.6.5 Planned IPF Changes

Major changes are planned for the IPF prior to Landsat-C launch. High density digital tapes will replace 70 mm film as the archival medium. Radiometric and geometric corrections of all data will be performed digitally prior to recording on the high density tape.

Film and CCT products will be made from the archival high density tape copy. In this manner, the quality of the sensor data will be fully preserved and full geometric corrections will be applied to all products. Figure 2-9 provides a flow diagram of the planned IPF system and Table 2-1 defines the system performance characteristics Steps are also being taken to drastically reduce the data delivery turnaround time for all data products to 1-2 days. The digital processing approach will significantly contribute to this goal.

User agencies, such as the EROS Data Center (EDC), are taking steps to accept data from the IPF in high density tape form. Equipment will be available to copy the archival high density tape onto CCTs and early generation film products

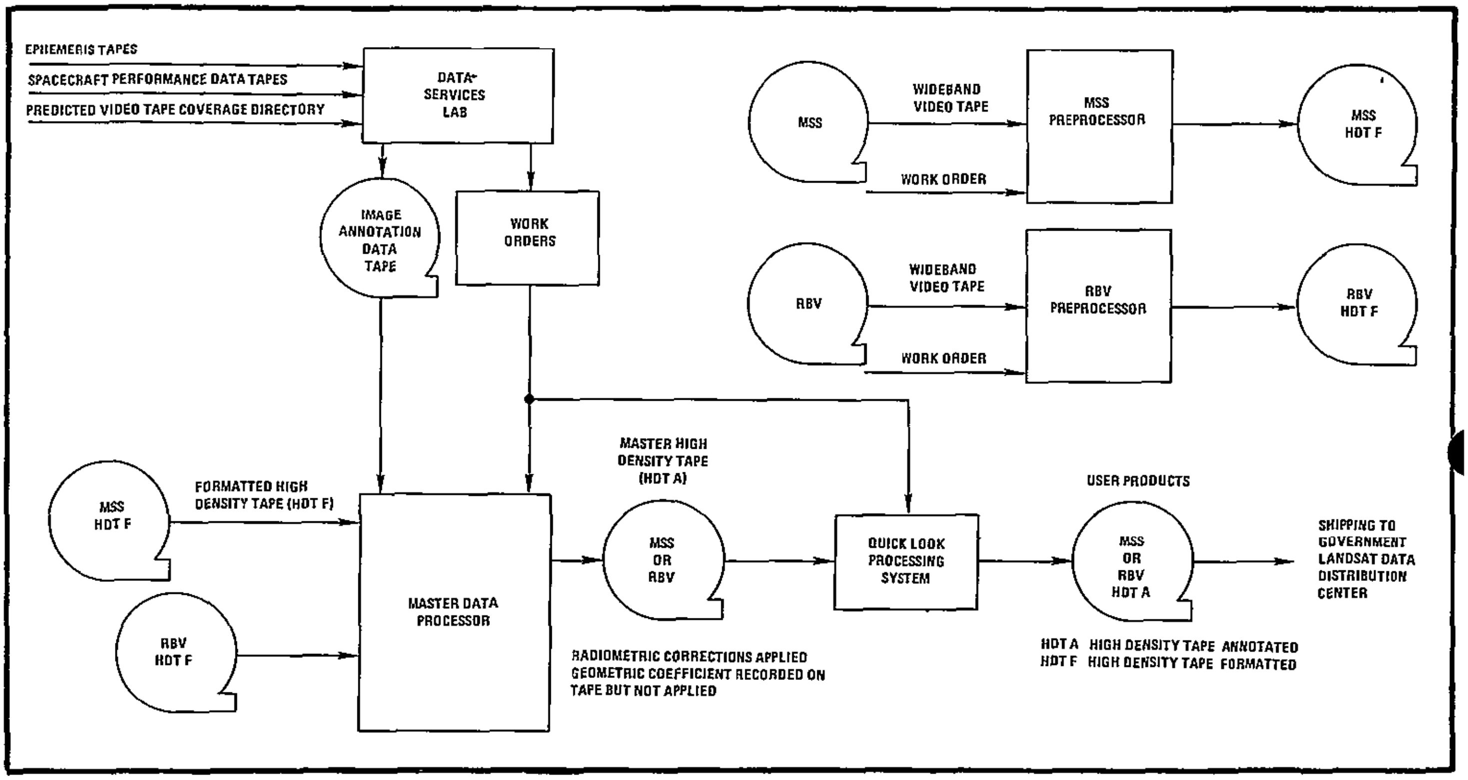


Figure 2-9. Video Processing Flow Diagram

Table 2-1. System Performance

Radiometric Calibration Accuracy	<2 quantum levels over full range
Geometric Correction Accuracy Nominal conditions with ground control points	<1 pixel* (99% of the time)
Without ground control points	Commensurate with sensor performance
Temporal Registration	<0 5 pixel (99% of the time)
Map Projections	Space Oblique Mercator (SOM), UTM, and Polar Stereographic

*Without terrain elevation correction

SECTION 3
APPLICATIONS

3.1 INTRODUCTION

This section provides new and prospective users of Landsat data with a broad overview of the data analysis methods and applications developed by Landsat investigators It is intended to point out some of those methods and applications that have proven successful in each of the various disciplines, and to stimulate the imaginations of prospective data users to find new ways of extracting and using satellite remotely-sensed information.

It should be noted for those who intend to work with digital data that computer compatible tapes produced from the original video tapes contain more radiometric and geometric information than tapes produced by the digitization of film products.

3.2 DISCIPLINE-ORIENTED OVERVIEWS

Applications of Landsat data have been related to various "earth sciences" disciplines from the inception of the program. These disciplines are. Agriculture/Forestry/Range Resources, Land Use Survey and Mapping, Mineral Resources, Geological, Structural and Landform Survey; Water Resources, Marine Resources and Ocean Survey, Meteorology; and Environment Important to all these fields of investigation is the development of new techniques for the interpretation of data to be used in conjunction with those already established

The following synopses illustrate some of the major applications devised to date, the techniques employed in developing them, and in parenthesis, the names of NASA Principal Investigators reporting them. A complete list of PIs is included in Appendix J.

3.2.1 Agriculture/Forestry/Range Resources

Landsat data users have demonstrated the capability to monitor and inventory many different resources within this discipline.

Crop acreage inventory application studies have identified the following techniques as contributing to high crop identification and area measurement accuracies: preliminary stratification of the data, the use of temporal (multidate) data, unequal probability analysis and gray level histogram trimming Stratification, generally done using photointerpretation, significantly reduces the number of classes that must be considered during detailed analyses, thus reducing the time required to do the classification and improving overall classification accuracy (Draeger, Erb). Temporal analysis has been found to either improve accuracy beyond that of single date analysis or to make possible the earlier achievement of an equivalent accuracy level (Erb, Schaller). Unequal probability analysis assumes that not all species have an equal probability of appearing in the area under study and makes final identification decisions using prior knowledge of probability of occurrence (VonSteen) Gray level histogram trimming, an interactive, individual-band gray level range adjustment technique, has been used very successfully for training signature refinement (Dietrich). In addition to demonstrating the usefulness of these techniques, investigators studying crop inventory applications have found that classification accuracies using bands 5 and 7 only, are as high as when bands 4, 5, 6, and 7 are used for signature development and classification.

Multistage (multilevel) sampling techniques have been used successfully in timber class identification and volume estimation, and forest fire fuel mapping and modeling (Nichols). This technique involves the integration of satellite, aircraft, and ground data and has proven to be an efficient means of gathering forest data. As in the case of crop inventory applications, stratification has also been useful as a basic tool in forest survey applications.

Soil association identification and mapping have been accomplished by both photointerpretation and ADP techniques. The procedures used generally include stratification using vegetation, topography and temporal data as information sources (Drew) In addition, density slicing has proven to be especially useful in the mapping of soil associations found in predominantly sandy regions. Color composite images have been used to identify different features of soil associations in a wide variety of climatic, geographic and topographic conditions (Westin). Pure ADP techniques using training sets and pixel count have been used to discriminate organic and mineral soils (Landgrebe)

Range cover and forage production applications have involved the use of regression analyses and band-ratioing techniques. CCT-extracted band 5 radiance values have been found to be strongly correlated with vegetative biomass (Drew), and the ratioing of bands 5 and 7 has produced measurement accuracies to within 10% of the true value 95% of the time (Rouse). A related application, vegetation mapping according to the UNESCO scheme published in 1974, has been shown to be feasible using Landsat data (Williams).

Stress detection is an important potential application of Landsat data that has, at best, been limitedly successful.

3.2.2 Land Use Survey and Mapping

Various Landsat experimenters have demonstrated that broad but meaningful regional land use classification maps can be generated. The technique used by one experimenter (Simpson) consisted of tracing polygons (shapes containing a predominant land use characteristic) from 1 1,000,000 scale imagery. These land use polygon chips were then transferred to a standard geographical map of the region using the grid coordinate annotation of the imagery, with each class color-coded A land use map, "Northern Megalopolis" (United States), contained the following classes: Commercial and Industrial, Residential High Density, Residential Low Density, Transportation, Developed Open Space (urban), Rural Open Land (with and without residential), Agricultural, Woodlands, Marshlands, Sand and Rock Outcrops, and Water

Other experimenters (Erb, Thompson, Raje) have used computer analysis of the four MSS spectral bands to automatically identify the class of land use through definition of decision boundaries in this four-dimensional space, and correlation of each four-dimensional signature cluster to a known (ground truth) land use test site. This technique can be applied in both unsupervised and supervised modes of operation.

Unsupervised clustering is accomplished automatically by defining the boundary vectors of significant clusters of data samples in the population. Usually this is done in response to a query for a specific number (n) of clusters that the user is interested in defining, e.g , "n" land use classes. After processing and coding, the user must correlate the spatial arrangement in the hardcopy output of the machine to known ground truth test sites in order to interpret the data. Additional iterations are often necessary to correct for errors of commission or omission by trimming the decision boundaries of each cluster.

Supervised interactive classification is generally performed on smaller capacity machines using extensive software and a real-time CRT display. It is usually done for each class through selection by the operator of a spatial cluster of data samples that he knows to best represent each land use class of interest The machine reads these data points, statistically analyzes them and stores the boundary characteristics of the four-dimensional radiometric cluster for classification of all other data points within the particular data frame The process is repeated for each of the classes; the theme clusters are trimmed until the complete data frame is classified.

It should be noted that the success of these techniques depends to a large extent on establishing and surveying a sufficient number of control test sites, with ground truth for each class, to permit confident visual signature extension.

The same manual and digital processing techniques described can be used to outline the natural resources in large regions, the difference being in the selection of polygon characteristics.

Landsat images also have been used by professional cartographers (Colvocoresses, Wray, McEwen) to generate experimental photomaps at scales as large as 1:250,000, using the fundamental false-color composite product as the base material and fine-lining over it all other nonphysical information normally found on maps, such as political boundaries, names and identifications, and reference coordinates. The use of such imagery for periodic updates of maps at scales as large as 1:100,000 has been found to be of value by cartographers.

3.2.3 Mineral Resources, Geological, Structural and Landform Survey

In the area of mineral and petroleum resources, Landsat data have been effectively used to pinpoint areas of prospective mineral (non-metallic and metallic) and hydrocarbon resources of economic value. Standard photointerpretation of imagery to identify significant structural features (linears, faults, etc.) has been the most popular approach, although advanced interpretive techniques, including photographic enhancement, electronic enhancement, and digital image processing have been especially successful in several applications. Photolinear maps compiled from analysis of MSS bands 5 and 7 have been the basis for identifying potential resource areas Analysis of areas characterized by a high number of linears or linear intersections plus comparison with known resource locations and the use of additional supportive data, has been the method used most often for finding new resource potentials. Low-sun-angle and snow-enhanced imagery are frequently found optimal for linears mapping A multilevel approach, combining Landsat-derived maps with aircraft photography, geophysical data, and ground truth, continues to yield the best results.

A new technique to complement standard interpretive techniques, using Landsat spectral band ratios to distinguish potential mineralized zones, has also been developed (Rowan). With this technique, enhanced color and black and white images are produced by digital computer ratioing and contrast stretching (e.g , band 4/5 blue, band 5/6 yellow, band 6/7 magenta) Investigators have succeeded in mapping hydrothermally altered areas and in locating potential copper porphyry deposits using this method (Schmidt). In addition, a technique for digital spatial filtering of imagery data has been used to enhance linear patterns, as well as a technique for the electronic enhancement of linears (Goetz). Still another procedure employs standard false-color composites, which are especially valuable for lithologic mapping and in recognizing anomalous surface tonal characteristics.

Recent studies have indicated that Landsat imagery also has many applications in engineering and environmental geology. Potential ground water resources can be identified by a combination of structural analysis of the imagery, vegetation mapping and surficial moisture content mapping The location of potential ground water sources has been achieved using computer-ratioed, "stretched" images, coupled with optical-directional "filtering" (Goetz). Standard false-color composites and digitally processed color ratioed-stretched images have proven useful in mapping differing soil moisture conditions along the route of a planned highway (Krinsley). Identification of fractures and linears using bands 5 and 7 can be used to map potential landslide areas, unsuspected active faults adjacent to populated areas or highway routes and fractures cutting underground mining areas. Photomosaics compiled using Landsat imagery may reveal many previously unknown active faults (Gedney), and extensive erosion areas can be mapped using standard imagery (Morrison).

Satellite imagery lends itself well to the field of geological mapping and interpretation. In areas where rock exposures are good because of low vegetation cover, major geologic features such as folds, fault offsets, volcanic flows, contacts between different units, and many types of landform can be effectively mapped. The resolution and synoptic view of the imagery allows these structures to be mapped using standard Landsat black and white prints and transparencies to scales of 1:250,000. Computer-produced geologic maps can be generated at even larger scales, provided sufficient data are available. Landsat-derived geologic maps can be compiled into detailed structures, landforms, or lithologic (rock unit, but not type) maps. Results of studies reveal that present Landsat resolution precludes the identification of particular rock types, by lithology or by chemical composition Only a few rock types are readily and consistently recognizable (e g., basalts in flows) (Blodget).

3.2.4 Water Resources

The management of the earth's fresh water resources can also be aided through the use of Landsat data. Considering, for example, snow survey versus snowmelt runoff prediction, Landsat is providing data for accurately assessing areal snow extent (Wisnet, Barnes), particularly in small river basins (<3500 km^2). The MSS has also been employed to monitor glaciers, predict snowmelt runoff, and detect so-called "melting" snow surfaces. Satellite data of snow conditions are useful to many federal and state agencies, especially where snowmelt significantly contributes to spring and summer river discharges (Schumann). Such information permits more efficient utilization of snow as a valuable resource; e g., flood prediction, hydroelectric power generation, and water supply Landsat imagery has proven to be a useful tool for mapping snow areal extent and relating this parameter to seasonal runoff.

Using black and white 9 5-inch transparencies (band 7) and conventional photointerpretation techniques, Norwegian investigators (Odegaard, Ostrem) were able to use snow cover area determination, in conjunction with an established network of ground-based snow pillow sensors, to accurately forecast seasonal snowmelt runoff, thereby maximizing the utility of a hydroelectric facility and at the same time minimizing possible flood damage below the dam.

Investigations have shown that the high absorption characteristic of band 7 (Cowell, Higer, Anderson) makes possible the accurate delineation of surface water boundaries This band has been especially useful in mapping flood inundated areas as well as in delineating areas of potential inundation that are characterized by high soil moisture content. Landsat data have been used on an operational basis to map the extent of flood waters in parts of the United States and many foreign countries. Specifically, Landsat data have been useful for rapid evaluation of damage due to flood water, assessment of flood water control projects, land use planning, and for reservoir management.

The digital processing of Landsat data also allows the rapid analysis of hydrologic land use patterns for watershed surveys (Blanchard, Wagner). Extractable land use classes include accurate measurement of surface water, agriculture, urban, residential, forest, marsh, and flood-prone areas. Thematic classifications of watersheds have proven useful for monitoring watershed development as well as planning zoning legislation

For the first time, Landsat MSS satellite data have provided environmentalists with the capability to monitor the water quality of large ecosystems (Yarger, Rogers), such as rivers and bays, on a time-effective basis Although quality analysis of aqueous solutions involves a variety of analytical procedures, a limited number of quality parameters can be monitored via satellite remote sensing. At present, the detectable quality parameters are related to suspended sediment in water. Digital processing of Landsat data has been used to differentiate between organic and inorganic sediment in inland waters. Although it is not presently possible to establish detailed quantitative relationships between sediment loads and MSS reflectances, it is possible to detect nuisance-level water pollution levels.

Landsat investigators have reported success in detecting algal blooms and areas of high inorganic sediment in surface waters. The detection of algal blooms can be related to water of high organic nutrient content (nitrogen and phosphorous) resulting from insufficient wastewater treatment and agricultural runoff Detection of high inorganic sediment has been useful in locating areas of inadequate erosion control and monitoring sludge disposal operations.

3.2.5 Marine Resources and Ocean Survey

Landsat data have been used successfully in several aspects of marine resources studies. In the area of bathymetry, MSS data have been used to measure depths up to 20 meters with ±10% accuracy and up to 40 meters with ±20% accuracy in clear water (Polcyn). Three methods for extraction of water depth information from MSS CCTs have been developed. (A single channel method, a ratio method, and an optimum decision boundary method) The ratio method (using bands 4 and 5 where possible) gives the best depth values and tends to negate adverse effects of differing bottom conditions (sand, mud, etc.). With adequate ground truth, an absolute depth chart can be constructed.

Monitoring the location and movement of sea ice has special implications for arctic sea navigation (Barnes). Here, the method of multispectral analysis is useful for distinguishing ice floes from surrounding brash ice and ice cakes, for detecting puddling on the ice surface as opposed to cracks or fractures through the ice and for identifying broken cloud fields over ice surfaces. In areas of nearly solid ice cover, greater detail is evident in band 7 primarily because differences in reflectance between ice floes, brash ice and cracks and openings are greater Also, reflectance variations within some ice floes, which are evident in band 7, may be associated with hummocks, ridges or refrozen cracks. Bands 4 and 5 appear to be better for mapping ice boundaries, whereas band 7 provides valuable information on ice type and ice surface features. Ice features as small as 20 to 100 meters across have been detected Synoptic coverage and large image side lap at high latitudes permits repetitive coverage for monitoring changes and movements for periods of up to four days.

Biologically rich areas of the ocean have been located by enhancing the low spectral radiances that are characteristic of water bodies on CCTs (Szekielda). This brings out considerable detail in surface water that is unavailable on the original images. Upwelling water (Hendrickson) appears as an area of lower reflectance. Such areas may disrupt flow patterns of turbidity streamers in water moving under tidal influence along a coast Algal blooms in band 6 reveal more detail than in bands 4 or 5 (Strong) By comparing spectral signatures from turbid and chlorophyll-rich ocean water, a process can be derived to separate the two effects In one Landsat experiment (Maughan, Stevenson), distribution of photographically detected adult menhaden was significantly correlated with secchi disk visibility, surface salinity, water color and depth. All detected menhaden schools were located in areas of lowest band 5 image density.

Surveying currents and the results of ocean dynamics worldwide would be an important contribution to navigation as well as to the harvesting of the sea's resources. Some findings to date (Pirie, Sharma) indicate that turbid waters introduced into relatively clear oceanic water at the mouths of estuaries serve as a natural tracer to delineate circulation patterns, and that complex, fast-changing microcirculation patterns develop during each tidal cycle (Strong, Hendrickson). Conventional ship data reveal overall circulation but fail to show sub-gyres as seen in Landsat imagery. Band 5 gives the most accurate representation for suspended sediment boundaries, bands 4 and 5 give indications of sediment concentrations. Bands 6 and 7 delineate the shoreline, and discriminate water from land in marsh areas. Images have been analyzed (Maul) to delineate surface and subsurface sediment distribution and to differentiate nearshore morphologic units and to map current effects (Klemas). It is also possible to measure the seaward extent of suspended sediment transport and to differentiate sediment levels within individual lobes.

3.2.6 Meteorology

The primary meteorological applications of Landsat data have been in the study of mesoscale phenomena. The resolution, spectral bands and synoptic view of Landsat provide a perspective of localized meteorological patterns that cannot be obtained with conventional weather satellites. Most investigators in meteorology have analyzed Landsat imagery through photointerpretation techniques and many have also successfully collected meteorological data via the Landsat DCS.

In air pollution studies, the resolution and spatial extent of the imagery allow detailed observation of a "regional air shed" or air quality control region. Air sheds have been identified and observed (Lyons) by noting the direction and extent of pollution plumes generated by an industrial complex. Experience has shown that these particulate plumes can be seen best over water in either band 5 or 6, due to optimum contrast between the low albedo water surface and higher albedo particulate plume. Detection of smoke plumes over land is more difficult unless the plumes are unusually dense. Land surfaces are generally much brighter than water and exhibit marked spectral and seasonal variations in radiance. Observing the intra-or inter-regional transport of pollutants can be useful in assessing a region's ability to meet and maintain air quality standards. The feasibility of this type of air pollution monitoring, under certain conditions, has been demonstrated.

In cloud studies, the structure and arrangement of clouds from small cumulus cells to thin cirrus can be uniquely observed with Landsat. Its resolution provides details that are not obtainable with conventional meteorological satellites. The multispectral imaging capability of the imagery is most useful to the meteorologist for selectively penetrating haze and thin clouds, revealing cloud shadows, delineating snow cover from vegetation, and demarcating land and water boundaries. Using the multispectral images, varying structures of the clouds can be observed. Band 7 effectively penetrates most haze and thin clouds, revealing only the thicker cloud structures, while band 4 displays the entire cloud or haze pattern. Complex mesoscale gravity waves in low stratus and fog have been observed (Lyons) over lakes, and cloud detail apparent in inadvertent weather modification, lake front breezes, mesoscale spiral vortices and lake shore convergence and snows have been revealed. The possibility of detecting thin cirrus related to areas of clear air turbulence and the core of a jet stream has been shown (Tsuchiya); investigators have also observed localized patterns of orographic lifting, thermal convergence and energy balance relationships.

Investigators (Bowden, Hollyday) have viewed the actions and aftereffects of localized severe weather The Landsat view of a Santa Ana wind in progress, for example, gave additional insights into the general flow patterns of this intense, damaging wind. Particular areas of heavy wind erosion could be found by tracing the origins of large dust plumes In another instance, the path of a particularly devestating tornado was readily observable in the Landsat data of a national forest.

One of the most effective means of collecting ground truth meteorological data for many Landsat investigations has been with the instrumented data collection platform (DCP). Seven Landsat DCPs were utilized (Kahan) in a major winter weather modification program in the Colorado River Basin. The DCPs returned hydrometerological data such as wind speed and direction, temperature, humidity, snow depth and density, and streamflow. Through a communications network, collected data were available to the users within 3 to 8 hours of DCP transmission.

3.2.7 Environment

From the platform of the earth-orbiting satellite, valuable information can be collected on the quality of this planet's environmental systems. While the satellite's multispectral sensor bandwidths were selected principally to reveal the content, quantity and condition of vegetated surfaces, they also yield information on water quantity and quality and on land surfaces barren of vegetation. The synoptic scale of Landsat imagery is valuable for integration of various simultaneous conditions and changes within an entire region, allowing holistic monitoring of environmental systems. At the same time, the acre-sized resolution cell provides a level of detail that is valuable for quantitative environmental monitoring. Perhaps the most significant characteristic of the satellite data is that they are available on a repetitive basis, and therefore allow evaluation and even quantification of environmental trends and changes caused by man

Vegetation classification and mapping from Landsat imagery are useful for many types of environmental studies. Using manual techniques, investigators (J. Anderson, McGinnies) have mapped the vegetation associations vital to wildlife habitat. Digital classification of multispectral data from CCTs has been of great value in monitoring large areas for changes in wildlife habitat conditions such as vegetation density and water quantity (Lent). The satellite data reveal vegetation type and vitality of coastal and inland wetlands, which are of great importance to migratory waterfowl and to many aquatic and marine creatures. In addition, manual comparison of images has been valuable for monitoring the encroachment of man upon the coastal zone (Yunghans). Changes due to development, as small as two acres, have been detected. Also of significance to wildlife studies is the capability of mapping permafrost zones in arctic regions (D. Anderson), which are almost inaccessible except through satellite sensing. Vegetation maps of warmer climes have been used to detect breeding sites for locusts and other agricultural pests (Pedgley)

Because digital analysis retains the spectral and spatial resolution of each pixel, this means of Landsat data analysis has been valuable for water quality studies. Reflectance level, particularly of band 5, can be used to monitor turbidity content throughout a body of water where a few surface readings have been taken. Digital classification of repetitive scenes can show sedimentation trends in lakes, and dispersal patterns of outfalls (Rogers, Wezernak, Yost, Fontanel). Digital land use classification of watersheds has been shown to be a reliable indirect indicator of lake and reservoir quality, and a means of identifying areas where water quality changes are likely to occur. Thus satellite imagery can be used to detect industrial and municipal waste dumps in nearshore waters, and some correlations to chlorophyll content have been reported (Rogers, Yunghans, Klemas).

Multispectral Landsat imagery shows a high contrast between vegetated and non-vegetated surfaces, and thus is readily applicable to monitoring large scale construction projects and surface mining operations. Black and white band 7 images have been used on a regular basis to update maps of strip-mining regions (Sweet). Digital classification of both multiple band and band-ratioed imagery allows distinction of stripped and partially revegetated surfaces, and can be used to measure the area affected by mining operations with a high degree of accuracy (Rogers, A. Anderson).

Landsat imagery has been used to detect and monitor certain types of large scale environmental changes, such as beach erosion (Maruyasu), forest fires (A Anderson), and floods. Investigations are continuing to determine the feasibility of using Landsat to study air pollution, oil spills, vegetation disease and various types of water pollution.

3.3 SPECTRAL BAND INFORMATION DESCRIPTORS

The Landsat MSS remotely senses energy reflected from the earth in four different ranges of the electromagnetic spectrum. The radiation sensed by the scanner varies with the characteristics of the emitting (reflecting) body as to wavelength and intensity, but all spectral returns are converted into digital values in their respective bands The digital value depends upon the strength of the signal received. When these digital values are reproduced as imagery each band presents its own unique picture of the same scene. Further, certain objects in a scene may yield more information about themselves in one spectral band than in another With this background, Table 3-1 was prepared to aid users in selecting the band that will probably be most helpful to them in their particular area of study. The chart represents a consensus of the findings and opinions of the various investigators working in the areas encompassed by the disciplines discussed here. In cases where more than one band is listed, investigators have

Table 3-1. Spectral Band Information Descriptors

MSS Spectral Bands	Airfields	Air Pollution	Atmospheric Sensitivity	Burned Rangeland	Chlorophyll (Land)	Chlorophyll (Sea Water)	Cloud Penetration	Cloud-Snow Differentiation	Clouds (Thin Cirrus)	Crop Differentiation	Defoliation	Eddies	Flood Plains	Forests	Geologic Features	Grass Fires	Growth State	Haze	Ice	Igneous Rocks	Iron (Ferric)	Irrigated Fields	Jet Contrails	Lakes	Lake Eutrophication	Landform Features	Large Bridges	Large Horizontal Concrete Structures	Lithology
4		X	X						X								X	X	X		X		X		X				
5	X	X			X				X		X	X		X							X		X			X		X	X
6						X		X							X					X							X		
7				X		X	X			X	X	X	X		X	X	X		X	X		X		X					

MSS Spectral Bands	Marshes	Metamorphic Rock Alluvium Differentiation	Rivers	Roads	Serpentine Outcrop	Shallow Water	Shoals	Shores	Small Lakes	Snow Detection	Snow Lines (Transient On Glacier)	Snow Lines (Forest)	Soil Associations	Soils Discrimination	Soil Moisture Detection	Stream Channels	Stress	Surface Water	Tectonic Features	Topography	Turbidity	Urban Areas	Water Boundaries	Water Depth (Bathymetry)	Water Pollution	Water Sedimentation	Wetlands	Wooded Areas	
4				X		X	X			X		X									X	X		X	X	X		X	
5				X									X	X	X		X			X	X	X		X	X	X		X	
6	X		X					X			X		X			X		X	X				X				X		
7		X	X		X			X	X					X				X	X			X	X				X		

found that more than one band was especially useful.

3.4 APPLICATIONS SYSTEMS VERIFICATION AND TRANSFER PROJECTS (ASVTs)

Certain quasi-operational projects have been selected by NASA to demonstrate the applicability of Landsat data to the solutions of resource management problems These projects are called Applications Systems Verification and Transfer projects (ASVTs). When each test project is completed a decision will be made as to whether or not it is cost effective to go operational with the Landsat information. A description of four of these ASVTs is given here. It is anticipated that more ASVTs will be identified in the future

3.4 1 Snow Cover and Runoff Prediction

The object of this project is to measure various snow parameters with remote sensors and use the measurements as inputs to runoff computations. Data from various remote sensing platforms and various sensors, covering different portions of the electromagnetic spectrum, will be subjected to analysis using standard photointerpretation techniques and more sophisticated computer techniques. Data will be collected in four different snow areas in the U.S. the Pacific Northwest, California, Arizona, and Colorado. The effort will be implemented in cooperation with the following federal, state and local water resources management agencies: The U S. Army Corps of Engineers, the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, the U.S. Forest Service, the U.S. Soil Conservation Service, the Bonneville Power Administration, the Arizona Salt River Project, the California Department of Water Resources and the Colorado Division of Water Resources

3.4.2 Louisiana Environmental Information System

The object of this project is to test and demonstrate an automated environmental information system, based on remotely sensed data, for updating basic environmental data in a predominantly wetlands area. The U.S Army Corps of Engineers has a continuing need for basic environmental information for planning projects and assessing their resulting impact They have requested NASA to assess an atlas, "Inventory of Basic Environmental Data, South Louisiana," produced from formerly existing data, to determine how much of the data could be updated using remote sensing. Data regarding land use and vegetation classification were identified as candidates for automated classification utilizing remote sensing data.

A number of Earth Resources Laboratory Sustaining Research and Technology projects in South Louisiana and Mississippi, and associated software and hardware projects, have provided the basis for developing an automated system to meet the user agency requirements South Louisiana is a suitable test area because of logistics, applicability of past studies, user agency interest, and predominance of marsh in the area.

Simplified pattern recognition software, suitable for general purpose computers, and a low cost image display system will be utilized The system will accept satellite and aircraft multispectral scanner data and other types of data for correlative purposes. The system definition documentation and training will be oriented to user implementation of the system. The demonstration tests will prove the feasibility of using the system to update a variety of environmental thematic data; e.g., marsh salinity regions.

3.4.3 Natural Resources Information System

The object of this project is to test and demonstrate an automated natural resources inventory system based on remotely sensed data oriented to state or regional use, and directed at specific applications. States and other governing bodies have a need for accurate, up-to-date natural resources inventory information for managing resources, optimizing growth and development and minimizing environmental impact The large geographical areas involved make surface inventory difficult and encourage the use of remote sensing. The resulting large quantities of data imply the desirability of automatic processing, access and correlative capability. The effort for the past three years has been oriented to the development of software, hardware and disciplinary techniques suitable for incorporation into such an automated system, with the State of Mississippi as the test area. This system will also use simplified pattern recognition software and a low cost image display system. The project will demonstrate the system in state facilities and will be oriented to the production of inventories of timber, land use, water resources and wildlife habitat It will require the use of a prototype operational semi-automatic system, with Landsat MSS and ground truth data.

The utility of inventories made with remotely sensed data will be greatly enhanced in specific applications through the development of an information system designed to combine natural resources inventory data with other data; e.g., soils, climate, and population densities. Such an information system will be developed within a framework that allows geographic referencing. A utility assessment, including cost-benefit studies, will be made by following the use of such information through the decision-making process associated with each application.

3.4.4 Large Area Crop Inventory Experiment (LACIE)

LACIE is an interagency experimental demonstration project involving the U.S. Department of Agriculture (USDA), the National Oceanic and Atmospheric Agency (NOAA) of the U.S. Department of Commerce, and NASA The project is designed to test the degree to which computer-assisted analysis of space-acquired data may enhance the USDA's operational crop forecasting programs. It is intended to demonstrate the capability of relatively new remote sensing and data processing systems in combination with existing techniques and historical data to forecast the production of an important world crop Wheat has been selected as the test crop for the LACIE demonstration.

LACIE will utilize Landsat in conjunction with meteorological satellites and conventional meteorological and climatological data sources Landsat multispectral data gathered repetitively over selected sites will be classified and used to measure crop area, while meteorological data are used in statistical models to predict crop yield. Area and yield estimates will then be combined to arrive at crop production estimates.

The initial phase of LACIE will concentrate primarily on the United States and Canada. It will then be extended to include the major wheat growing regions of the world

SECTION 4
OUTPUT DATA PRODUCTS

4.1 INTRODUCTION

Landsat data products produced by the NASA Image Processing Facility (IPF) at GSFC are discussed in this section. Product availability to users through the IPF, the EROS Data Center, the U.S. Department of Agriculture Western Aerial Photo Laboratory and the NOAA Environmental Data Service is discussed in detail in Section 5

Figure 4-1 summarizes the original output data products produced by the IPF. Within this section, they are grouped into three areas for discussion: photographic products, computer compatible tapes (CCTs) and Data Collection System products.

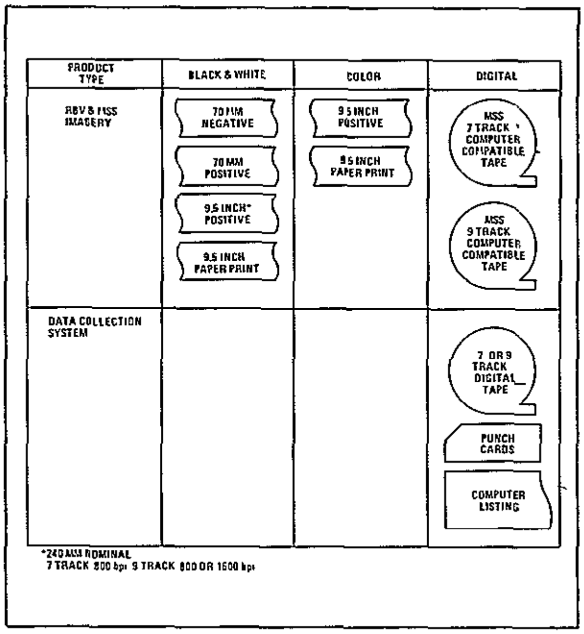


Figure 4-1. Landsat Original Output Products

4.2 PHOTOGRAPHIC PRODUCTS

The following information will be useful to users when considering Landsat photographic products

1. All imagery contains radiometric and certain spatial corrections introduced during the process of videotape-to-film conversion The term "system-corrected imagery," which refers to these corrections, applies to all imagery.

2. Generation number assigned to photographic products is referenced to the initial, original archival output from the electron beam recorder, which is designated as the first generation. Each successive photographic product generated adds one generation Thus, an enlargement from a 70mm archival image is a second generation product.

3. Relationships between sensors, wavelengths, and IPF band codes are shown in Table 4-1.

Table 4-1 Sensor Band Relationships

Landsat 1 and 2		
Sensor	Wavelength (μm)	IPF Band Code
RBV	0 475 - 0 575	1
	0 580 - 0 680	2
	0 690 - 0 830	3
MSS	0 5 - 0 6	4
	0 6 - 0 7	5
	0 7 - 0 8	6
	0 8 - 1 1	7
Landsat C		
Sensor	Wavelength (μm)	IPF Band Code
RBV	0 505 - 0 750	*
MSS	0 5 - 0 6	4
	0 6 - 0 7	5
	0 7 - 0 8	6
	0 8 - 1 1	7
	10 4 - 12 6	8

*An IPF band code will not be designated for the Landsat-C RBV Instead, the letters A, B, C and D will be assigned to the four Landsat-C RBV images that approximately overlap one MSS image (Refer to Figure B-11)

4. Photographic products are available in two basic film sizes - 70mm and 9 5 inch (240mm nominal) - although facilities other than IPF have derived more sizes

from the 70mm film imagery. IPF processing uses the spacecraft altitude at "image center time" to scale each Landsat 1 and 2 and Landsat-C MSS 70mm image to 1.3,369,000. When the image on 70mm film is enlarged by a factor of 3.369 and printed on 9.5 inch film, the scale is 1:1,000,000. Scaling for corresponding Landsat-C RBV imagery is twice that of Landsat 1 and 2 and Landsat-C MSS imagery.

4.2.1 Image Production

The production flow through the IPF for each of the photographic products shown in Figure 4-1 is illustrated in Figures 4-2 through 4-4.

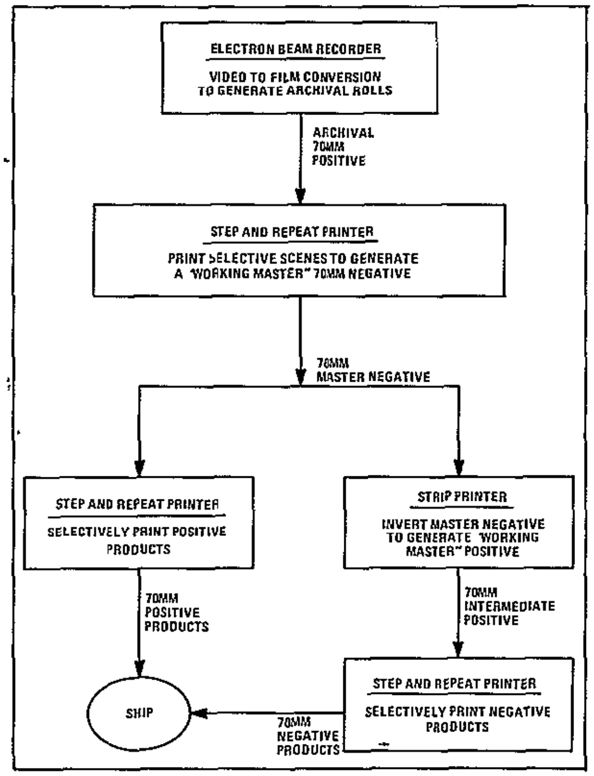


Figure 4-2. Production Flow of a 70mm Positive and Negative Product (Black and White Only)

4.2.2 Image Format and Annotation

A sample of the Landsat 1 and 2 RBV and MSS image format, including registration marks, tick marks, gray scale and alphanumeric

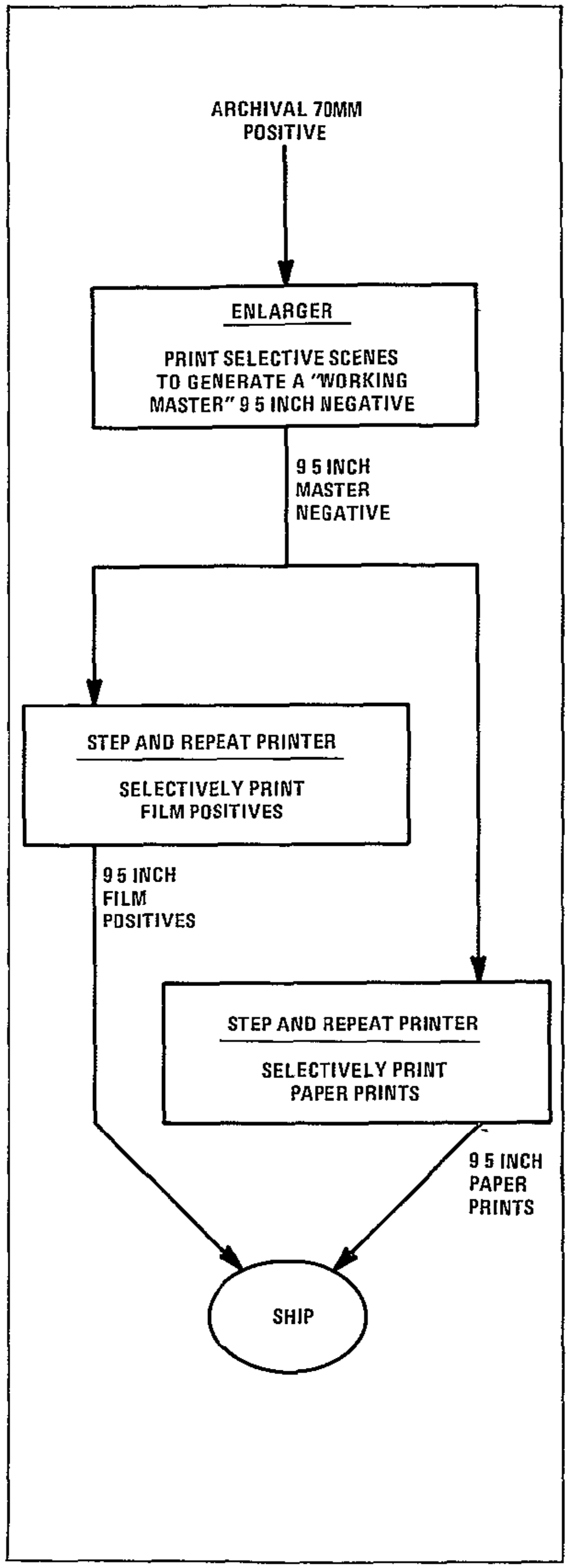


Figure 4-3. Production Flow of a 9.5-inch Black and White Film or Paper Product

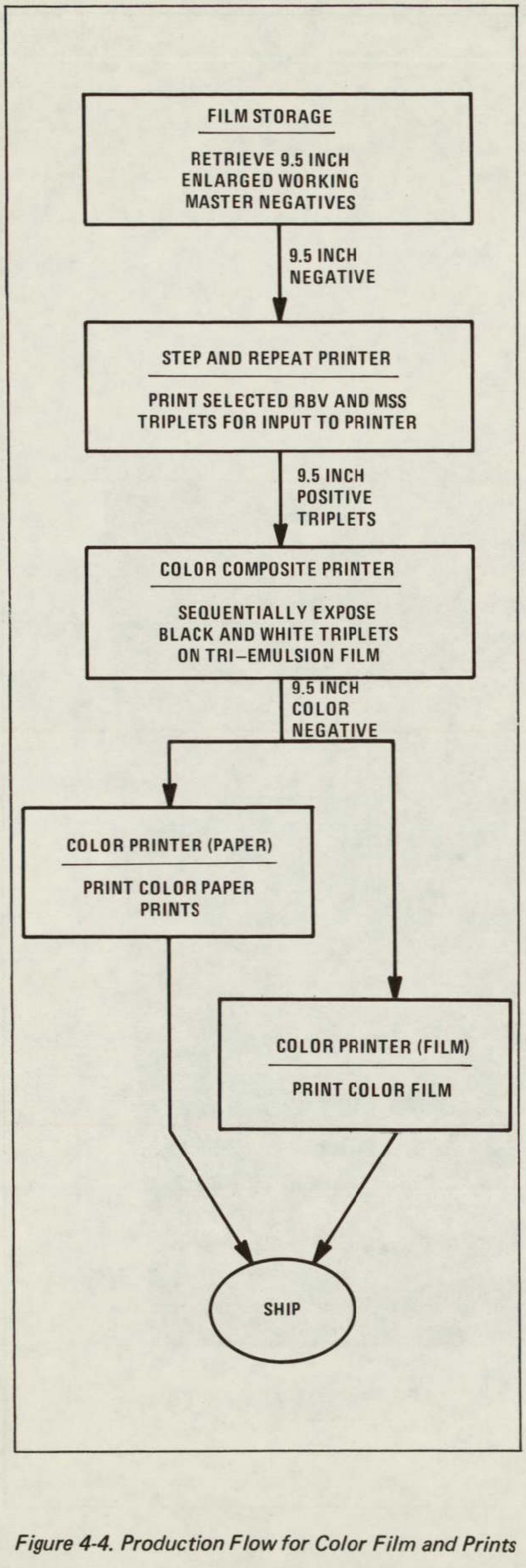


Figure 4-4. Production Flow for Color Film and Prints

annotation, is shown in Figure 4-5. The RBV image format is identical, except that it contains fiducial references (reseau and anchor marks). The spacecraft heading is always toward the annotation. The annotation for Landsat-C RBV is depicted in Figure 4-9, which shows in detail the annotation block for all film imagery.

The dimensions for the 70mm and 9.5 inch RBV and MSS film products are given in Figure 4-6.

4.2.2.1 Registration Marks

Four registration marks are placed beyond the image corners to facilitate alignment of different spectral images of the same scene from the same payload sensor. The image is positioned within the writing area so that when the registration marks from two or more spectral images are superimposed, the imagery will be registered. The dimensional details of these registration marks are shown in Figure 4-7.

The intersection of diagonals drawn through the four registration marks is the format center of the image. The format center of a scene imaged at the same time by both the RBV and MSS will be identical. Annotation not otherwise specified refers to properties at the format center.

4.2.2.2 Tick Marks

Latitude and longitude tick marks are placed outside the edge of the image writing area at intervals of 30 arc minutes. The geographic reference marks are annotated in degrees-minutes with the appropriate direction indicator. At latitudes above 60 degrees north or south, tick marks are spaced at one-degree intervals to prevent crowding.

4.2.2.3 Gray Scale

A 15-step gray scale tablet is exposed on every frame of imagery as it is produced on the electron beam recorder (EBR). This scale is subject to the same copying and processing

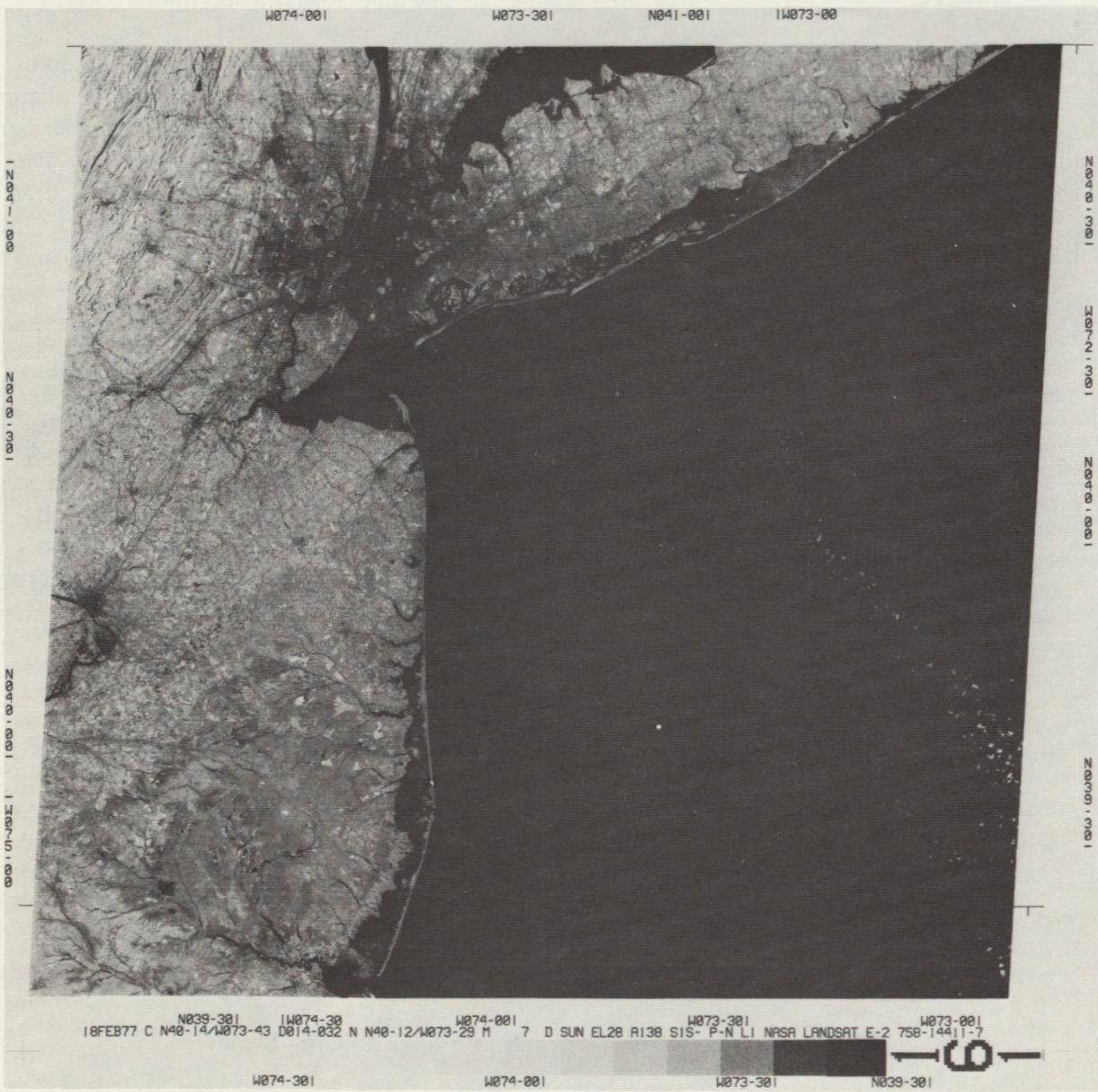
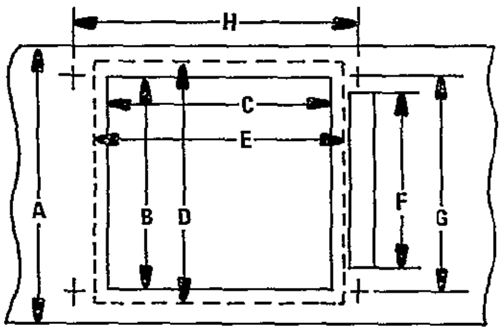


Figure 4-5. MSS Image Format – 9.5-inch Film (Not to Scale)

⑤



Dimension Code	Description	70 mm		Enlarged ① 9 5 inch	
		RBV	MSS	RBV	MSS
A	Film Width	70	70	240	240
B	Nominal Image Size (cross track)	55 ② 58 3	55 ②	185 3 ④ 196 4	185 3
C	Nominal Image Size (in track)	55 ② 58 3	53 ③	185 3 ④ 196 4	178 5
D	Writing Area (cross track)	60	60	202 2	202 2
E	Writing Area (in track)	60	55 5	202 2	190 4
F	Annotation Block Length	51 6	51 6	173 7	173 7
G	Registration Mark Separation (cross track)	58 6	58 6	197 5	197 5
H	Registration Mark Separation (in track)	64	59 5	215 7	200 5

NOTES

① Processing uses spacecraft altitude at "image center time" to scale each 70 mm image to a ratio of 1 3369 000, except for Landsat C RBV imagery which is scaled to a ratio of 1 1 684,500 The enlarging factor is 3 369 which provides a scale of 1 1,000 000 in all enlarged images indicated, except for Landsat C RBV wherein the scale becomes 1 500,000

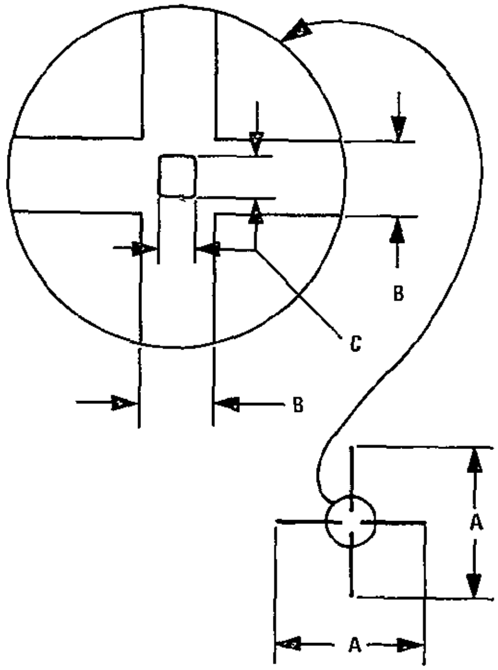
② 55 equivalent to 185 2 km (100 nm) except for Landsat C RBV } at 918 6 km (496 n m) altitude
58 3 equivalent to 98 2 km (53 nm) for Landsat C RBV

③ 53 equivalent to 178 3 km (96 3 nm)

④ 185 3 applicable, except for Landsat C RBV
196 4 applicable for Landsat C RBV

⑤ All dimensions given in millimeters (mm)

Figure 4-6. Product Dimensions



Dimension	70 mm RBV	70 mm MSS	9 5 in RBV	9 5 in MSS
A	2 0	2 0	6 74	6 74
B	0 0532	0 0468	0 1793	0 1578
C	0 0266	0 0234	0 0896	0 0788

NOTE Dimensions are in millimeters

Figure 4-7. Registration Mark Details

as the image to which it is attached. The gray scale gives the relationship between a level of gray on the image and the electron beam density used to expose the original image. The electron beam density is related to the sensor signal voltage which, in turn, is related to the energy incident on the sensor.

The annotation gray scale for MSS imagery corresponds to zero radiance at step 15 (black on positives) and maximum radiance as given by Figure C-5 at step 1 (white on positives). The radiance varies linearly with gray step transmission between these values with the difference between each step corresponding to 1/14th of the maximum radiance.

The transmission of the steps in the RBV annotation gray scale varies linearly with the camera voltage, between 320 and 1100 millivolts The voltage difference between each step is 1/14th of [1100 - 320] or 55.7 millivolts. The radiance in front of the lens for a 12-millisecond exposure is obtained from Table B-3 for the voltage corresponding to the gray scale step. The radiance for the actual exposure time is found by multiplying values given for 12 ms, by 12/t, where t is the exposure derived from the image annotation, as explained in Figure 4-9, item e, considered together with Note 3 in Table 4-5.

The gray scale tablet is a macroscale tablet and cannot be used reliably for microscale image radiometry, because the areas, on the order of a few picture elements, are subject to influence by neighboring areas (modulation transfer function effects, chemical development adjacency effects) and do not supply enough data points to average noise down to a low figure.

The dimensions of the gray scale and alphanumeric annotation blocks are shown in Figure 4-8.

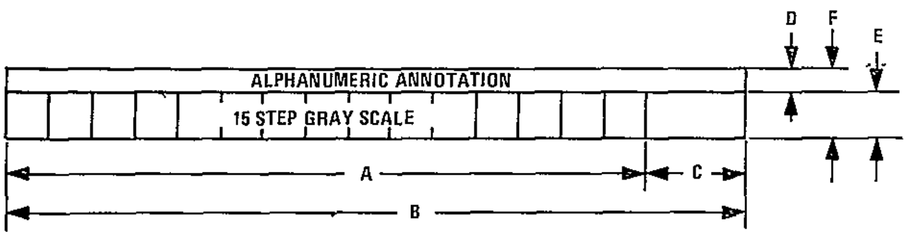
4.2.2.4 Alphanumeric Annotation

Figure 4-9 details the type of alphanumeric annotation shown at the bottom of Figure 4-5 Items a through i explain the data contained in this annotation.

4.2.3 Delivered Form

4.2.3.1 Landsat 1 and 2

Most photographic products are delivered in cut form. In special cases, film products are delivered in roll form Prints are always delivered in cut form.

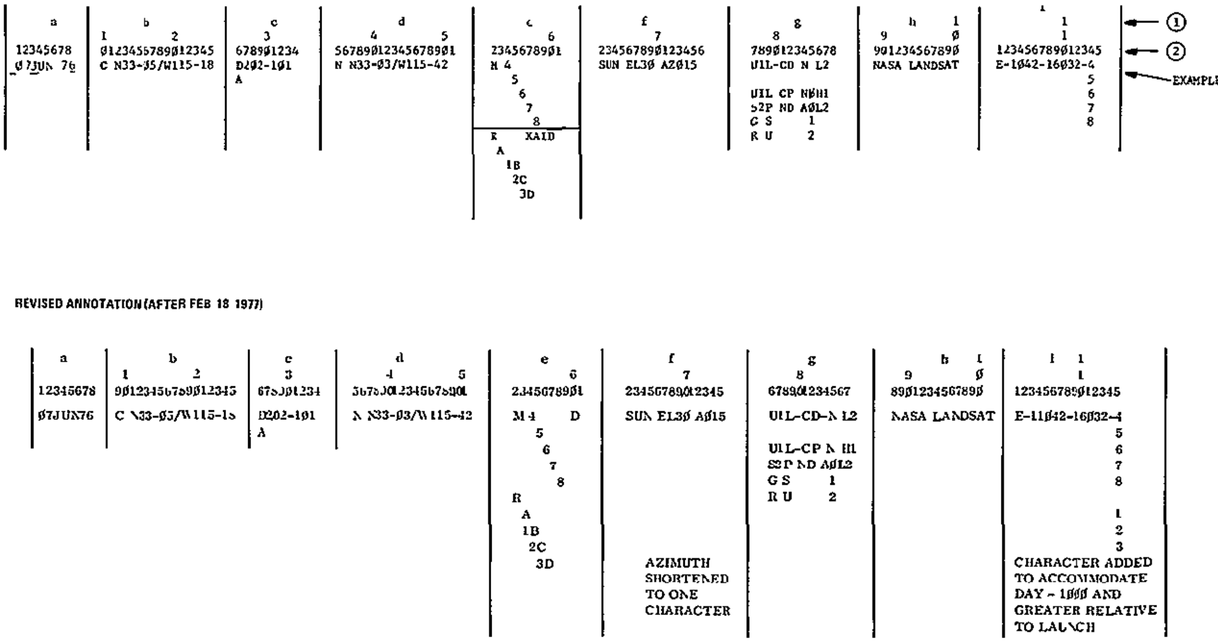


Dimension Code	70 mm	9 5 in
A	45 0	151 6
B	51.6	173 7
C	6.6	22 1
D	0 8	2 7
E	2 0	6 7
F	2 8	9 4

NOTE. Dimensions are in millimeters The nominal 9.5-inch dimensions are a 3 369 enlargement of the 70-mm dimensions

Figure 4-8. Product Annotation Block Dimensions

ORIGINAL ANNOTATION



Notes ① The letters "a" through "i" refer to items in this illustration that explain the annotation block.
② Character "position" in the annotation block.
③ ƀ = blank.

a Character Positions 01-08 07 JUN 76ƀ
Day month and year of picture exposure

b Character Positions 09 25
CƀN33-05/W115-18ƀ
Format Center Latitude and longitude at the center of the RBV and MSS image format is indicated in degrees and minutes

c. Character Position 26 34 D202 101ƀ
The "D" indicates spacecraft is descending an "A" indicates spacecraft is ascending
Nominal path and row identifier The 202 is path number and 101 is row number

d Character Positions 35 51
NƀN33-03/W115-42ƀ
Nominal latitude and longitude

e Character Positions 52-61
Characters in this group are sensor and spectral band specific
For RBV Images

52 56	Sensor spectral band or Landsat C identification code
57 58	RBV Shutter Duration Code The "XA" refers to shutter speed
59	Aperture Correction Indicator I Aperture correction "in" O Aperture correction out
60	"D" indicates direct transmission. "R" indicates stored data played back from the satellite WBVT recorder
61	Blank

For MSS images

52 58	The sensor spectral band identification code
60	"D" indicates direct transmission "R" indicates stored data played back from the satellite WBVT recorder
61	Blank

f Character Positions 62 75 SUNƀEL30ƀ A015ƀ
Sun Angles the sun elevation angle and sun azimuth angle measured clockwise from true North at the time of midpoint of MSS frame is specified to the nearest degree
Blank for ascending node coverage

g Character Positions 76 87 U1L CD NƀL2ƀ

Character position 76 defines the type of geometric correction applied to the data
"U" = uncorrected
"S" = system level
"G" = geometrically corrected based on geometric GCP s
"R" = geometrically corrected based on relative GCP s

Character position 77 indicates the scale of the image
"1" = 185 km x 185 km (~100 nm x 100 nm)
"2" = 92.5 km x 92 5 km (~50 nm x 50 nm)

Character position 78 defines the projection
"L" = Lambert projection
"P" = polar stereo projection
"S" = space oblique projection
"U" = UTM projection

Character position 80 indicates the resampling algorithm
"C" = cubic
"N" = nearest neighbor

Character position 81 indicates the type of ephemeris data used to compute the image center
"P" = predictive
D = definitive (for system level correction only)

Character position 83 gives the processing procedure
"N" = normal processing procedure
"A" = abnormal processing procedure

Character position 84 defines whether an earth image or whether a RBV calibration image has been processed
blank = earth image
Either "0" "1" or "2" = RBV Radiometric calibration images indicating lowest to highest exposure level respectively

Character position 85 indicates the sensor gain options
"H" = high gain
"L" = low gain

Character position 86 shows the type of MSS transmission
"1" = linear mode
"2" = compressed mode

h Character Positions 88 100
NASAƀLANDSATƀ
Identifies the agency and the project

i. Character Positions 101 115
E 11042 16032-4
Frame identification number Each image or frame will have a unique identifier which will contain encoded information consisting primarily of time of exposure relative to launch Its format is E ADDDD-HHMMS B and is interpeted as follows

"E"	Encoded Project Identifier
A	Landsat Mission 1 Landsat 1 2 Landsat 2 3 Landsat 3
DDDD	Day number relative to launch at time of observation
HH	Hour at time of observation
MM	Minute at time of observation
S	Tens of seconds at time of observation
B	NDPF identification code (RBV A B C D MSS 4 5 6 7 8) 1 2 3

Figure 4-9. Details of Annotation Block

Roll form products appear as shown in Figure 4-10. Note that the MSS images are grouped by spectral band, that is, sequentially adjacent images on the roll are for sequential geographical areas. These images are followed by the same sequence of adjacent images in the next spectral band, etc.

4.2.3.2 Landsat-C

Landsat-C imagery data will be processed through the Image Processing Facility (IPF), converted to High Density Tape and supplied to the Landsat Data Distribution Centers in digital form either via communication links or shipment of High Density Tape copies High Density Tape, computer compatible tape and photographic products will also be provided by the IPF to selected special tasks and special users

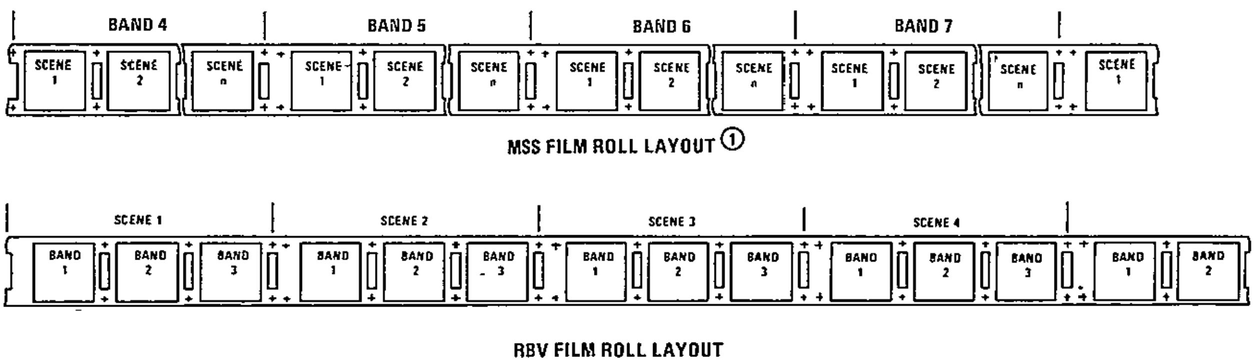
4.3 MSS COMPUTER COMPATIBLE TAPES

Digital data are available in the form of computer compatible tapes (CCTs). These tapes are standard 0.5-inch polyester-base magnetic tapes, whose physical characteristics are given in Figure 4-11 and Table 4-2, logical characteristics are discussed in Subsection 4 3.2. One, two, or four CCTs, comprising a set, contain one scene of digital imagery. The external label on each tape contains the arrangement and type of information shown in Figure 4-12. Additional information may be found in NASA/GSFC Document X-563-75-223, "Generation and Physical Characteristics of the Landsat 1 and 2 MSS Computer Compatible Tapes."

4.3.1 CCT Physical Format

CCTs are in two basic physical formats

1. Nine-track, 1600 or 800 bpi - For the nine-track CCT, the alphanumeric data are in EBCDIC and the video data are in binary. Three 8-bit bytes are contained in three frames. (Frames are



NOTE ① THE MSS VIDEO TAPE TO-FILM CONVERSION PERFORMED BY THE BULK PROCESSING ELECTRON BEAM RECORDER (EBR) "GROUPS" THE IMAGES ON THE ARCHIVAL FILM ROLL BY SPECTRAL BANDS AS ILLUSTRATED THE NUMBER OF IMAGES, n, IN A SPECTRAL 'GROUP" IS DETERMINED BY THE NUMBER OF SCENES ON THE MSS VIDEO TAPE THIS NUMBER CAN VARY FROM SOME NOMINAL MINIMUM OF, SAY 12, TO A MAXIMUM OF 48 [A SCENE MEANS ONE 25 SECOND, 185 2 BY 178 3 km (100 BY 96 3 nm) OBSERVATION] THE INTEGRITY OF THIS SPECTRAL GROUP WILL BE MAINTAINED IN THE ROLL FORM PRODUCTS THAT ARE SENT TO THE USER A GIVEN ROLL WILL CONTAIN ALL SPECTRAL IMAGES FOR EACH SCENE

Figure 4-10. Landsat 1 and 2 Corrected Roll Film Scene/Band Layout

Table 4-2 MSS CCT Operational Data Format Definitions

		Tape Recording
Tape:		0.5 inch wide; 2400 ft. long, 1.5 mil thick, Mylar or polyester base.
Load Point Marker (LPM)		Placed parallel to and not more than 1/32 inch from the edge of the tape nearest the operator when reel is mounted, providing a leader of at least 10 feet.
End of Tape Marker (EOT)		Placed parallel to and not more than 1/32 inch from the edge of the tape nearest the tape unit when the tape is mounted, providing a leader of at least 14 feet. Phase encoding for 1600 bits per inch (bpi).
Recording Method:		NRZ 1 (non-return to zero, change on ones) for 800 bpi.
7-track	Interchange code:	Video data, packed binary; alphanumeric ID data in packed binary EBCDIC.
	Recording format:	7 channels, 6 information bits plus parity, packed binary.
	Recording density:	800 bpi.
9-track	Interchange code.	Video data, binary; alphanumeric ID data, EBCDIC.
	Recording format:	9 channels, 8 information bits plus parity, binary.
	Recording density:	1600 or 800 bpi.
		Tape Records
Data Records:		Records of logical data are separated by inter-record gap.
Record Size:		Minimum: 12 bytes; maximum: limited by computer memory.
Initial Gap: (IG)		0.94 inch after load point marker.
Inter-record Gap: (IRG)		0.06 + 0.15, - 0.10 inch.
Tape Mark (End of File, EOF):		3.5 inch, followed by one byte (x '13'), followed by a longitudinal check character (LRC) only.
		Validity Checks
Vertical:		Odd parity is used.
Longitudinal:		Longitudinal redundancy check (LRC), cyclic redundancy check (CRC) characters written automatically following data records.
Physical Spacing		Refer to Figure 4-11 for description.

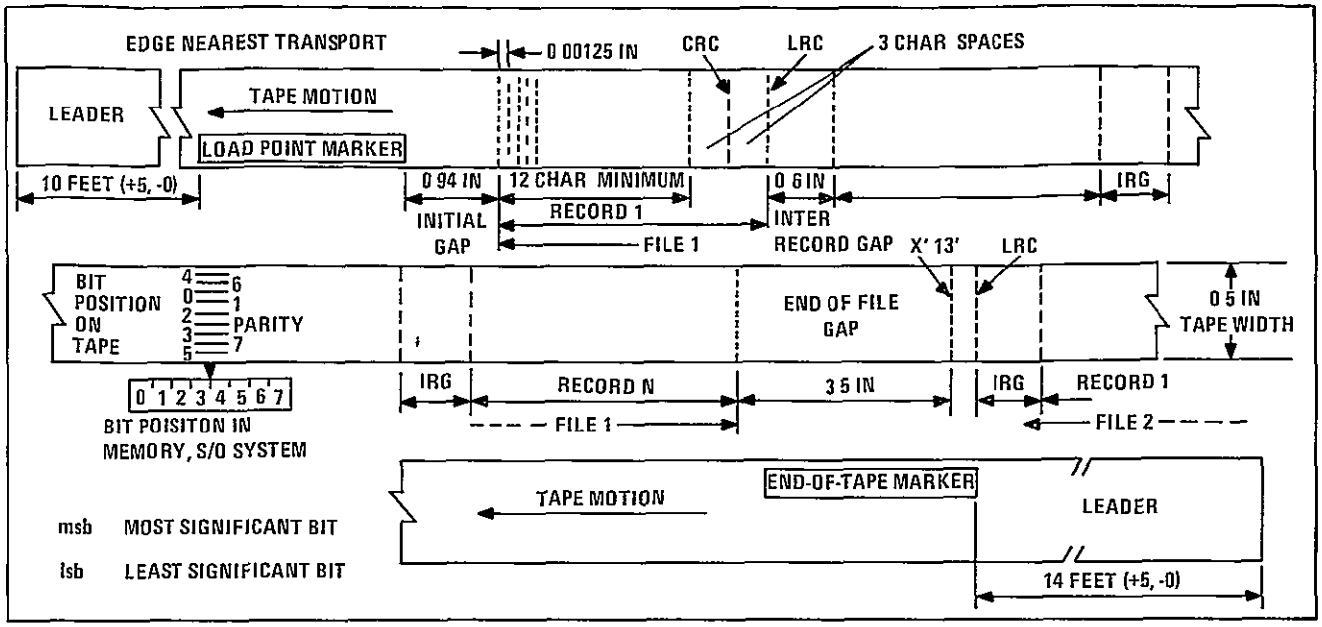


Figure 4-11 Physical Spacing of Records on MSS CCTs

areas; each is one recording position in length, extending across the tape, perpendicular to the direction of tape movement.)

2. Seven-Track, 800 bpi - The seven-track CCT contains packed binary video data and packed EBCDIC alphanumeric data. In the "packed" configuration, three 8-bit bytes are contained in four frames The record layout and bit structure are identical to the layout and structure of the nine-track CCT.

9-TRACK COPY CCT DATE.. / . . / .
W O # . . . . USER ID . ...
SCENE ID . . . . -MB
REELS 1&2 OF 4 BPI . .

Figure 4-12 MSS CCT External Tape Label

4.3.2 Logical Format and Data Content of CCTs

The full frame 185.2-by-185.2 km (100-by-100 nm) image is segmented into four 46.3-by-185.2 km (25-by-100 nm) strips in the direction of spacecraft heading, for conversion into CCT format.

4.3.2.1 Video Data Format and Content

The video data are spectrally interleaved The interleaving is done in groups of 8 bytes, 2 bytes from each spectral band. The absence of an expected scan line is identified on a CCT by the use of a special code that does not occur in ordinary imagery Missing scan lines are identified by the occurrence of the byte X 'CC' (11001100) at the start of the ordinary scan line byte sequence on the CCT An ordinary scan line byte sequence is defined as the first quarter scan line of video data.

Radiometric calibration data for each spectral band is also inserted as a 56-byte calibration group following each block of 3n 8-byte groups of interleaved video data The letter "n" is used to represent that multiplier of the number "24" which is needed to calculate the adjusted video data scan line length (LLA). The resulting multiple of 24 is constrained to be the smallest such multiple which is at least as great as the maximum line length code (LLC) determined for a given scene, plus 6. All line lengths are, of course, measured in pixels, or bytes. Additional detail will be found in Appendix D of this handbook.

Figures 4-13 through 4-15 illustrate the CCT video data format and content, symbols used in these illustrations are defined in Table 4-3.

The video data word consists of eight bits, of which only six are used if the data mode is linear and seven are used if the data mode is decompressed All video data-bit words are right-justified. Bits which are not used for video data are used as flags, as when 11111111 is used as the spatial registration fill character (X 'FF'). The decompressed mode arises when data has been transmitted from the satellite in a compressed mode. The decompressed mode yields radiance values represented by byte values ranging from 0 to 127, instead of 0 to 63, as with the linear mode

4.3.2.2 Identification (ID) Record

The ID record contains a combination of binary and EBCDIC information that is used to identify the video data of each file. This 40-byte record is therefore the first record on a CCT, and appears thereafter at the start of each file if there is more than one file on the tape. Figure 4-16 shows the organization of the ID record.

The first word in the ID record is the scene/frame ID, given in terms of days, hours, minutes, and tens of seconds since launch In addition, this record indicates the spectral band (Landsats 1 and 2 = bands 4-7, set to zero), sequential subframe ID (subframes unavailable, set to zero), and by character 1, whether the data are from Landsat 1 or Landsat 2 Characters 13-16 contain the sequencing numbers, e g., 1 of 2, 2 of 2, which would distinguish the tapes in a set of two. Characters 17-18 contain the data record length in binary, i.e., the length of the adjusted scan line plus 56 bytes of calibration information Characters 19-26 contain the binary frame ID, which is the binary representation of the scene/frame ID and must be broken into days, hours, minutes, seconds, etc , to be read. Characters 27-28, the binary strip ID, are not used and are set to zero. Characters 29-36 contain the image annotation tape (IAT) ID, which identifies the IAT used in making the CCT Characters 37-38 contain the MSS data mode/correction code, which is a digital word that indicates the characteristics of the data such as decompression, calibration, and line length adjustment. (See Table 4-4 for the complete definition of the MSS data mode/correction code.) Characters 39-40 contain the MSS adjusted line length. All of the above information is defined in more detail in Table 4-4.

4.3.2 3 Annotation Record

The annotation record contains binary and EBCDIC data that provide information about the scene such as the format center, nadir and sun elevation This record also includes tick mark location information that associates the digitized scene with the latitude and longitude coordinate system. The annotation record is the second record of each file, thus occurring once or more per tape dependant upon format, and contains 624 characters. This record is actually a composite of two records taken directly from the image annotation tape. The first 144 characters comprise the annotation block, and the next 480 characters comprise the image location record Figure 4-17 defines the sequence of information in the annotation record.

4.3.2.3.1 Annotation Data Block

The information included in the image annotation data block allows user interpre-

Table 4-3. Explanation of Symbols Used (Figure 4-13 through 4-15)

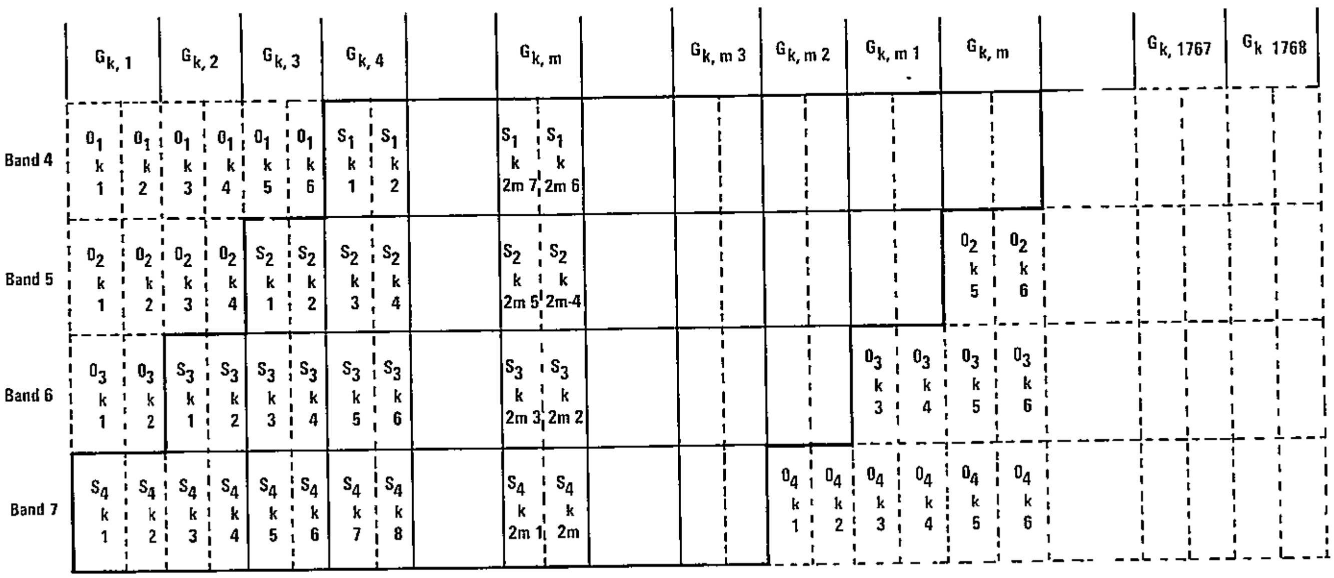
Item/Symbol	Description
S_{bkj}	Sample within a scan line corresponding to a specified video picture element (pixel) location where b = Spectral band designator ($1 \leq b \leq 5$) k = Sequential scan line index j = Sample number within line length-adjusted scan line S_{bkj} Comprise 6 or 7 bits of video right justified in an 8-bit byte
$G_{k,m}$	Group of 8 spectrally interleaved, spatially registered samples, 2 bytes from each of bands 4-7, where k = Sequential full frame scan line index m= Sequential group within an inter-leaved scan line $G_{k,m}$ contains video samples S_{bkj} in the order

$S_{1,}$	$S_{1,}$	$S_{2,}$	$S_{2,}$	$S_{3,}$	$S_{3,}$	$S_{4,}$	S_{4}
k	k	k	k	k	k	k	k
2m-7	2m 6	2m 5	2m 4	2m-3	2m-2	2m-1	2m

Item/Symbol	Description
	An interleaved entire scan line may contain a maximum of 1768 $G_{k,m}$ groups
$CAL_{b,k}$	Calibration data and line length information for scan line k of band designated b Each $CAL_{b,k}$ is a 14-byte string
R_{ik}	Record corresponding to a specific set of S_{bkj} comprising a segmented interleave scan line where i = Image segment and computer compatible tape (CCT) file number k= Sequential scan line index
B_{ik}	Fifth spectral band record where i = Image segment and CCT file number k= Sequential spectral band (designated 5) scan line index
$L_{i,p}$	Line set number assigned to a set of three 4-band* records (plus one 5th band record for Landsat-C) where i = Image segment and CCT file number p= Sequential line set number For Landsat-1 and 2, each L_{ip} contains three 4 band records For Landsat C, each L_{ip} contains three 4 band records plus one fifth band record
IDA	Two data records consisting of scene and annotation data for each image strip recorded on CCT
EOF	End of file

*"4-band" refers to MSS bands 4-7,
"5th band" refers to MSS band 8

Note Spectral band designators 1-5 refer to MSS bands 4-8, respectively



Notes 1 BAND TO BAND 2 BYTE SPATIAL MISREGISTRATION IS CORRECTED BY INSERTION OF DUMMY BYTES, $0_{k,j}$ RECORDED ON CCT AS $0_{k,j}$ = FF (HEXADECIMAL)

2 VIDEO DATA SAMPLES RECEIVED (EITHER VARIABLE OR ADJUSTED LENGTH SCAN LINES) ARE DENOTED S_{bkj} WHERE b = MSS SPECTRAL BAND DESIGNATOR(1, 2, 3, 4)
k = FULL FRAME SCAN LINE NUMBER (1, 2, 2340)
j = SAMPLE INDEX PER SCAN LINE

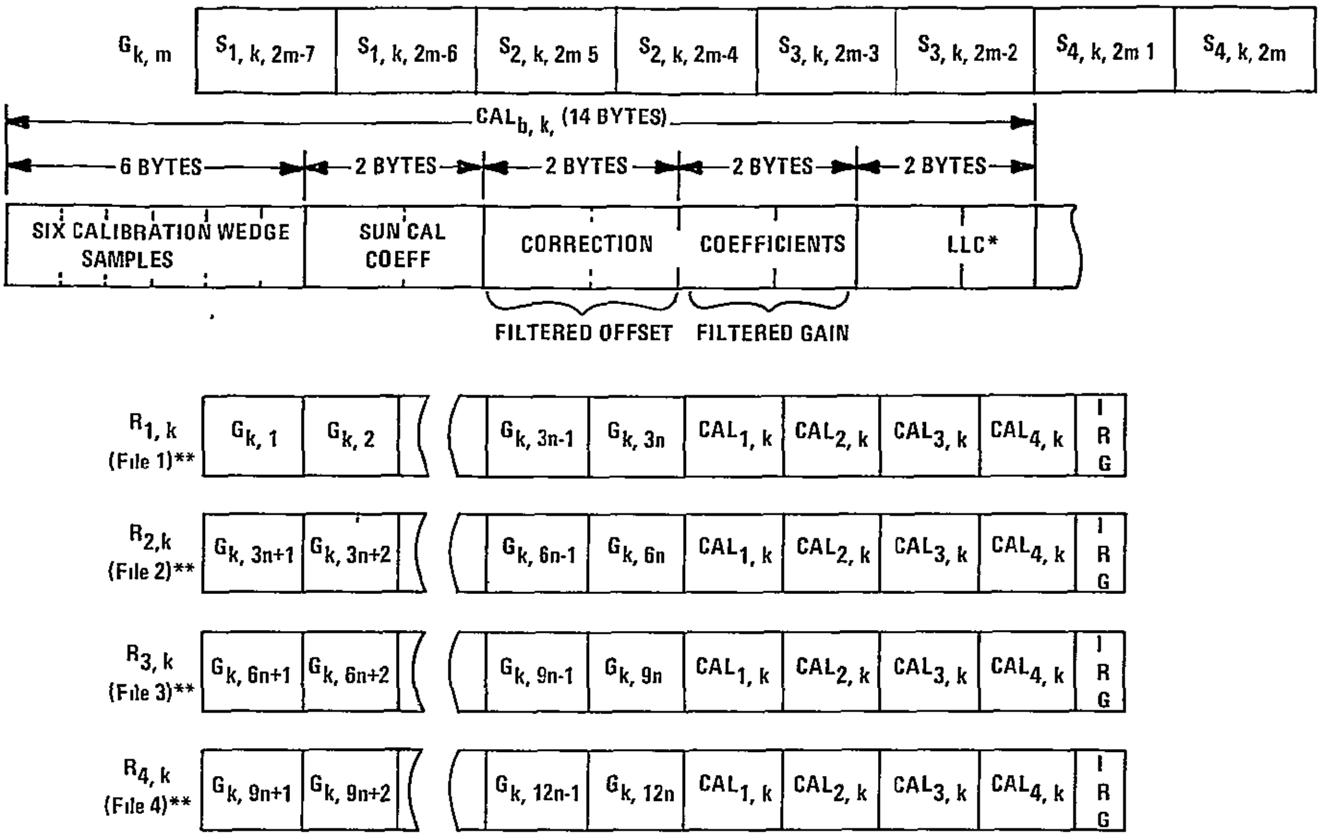
3 SPECTRAL BAND INTERLEAVING ON CCT IS ACCOMPLISHED BY RECORDING $G_{k,m}$, GROUPS IN THE SEQUENCE

S_1	S_1	S_2	S_2	S_3	S_3	S_4	S_4
k	k	k	k	k	k	k	k
(2m 7)	(2m+6)	(2m 5)	(2m 4)	(2m 3)	(2m 2)	(2m 1)	(2m)

WHERE m = GROUP INDEX (1, 2 , (M 1), M)
M = NUMBER OF MEMORY ADDRESS LOCATIONS ASSIGNED PER INPUT SCAN LINE, MAXIMUM VALUE OF M = 1768 LOCATIONS

THE VIDEO DATA SAMPLE INDEX j IS A FUNCTION OF THE GROUP INDEX, m, DUMMY SAMPLES ARE INSERTED FOR THE CONDITIONS $j(m)<1$ OR $j(m)>(2M\ 6)$

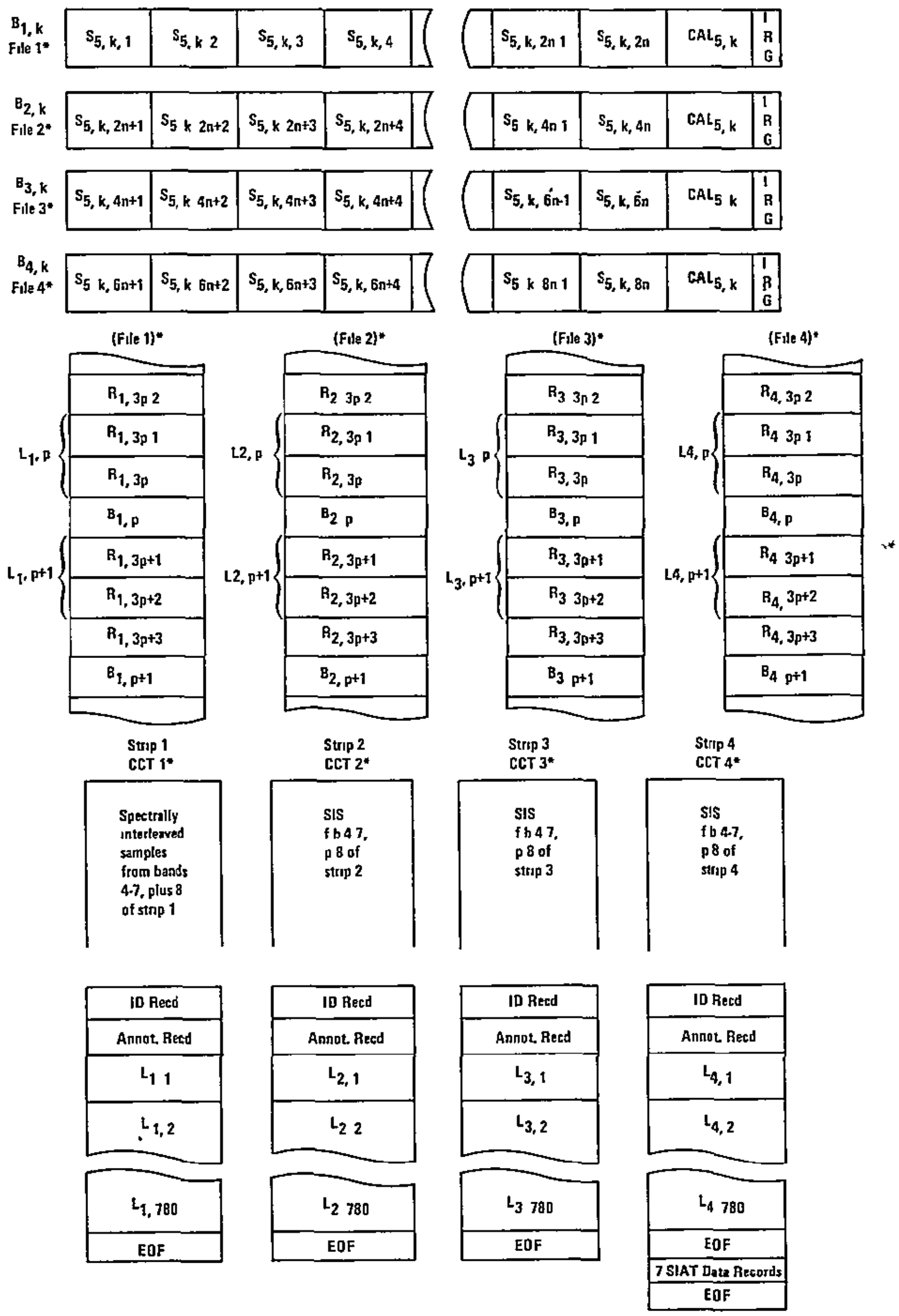
Figure 4-13 MSS Spatial Registration Illustration, Bands 4 through 7, K^{th} Scan Line



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

**Each file contains one 46.3 by 185.2 km (25 by 100 nm) strip of the scene as described in Section 4.3.2. For the one-CCT format, the four files follow sequentially on one CCT 2400 feet in length with a bit-density of 1600 bpi. For the two-CCT format, files 1 and 2 follow sequentially on CCT 1 and files 3 and 4 on CCT 2. These tapes are 2400 feet in length with a bit density of 800 bpi. For the four-CCT format, each of the four files corresponds to a like-number CCT, 2400 feet in length with a bit density of 800 bpi. All formats include an ID record and an annotation record as the first and second records, respectively, of each film, and special image annotation tape (SIAT) information (used in original CCT generation) is included after the last file of each scene.

Figure 4-14. Full Scene Interleaved Record Format



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

**Each file contains one 46.3 by 185.2 km (25 by 100 nm) strip of the scene as described in Section 4.3.2. For the one-CCT format, the four files follow sequentially on one CCT 2400 feet in length with a bit density of 1600 bpi. For the two-CCT format, files 1 and 2 follow sequentially on CCT 1 and files 3 and 4 on CCT 2. These tapes are 2400 feet in length with a bit density of 800 bpi. For the four-CCT format, each of the four files corresponds to a like-number CCT, 2400 feet in length with a bit density of 800 bpi. All formats include an ID record and an annotation record as the first and second records, respectively, of each film, and special image annotation tape (SIAT) information (used in original CCT generation) is included after the last file of each scene.

Figure 4-15. Full Scene, Four-CCT Format

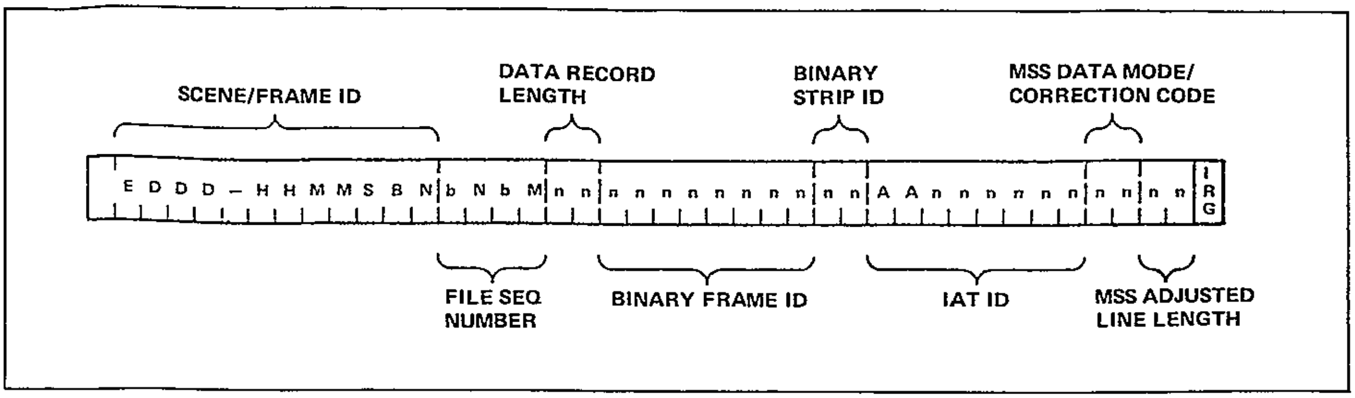


Figure 4-16. ID Record Organization (40 Characters, EBCDIC and Binary Code)

Table 4-4 ID Record Information Definitions

Char	Information	Format	Code
1-12	Scene/Frame ID	EDDD-HHMMSBN*	EBCDIC
13-16	File Sequencing Numbers File N of M (b = blank char)	bNbM	EBCDIC
17-18	Data Record Length (bytes)	nn	Binary
19-26	Binary Frame ID	nnnnnnnn**	Binary
27-28	Binary Strip ID	oo	Binary
29-36	IAT Identification (from Header record on IAT)	AAnnnnnn	EBCDIC
37-38	MSS Data Mode/Correction Code*** Unitary Code	nn	Binary
39-40	MSS Adjusted Line Length	nn	Binary

*E — Encoded Project Identifier (Landsat 1 - 1 or 5, Landsat 2 - 2 or 6)
DDD— Day number relative to launch at time of observation
HH — Hour at time of observation
MM — Minute at time of observation
S — Tens of seconds at time of observation (truncated not rounded numbers)
B — IPF Identification Code (Landsat 1 and 2, bands 4&7, set to zero)
N — Sequential Subframe ID (only full frame available, set to zero)
**The Binary Frame ID is the binary representation of the Scene/Frame ID

Character	
19	Encoded Project Identifier (Same as *E above)
20-21	Days since launch, this number is determined by extracting the six right-most bits from bytes (characters) 20 and 21 and combining them into one word (six bits from byte 20 followed by six bits from byte 21)
22	Hour at time of observation
23	Minute at time of observation
24	Tens of seconds at time of observation (truncated, not rounded numbers)
25	Spectral Band Identifier (IPF Identification Code, set to zero)
26	Sequential Subframe ID (set to zero)

For characters 22 through 26, the six right-most bits are used

***Bits 0-7 of this two-character word are zero
Bits 8-15 have the following significance

Bit		
8	= 1 for Sun Cal Data,	= 0 otherwise
9	= 1 for Calibration Wedge,	= 0 otherwise
10	= 1 for Compressed Data,	= 0 otherwise
11	= 1 for Hi gain on band 1,	= 0 otherwise
12	= 1 for Hi gain on band 2,	= 0 otherwise
13	= 1 for Decompression,	= 0 otherwise
14	= 1 for Calibration,	= 0 otherwise
15	= 1 for Line Length Adjust,	= 0 otherwise

tation of the imagery. These data are specified at the time of the center scan line of the MSS. frame, all decimal points and special characters are included. The annotation block data format consists of 144 EBCDIC characters (72 sixteen-bit words), whose format and content are defined in Table 4-5.

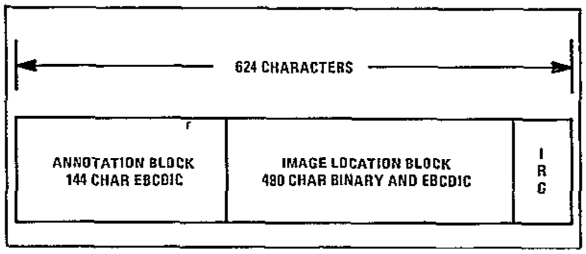


Figure 4-17. Annotation Record Information Sequence

4.3.2.3.2 Image Location Data Block

The image location data consist of 240 sixteen-bit words that describe the tick marks that associate the scene with latitude and longitude. There can be a maximum of six tick marks per side (i e , left side, right side, top and bottom), and the image location data includes this tick mark information for RBV as well as MSS data.

The tick mark location data consist of four types: the tick position, the special tick character, the direction (N, S, E or W), and the value in degrees and minutes. Each tick mark is denoted by a 16-bit signed binary integer fraction that specifies its position along the edge of the scene, followed by eight EBCDIC characters

The 16-bit signed integer fraction represents the location of the tick mark along the edge of the scene and takes on values from +1/2 to -1/2. The most significant bit of the integer fraction indicates the sign of the fraction If the bit is a one, the fraction is negative, if it is a zero, the fraction is positive. The tick mark reference system has been chosen so that the origin is at the format center. The corners of the scene writing area may be designated A (1/2, -1/2), B(-1/2, -1/2), C(1/2, 1/2) and D(-1/2, 1/2), as in Figure 4-18. The value that locates the tick marks along the edges is

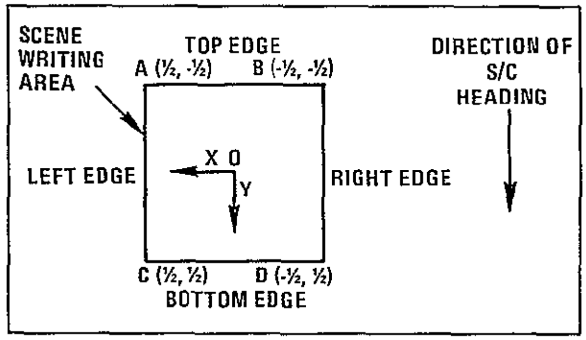


Figure 4-18 Tick Mark Reference System

therefore given in terms of a 16-bit binary integer fraction with the binary point to the left of bit position 1.

The special tick characters are either an X'4F', an EBCDIC vertical bar that is used along the top and bottom edges of the scene, or an X'7E', an EBCDIC equals sign that is used to represent the ticks on the left and right sides of the scene. The direction is represented by an EBCDIC character that represents north, south, east, or west (N, S, E or W). The value of the latitude or longitude is given in degrees (3 characters) and minutes (2 characters).

There are two formats used to represent the location of tick marks. The tick marks are usually written first and are followed by the value of the latitude or longitude. If there is not enough room on any one of the sides for the last tick mark, then the value of the latitude or longitude is written first and is followed by the tick character for the last tick mark. An illustration of the two tick mark formats follows

Format 1

Position. 16-bit signed binary fraction
Tick mark annotation:

Tick mark character: X'4F' or X'7E'
Direction, one character· N, S, E or W
Value

Degrees, three characters.
Constant. '—'
Minutes, two characters 00 or 30

Format 2

Position· 16-bit signed binary fraction Tick mark annotation.

Direction, one character: N, S, E or W
Value, six characters· same as Format 1
Tick mark character: X'4F' or X'7E'

Each of the eight tick mark tables (one for each MSS and RBV edge) contains the tick mark data arranged in positional order from the top of the table downward with the top edge tick mark table being given first. The unused tick mark locations are signified by a zero in the position words and X'FF' in all of the annotation characters.

The tick mark record format defined in the 16-bit words is as follows:

RBV tick mark set:

Character	Description
B(1)	Position, tick mark No. 1
B(2)-B(5)	Annotation, tick mark No. 1
B(6)	Position, tick mark No. 2
B(7)-B(10)	Annotation, tick mark No. 2
B(11)	Position, tick mark No. 3
B(12)-B(15)	Annotation, tick mark No. 3
B(16)	Position, tick mark No. 4
B(17)-B(20)	Annotation, tick mark No. 4
B(21)	Position, tick mark No. 5
B(22)-B(25)	Annotation, tick mark No 5
B(26)	Position, tick mark No. 6
B(27)-B(30)	Annotation, tick mark No. 6
B(31)-B(60)	Left edge tick mark table
B(61)-B(90)	Right edge tick mark table
B(91)-B(120)	Bottom edge tick mark table

MSS tick mark set:

Character	Description
B(121)-B(240)	Format is the same as that for the RBV tick mark set

It should be noted that the scene on the CCT contains 2340 scan lines (2256 scan lines for the film image, plus 42 scan lines of data preceding the film image and 42 scan lines following the film image). The tick marks are applied to the film image as shown in Figure 4-19.

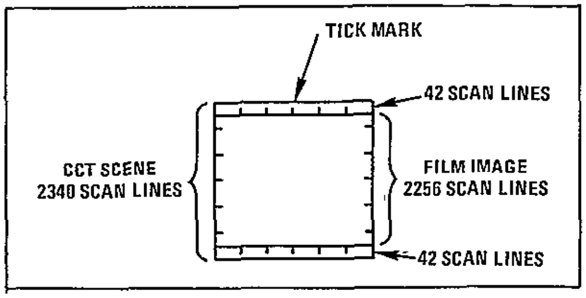


Figure 4-19. CCT and Film Image Comparison

4.3.2.4 Special Image Annotation Tape (SIAT) Data File

This file consists of seven records. The first record is a 2048 byte record which contains the SIAT logical tape header. The second record contains 216 bytes of Processing Information Data. The third record contains 204 bytes of Spacecraft and Sensor Performance Data. The fourth record contains 144 bytes of Annotation Block Data (Table 4-5). The fifth record contains 76 bytes of RBV Computational Data. Record six contains 326 bytes of MSS Computation Data. The seventh record contains 480 bytes of Image Location Data.

Detailed descriptions of each of these records are shown in Tables 4-6A through 4-6G

4.4 DATA COLLECTION SYSTEM PRODUCTS

The IPF produces three types of Data Collection System (DCS) data products punched cards, computer listings and magnetic tapes. These products along with their contents and formats are described in Figures 4-20 through 4-22. DCS data transmission format is listed in Table 4-7

Table 4-5 Annotation Block Data

Characters	Description
	(Day, Month, Year of Exposure – The date at Greenwich, month, and year of picture exposure)
1-2	Date of Exposure, day of month, numerals
3-5	Date of Exposure, month of year, abbreviated to three alpha characters
6-7	Date of Exposure, year, abbreviated to two numerals
8-10	Constant: 'bCb' (signifies Format Center). (Format Center – The center of the RBV and MSS image format is indicated in terms of latitude and longitude in degrees and minutes. The MSS format center is identical to the corresponding RBV format center. Format center is defined as the point of contact with the earth, of the geometric extension of the spacecraft yaw attitude sensor axis to the earth's surface)
11	Latitude direction, 1 alpha, N or S
12-13	Latitude, degrees, two numerals
14	Constant: '–'
15-16	Latitude, minutes, two numerals
17	Constant. '/'
18	Longitude, direction, 1 alpha, E or W
19-21	Longitude, degrees, three numerals
22	Constant: '–'
23-24	Longitude, minutes, two numerals
25-27	Constant: 'bNb' (signifies Nadir) (Nadir – The latitude and longitude of the nadir (the intersection with the earth's surface of a line from the satellite perpendicular to the earth ellipsoid) is indicated in degrees and minutes)
28	Latitude direction, 1 alpha, N or S
29-30	Latitude, degrees, two numerals
31	Constant: '–'
32-33	Latitude, minutes, two numerals
34	Constant: '/'

Table 4-5. Annotation Block Data (Continued)

Characters	Description
35	Longitude, direction, 1 alpha, E or W
36-38	Longitude, degrees, three numerals
39	Constant: '–'
40-41	Longitude, minutes, two numerals
42	Constant: 'b'
43-54	Blank Field 1 (12 characters long)
55-60	Constant: 'SUNbEL'
61-62	Sun elevation, degrees, two numerals (Sun Elevation – The sun elevation angle at the time of mid-point of MSS frame is indicated to the nearest degree)
63-65	Constant: 'bAZ'
66-68	Sun aximuth, degrees, three numerals (Sun Azimuth – The sun azimuth angle from true North at the time of midpoint of MSS frame is indicated to the nearest degree)
69	Constant: 'b'
70-72	Satellite Heading (including yaw), degrees, three numerals (Satellite Heading – The satellite true heading is indicated to show the orientation of the imagery. The heading includes yaw and is indicated to the nearest degree)
73	Constant: '–'
74-77	Revolution number, four numerals (Rev Number – The consecutive rev number for the Landsat spacecraft is indicated.)
78	Constant. '–'
79	MSS data acquisition site, abbreviated to one alpha, A, G, or N (Data Acquisition Site – A one-letter acronym designates the data acquisition site. This will be either Alaska, (A), Goldstone, (G), or NASA Tracking and Training Facility (N).)
80	Constant. '–'
81	Constant: '1'

Table 4-5 Annotation Block Data (Continued)

Characters	Description
82	Constant: '–'
83-84	Blank Field 2 (two characters long)
85	Type of orbit data: Predicted = P; Definitive = D
86	Constant. '–'
87-88	Blank Field 5 (two characters long)
89-101	Constant: 'bNASAbERTSbE-' Frame Identification (Frame Identification Number – Each image or frame has a unique identifier that contains encoded information. This identifier is used for an information retrieval system and consists primarily of time of exposure relative to launch information. The Initial Image Generating Subsystem adds the appropriate spectral band number. Also part of the frame identification number is a "regeneration of images" identifier, which is added to the imagery by Initial Image Generation when appropriate.)
102	Landsat mission number = S
103-105	Day number relative to launch = DDD S = 1 for Landsat 1, DDD $\leq$ 999 S = 5 for Landsat 1, DDD > 999 S = 2 for Landsat 2, DDD $\leq$ 999 S = 6 for Landsat 2, DDD > 999
106	Constant: '–'
107-108	Hour at time of observation
109-110	Minutes
111	Tens of seconds
112	Constant: '–'
113	Blank Field 3 (one character long)
114	Blank for earth images (RCI Images – A 0, 1, or 2 indicates one of the 3 exposure levels for radiometric calibration, where 0 corresponds to the minimum exposure level, and 2 corresponds to the maximum. A blank signifies no RCI images)
115-116	Blank Field 4 (two characters long) During Initial Image Generation Processing, the sensor code will be inserted on the imagery into Blank Field 1; the gamma (normal 'N-', or abnormal 'A-') into Blank Field 2; the spectral identifier into Blank Field 3; the regeneration number of the processed image (when necessary) into Blank Field 4; and the type of MSS signal encoding ① into Blank Field 5.

Table 4-5 Annotation Block Data (Continued)

Characters	Description
117-140	24 blank characters if RBV ② is off
141-144	4 blank characters if MSS is off
	Otherwise:
⑤ 117-121	Direct or recorded data: '1bbDX' or 1bbRX'
⑤ 122-123	Shutter Setting ③ and Aperture Correction Indicator, ④ RBV 1; aa
⑤ 124-129	Direct or recorded data: 'bb2bDX' or 'bb2bRX'
⑤ 130-131	Shutter Setting and Aperture Correction Indicator, RBV 2; aa
⑤ 132-137	Direct or recorded data: 'bbb3DX' or 'bbb3RX'
⑤ 138-139	Shutter Setting and Aperture Correction Indicator, RBV 3; aa
⑤ 140	Constant. 'b'
⑤ 141-142	Direct or recorded MSS data: 'Db' or 'Rb'
⑥ 143-144	MSS data acquisition site, 'A-', 'G-', or 'N-'

① MSS signal code:
- 1 = Linear data mode
- 2 = Compressed data mode } Not applicable for band 7
- H = High gain option
- L = Low gain option } Not applicable for bands 6 and 7

② No requirement for CCTs for Landsat 1 and 2 RBV imagery

③ Shutter setting code, applicable to Landsat 1 and 2 RBV annotation only:

Setting	Duration of Exposure (ms)		
	Camera 1	Camera 2	Camera 3
A	4.0	4 8	6.4
B	5.6	6.4	7.2
C	8.0	8 8	8.8
D	12.0	12.0	12.0
E	16.0	16.0	16.0

④ Aperture correction indicator:
- I = aperture correction in
- O = aperture correction out

⑤ Blank Field 1 data

⑥ MSS data for characters 79-80, as applicable

Table 4-6A. SIAT Data File Records, Record 1 - SIAT Logical Tape Header

Byte	Length	Content	Format
1	8	SIAT Number	EBCDIC (ttadddnn)
9	10	Date of Tape Preparation	EBCDIC (ƀddƀmmmƀyy)
19	10	Zero	Binary
29	8	SIAT Number	EBCDIC (ttadddnn)
37	8	RBV Tape Number	EBCDIC (ttadddnn or blanks)
45	8	MSS Tape Number	EBCDIC (ttadddnn or blanks)
53	2	Number of Data Files on Logical SIAT	Integer
55	2	Zero	Binary
57	2	Zero	Binary
59	2	Number of RBV/VTC	Integer
61	2	Number of MSS/VTC	Integer
63	2	Number of RBV/TFC	Integer
65	2	Number of MSS/TFC	Integer
67	2	Zero	Binary
69	2	1st-64th RBV Scene ID's	EBCDIC addd-hhmmsƀƀ
837	768	1st-64th MSS Scene ID's	EBCDIC addd-hhmmsƀƀ
1605	444	Zero	Binary

Table 4-6B SIAT Data File Records, Record 2 - Processing Instruction Data

Starting Byte No.	and Length (Bytes)	Information	Format
1	2	No. of Scenes Remaining, RBV/VFC	Binary
3	2	No. of Scenes Remaining, MSS/VFC	Binary
5	2	No. of Scenes Remaining, RBV/VTC	Binary
7	2	No. of Scenes Remaining, MSS/VTC	Binary
9	2	Not Used	Binary Zero
11	2	Not Used	Binary Zero
13	10	Scene ID	EBCDIC ndd-hhmms
23	10	Preceding Closest RCI ID from W.O.	EBCDIC ndd-hhmms
33	10	Succeeding Closest RCI IF from W.O.	EBCDIC ndd-hhmms
43	1	Mission No. (1 or 2)	Binary
44	1	Day Number from Launch	Binary (most significant part; least signif. bit is 2^6)
45	1	Day Number from Launch	Binary (6-bit least signif. part; 6 bits avail.)
46	1	Hours of Day	Binary
47	1	Minutes of Hour	Binary
48	1	Tens of Seconds	Binary
49	2	Not Used	Binary Zero
51	8	Band 1 Information from PIAT W.O.	EBCDIC 1aaaaabb
59	8	Band 2 Information from W.O.	EBCDIC 2aaaaabb
67	8	Band 3 Information from W.O.	EBCDIC 3aaaaab
75	8	Band 4 Information from W.O.	EBCDIC 4aaaaaab
83	8	Band 5 Information from W.O.	EBCDIC 5aaaaaab
91	8	Band 6 Information from W.O.	EBCDIC 6aaaaaab
99	8	Band 7 Information from W.O.	EBCDIC 7aaaaabb
107	8	Band 8 Information from W.O.	EBCDIC 8aaaaabb
115	72	Special Instructions to Precision Processing Operator from W.O.	EBCDIC
187	1	Mission No.	Binary
188	1	Day No. from Launch	Binary (most signif. part; least signif. bit is 2^6)
189	1	Day No. from Launch	Binary (6-bit least signif. part; 6 bits avail.)
190	1	Hours of Day	Binary
191	1	Minutes of Hour	Binary
192	1	Tens of Seconds	Binary
193	1	Not Used	Binary Zero
194	1	Not Used	Binary Zero
195	6	Output Frame ID	Same as Item 38
201	1	Not Used	Binary Zero
202	1	Not Used	Binary Zero
203	2	Processing Code from SIAT Generation Work Order	Binary
205	2	Processing Code for MSS	Binary
207	2	Polar Stereo Projection	Hexadecimal
209	8	Flag	Binary Zero
216	Total Bytes		
Inter-Record Gap			

Table 4-6C SIAT Data File Records, Record 3 - Spacecraft Performance Data

Starting Byte No.	and Length (Bytes)	Information	Format
1	8	RBV 1 Mode of Transmission	EBCDIC RBVb1bba
9	2	RBV 1 Exposure Duration	EBCDIC Xa
11	2	RBV 1 Aperture Correction Indicator	EBCDIC ab
13	8	RBV 2 Mode of Transmission	EBCDIC RBVbb2ba
21	2	RBV 2 Exposure Duration	EBCDIC Xa
23	2	RBV 2 Aperture Correction Indicator	EBCDIC ab
25	8	RBV 3 Mode of Transmission	EBCDIC RBVbbb3a
33	2	RBV 3 Exposure Duration	EBCDIC Xa
35	2	RBV 3 Aperture Correction Indicator	EBCDIC ab
37	12	MSS 4 Mode of Transmission	EBCDIC MSSb4bbbbbab
49	12	MSS 5 Mode of Transmission	EBCDIC MSSbb5bbbbab
61	12	MSS 6 Mode of Transmission	EBCDIC MSSbbb6bbbab
73	12	MSS 7 Mode of Transmission	EBCDIC MSSbbbb7bbab
85	12	MSS 8 Mode of Transmission	EBCDIC MSSbbbbb8bab
97	2	MSS Sensor Gain	Binary, bits 1 & 2 for bands 4 & 5 respect., 1 = high Bits 3-16 are zero
99	1	MSS Sensor Encoding	Binary, bits 1-3 for bands 4-6 respect. 1 = compressed. Bits 4-8 are zero
100	1	Not Used	Binary Zero
101	8	SPDT Tape ID	EBCDIC SPndddnn
109	4	MSS SUN CAL DAY	EBCDIC 0DDDD
113	48	MSS SUN CAL's SENSORS 1-24	Binary Scaled 2^{-12}
151	36	Not Used	Binary Zero
197	4	MSS SUN CAL DAY desired	EBCDIC 'bbb' 'Fill' or 'BADb'
201	4	MSS SUN CAL FLAG	EBCDIC 'DDD'
204	Total Bytes		
Inter-Record GAP			

Table 4-6D SIAT Data File Records, Record 4 - Annotation Block Data

Starting Byte No.	and Length (Bytes)	Information	Format
1	2	Day of Month Exposure	EBCDIC nn
3	3	Month of Exposure	EBCDIC aaa
6	2	Year of Exposure	EBCDIC nn
8	3	Constant	EBCDIC bCb
11	6	Latitude of Format Center	EBCDIC ann-nn
17	1	Constant	EBCDIC /
18	7	Longitude of Format Center	EBCDIC annn-nn
25	3	Constant	EBCDIC bNb
28	6	Latitude of Nadir	EBCDIC ann-nn
34	1	Constant	EBCDIC /
35	8	Longitude of Nadir	EBCDIC annn-nnb
43	12	Blank Field 1	EBCDIC blanks
55	8	Sun Elevation at Nadir (Deg)	EBCDIC SUNbELnn
63	6	Sun Azimuth at Nadir (Deg)	EBCDIC bAZnnn
69	4	Satellite Heading (Deg)	EBCDIC bnnn
73	6	Rev. Number	EBCDIC -nnn-
79	4	RBV Data Acquisition	EBCDIC a-1-
83	2	Blank Field 2	EBCDIC bb
85	2	Type of Orbit Data (Pred. or Defin.)	EBCDIC a-
87	2	Blank Field 5	EBCDIC bb
89	13	Constant	EBCDIC bNASAbERTSbE-
102	10	Scene Identification	EBCDIC nddd-hhmms
112	1	Constant	EBCDIC -
113	1	Blank Field 3	EBCDIC b
114	1	RCI Images Calibration Level	EBCDIC n (or blank)
115	2	Blank Field 4	EBCDIC bb
117	5	RBV 1 Mode (Direct or Recorded)	EBCDIC 1bbaX (or blanks)
122	2	RBV 1 Shutter Setting, Aperture Correction Indicator	EBCDIC aa (or blanks)
124	6	RBV 2 Mode	EBCDIC bb2baX (or blanks)
130	2	RBV 2 Shutter Setting, Aperture Correction Indicator	EBCDIC aa (or blanks)
132	6	RBV 3 Mode	EBCDIC bbb3aZ (or blanks)
138	2	RBV Shutter Setting, Aperture Correction Indicator	EBCDIC aa (or blanks)
140	5	MSS Mode (Direct or Recorded) and Acquisition Site	EBCDIC baba- (or blanks)
144	Total Bytes		
Inter-Record GAP			

Table 4-6E SIAT Data File Records, Record 5 - RBV Computational Data

Starting Byte No. and Length (Bytes)		Information	Format
1	8	Spacecraft Time of Exposure	4-bit BCD 00000dddhhmmsscc
9	8	Greenwich Mean Time of Exposure	4-bit BCD 000dddhhmmssmmm0
17	2	Normalized Altitude Change	Binary fraction
19	10	GMT Date of Exposure	EBCDIC bddbmmmbyy
29	8	GMT Time of Exposure	EBCDIC bhhmm:ss
37	4	Latitude of Format Center	Binary
41	4	Longitude of Format Center (10^{-6} Radians)	Binary
45	4	Latitude of Nadir (10^{-6} Rad)	Binary
49	4	Longitude of Nadir (10^{-6} Rad)	Binary
53	4	Spacecraft Altitude (meters)	Binary
57	4	GMT of Exposure (Milliseconds of Day)	Binary
61	4	S/C Flight Path Heading (10^{-6} Rad)	Binary
65	4	Pitch (10^{-6} Rad)	Binary
69	4	Roll (10^{-6} Rad)	Binary
73	4	Yaw (10^{-6} Rad)	Binary
76 Total Bytes			
Inter-Record GAP			

Table 4-6F SIAT Data File Records, Record 6 - MSS Computational Data

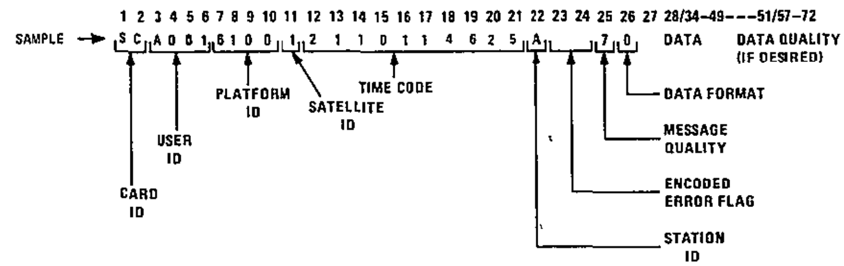
Starting Byte No. and Length (Bytes)		Information	Format
1	8	Spacecraft Time of Scene Center	4-bit BCD 00000dddhhmmsscc
9	8	GMT of Scene Center	4-bit BCD 000dddhhmmssmmm0
17	2	Normalized Altitude Change at Image Center - 13.80300	Binary fraction
19	2	Same as 102 at I.C. - 10.35225	Binary fraction
21	2	Same as 102 at I.C. - 6.90150	Binary fraction
23	2	Same as 102 at I.C. - 3.45075	Binary fraction
25	2	Same as 102 at I.C. Time	Binary fraction
27	2	Same as 102 at I.C. + 3.45075	Binary fraction
29	2	Same as 102 at I.C. + 6.90150	Binary fraction
31	2	Same as 102 at I.C. + 10.35225	Binary fraction
33	2	Same as 102 at I.C. + 13.80300	Binary fraction
35	2	Altitude (N.M./32) at time of 102	Binary
37	16	8 Values of Alt. at the times of Items 103-110, respectively	Binary, 2 bytes per value
53	2	Vehicle Roll at Image Center Time (Rad.)	Binary fraction
55	2	Vehicle Pitch at I.C. (Rad)	Binary fraction
57	2	Vehicle Yaw at I.C. (Rad)	Binary fraction
59	2	Roll at Time of Item 102 (Rad)	Binary fraction
61	16	8 Values of Roll at the times of Items 103-110, respectively	Binary fraction, 2 bytes per value
77	2	Pitch at time of Item 102 (Rad)	Binary fraction
79	16	8 Values of Pitch at the times of Items 103-110, respectively	Binary fraction, 2 bytes per value
95	2	Yaw at Time of Item 102 (Rad)	Binary fraction
97	16	8 Values of Yaw at the Times of Items 102-110, respectively	Binary fraction, 2 bytes per value
118	2	Image Skew (Rad)	Binary fraction
115	2	Normalized Velcoity Change	Binary fraction
117	4	Mean Pitch (10^{-6} Rad)	Binary
121	4	Mean Roll (10^{-6} Rad)	Binary
125	4	Mean Yaw (10^{-6} Rad)	Binary
129	4	Mean Pitch Rate (10^{-6} Rad/Sec)	Binary

Table 4-6F SIAT Data File Records, Record 6 - MSS Computational Data (Continued)

Starting Byte No.	and Length (Bytes)	Information	Format
133	4	Mean Roll Rate (10^{-6} Rad/Sec)	Binary
137	4	Mean Yaw Rate (10^{-6} Rad/Sec)	Binary
141	4	Mean Altitude (meters)	Binary
145	4	Mean Altitude Rate (Meters/Sec)	Binary
149	4	GMT Milliseconds of Day at ICT - 25 sec	Binary
153	4	GMT Milliseconds of Day at ICT - 25 sec	
157	4	GMT Milliseconds of Day at ICT - 15 sec	Binary
161	4	GMT Milliseconds of Day at ICT - 10 sec	Binary
165	4	GMT Milliseconds of Day at ICT - 5 sec	Binary
169	4	GMT Milliseconds of Day at ICT	Binary
173	4	GMT Milliseconds of Day at ICT + 5 sec	Binary
177	4	GMT Milliseconds of Day at ICT + 10 sec	Binary
181	4	GMT Milliseconds of Day at ICT + 15 sec	Binary
185	4	GMT Milliseconds of Day at ICT + 20 sec	Binary
189	4	GMT Milliseconds of Day at ICT + 25 sec	Binary
193	44	Eleven Values of Nadir Latitude at Times of Items 160-170 (10^{-6} Rad)	Binary
237	44	Eleven Values of Nadir Longitude at Times of Items 160-170 (10^{-6} Rad)	Binary
281	44	Eleven Values of Altitude at Times of Items 160-170 (Meters)	Binary
324	Total Bytes		
Inter-Record GAP			

Table 4-6G SIAT Data File Records, Record 7 - Image Location Data

Starting Byte No.	and Length (Bytes)	Information	Format
1	10	RBV, Top Edge, Tick Mark No. 1 Position and Annotation	Binary fraction and EBCDIC
11	50	5 More Tick Marks as Above for the Same Edge	↓
61	60	Same as Items 204 and 205 for the Left Edge	↓
121	60	Same as Above for the Right Edge	↓
181	60	Same as Above for the Bottom Edge	↓
241	240	Same as Items 204-208 for the MSS	
480 Total Bytes			
END OF FILE			



CARD COLUMN	CONTENT
1 2	CARD ID { VC TO INDICATE VARIABLE REQUEST; SC TO INDICATE STANDING REQUEST
3-6	USER ID CONSISTING OF 4 ALPHANUMERIC CHARACTERS
7 10	PLATFORM ID CONSITING OF OCTAL DIGITS RANGING FROM 6001 7750
11	SATELLITE ID 1 FOR ERTS A, 2 FOR ERTS B
12 21	TIME CODE REPRESENTING THE GREENWICH MEAN TIME WHEN THE PLATFORM TRANSMITTED THE DATA THE FORMAT IS YDDDHHMMSS WHERE Y = YEAR OF RECEPTION LAST DIGIT OF YEAR RANGING FROM 1 TO 9 DDD = JULIAN DAY OF YEAR HH = HOUR OF DAY MM = MINUTES SS = SECONDS
22	RECEIVING STATION ID WHERE A = FAIRBANKS ALASKA G = GOLDSTONE CALIFORNIA N = GREENBELT MARYLAND (NTTF)
23 24	ENCODED ERROR FLAG WHERE 32 = INVALID RECEIVING STATION ID 16 = INVALID PLATFORM ID 8 = POOR PLATFORM QUALITY 4 = INVALID TIME CODE 2 = DUPLICATE MESSAGE 1 = REDUNDANT MESSAGE 0 = NO ERROR DETECTED A SUMMED VALUE TO INDICATE ANY COMBINATION OF THE ABOVE 63 = ALL OF THE ABOVE CONDITIONS EXIST
25	MESSAGE QUALITY WHERE 0 = LONG OR SHORT MESSAGE DEPENDING UPON SYNCHRONIZATION 1 7 = TO INDICATE LOWEST TO HIGHEST QUALITY
26	DATA FORMAT FLAG WHERE 0 = OCTAL DIGITS (22 COLUMNS) H = HEXIDECIMAL DIGITS (16 COLUMNS)
28 49	FOR OCTAL DIGITS,
34 49	FOR HEXADECIMAL DIGITS
51 72	QUALITY DIGITS (IF DESIRED) FOR OCTAL
57 72	QUALITY DIGITS (IF DESIRED) FOR HEXADECIMAL

NOTE PRESENCE OF QUALITY BITS IS OPTIONAL SUB ECT TO USER REQUEST
OCTAL DIGITS ARE GIVEN FOR 66 BITS WHERE LAST TWO BITS ARE ALWAYS ZERO
OCTAL PLATFORM ID IS BASED ON 12 BIT SYNC/ID BIT PATTERN

Figure 4-20. DCS Data Card Format

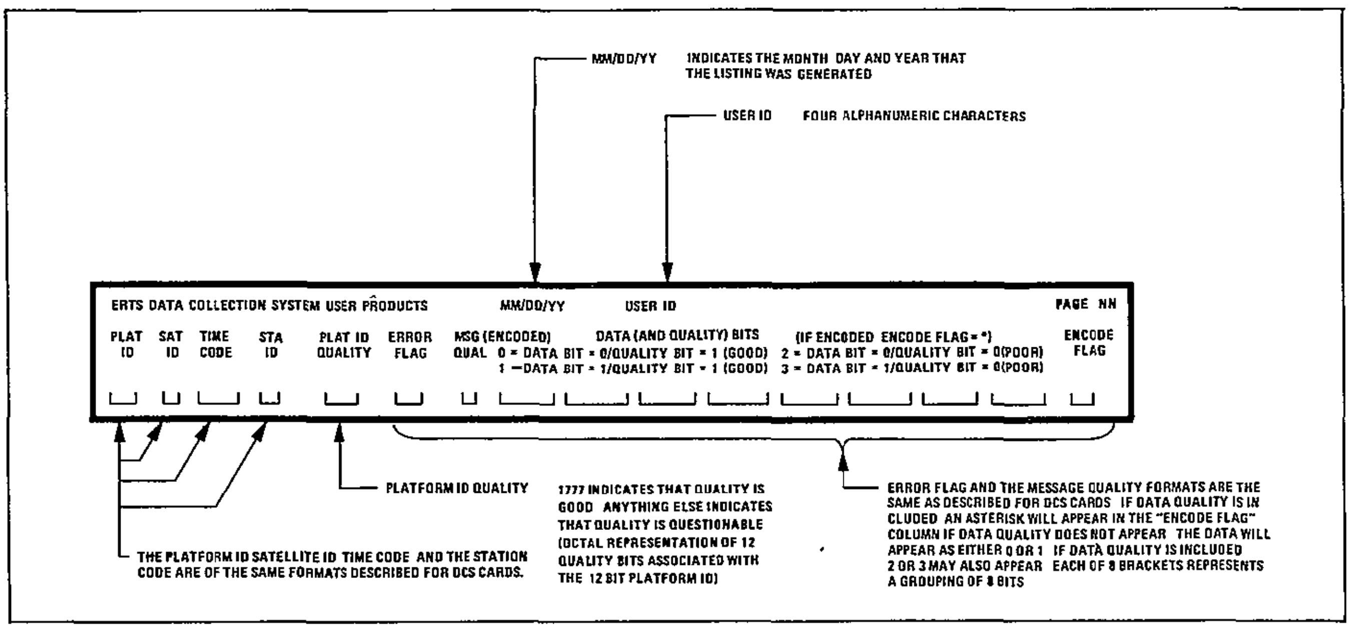
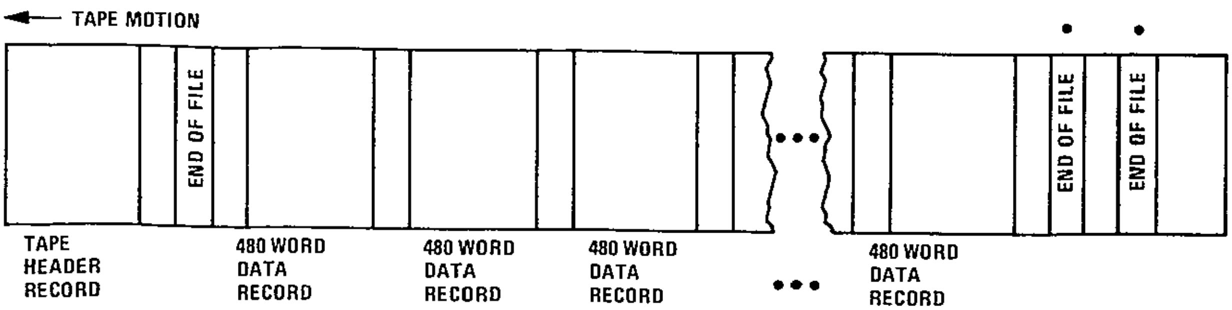


Figure 4-21. DCS Computer Listing Format



HEADER RECORD FORMAT SEE BELOW
RECORDS CONSISTS OF 60 DATA BLOCKS (480 WORDS)
EACH DATA BLOCK CONSISTS OF ONE DATA TRANSMISS'ON (8 WORDS)
EACH DATA TRANSMISSION IS IN THE FORMAT SHOWN IN TABLE 3 6

HEADER RECORD FORMAT

STANDING REQUEST TAPE STaDDDnnUUUUYY/MM/DD
VARIABLE REQUEST TAPE VTaDDDnnUUUUYY/MM/DD

WHERE

a = SATELLITE NUMBER (1 OR 2)
DDD = DAYS SINCE LAUNCH (OF TAPE GENERATION)
nn = SEQUENCE NUMBER (BINARY)
UUUU = USER ID
YY/MM/DD = DATE OF PROCESSING (STANDING ORDER) OR DATE OF REQUEST (VARIABLE REQUEST)

Figure 4-22 DCS Magnetic Tape Format

Table 4-7. DCS Data Transmission Format

Word	Bit	Item	Mode	Format
1	0-15	Platform ID	Binary	XXXX
	16-23	Satellite ID	EBCDIC	1 or 2
	24 31	Station ID	EBCDIC	A/G/N
2	0 15	Days (GMT)	Binary	1 366
	16 31	Days Since Launch	Binary	1-N
3	0 7	Hours (GMT)	Binary	0 23
	8-15	Minutes (GMT)	Binary	0-59
	16 23	Seconds (GMT)	Binary	0-59
	24 31	Year (GMT)	EBCDIC	0 9
4	0-5	Not Used	Binary	0
	6 15	Platform ID Quality	Binary	'3FF'
	16 17	Not Used	Binary	0
	18-23	Error Flags		
		Invalid Station Code	Bit 18	(1=set)
		Invalid Platform ID	Bit 19	(1=set)
		Poor Platform ID Quality	Bit 20	(1=set)
		Invalid Time Code	Bit 21	(1=set)
		Duplicate Message	Bit 22	(1=set)
		Redundant Message	Bit 23	(1=set)
	24 28	Not Used		
	29 31	Message Quality	Binary	0 7
5	0 31	Data Bits	Binary	
6	0 31	Data Bits	Binary	
7	0 31	Quality Bits	Binary	
8	0 31	Quality Bits	Binary	

SECTION 5
USER SERVICES

5.1 INTRODUCTION

The success of the Landsat program has generated widespread interest in acquiring and using Landsat data products. This section provides the information needed to obtain these products and describes the services and facilities available to potential Landsat data users.

Only those facilities that have been officially designated by NASA and/or other government agencies as repositories of Landsat data are described, thus it is not an all-inclusive list. The following facilities are discussed. (1) USGS Earth Resources Observation Systems (EROS) Data Center (EDC), (2) NOAA Satellite Data Services Branch (SDSB); (3) U.S. Department of Agriculture Aerial Photography Field Office (APFO), (4) NASA Image Processing Facility (IPF), and (5) the Information Transfer Laboratory (Intralab) at the Goddard Space Flight Center

Landsat data products may be purchased by anyone, including citizens of foreign countries, from the EEC, the SDSB or the APFO. The IPF no longer supplies Landsat data products directly to users, but instead supplies second generation master negatives to the three dispensing facilities.

5.2 EROS DATA CENTER

The EROS Data Center (EDC), at Sioux Falls, South Dakota, is operated by the U.S. Geological Survey EROS Program to provide access to Landsat imagery, aerial photography acquired by the U.S. Department of the Interior, and photography and imagery acquired by NASA from research aircraft and from Skylab, Apollo, and Gemini spacecraft. The primary functions of the EDC are data storage, reproduction, dissemination and user assistance and training. The EDC and its principal facility, the Karl E. Mundt Federal Building, were dedicated August 7, 1973.

At the heart of the EDC is a computer complex that controls a data base of over 6 million images and photographs of the earth's surface features, performs searches of specific geographic areas of interest, and serves as a management tool for the entire data reproduction process. The computerized data storage and retrieval system is based on a geographic system of latitude and longitude, supplemented by information about image quality, cloud cover, and type of data.

Guidance in the use of remotely sensed data is available at the EDC through scheduled training courses and workshops. The scientific teaching staff at the center periodically offers discipline-oriented courses in subjects such as agriculture, forestry, geography, geology, and hydrology. Visitors to the EDC can also receive assistance in the operation of specialized equipment such as densitometers, additive color viewers, zoom transfer scopes, and stereo viewers, and in the use of computerized multispectral systems to classify specific phenomena.

The EROS Data Center also functions as an integral part of the National Cartographic Information Center (NCIC) system for those requesting information about available aircraft or space imagery and for those wanting to place orders for these data. The NCIC is headquartered in the Geological Survey National Center in Reston, Virginia. It services customers requiring information on the availability of cartographic data, including multi-use mapping, geodetic control, areial photography and space imagery. Qualified personnel in the fields of topography, geodesy, photogrammetry, photography and cartography provide help to those with specialized needs. This service is readily available by a direct terminal link to the EDC's computer data base. Inquiries and orders for data are transmitted daily from NCIC to the EDC to provide a timely response to customer needs.

NCIC field offices with computer links are located at:

Topographic Office
U.S. Geological Survey
900 Pine Street
Rolla, MO 65401
Phone. 314-364-3680
Hours; 7·45 — 4:15

Air Photo Sales
U.S. Geological Survey
Federal Center, Building #25
Denver, CO 80225
Phone: 303-234-2326
Hours: 7:45 — 4.15

NCIC Information Unit
National Center — Stop 507
12201 Sunrise Valley Drive
Reston, VA 22092
Phone· 703-860-6045
Hours: 7:45 — 4:15

Map and Air Photo Sales
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025
Phone: 415-323-2157
Hours 7 45 — 8:15

5.2.1 Data Files

Imagery archived at the EDC can be reviewed by users in three ways: (1) by using the EROS Data Reference Files, (2) by using the EROS Applications Assistance Facilities, or (3) by direct contact with the EDC.

The EROS Data Reference Files have been established throughout the United States to maintain microfilm copies of Landsat data available from the EDC and to provide assistance to the user in reviewing and ordering data. This allows the user to view microfilm copies of the data before placing an order directly with the EDC. Applications assistance, however, is not provided. The addresses, telephone numbers, and hours of operation of the ten EROS Data Reference Files are listed below:

EROS Data Reference File
Public Inquiries Office
U.S. Geological Survey
108 Skyline Building
508 Second Avenue
Anchorage, Alaska 99501
Phone: 907-277-0577
Hours: 9:00 — 5 30

EROS Data Reference File
Topographic Office
U.S. Geological Survey
900 Pine Street
Rolla, Missouri 65401
Phone: 314-364-3680
Hours: 8:00 — 5:00

EROS Data Reference File
Public Inquiries Office
U.S. Geological Survey
Room 7638, Federal Building
300 North Los Angeles Street
Los Angeles, California 90012
Phone. 213-688-2850
Hours: 9:30 — 4:00

EROS Data Reference File
Water Resources Division
U.S. Geological Survey
Room 343, Post Office and Court House Building
Albany, New York 12201
Phone: 518-474-3107 or 6042
Hours: 8:00 — 4.30

EROS Data Reference File
University of Hawaii
Department of Geography
Room 313C, Physical Science Building
Honolulu, Hawaii 96825
Phone· 808-944-8463
Hours· 8·00 — 4:00

EROS Data Reference File
Water Resources Division
975 West Third Avenue
Columbus, Ohio 43212
Phone. 614-469-5553
Hours 8:00 — 4:30

EROS Data Reference File
U S. Geological Survey
5th Floor
80 Broad Street
Boston, Massachusetts 02110
Phone: 617-223-7202
Hours: 9:00 — 5 00

EROS Data Reference File
Bureau of Land Management
729 NE Oregon Street
Portland, Oregon 97208
Phone. 503-234-3361, Ext. 4000
Hours: 8.00 — 4 00

EROS Data Reference File
Public Inquiries Office
U.S. Geological Survey
Room 678, U.S. Court House Building
West 920 Riverside Avenue
Spokane, Washington 99201
Phone: 509-456-2524
Hours: 9.00 — 4:30

EROS Data Reference File
Maps and Surveys Branch
Tennessee Valley Authority
20 Haney Building
311 Broad Street
Chattanooga, Tennessee 37401
Phone. 615-755-2149
Hours: 8 00 — 4.00

Requests can also be made to the EDC for information about imagery of a specific area, initiating a geographic search using the center's central computer complex. These requests can be made by mail, personal visit, or phone, either directly to the EROS Data Center or to one of the EROS Applications Assistance Facilities. Users may request a geographic search using any of three options:

1. Point search — all images or photographs, any portion of which fall over the designated geographic point, will be listed.

2. Area rectangle (any area of interest defined by four sets of corner coordinates in latitude and longitude) — all images or photographs with any coverage of the area will be listed The area must not exceed 200 one-degree squares; e.g , 10^{o} latitude by 20^{o} longitude.

3 Enclosed map (any point or area indicated) — all images or photographs meeting the criteria for (1) or (2) will be listed.

When requesting a geographic search from the EDC, users should be sure to provide all relevant information. This should include acceptable dates and seasons, type of imagery preferred (color, false-color infrared, or black and white), acceptable degree of cloud cover, and acceptable quality. Most importantly, however, geographic areas must be clearly identified and should be limited in size as much as possible to avoid a potentially long computer listing and the need to review large numbers of choices. Latitude and longitude coordinate specification is preferred, since this is the method required for the computer geographic search. A description of the intended application and use of the data will also assist the EDC, and may result in a more concise response to the inquiry.

The computer printout received as a result of the geographic search lists all images available over or close to the user's specified area of interest. With the printout, the user will also receive detailed instructions on how to interpret the printout and order the images selected, as well as an up-to-date price list. Briefly, the computer printout provides the following information for each item listed: type of coverage, type and size of master film source, photo/scene identification number, indication of master film quality, percentage of cloud cover, date acquired, and scene center point (latitude/longitude). On the listing, Landsat imagery is indexed and listed by individual frame. Thus each entry on the computer listing describes a single image that can be ordered directly by unique identification number. NASA aerial photography is indexed either by individual photograph or by strip, which describes two or more successive forward overlapping photographs along an aircraft flight line. Each entry on the computer listing describes a single photograph or adjoining scenes that are successive photograph frames on the master film roll.

Aerial mapping photography, acquired over the past 25 years by various federal agencies for mapping the U.S., is not listed by individual photograph during a geographic search. These photographs are listed in photo indexes, which contain many overlapping photos and from which individual photographs can be ordered. The photo indexes can be ordered from EDC by supplying the geographic coordinates of the area of interest.

5.2.2 Applications Assistance

Training and assistance in the techniques required for the analysis of remotely sensed data are provided by the Application Assistance Branch of the EDC. All inquiries regarding applications assistance and training courses at the EDC should be addressed to:

Applications Assistance Branch
EROS Data Center
Sioux Falls, South Dakota 57198
Phone: 605-594-6511, Ext. 111
Phone (FTS) 784-7511

Several Applications Assistance Facilities maintain microfilm copies of data archived at the EDC and provide computer terminal inquiry and order capability to the EDC's central computer complex. Scientific personnel are available for assistance in applying the data and to aid in ordering data.

It is recommended that Applications Assistance Facilities be contacted by phone or mail in advance, so that suitable arrangements can be made for a visit. The present facilities are:

EROS Applications Assistance
Facility
U.S. Geological Survey
Room 202, Building 3
345 Middlefield Road
Menlo Park, California 94025
Phone: (FTS) 415-323-2727
Phone: (Commercial) 415-323-8111
Hours. 8 00 — 415

EROS Applications Assistance
Facility
EROS Data Center
U.S. Geological Survey
Sioux Falls, South Dakota 57198
Phone 605-594-6511
Hours. 8:00 — 4 30

EROS Applications Assistance
Facility
U S. Geological Survey
Room B-207-A, Building 1100
National Space Technology
Laboratories
Bay St. Louis, Mississippi 39520
Phone: 601-688-3541
Hours: 8 00 — 4 30

EROS Applications Assistance
Facility
HQ Inter American Geodetic Survey
Headquarters Building
Drawer 934
Fort Clayton, Canal Zone
Phone: 83-3897
Hours: 7:00 — 3:45

EROS Applications Assistance
Facility
U.S. Geological Survey
Suite 1880
Valley Bank Center
Phoenix, Arizona 85073
Phone: 602-261-3188
Hours: 8:00 — 5:00

EROS Applications Assistance
Facility
U.S Geological Survey
1925 Newton Square East
Reston, Virginia 22090
Phone: 703-860-7868
Hours: 8:00 — 4:15

EROS Applications Assistance
Facility
University of Alaska
Geophysical Institute
College, Alaska 99701 (Fairbanks)
Phone 907-479-7558
Hours: 8:00 — 5:00

5.2.3 Product Order Placement

Orders for reproductions of data from the EDC can be placed by personal visit, telephone or mail. Orders can also be placed at any of the EROS Applications Assistance Facilities (see Section 5.2.2).

The standard photo products available from the EDC are listed in Table 5-1. All inquiries regarding products, ordering procedures and costs should be directed to:

User Services
EROS Data Center
Sioux Falls, South Dakota 57198
Phone: 605-594-6511, Ext. 151
Phone (FTS) 784-7511

Table 5-1. EDC Standard Products

Product format	Black and White		Color	
	Paper	Film	Paper	Film
Contact				
70 mm	–	X	–	X
5 x 5 inch	X	X	X	X
10 x 10 inch	X	X	X	X
Enlargements				
10 x 10 inch	X	X	X	–
15 x 15 inch	X	–	X	–
20 x 20 inch	X	–	X	–
30 x 30 inch	X	–	X	–
40 x 40 inch	X	–	X	–
Microfilm				
16 mm	–	X	–	X
35 mm	–	X	–	X

All orders must be accompanied by check, money order, purchase order, or authorized account identification; processing cannot be initiated until valid and accurate payment is received. All checks or money orders should be made payable to the U.S. Geological Survey. Standing (open) accounts may be established by repetitive users. All shipments from the EDC are prepaid. The EDC suggests that users allow a minimum of two to three weeks for delivery of all orders. A longer time may be required for the production of computer compatible tapes or the completion of very large or complex orders

5.2.3.1 Landsat Data Standing Order Placement

Two basic options are available for placing standing orders for either data or information from the EDC:

1. The user may specify an area for which any new Landsat imagery will be automatically printed and shipped to the user.
2. The user may specify an area for which the EDC will notify the user of any new imagery and the order can be subsequently placed.

Should the user decide to place a standing order for new data (option 1), the user must agree to accept all data for the specified geographic area if it meets the user's specifications for cloud cover, quality, and type of remotely sensed data. Any image having any part within the defined geographic location will be shipped. If option 2 is selected, the minimum requirement is that some data must be ordered at least once every 120 days, otherwise the standing order for this information will be automatically cancelled.

5.2.3.2 Custom Processing

Custom processing to unique scale and image format is also available from the EDC. These products normally require longer periods of time for completion. Pricing is considerably higher than for the standard products.

5.2.3.3 Priority Services

A priority system for rapid delivery of products is available whereby orders will be shipped within 5 working days of receipt. A higher price is also required for this service. Priority processing will be accepted only when imagery is specifically identified and standard products are ordered. If for any reason shipment is not made within the 5 days, the cost for each product reverts to standard price and a refund or credit is made.

5.3 SATELLITE DATA SERVICES BRANCH

The NOAA Satellite Data Services Branch (SDSB) was inaugurated in November 1974 by mutual agreement between the Environmental Data Service (EDS) and the National Environmental Satellite Service (NESS) and is now fully operational. This unit, a branch of the Information Services Division of the National Climatic Center (NCC), is located at the World Weather Building, Suitland, Maryland. It has assumed the responsibility of archiving all environmental and earth resources data received from meteorological satellites, Landsat and Skylab. It is collocated with operational elements of the NESS.

Because various types of satellite data are often useful in conjunction with Landsat data, it is important to note that the archival holdings of the SDSB contain most of the data from the early Tiros series of experimental satellites, imagery from the Nimbus spacecraft, the full earth disc photographs of the ATS 1 and 3 geostationary satellites, the myriad of images received from the original ESSA and the current NOAA series, and both the full disc and "sectorized" images of the operational SMS 1 and 2 geosynchronous satellites.

5.3.1 Browse Files

Although the SDSB does not presently have a grographic search capability, NOAA has established 21 Browse Files throughout the U.S. to allow the general public wide access to information concerning Landsat imagery

The NOAA Browse Files consist of a 16 mm microfilm (and reader) of one channel of Landsat data, standard catalogs identifying each image, documentation giving additional Landsat system information, a list of products available, prices of these products, and detailed ordering procedures. All of the necessary material and information for the requester to make a proper evaluation of the data and subsequently order those products that he requires can be obtained from the Browse Files. The 21 NOAA Browse Files, by location, address and telephone number, are listed below

University of Alaska
Arctic Environmental Information
and Data Center
142 East Third Avenue
Anchorage, Alaska 99501
Phone: 907-279-4523

Inter-American Tropical Tuna
Commission
Scripps Institute of Oceanography
Post Office Box 109
LaJolla, California 92037
Phone 714-453-2820

National Geophysical and Solar
Terrestrial Data Center
Solid Earth Data Service Branch
Boulder, Colorado 80302
Phone: 303-499-1000, Ext. 6915

Lake Survey Center - CLx13
630 Federal Building & U.S. Courthouse
Detroit, Michigan 48226
Phone: 313-226-6126

National Weather Service, Central
Region
601 East 12th Street
Kansas City, Missouri 64106
Phone 816-374-5672

National Weather Service, Eastern
Region
585 Stewart Avenue
Garden City, New York 11530
Phone. 516-248-2105

National Oceanographic Data Center
Environmental Data Service
2001 Wisconsin Avenue
Washington, D.C. 20235
Phone. 202-634-7510

Atlantic Oceanographic and
Meteorological Laboratories
15 Rickenbacker Causeway,
Virginia Key
Miami, Florida 33149
Phone· 305-361-3361

National Weather Service, Pacific
Region
Bethel-Pauaha Building, WFP 3
1149 Bethel Street
Honolulu, Hawaii 96811
Phone: 808-841-5028

National Ocean Survey - C3415
Building #1, Room 526
6001 Executive Boulevard
Rockville, Maryland 20852
Phone: 301-496-8601

Atmospheric Sciences Library - D821
Gramax Building, Room 526
8060 - 13th Street
Silver Spring, Maryland 20910
Phone. 301-427-7800

National Environmental Satellite
Service
Environmental Sciences Group
Suitland, Maryland 20233
Phone. 301-763-5981

Northeast Fisheries Center
Post Office Box 6
Woods Hole, Massachusetts 02543
Phone. 617-548-5123

University of Wisconsin
Office of Sea Grant
610 North Walnut Street
Madison, Wisconsin 53705
Phone· 608-263-4836

National Climatic Center
Federal Building
Asheville, North Carolina 28801
Phone 704-258-2850, Ext. 620

National Severe Storms Lab
1313 Halley Circle
Norman, Oklahoma 73069
Phone: 405-329-0388

Remote Sensing Center
Texas A & M University
College Station, Texas 77843
Phone: 713-845-5422

National Weather Service, Southern
Region
819 Taylor Street
Fort Worth, Texas 76102
Phone· 817-334-2671

National Weather Service, Western
Region
125 South State Street
Salt Lake City, Utah 84111
Phone: 801-524-5131

Atlantic Marine Center - CAM02
439 West York Street
Norfolk, Virginia 23510
Phone: 804-441-6201

Northwest Marine Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112
Phone: 206-442-4760

5.3.2 Product Order Placement

The SDSB can provide the following Landsat data products.

1. Duplicate 70 x 70mm negatives
2. Contact size 70 x 70mm or enlarged 9.5 in. x 9.5 in. positive transparencies.
3. Paper print enlargements in various sizes from 9.5 x 9.5 in. to 40 x 60 in.
4. 35mm slides

Landsat data should be ordered, when possible, using the order blanks available at the Browse Files listed in Section 5.3.1. However, data products can also be ordered by letter request to the SDSB. Inquiries regarding products, ordering procedures and costs should be directed to:

Satellite Data Services Branch, D543
National Oceanic and Atmospheric Administration
World Weather Building, Room 606
Washington, D.C. 20233
Telephone: 301-763-8111/8112

Landsat imagery must be requested by scene identification number or by geographical coordinates, date and time. The requester should also indicate the MSS or RBV channel desired or, if unknown, state the use to be made of the imagery to allow the SDSB personnel servicing the request to select the most advantageous channel. Standing order service may be arranged by the user and the SDSB on an individual basis.

Besides the photographic imagery provided by the SDSB, copies of the original digital data received from Landsat are frequently requested. To satisfy these requests, SDSB obtains the specified data on computer compatible magnetic tapes from the EROS Data Center and then reships them to the user. The SDSB plans to begin supplying CCTs directly to requesters in the near future.

5.4 AERIAL PHOTOGRAPHY FIELD OFFICE

The Aerial Photography Field Office (APFO), in Salt Lake City, Utah, is part of the Administrative Services Division of the Agriculture Stabilization and Conservation Service (ASCS), U.S. Department of Agriculture. Established in the mid-1930s, the APFO film library has files of Landsat and Skylab imagery in addition to the conventional ASCS aerial photography and some black and white and color infrared photography from various government agencies.

APFO receives a master file of 70mm negatives of all Landsat imagery from the NASA/Goddard Space Flight Center. In addition, APFO has accumulated a library of over 1,700 color composite negatives (MSS bands 4, 5 and 7) of Landsat imagery. A computer listing of color composite negatives on file is maintained and may be sorted by scene identification number, latitude and longitude and file number. Each scene also has a quality number ranging from 1–9 that indicates extent of scan lines, cloud cover, etc.

5.4.1 Browse File

As in the case of the SDSB, the APFO maintains a Browse File to serve its users It has also begun developing a geographic search and inquiry system for the future. Currently, Landsat data computer query and search are accomplished by remote terminal from the Marshall Earth Resources Information Transfer System (MERITS) at Huntsville, Alabama. However, plans are being implemented whereby APFO will establish and maintain its own Landsat data retrieval system patterned after the Marshall system.

The APFO Browse File provides a microfilm copy of its holdings plus catalogs, photographic indices and trained personnel to assist the user in ordering data products

5.4.2 Product Order Placement

Landsat imagery and NASA aircraft photography may be ordered directly from the

APFO. Inquiries regarding products, ordering procedures and costs should be directed to:

U.S. Department of Agriculture — ASCS
Aerial Photography Field Office
Administrative Services Division
2505 Parley's Way
Salt Lake City, Utah 84109
Telephone: 801-524-5856

Reproductions of Landsat imagery are available in a variety of scales ranging from 1:3,369,000 (70mm) to 1:250,000 (40 x 40 in.) in black and white or color and on paper or film. ASCS aerial photography is also available at the APFO as well as at county ASCS offices

Standing orders for imagery may be established with the APFO on an individual basis.

5.5 IMAGE PROCESSING FACILITY

The Image Processing Facility (IPF), formerly the NASA Data Processing Facility (NDPF), began operations with the launch of the first of the earth resources satellites, Landsat 1, in July of 1972. From that time until approximately the launch of Landsat 2 in January of 1975, the Support (User) Services Section of the IPF functioned as the primary source of data for NASA investigators and user agencies Since the launch of Landsat 2, however, the role of the IPF has been significantly altered. With the exception of certain instances where federal government agencies require occasional data on a fast turn-around basis (e.g., disaster assessment) or for some operational requirement, the IPF supplies Landsat data only to the three above-mentioned federal data centers As the single U.S. source for processing video telemetry data from Landsat, the IPF also sends second generation master negatives of all processed Landsat imagery to these agencies on a daily basis. Products are then generated from these negatives, at the agencies, for sale at nominal prices to the public. The original archival or first generation positive film is stored on rolls at the IPF.

Of the services originally offered by the IPF, the reception, processing, and distribution of Data Collection System products are still handled solely by the IPF The 70mm Browse Facility continues to provide the same range and quality of services to data users that it has from its inception The IPF sends computer compatible tapes (CCTs) to the EROS Data Center for reproduction, to be made available there as requested by the public and the dispensing agencies

Reference should be made to Appendix H of this handbook for a more detailed, inclusive description of the IPF.

5.5.1 Browse Facility

NASA provides a Browse Facility at the Goddard Space Flight Center (Building 23, Room E408) where visitors may examine archived Landsat data, make use of their reference facilities, and view IPF output products.

A full-time Browse Facility assistant is available to instruct and assist visitors in the capabilities and operational aspects of the facility The assistant will place orders for catalogs or microfilm for investigators desiring retention copies and will instruct and aid investigators in the use of the IPF information systems data base search and query system. The assistant is also available to demonstrate the use of catalogs, atlases and user guides A log of all reference material is maintained in the Browse Facility and is available to visitors. The assistant will provide instruction for the operation of light tables, microfilm viewing equipment, and the cathode ray tube (CRT) terminal

Information about every image processed from Landsat video data tapes is maintained in the IPF information systems data base, and includes the following parameters:

- Observation ID
- Orbit No
- Station ID
- Ephemeris Type (Best fit or predicted)
- Transmission Mode (Direct or Recorded)
- Altitude
- Heading
- Track
- Sun Elevation
- Sun Azimuth
- Quality (good, fair, poor)
- Cloud Cover (percent)
- Geographic Area
- Time
- Sensor
- Image Product (type and spectral band)

To permit investigators to conveniently search this data base, a special computer program known as Query Processing is available. It can be used either in a batch mode or in an interactive mode directly from the remote CRT terminal in the Browse Facility. The program is such that a search can be made for given time periods, given geographical areas or imagery parameter information. Moreover, the program is sufficiently flexible to allow almost any logical combination of search criteria to be specified.

The normal output of a search is the number of images found that meet the specified search criteria. Additional outputs can be specified as follows.

1. A listing of all image identification numbers for those images satisfying the search.
2. A display catalog output, as shown in Figure 5-1, containing one-line descriptions of each image that satisfies the search criteria. The information for each image is similar to that contained in the standard catalogs
3. A display image output that is a print-out of all data in the data base for each image that satisfies the search criteria. (See Figure 5-2.)

5.5.2 Product Order Placement

Although Landsat imagery and CCTs can not be obtained directly through the IPF, DCS data are still available

For those desiring DCS data, it may be requested on a standing order basis or on a Data (Variable) Request basis. All orders must specify product type and platform number, and will be processed on an individual basis by IPF Support Services personnel. Users may discuss DCS data products with representatives who are trained to assist them in formatting their requests Contact may be by phone, mail or personal visit to the following address:

IPF Support Services
Code 563
Building 23, Room E409
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771
Phone: 301-982-5406

5.6 INFORMATION TRANSFER LABORATORY (INTRALAB)

The Information Transfer Laboratory is an activity of Goddard Space Flight Center designed to foster the operational use of remote sensing, especially Landsat, technology. Intralab provides an opportunity for users to acquire hands-on experience in the application of remote sensing technology to problems of immediate concern to their operational needs. Users work with Intralab discipline specialists and contemporary image processing and analysis facilities in conducting short duration projects.

KEY TO IMAGE CLARITY

G = GOOD
F = FAIR
P = POOR

THE IMAGES INDICATED BELOW ARE ON MICROFILM ROLL NUMBER 001

OBSERV ID	ORB	TRANS MODE R	TRANS MODE M	STAT R	STAT M	TOT CC	EPH	PROD	QUALITY RBV MSS 12312345	PICTURE CENTER LONG	PICTURE CENTER LAT	SUBST POINT LONG	SUBST POINT LAT
1010 05435	0173	D	D	GL	GL	21	R	10	GGGGGGG	120 55	36 21	-120 56	36 32
1010 05442	0173	D	D	GL	GL	32	R	11	GGGGGGG	121 02	34 93	-121 12	35 12
1010 05444	0185	D	D	FA	FA	11	R	20	GGGGGGG	148 12	63 03	-148 22	63 03
1010 05451	0185	D	D	FA	FA	31	R	17	GGGGGGG	148 28	62 00	148 33	62 00
1010 05453	0185	D	D	FA	FA	32	R	18	GGGGGGG	148 36	60 98	148 36	60 98
1010 05460	0196	D	D	GD	GD	51	R	13	GGGGGGG	80 84	41 79	80 83	41 83
1010 05462	0196	D	D	GD	GD	11	R	14	GGGGGGG	81 09	40 75	81 03	40 76
1010 05465	0196	D	D	GD	GD	21	R	15	GGGGGGG	81 07	39 58	81 06	39 63
1010 05471	0196	D	D	GD	GD	11	R	16	GGGGGGG	81 08	38 47	81 07	38 51
1010 05474	0196	D	D	GD	GD	32	R	12	GGGGGGG	81 12	37 40	81 09	37 42
1015 08000	0173	D	D	GL	GL	41	R	10	GGGGGGG	120 55	36 21	120 56	36 32
1015 08002	0173	D	D	GL	GL	42	R	11	GGGGGGG	121 02	34.93	121 12	35 12
1016 08030	0185	D	D	FA	FA	41	R	20	GGGGGGG	148 12	63 03	148 22	63 00
1016 08032	0185	D	D	FA	FA	41	R	17	GGGGGGG	148 28	62 00	148 33	62 00
1016 08035	0185	D	D	FA	FA	42	R	18	GGGGGGG	-148 36	60 98	148 36	60 98

Observation Identifier
Orbit Number
Transmission Mode for RBV (R) and MSS (M)
D – Direct, R – Recorded
Receiving Site for RBV (R) and MSS (M)
GL – Goldstone, FA – Fairbanks, GD – GSFC
% Cloud Cover
Ephemeris, R – Refined,
P – Predicted
Number of Products Available
Image Quality per Band
Picture Center
Subsatellite Point

Figure 5-1. Query Search – Display Catalog Output Sample

OBSERVATION ID 1018 05453

ORBIT NUMBER	0196	TRANSMISSION MODE RBV	DIRECT
TOTAL CLOUD COVER	10	TRANSMISSION MODE MSS	DIRECT
STATION–RBV	GOLDSTONE	SUBSAT POINT (LONG)	–80 83
STATION–MSS	GOLDSTONE	SUBSAT POINT (LAT)	41 83
EPHEMERIS TYPE	R	PICTURE CENTER (LONG)	–80 84
ALTITUDE	492 32	PICTURE CENTER (LAT)	41 79
HEADING	36 38	SUN ELEVATION	33 70
TRACK	48 32	SUN AZIMUTH	40 62
BLOCK	U S CONTINENT	LAST SYCI DISTRIBUTION:	

SENSOR QUALITY

RBV 1	RBV 2	RBV 3	MSS 1	MSS 2	MSS 3	MSS 4	MSS 5
G	G	G	G	G	G	G	0

IMAGE DESCRIPTORS
FORESTRY RIVERS

NUMBER OF PRODUCTS PRESENT 13

PRODUCT	P-CL	BAND INDICATOR	11111110
DATE PRODUCED	09/15/71	LAST REQUEST DATE	09/15/71
PRODUCT	SCCI	BAND INDICATOR	11000000
DATE PRODUCED	09/15/71	LAST REQUEST DATE	09/15/71

Figure 5-2. Query Search – Display Image Output Sample

Although individual projects vary widely in scope and technical approach, certain aspects are common to all:

1. Proposed tasks are evaluated by Intralab. Task must:

   a. Have an identifiable value for operational implementation
   b. Not be routinely solvable with existing resources
   c. Be sharply focused and of limited duration (several month technical phase)
   d. Be consistent with available Intralab resources

2. Active user participation in project design and performance is essential:

   a. Users assign personnel to work with the Intralab staff
   b. Users collect the necessary surface observations and/or supporting data
   c. Intralab acquires and supplies remotely sensed data
   d. Data analysis and interpretation are conducted by a joint user/Intralab team

3. Completed tasks are fully documented by the user/Intralab teams, with particular attention to:

   a. Techniques commensurate with the user's operational requirements
   b. Cost effectiveness of the techniques
   c. Identification of the characteristics of remote sensing systems that more fully satisfy user requirements

4. Intralab recognizes a responsibility to share these experiences with broader user communities having similar information needs. All documentation is publically available, and is disseminated through appropriate NASA and other offices.

For further information contact.

Intralab
Code 923
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

5.7 ADDITIONAL LANDSAT PRODUCT INFORMATION

5.7.1 Landsat Standard Catalogs

As part of its support services function, the IPF produces two standard Landsat catalogs: the U S. Standard Catalog (listing all data processed by the IPF of the U.S. and parts of Canada and Mexico), and the Non-U.S Standard Catalog (listing data processed by the IPF over all other areas of the world). Cumulative U.S Standard and Non-U.S. Standard Catalogs are published on a yearly basis. Catalogs for Landsat 1 are available for the periods of launch to July 1973, July 1973 to July 1974, and July 1974 to July 1975. For Landsat 2 the publishing schedule will be from launch to January 1976, January 1976 to January 1977, etc. To supplement the cumulative catalogs, monthly catalogs are issued listing the data processed during the month of issue.

Each of the standard catalogs also contains an outline map. The U.S. Standard Catalog has outline maps of the United States, including Alaska and Hawaii (see Figure 5-3), and the Non-U.S. Standard Catalog contains an outline map of the world (see Figure 5-4). Each of these maps graphically depicts the areas covered by the images listed in the catalog. In addition, the U.S. outline map shows an estimate of the cloud cover contained in the imagery by a four-shade spectrum along the subsatellite path for each north to south pass. No shading indicates that no imagery was collected.

A large part of each standard catalog consists of computer listings produced from the IPF information system data base. All listings are in sequence by observation identifier. Figure

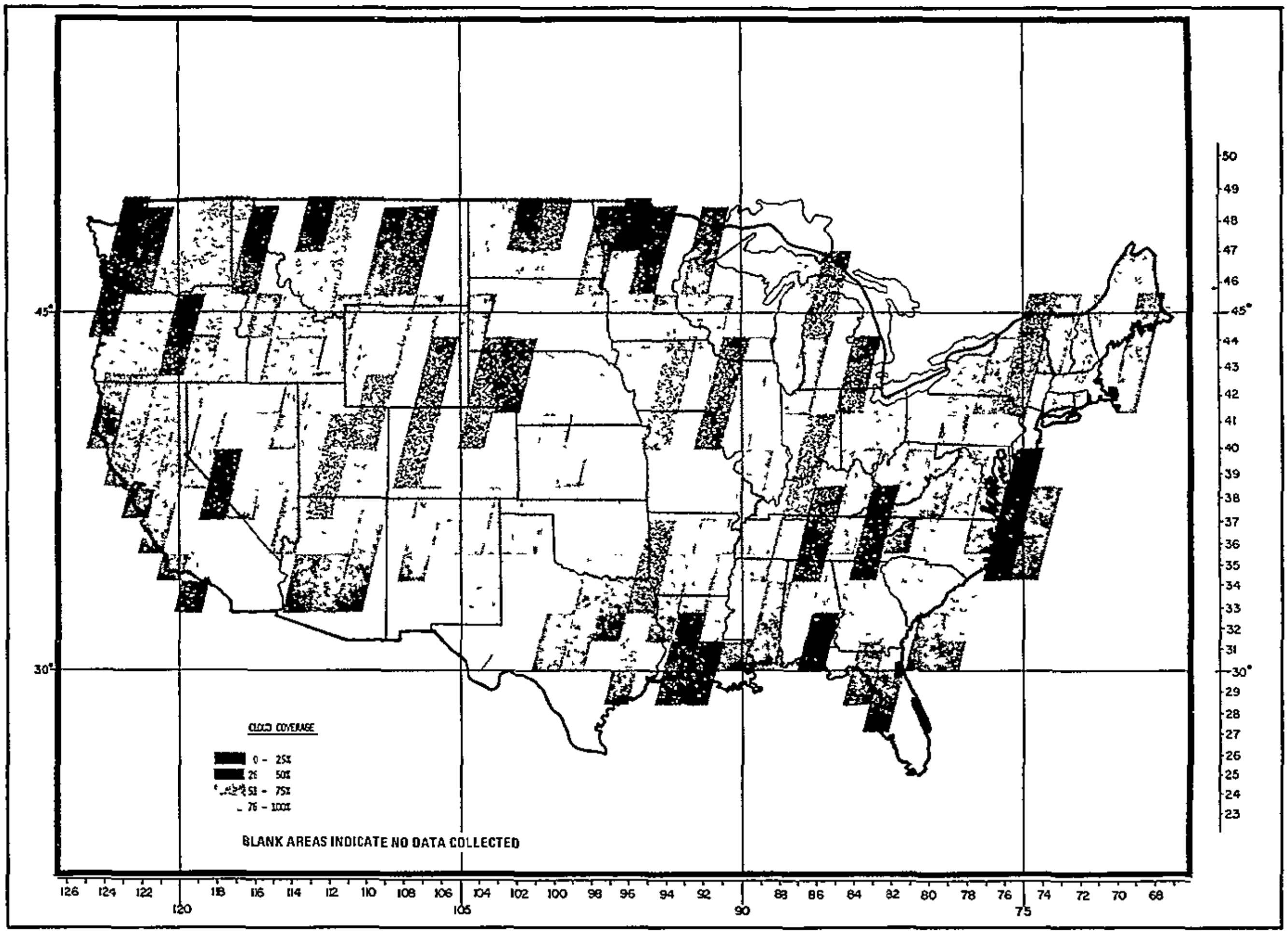


Figure 5-3 Sample Continental U.S. Outline Map

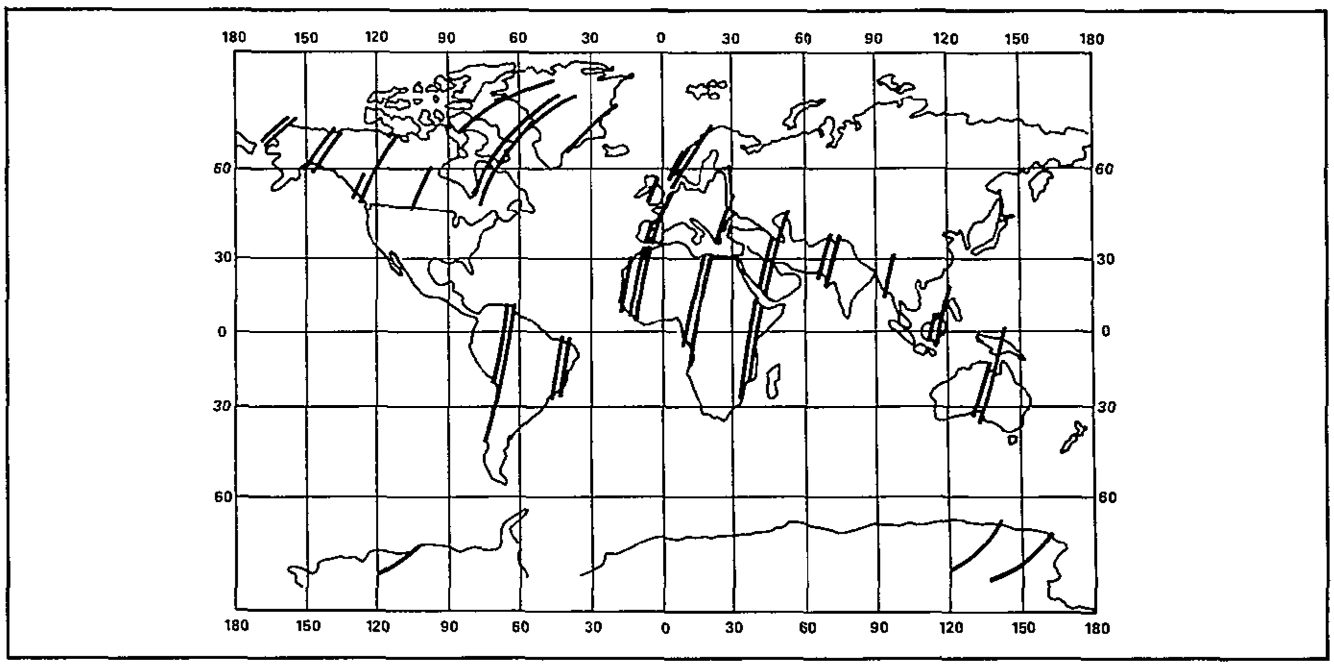


Figure 5-4. Sample World Map

5-5 explains the format and content of this identification code. All orders, announcements, queries and image annotations utilize these identifiers. A sample catalog page with an explanation of its contents is shown in Figure 5-6.

Landsat standard catalogs are on sale to the general public through both the EROS Data Center and the Government Printing Office. Inquiries should be directed to:

User Services
EROS Data Center
Sioux Falls, SD 57198

or

Main Government Printing
Office Book Store
Attention: NASA Publications Clerk
710 North Capital Street
Washington, D.C. 20402

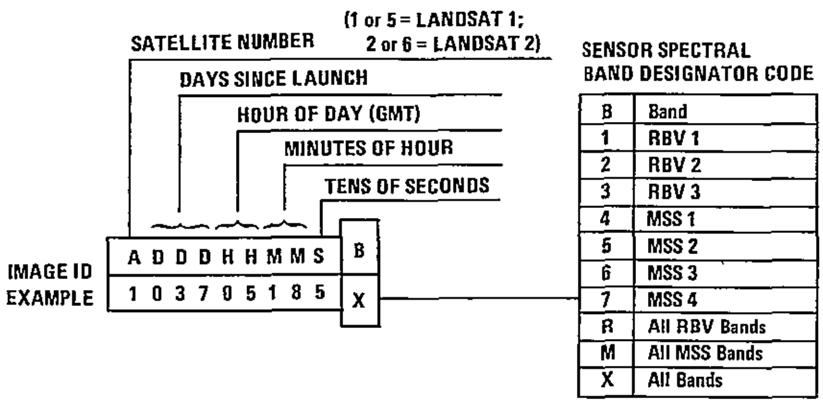


Figure 5-5 Observation Identification Number Format

Standard Catalog Format The data format for the U.S and Non U.S catalogs is identical Below is a sample catalog entry with a description of each data item

A Sample Catalog Format

② Page 1

① 09/30/72 STANDARD CATALOG FOR USA FROM 07/24/72 TO 09/23/72

④ OBSERV ID	⑤ MICROFILM ROLL NO POSITION IN ROLL RBV	MSS	⑥ DATE	⑦ CLOUD COVER %	⑧ PRINCIPAL POINT OF IMAGE		⑨ SUN ELEV	SUN AZIM	⑩ IMAGE QUALITY RBV MSS 1 2 3 4 5 6 7 8	⑪ PRODUCT TYPES ALREADY MADE BULK	BULK COLOR	PREC	PREC COLOR	DIGITAL
1057 16373	00000/0000	10002/0589	09/18/72	70	25 836N	99 345W	53 5	126 9	G G G G	M				
1057-18140	00000/0000	10002/0590	09/18/72	90	48 704N	117 503W	39.2	150 6	G	M				
1057-18143	00000/0000	10002/0591	09/18/72	50	47 284N	118 114W	40 2	149 4	G G G G	M				
1057-18145	00000/0000	10002/0592	09/18/72	30	45 868N	118 701W	41 3	148 2	G G G G	M				
1057-18152	00000/0000	10002/0593	09/18/72	20	44 448N	119 266W	42 3	146 9	G G G G	M				
1057-18154	00000/0000	10002/0594	09/18/72	10	43 028N	119 811W	43 3	145 7	G G G G	M				
1057-18161	00000/0000	10002/0595	09/18/72	10	41 612N	120 337W	44 3	144 4	G G G G	M				
1057-18163	00000/0000	10002/0596	09/18/72	20	40 192N	120 847W	45 3	143 0	G G G G	M				
1057 18170	00000/0000	10002/0597	09/18/72	10	38 784N	121 344W	46 2	141 6	G G G G	M				
1057 18172	00000/0000	10002/0598	09/18/72	20	37 358N	121 827W	47 1	140 2	G G G G	M				
1057-18175	00000/0000	10002/0599	09/18/72	30	35 930N	122 297W	48 0	138 7	G G G G	M				
1057-18181	00000/0000	10002/0600	09/18/72	40	34 490N	122 743W	48 9	137 2	P P P P	M				

B Description of Data Items

① Date of Catalog Listing
② Period of Coverage
③ Special Keys to Data
④ Observation ID

1010 15165
- Tens of Seconds
- Minutes of Hour
- Hour of Day since launch (GMT)
- Day since launch
- Satellite Number (1 or 5 = LANDSAT 1, 2 or 6 = LANDSAT 2)

⑤ RBV and MSS microfilm roll and image position on roll Note RBV and MSS images for a given observation may be on two different microfilm rolls
⑥ Date of observation
⑦ Estimated Percent of Cloud Cover
⑧ Latitude and Longitude at observation center (Degrees to thousandths)
⑨ Sun elevation and azimuth at observation center
⑩ Image Quality reference 3
⑪ Image/Data product availability, reference 3

③ Keys
Cloud Cover % — 0 to 100 = % of cloud coverage * * = No Data Available
Image Quality — Blank = Band not present R = Recycled G = Good F = Fair but usable P = Poor image C = Calibration images
Product Types Already Made — R = Made from RBV bands only M = Made from MSS bands only B = Made from both RBV and MSS

Figure 5-6. Annotated Sample of Standard Catalog

5.7.2 Microfilm

Once a month, in conjunction with preparation of the standard catalogs, the IPF produces 16mm microfilm (MSS, band 5) depicting imagery processed during the month. These images are intended only to indicate to users what imagery is available and are not suitable for data analysis.

The microfilm data is also divided into U.S. and non-U.S. segments. Each set of microfilm images is in exact correspondence to the standard catalogs and can be used in conjunction with the catalog for selecting desired images. The catalog contains roll and position numbers and data which, along with the microfilm image, provide the user with enough information to decide whether or not the image is useful.

Because the microfilm images are intended to provide only a summary of the data available, the images are limited to one band each for the RBV (if available) or MSS. Only the RBV band 2 images and the MSS band 5 images are reproduced.

Each image is a photograph of a system corrected image and contains the image identifier and full annotation block as described in Section 4.

A typical roll of microfilm contains the following:

1. 1 Leader Frame of Microfilm Identification
2. Up to 1000 Frames of RBV Images (where available)
3. Up to 1000 Frames of MSS Images

The microfilm is on open reels suitable for mounting by the user in a cartridge. Two rapid search capabilities are incorporated on the microfilm. The first allows counting images for precise location and requires a counting capability on the viewer being used. The second is a moving bar indicator that permits gross location of images to within about 20 images. Details of these two schemes are described in the standard catalogs.

The RBV and MSS image frames per observation are alternated on the roll of microfilm as shown in Figure 5-7.

A complete set of microfilm data is maintained in the IPF Browse Facility and complete sets are sent both to the EDC and APFO. Users may purchase copies of the microfilm sets through EDC User Services.

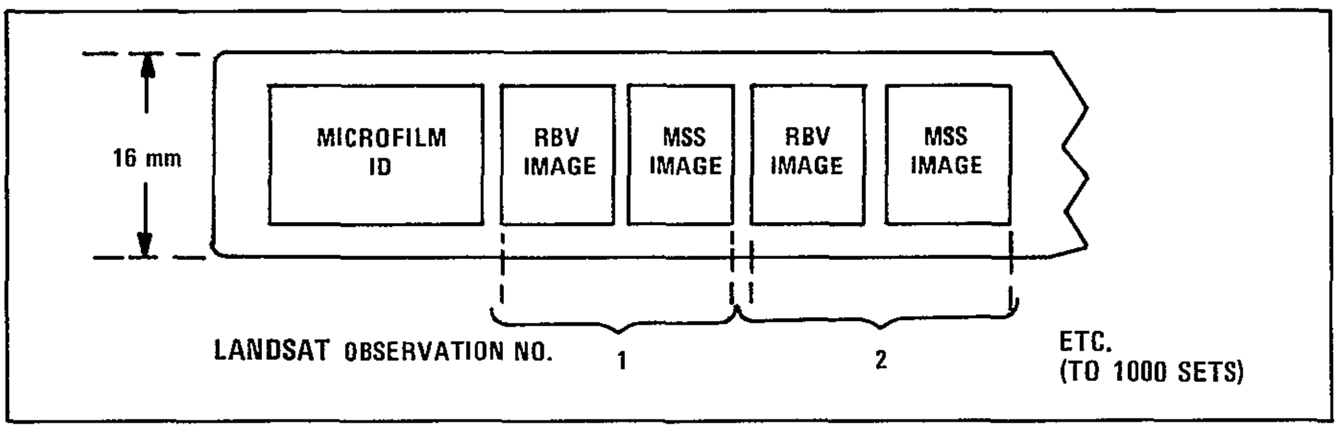


Figure 5-7. Sample Format of Microfilm Roll

APPENDIX A
OBSERVATORY

The Landsat 1 and 2 Observatories (Figure A-1) are earth-pointing stabilized spacecraft consisting of integrated subsystems that provide the power, environment, orbit maintenance, attitude control, and information flow required to support the payloads for a period of at least one year in orbit. They weigh approximately 953 kilograms (2100 lb) and have an approximate overall height of 3 meters (10 ft) and a diameter of 1.5 meters (5 ft), with solar paddles extending out to a total of 4 meters (13 ft).

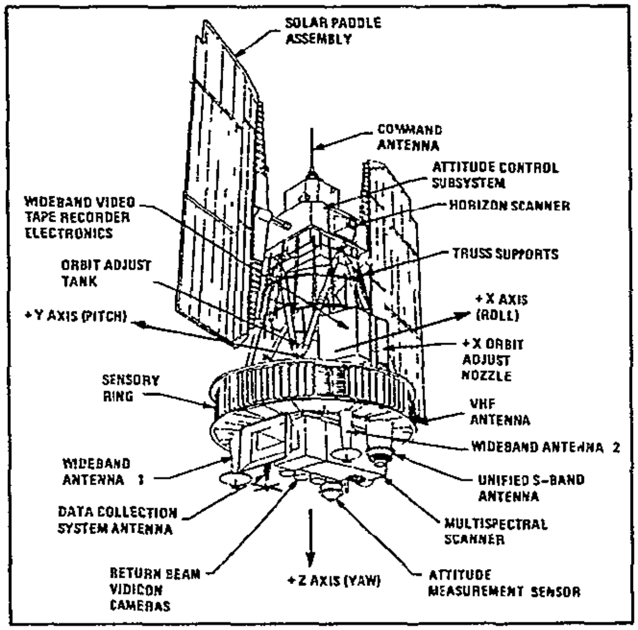


Figure A-1. Landsat 1 and 2 Observatory

A.1 ATTITUDE CONTROL SUBSYSTEM

The Attitude Control Subsystem (ACS) provides spacecraft alignment with both local earth-vertical and orbit velocity vectors, and provides rate control about the pitch, roll and yaw axes. The ACS achieves pointing accuracies of the spacecraft axes within 0.4 degree of the local vertical (about the pitch and roll axes) and within 0 6 degree of the velocity vector (about the yaw axis). The rotation rates encountered during multispectral scanner (MSS) and return beam vidicon (RBV) operations are less than 0.015 degree per second about all axes These rates produce image motions which are negligible during the short exposure of the RBV cameras, but cause a slight distortion in the MSS images. Compensation for these distortions is provided during ground image processing in the NASA Image Processing Facility (IPF) by applying correction factors for the measured attitude rates.

The 3-axis active ACS uses horizon scanners for roll and pitch attitude error sensing. The rate gyros sense yaw rate and, in a gyro compassing mode, sense yaw attitude. A torquing system uses a combination of reaction jets to provide spacecraft momentum control and large control torques when required; flywheels are utilized for fine control and residual momentum storage.

A.2 ATTITUDE MEASUREMENT SENSOR

The Attitude Measurement Sensor (AMS) is an independent component (not used for attitude control purposes) that determines precise spacecraft pitch and roll attitude. This data is used for image location and correction during ground processing. The AMS detects the radiation level change in the 14 to 16 micron range between the earth's atmosphere and the spatial background and establishes the spacecraft pitch and roll axis positions relative to the local vertical. After ground compensation of telemetry data for variations due to seasonal-radiance and other effects, the pitch and roll attitude can be determined to within about 0.07 degree.

A.3 WIDEBAND VIDEO TAPE RECORDER SUBSYSTEM

Two wideband video tape recorders (WBVTR) record, store, and reproduce the data outputs from either the RBV or MSS during remote sensing operations Each recorder can record 30 minutes of either 3.2-MHz video analog data from the RBV or 15-Mbps digital data from the MSS. Data are recorded by four heads (on one wheel) rotating across the 2-inch wide tape. Recording and playback are each at 30 centimeters per second (12 in /sec) and are in the same direction. Total usable tape length is 548 meters (1800 ft) for each recorder.

The RBV analog video signal is transformed into the FM domain by video circuitry in the WBVTR. The signal is received as a negative analog signal, is dc level shifted, frequency modulated, amplified and recorded. To insure head switching during the horizontal blanking interval of the video signal during playback, the RBV signal is rephased to the WBVTR headwheel at the beginning of each triplet exposure during recording. In playback, the RBV signal is read out sequentially by the same four rotating heads, with appropriate switching, producing a continuous RBV signal in the FM domain. The signal is then demodulated on the ground, producing the original analog video waveform.

The MSS digital video data is received as a non-return to zero level (NRZ-L), 15-Mbps data stream. In the WBVTR, the data stream is re-clocked and then frequency modulates an FM carrier. The resulting frequency-shift keyed (FSK) signal is recorded by four rotating heads. The MSS data are recorded asynchronously, that is, the data stream and rotating heads are not synchronized. In playback, the MSS signal is read out sequentially by the same four rotating heads, with switching and demodulation producing a continuous NRZ-L, 15 Mbps data stream.

Each WBVTR can record and playback either RBV or MSS data at any given time. The selection of RBV data or MSS data for each WBVTR during record or playback, plus appropriate tape motion to select the proper tape location, is made by appropriate ground commands which can be stored by spacecraft equipment for subsequent remote execution

A.4 POWER SUBSYSTEM

The Power Subsystem supplies the electrical power required to operate all spacecraft service and payload subsystems During sunlight periods the subsystem delivers a maximum output of 980 Watts of regulated -24 Volts for short periods. This power is derived from the load sharing of the 550-Watt solar array panels and the eight, 4.5 Ampere-hour batteries The power requirements during payload operation are 480 Watts for real-time operation and 521 Watts for remote operation Considering the subsystem as an energy balanced system, it can support an average of 20 minutes of payload (both RBV and MSS) "ON — time" per orbit initially and 12.1 minutes after one year. The reduction in "ON — time" is mainly due to efficiency loss of the solar arrays from small particle impact during the year in orbit. However, the actual payload "ON — time" is limited by other system constraints (such as station pass time, record capability, etc.) to an average of 12 minutes per orbit

All power is provided from the batteries during the launch phase and while the spacecraft is within the earth's umbra. Energy from the solar array not required for spacecraft loads during the lighted periods is used to recharge the batteries and any excess power is dumped via auxiliary loads.

A.5 COMMUNICATIONS AND DATA HANDLING SUBSYSTEM

The Communications and Data Handling Subsystem (Figure A-2) provides for all spacecraft information flow and is composed of the Wideband Telemetry Subsystem and the narrowband Telemetry, Tracking and Command Subsystem.

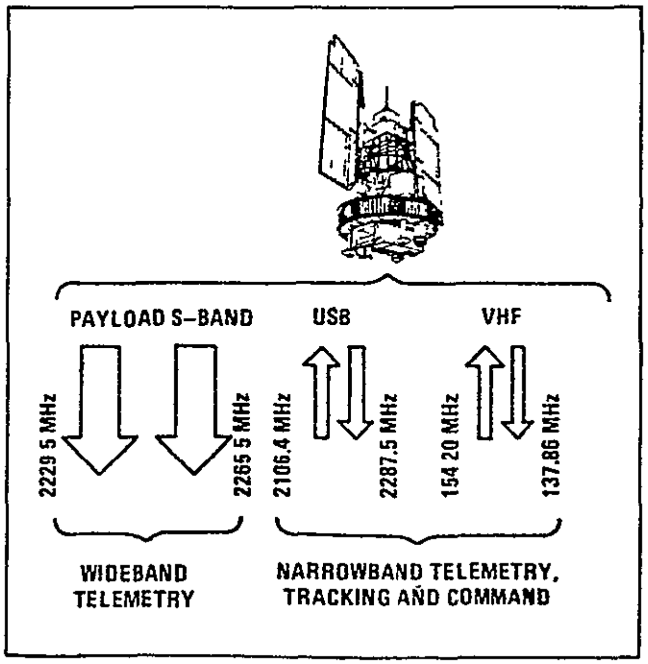


Figure A-2. Landsat Communication Links

A.5.1 Wideband Telemetry Subsystem

The Wideband Telemetry Subsystem accepts and processes data from the RBV, the MSS, and both wideband video tape recorders, and transmits it to the ground receiving sites.

The subsystem consists of two, 20-Watt S-band FM transmitters and associated filters, antennas, and signal conditioning equipment. As shown in Figure A-3 the subsystem permits transmission of any two data sources simultaneously, either real time or recorded, over either of the two downlinks (one data source each). Commandable power level traveling wave tube (TWT) amplifiers and shaped beam antennas provide maximum fidelity of the sensor data at minimum power. Cross-strapping and dual mode operation (two data sources) with a single TWT amplifier is available in the event of hardware malfunctions

A total of 912 telemetry points (576 analog, 16, 10-bit digital words; and 320, 1-bit binary words) can be sampled at rates between once per 16 seconds to five times in one second. The data is pulse code modulated (PCM) and can then be transmitted in real time either over the VHF or Unified S-Band (USB) links at a 1-kbps rate Up to 210 minutes can be stored on each of two narrowband tape recorders (NBTR) for subsequent playback at a 24-kbps rate. Analog data has 8-bit accuracy or 1 part in 256.

The USB equipment has the capability to transmit on separate subcarriers real-time telemetry (768 kHz), playback data (597 kHz), DCS data (1.024 MHz) and pseudo-random ranging information simultaneously over the same 2,287 5 MHz carrier. The playback data can be derived from either of the NBTRs or either of the auxiliary tracks of the WBVTRs.

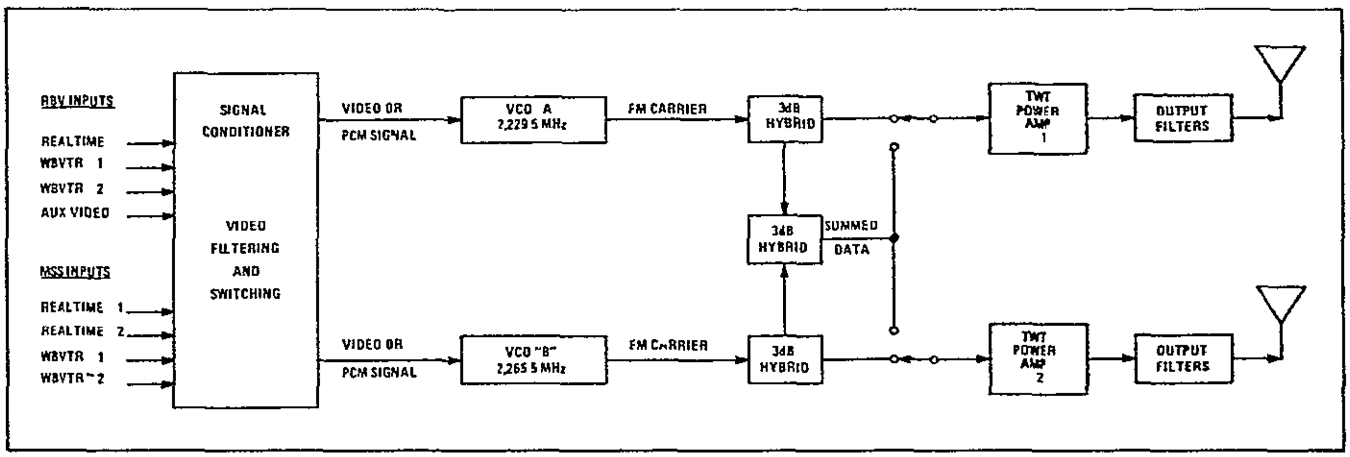


Figure A-3 Wideband Telemetry Subsystem Functional Block Diagram

A.5.2 Telemetry, Tracking and Command Subsystem

The Telemetry, Tracking and Command Subsystem collects and transmits spacecraft and sensor housekeeping data to the ground sites, provides tracking aids, receives commands from NASA's Space Tracking and Data Network (STDN), and implements those commands on board the spacecraft. In addition it provides the link for transmitting the Data Collection System (DCS) data.

Only real-time or playback data (from either of the NBTRs) can be transmitted at one time over the 137.86 MHz VHF equipment All three of the Landsat receiving sites normally use the USB downlink.

Commanding can be performed via either the VHF link at 154.20 MHz or by the USB link at 2,106.4 MHz into redundant sets of receivers on the spacecraft. These commands can be any of the 512 possible commands executable by the command/clock or any of the 8 commands recognizable by the command integrator unit. A total of 30 command/clock commands can be "stored" for execution outside of the range of the ground stations. All remote payload operations are performed using stored commands.

A.6 THERMAL CONTROL SUBSYSTEM

The Thermal Control Subsystem provides a controlled environment of 20 ± 10°C for spacecraft and sensor components Thermal control is accomplished by both semipassive (shutters and heaters) and passive (radiators, insulation, and coatings) elements Shutters are located on each of the peripheral compartments on the sensory ring, and are actuated by two-phase, fluid-filled bellows assemblies. These assemblies are clamped tightly to heat dissipating components and position the shutter blades to the proper heat-rejection level. Heaters are bonded at various locations in the sensory ring to prevent temperatures from falling below minimum levels during extended periods of low equipment-duty cycles. The heaters are energized selectively by ground command when the temperature level at these locations falls below a predetermined value. The upper and lower surfaces of the sensory ring are insulated to prevent gain or loss of heat through those areas External structure and radiating surfaces are coated to provide the required values of emissivity and absorptivity.

Passive radiators coated with a low-absorptivity, high-emissivity finish are used to assist the shutters in rejecting the heat from the sensory ring. Radiators are provided for the RBV, the MSS, the WBVTRs and the NBTRs.

A.7 ORBIT ADJUST SUBSYSTEM

The Orbit Adjust Subsystem (OAS) establishes the precise Landsat orbital parameters after orbit insertion and makes adjustments throughout the life of the mission to maintain overlapping coverage of sensor imagery and long-term repeatability.

The OAS is a monopropellant, hydrazine-fueled, propulsion system constructed as a single module consisting of three rocket engines, a propellant tank and feed system, a support structure and the necessary interconnect plumbing and electrical harnessing The OAS is mounted to the spacecraft sensory ring with a thruster located along each of the (+) roll, (-) roll, and (-) pitch axes, such that each thrust vector passes approximately through the spacecraft center of mass. With these thrust vectors, the orbit adjust subsystem can impart incremental velocities to the spacecraft to correct in-plane injection errors, inclination injection errors, and orbit perturbations due to atmospheric drag and other error sources over an orbital life of more than one year.

A.8 ELECTRICAL INTERFACE SUBSYSTEM

The Electrical Interface Subsystem functions include power switching, telemetry signal generation, switching logic, power fusing, data routing, time-code processing and automatic "shut-off" of equipment. Time-code data are received from the command/clock, assembled into storage registers and relayed to the RBV and MSS when requested. Timers associated with the payloads, WBVTR and S-Band Transmitter are provided to automatically remove power after 32 minutes of operation if the normal turn-off does not occur. Power switching (regulated and unregulated), transient load circuitry, and fusing are included in this subsystem for the RBV, MSS, WBVTRs and the OAS.

APPENDIX B
RBV SUBSYSTEM

B.1 THREE-CAMERA RBV SUBSYSTEM (Landsats 1 and 2)

The return beam vidicon (RBV) camera subsystem is used to obtain high resolution television picutres of the earth. Three cameras are used to take pictures of earth scenes simultaneously in three different spectral bands. The measured spectral response of the three cameras is shown in Figure B-1.

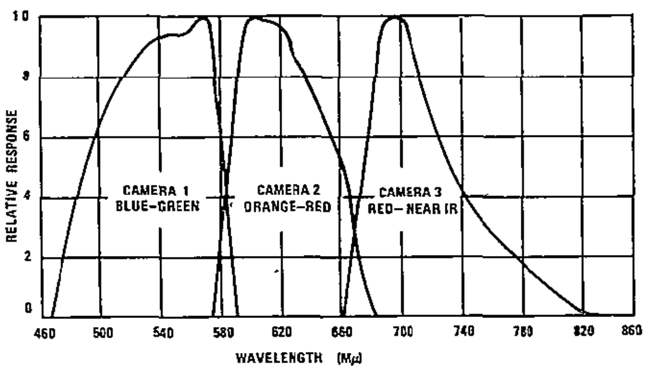


Figure B-1. Spectral Response, RBV Three-Camera System

Each camera contains an optical lens, a shutter, the RBV sensor, a thermoelectric cooler, deflection and focus coils, erase lamps and the sensor electronics. The cameras are similar except for the spectral filters contained in the lens assemblies to provide separate spectral viewing regions. The sensor electronics contain the logic circuits to program and coordinate the operation of the three cameras as a complete integrated system and provide the interface with the other spacecraft subsystems Table B-1 shows the major camera parameters and their performance requirements

B.1.1 Operation

The three RBV cameras are aligned in the spacecraft to view the same nominal 185 kilometers (100 nautical mile) square ground scene as depicted in Figure B-2. When the

Table B-1 RBV Camera Parameters

Parameter	Performance Requirements		
	Camera 1	Camera 2	Camera 3
Spectral Bandpass (nM)	475 to 575 blue-green	580 to 680 orange-red	690 to 830 red near IR
Video Bandwidth (MHz)	3 2	3.2	3 2
Peak Signal/rms Noise (dB)	33	33	31
Relative Aperture	f/2 66	f/2 66	f/2 66
Full Field Angle (deg)	16.2	16.2	16.2
Effective Focal Length (mm)	125 98 + 0.27 − 0 98	125 98 + 0 27 0 98	125 98 + 0.27 0 98
Highlight Brightness (MJ/cm²)	0 78	0 78	1 2
Shading inside 1 in circle Shading outside 1 in circle	≤15% ≤25%	≤15% ≤25%	≤15% ≤25%
Edge Resolution (% of center)	80%	80%	80%
Image Distortion	≤ 1%	≤ 1%	≤ 1%
Skew	≤±0 5%	≤±0 5%	≤±0 5%
Size and Centering	≤±2%	≤±2%	≤±2%
Read Horizontal Rate (lines/sec)	1 250	1 250	1 250
Active Horizontal Lines	4,125	4 125	4 125
Readout Frame Time (sec)	3 5 (3.3 active)	3.5 (3.3 active)	3 5 (3.3 active)
Readout Sequence	3	2	1
Three-Camera Cycle Rate (sec)	25	25	25
Exposure Time Matrix (msec)			
Expose 1	4 0	4 8	6 4
Expose 2	5 6	6 4	7 2
Expose 3	8 0	8 8	8 8
Expose 4	12 0	12 0	12 0
Expose 5	16 0	16 0	16 0

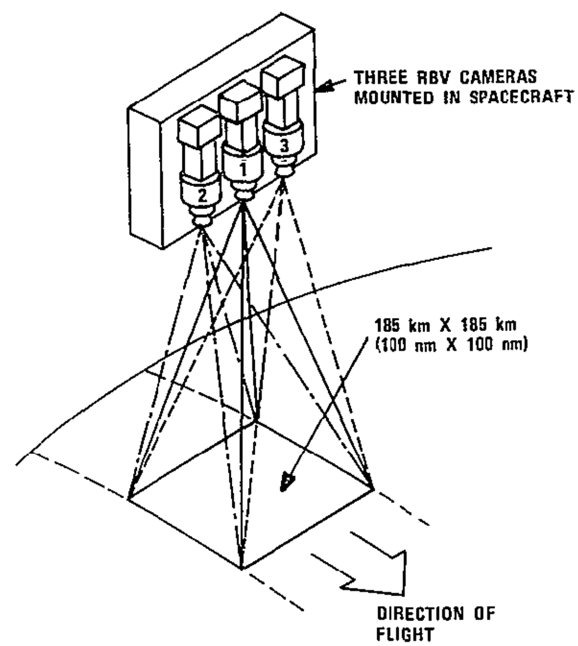


Figure B-2 RBV Scanning Pattern

cameras are shuttered, the images are stored on the RBV photosensitive surfaces, then scanned to produce video outputs. The three cameras are scanned in sequence during the last 10 5 seconds of the basic 25 second picture time cycle The video from each is serially combined with injected horizontal and vertical sync. The readout sequence is camera 3, then camera 2, then camera 1

The video data interval for each camera lasts for 3.3 seconds, lines 251 through 4375 of the composite video output. The format of the video data is presented in Figure B-3. The 720 microseconds of active video in each of the lines is replaced with 1 6 MHz sine wave when a camera is turned off and the camera controller-combiner is still operating.

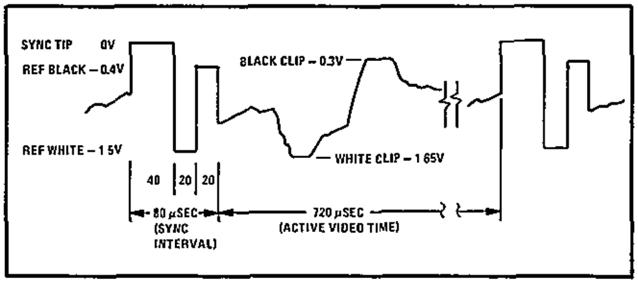


Figure B-3. Video Data Format for One Horizontal Line

Two modes of operation are possible and are selectable by ground command. Normally the continuous cycle mode is used.

1. Continuous cycle - This mode is the normal operating mode of the three-camera system. The system continues to take pictures every 25 seconds, the three cameras operating by one command, until the system is commanded off.

2. Single cycle - The camera will take one picture and then revert back to hold mode until a "start prepare" command is received. This mode allows a single 25-second picture cycle to be taken of selected areas with the enabled cameras.

In addition a calibration mode is provided and is exercised by ground command In this mode the erase lamps provide three different exposures to each camera which are nominally 0, 15 and 100 percent of the maximum specified input radiance for each camera (designated as Cal 0, 1 and 2 respectively).

B.1.1.1 Reseau Marks and Scan Orientation

A reseau pattern is inscribed on the photoconductive surface of the RBV tube. Figure B-4 shows the reseau pattern as it projects into the scene being viewed by the camera. The orientation of the pattern is indicated by using unique anchor marks in the pattern. These reseaus and anchor marks are detailed in Figure B-5. All dimensions shown in the figure are in millimeters measured on the faceplate of the RBV camera (multipliers for 70mm: 2 165; 242mm: 7.362). The arrows in Figure B-4 marked "H" and "V" (upper left hand corner) indicate the direction of the line and frame scan. The two digit numbers are assigned to identify each cross in the reseau pattern, the first digit is a row number and the second digit is a column number.

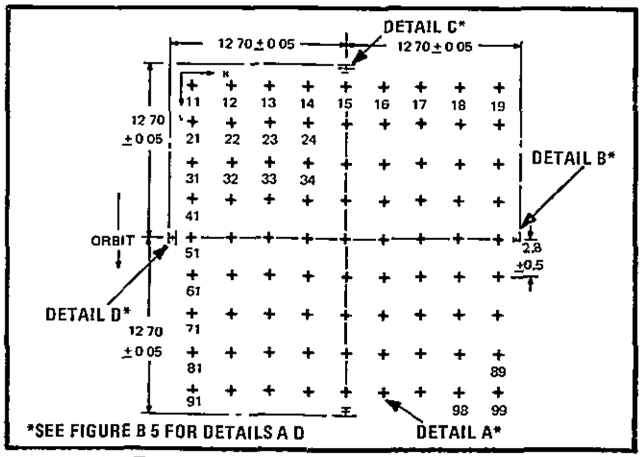


Figure B-4. Reseau Marks on Scene

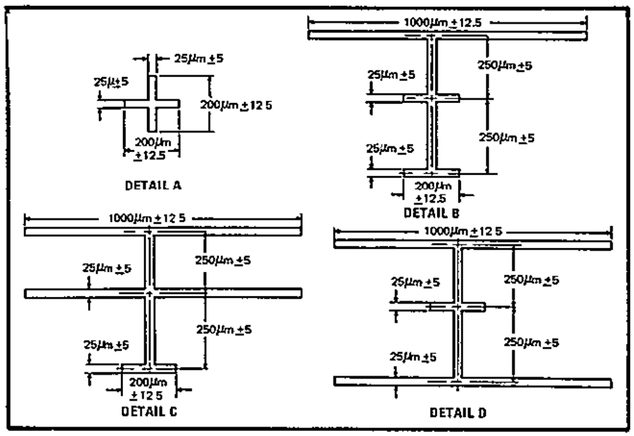


Figure B-5. Details of Reference Marks in Figure B-4

The orientation of the whole camera with respect to the projection of the reseau pattern into the scene is given by the "camera feet" indication in Figure B-6. The camera lens reverses and inverts the scene, so that the actual orientation of the reseau pattern on the vidicon in the camera is also inverted and reversed. The orbit track direction and shutter motion direction are also shown. The shutter mechanism in each RBV camera consists of two adjacent blades with offset cutouts which sweep across the vidicon aperture to provide the pre-commanded exposure time to each portion of the photoconductor. The shutter provides uniform exposure over the photoconductor within a maximum variation of ± 5 percent.

The unique anchor marks are located at the (nominal) edges of the scans. The edges will drift somewhat because of circuit tolerances (the overall size-centering tolerance is ± 2 percent), however, the starting point of the scan is somewhat tighter The reseau locations have been mapped on the vidicon faceplate with approximately 3 micrometer accuracy and are used during image generation to remove geometric distortions

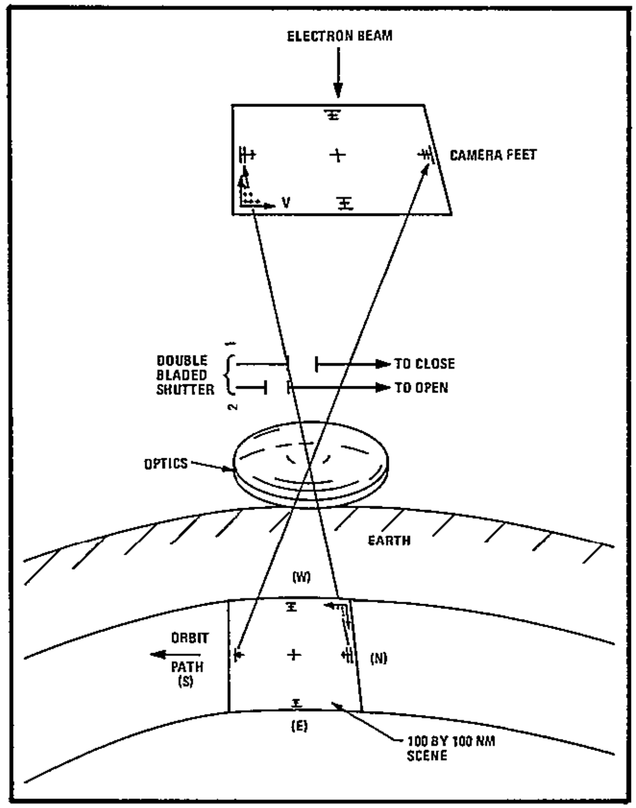


Figure B-6 Camera-Scene Orientation

B.1.2 Performance

B.1.2.1 Resolution

Measured square wave response, mathematically transformed into a sine wave response, for the RBV (lens, vidicon and amplifier) is shown in Figure B-7. An improvement in response, with a corresponding decrease in signal-to-noise ratio, is possible by utilizing the aperture compensation command. With this command each RBV camera employs a secondary amplifier system for the raw video which incorporates specific frequency response shaping networks It is important to note that this improvement applies to the cross-track direction only and cannot compensate for smear degradations occurring in the along-track direction. Annotation on each image states if aperture compensation was "in" or "out".

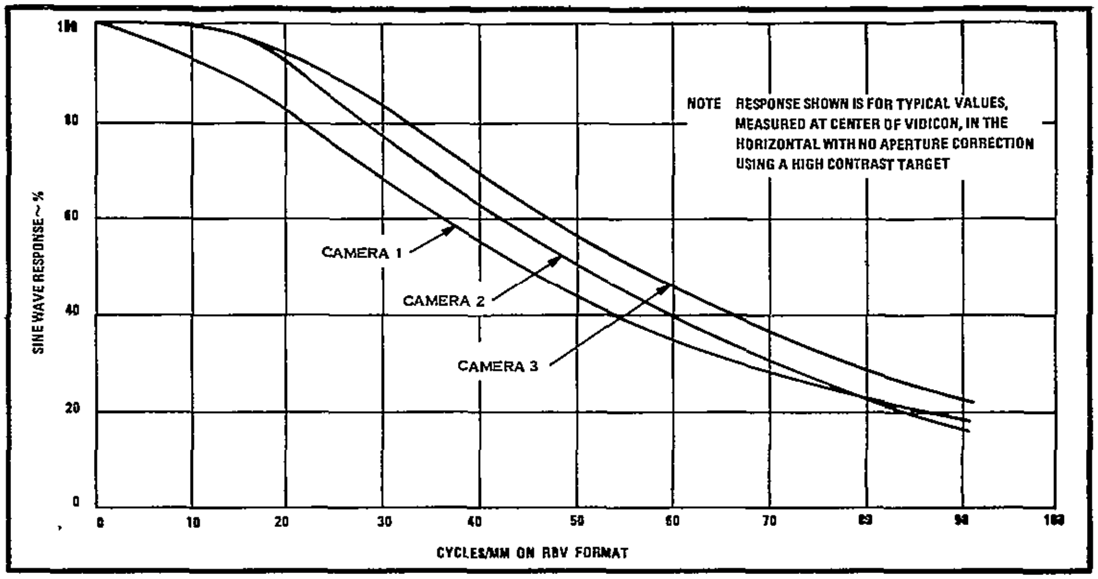


Figure B-7 Typical Sine Wave Response - RBV Camera

B.1.2.2 Geometric Fidelity

Table B-2 shows the raw internal RBV errors observed during test and includes, for reference only, the positional effect of these errors on the output image All errors are effects associated with the electromagnetic characteristics of the vidicon camera.

B.1.2.3 RBV Exposure Capabilities

The capability of the RBV cameras to recognize specific scene radiance is a function of the light transfer characteristics (LTC) and time of exposure of each camera. The LTC relates voltage output to radiance for mean levels or levels in large areas (near zero spatial frequencies). Figure B-8 is the measured LTC for the three cameras for the on-axis (center) location of the vidicon. The radiance is the equivalent spectrally-flat radiance in front of the lens within the bandpass of each camera.

The equivalent spectrally flat radiance is obtained by integrating the scene radiance and camera spectral responses.

$$N = \frac{\int R(\lambda)\, N_S(\lambda)}{\int R(\lambda)}$$

where

$R(\lambda)$ = Camera spectral response
$N_S(\lambda)$ = Scene spectral radiance

The camera spectral response is shown in Figure B-1.

The exposures for the various spectral bands corresponding to one Volt video output (white reference, defined as saturation exposure) are:

Band	μjoules/cm^2
1	0.552
2	0 598
3	0.985

The maximum mean radiance of a scene at the vidicon faceplate is related to the saturation exposures and exposure time by.

$$N = \frac{4T^2 Ex}{\pi t} \text{ (watts/cm}^2\text{ - ster)}$$

where

N = Mean radiance of scene at vidicon faceplate
T = Effective f number of lens
t = Exposure time
Ex = Saturation exposure

Based on this equation, Table B-3 delineates the exposure time settings along with the value of scene radiance at saturation of the vidicon.

Table B-2 RBV Internal Errors

ITEM	NAME OF ERROR	ILLUSTRATION OF ERROR TYPE	OBSERVED VALUE	IMAGE POSITIONAL EFFECT (m) 1σ
1	MAGNETIC LENS DISTORTION		1% OF MAXIMUM	432
2	S CURVE		0.200 MM AT CORNERS	418
3	SCALE		< ±1%	< 432
4	CENTERING		<0 75% EACH AXIS	< 982
5	NONLINEARITY		±1% MAXIMUM EACH AXIS	518
6	SKEW		< 0 26 DEGREE	< 210
7	RASTER ROTATION		< 0 1 DEGREE	< 75
8	OPTICAL DISTORTION		17 µm	125

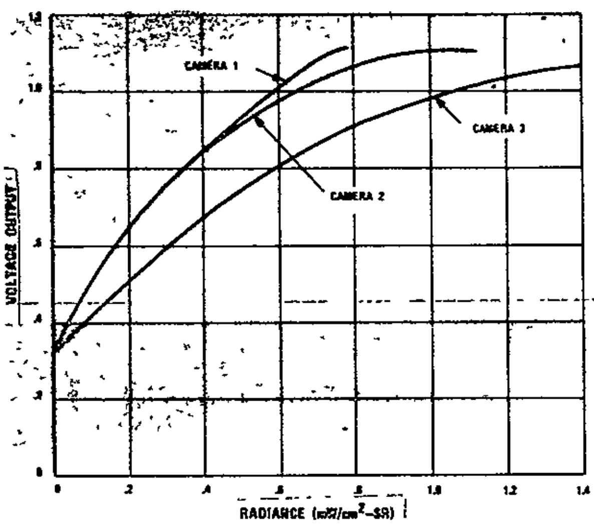


Figure B-8. RBV Light Transfer Characteristics

Table B-3 Scene Radiance at Saturation for Various Exposure Times

Exposure Set	Band 1		Band 2		Band 3	
	t	N_{SAT}	t	N_{SAT}	t	N_{SAT}
	(ms	(mw/cm^2-sr)	(ms)	(mw/cm^2-sr)	(ms)	(mw/cm^2-cr)
A	4	1 80	4 8	1 62	6 4	2 01
B	5 6	1 29	6 4	1 22	7 2	1 78
C	8	0 90	8 8	0 89	8 8	1 46
D	12	0 60	12	0 65	12	1 07
E	16	0 45	16	0 49	16	0 80

Table B-4 shows calculated values of scene radiance at sensor input for various solar zenith angles and typical Landsat scenery.

Table B-4. Total Scene Radiance (N) mW/cm^2-sr

Typical Scene	Band 1 (Zenith Angle)				Band 2 (Zenith Angle)				Band 3 (Zenith Angle)			
	0	30	45	60	0	30	45	60	0	30	45	60
Specular	4.21	3.83	3.01	2.21	3.39	3.38	2.79	2.02	3.04	2.63	2.16	1.54
Fresh Snow		2.91	2.32	1.61		2.56	2.12	1.54		1.85	1.52	1.09
Icy Snow		2.82	2.43	1 78		2.69	2.22	1.62		2.07	1 70	1.22
Clay		2.23	2 16	1.67		2.37	1.97	1.44		1.91	1.58	1 13
Sand		1.02	0.88	1.08		1.07	0.90	0.68		1 16	0.96	0.69
+1σ Plants		0 70	0.82	0.99		0.53	0.46	0.37		1.04	0.86	0.62
-1σ Plants		0.47	0 43	0.64		0.31	0.28	0.25		0.57	0.48	0.29
H_2O		0.60	0.54	0 46		0.33	0.3	0.26		0.25	0.22	0 17
Overcast	2.37	2.81	2.35	1.74	3.42	2.94	2.43	1 76	2.76	2.38	1.96	1.40

NOTE Typical values, not to be taken as absolute.

These values were calculated with a solar constant of 0.1322 W/cm^2, two atmosphere traverse and an atmospheric transmission of 0.8. These data are shown only as representative examples and should not be interpreted as precision values.

B.1.2.4 Radiometric Fidelity

Figure B-9 illustrates the RBV camera subsystem and graphically shows the effects of radiometric errors as an input is processed

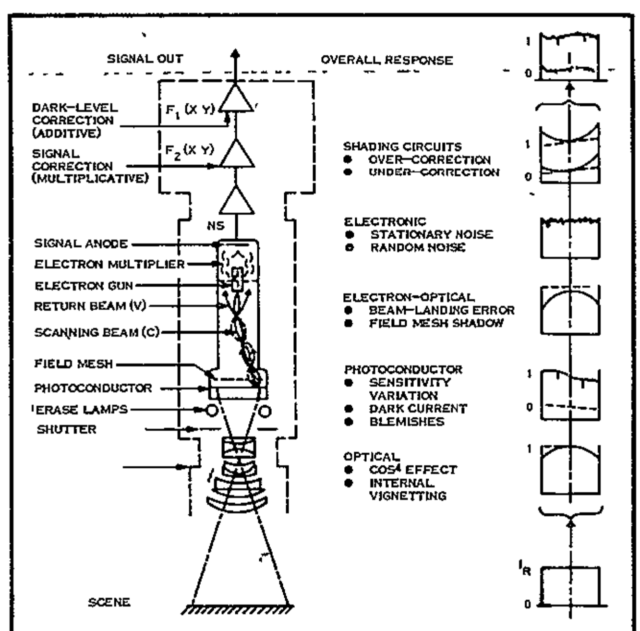


Figure B-9 RBV Camera Subsystem and Radiometric Error Sources through the camera subsystem. The relationship of camera voltage output to exposure varies for different spatial locations on the face of the vidicon, a phenomena called shading Shading also varies with signal level. The definition of black and white level shading is given in Figure B-10. As described in Appendix H shading is largely removed by corrections applied as images are generated on film in the IPF.

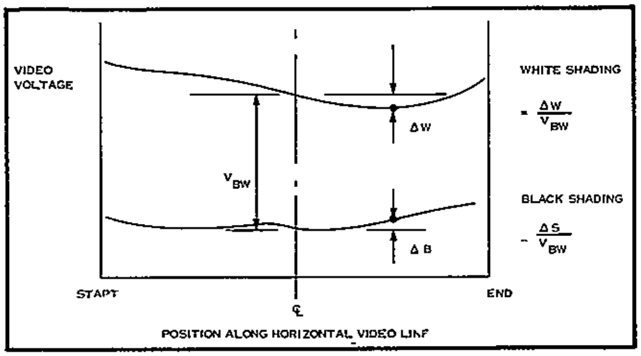


Figure B-10 Shading Definitions

B.2 TWO-CAMERA RBV SUBSYSTEM (LANDSAT-C)

On Landsat-C, ground scene information will be viewed through two RBV camera sensors as they are sequentially exposed. The ground scene radiance is integrated on the photosensitive surface of the vidicon during the exposure period. During the readout period, which immediately follows the exposure, the photosensitive surface is scanned and the scene radiance is converted into a video signal.

Each RBV camera sensor is being designed to cover a 98-kilometer (53 nm) square area. (Landsat 1 and 2 cover a 185 kilometer (100 nm) square per frame as described previously) This change is being made to provide increased ground resolution for area ground mapping. To increase the ground resolution, a focal length of 10 inches, twice that of Landsat 1 and 2, is required. The two RBV cameras will be used to provide side-by-side pictures, each approximately 98 km (53 nm) on a side, covering a total swath width of approximately 183 km (99 nm). This is depicted in Figure B-11.

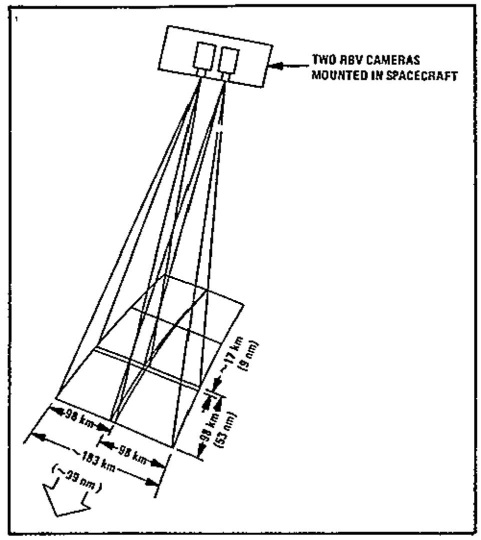


Figure B-11. Landsat-C RBV Scanning Pattern

Each camera can be operated independently of the other for either single frame or continuous coverage. The two cameras will each have the same broad-band spectral response (yellow into the near IR) of 505 to 750 nanometers. Table B-5 lists those parameters of primary importance to users. The major parameter changes from Landsat 1 and 2 are the spectral band, timing, camera focal length and improved shading corrections.

Table B-5 Landsat-C RBV Camera Parameters

Parameter	Performance Objective
Spectral Bandpass	505 to 750 nanometers*
Video Bandwidth	3 2 MHz
Peak Signal/rms Noise	33 dB
Lens, Effective Focal Length	236mm (nominal)*
Highlight Irradiance	2.013mW/cm^2-Sr*
Shading	≤15% within 1 in. circle ≤25% elsewhere
Image Distortion	≤1%
Skew	≤+ 0 5
Size and Centering	≤+ 2%
Read Horizontal Rate	1,250 lines/sec
Active Horizontal Lines	4,125 per frame
Readout Frame Time	3 5 sec (3 3 active)
Two-Camera Cycle Rate	12.5 sec*

*Denotes change from Landsat 1 and 2

APPENDIX C

MULTISPECTRAL SCANNER SUBSYSTEM

C.1 INTRODUCTION

The multispectral scanner subsystem (MSS) is a sensor system that produces a continuous strip image of the earth in various spectral bands. The Landsat 1 and 2 MSS responds to earth reflected sunlight in four spectral bands; the Landsat-C MSS will carry an additional band responding to thermal infrared radiation. The MSS continually scans the earth in a 185.2 km (100 nm) swath perpendicular to the Landsat orbital track. Scanning is accomplished in the crosstrack direction by an oscillating mirror, satellite motion along the orbit provides the along-track scan.

The analog signals produced by the MSS detectors are digitized and formatted into a 15 megabit data stream for transmission to an earth receiving station or for on-board recording. During subsequent signal processing by the NASA Image Processing Facility (IPF), the MSS data are transformed into framed imagery with a 10% overlap between frames and an area coverage approximately registered with that produced by the return beam vidicon (RBV) framing cameras. Conversion of continuous strip MSS data to corresponding framed imagery is accomplished by utilizing the known instant of RBV exposure and satellite position as provided by spacecraft clock signals and tracking station position data.

C.2 SPECTRAL RESPONSE

MSS spectral response for Landsat 1 and 2 and Landsat-C are shown in Table C-1. Note that bands 1, 2 and 3 designate the RBV subsystem spectral response bands. Landsat-C nomenclature may require alteration due to a contemplated reduction in the number of RBV cameras from three to two.

Table C-1. Spectral Response for Landsat MSS Bands

Band	Spectral Response (Micrometers)
4	0.5 - 0.6
5	0.6 - 0.7
6	0.7 - 0.8
7	0.8 - 1.1
8	10.4 - 12.6 (Landsat-C only)

Each MSS spectral band in Landsat 1 and 2 utilizes six detectors. Photomultipliers are used in bands 4, 5 and 6. Band 7 uses silicon photodiodes to achieve extended infrared response. Band 8 will employ two mercury-cadmium-telluride detectors.

With the exception of the band 8 detectors, all other detectors are coupled to the focal plane of the MSS optical system by means of square optical light pipes. The six light pipes corresponding to a given spectral band conduct the radiance at the focal plane to identical optical bandpass filters immediately preceding each detector. It is essential to understand that data in the various spectral bands are acquired sequentially (within 65 microseconds for Landsat 1 and 2) and not instantaneously. For Landsat-C, sequential acquisition of all 5 bands occurs in 800 microseconds

C.3 SCANNING GEOMETRY

The MSS scanning geometry is illustrated in Figures C-1 and C-2.

The nominal instantaneous field of view (IFOV) of each detector in bands 4, 5, 6, and 7 is 79 meters square as determined by the focal length of the telescope, the nominal altitude of the spacecraft and the dimensions of the light pipes at the focal plane. The IFOV of each band 8 detector is 237 meters square at nominal altitude. As the mirror scans the earth from west to east, the resulting image is seen by each bank of detectors in turn. As a result, six scan lines of video information are produced in bands 4, 5, 6 and 7 and two in band 8. The nominal mirror frequency is 13.62 Hz corresponding to a period of 73.42 milliseconds. The mirror scan and retrace periods are each 36.71 milliseconds. The time during which the earth scene is acquired in the west to east scans is 33.0 milliseconds. This avoids acquiring data during nonlinear motion intervals when mirror velocity is reversed.

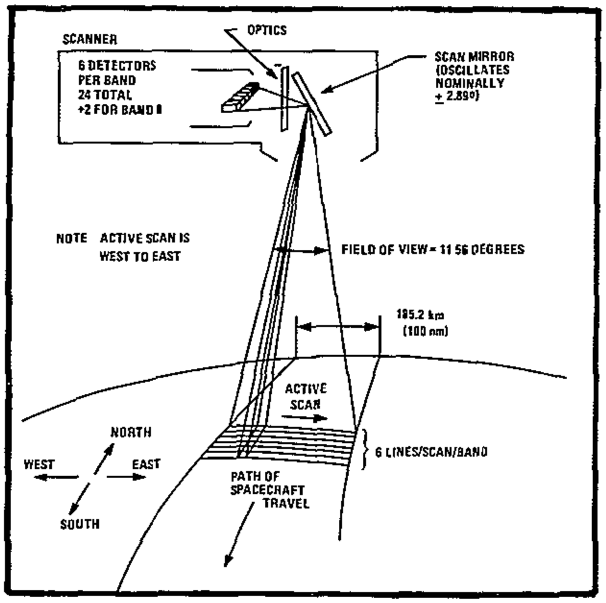


Figure C-1. MSS Scanning Arrangement

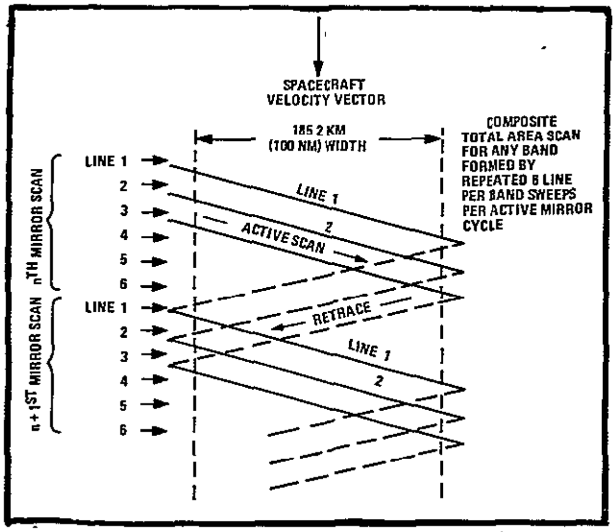


Figure C-2. Ground Scan Pattern for a Single MSS Detector

As the mirror scans west to east, the six scan lines of bands 4 through 7 and the two lines of band 8 correspond to an along-track swath distance of 474 meters (6 x 79 or 2 x 237). For the next swath to be contiguous to the preceding swath, the spacecraft must move in the along-track direction by 474 meters in one mirror period. Satellite nadir point velocity must then be 6.456 km/sec (474 ÷ 0.07342) or 3.484 nm/sec. Telescope focal length, spacecraft altitude, light pipe dimensions, spacecraft velocity and mirror period were chosen to achieve the cross-track contiguous coverage described above. The catadioptric telescopes employed in Landsat 1 and 2 have focal lengths of 82.09 cm (32.32 inches) and 82.3 cm (32.4 inches) respectively.

During every mirror retrace period, the radiance from the earth scene is blanked out by a mechanical shutter. The individual sensors in bands 4 through 7 are exposed every other mirror retrace to a rotating variable density wedge optical filter illuminated by on-board calibration lamps. Band 8 detectors are exposed to temperature references during alternate mirror retraces when bands 4 through 7 are not being calibrated. The resulting calibration data are subsequently utilized to perform radiometric corrections to the MSS detector signals.

C.4 LIGHT PIPE ARRAY AND DETECTOR SAMPLING

The MSS electronic subsystem is designed to sequentially sample the individual MSS detectors to produce a serial digital data stream.

Figure C-3 illustrates the physical arrangement of the square light pipes placed in the focal plane of the MSS telescope. Each light pipe conducts radiance at the focal plane to an individual detector. S1 . . . . S24 denotes the order in which the resulting detector signals are sampled. Detectors A, B, . . ., F designate detectors within a given spectral

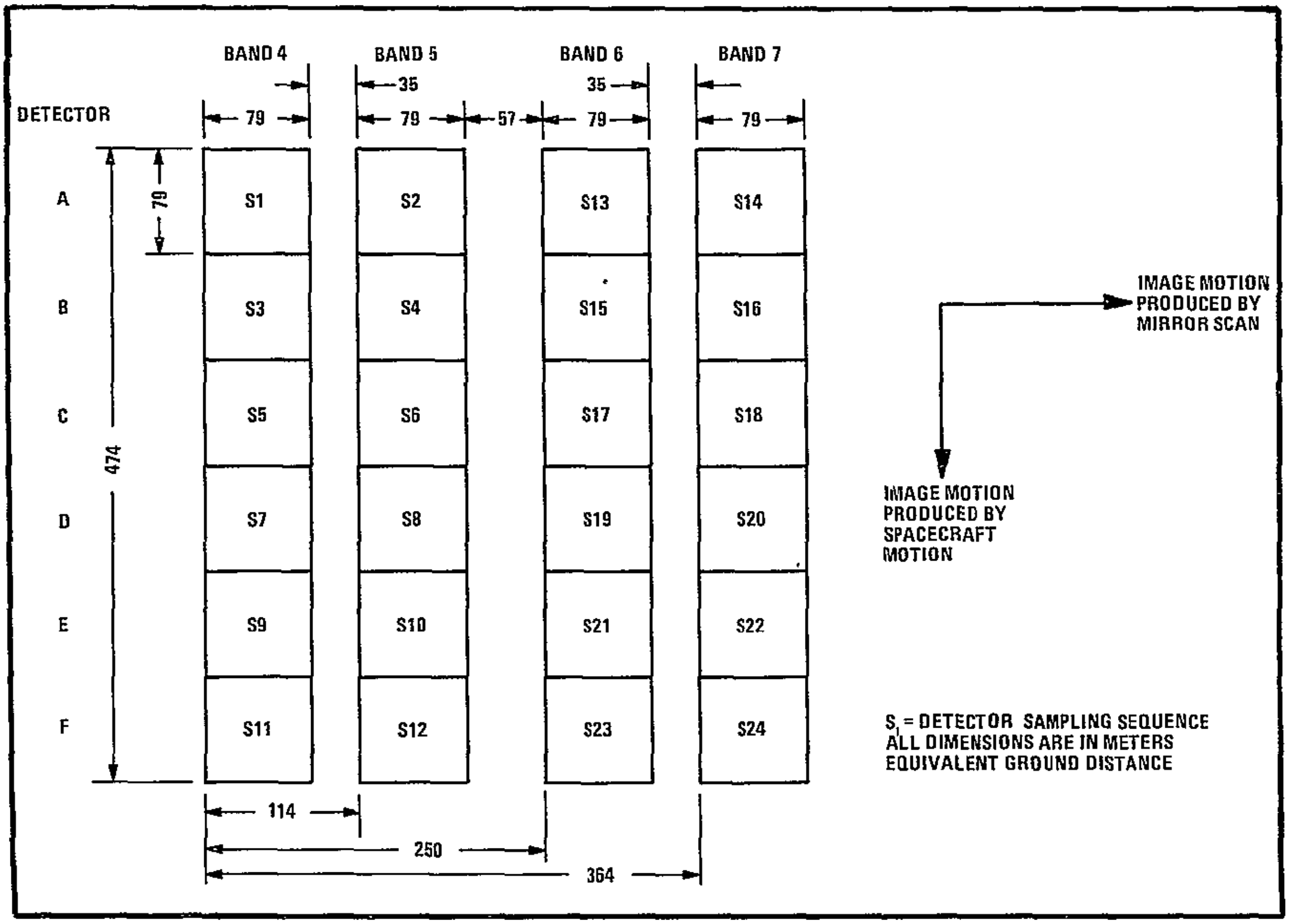


Figure C-3. Landsat 1 and 2 Light Pipe Array and Detector Sampling Sequence

band. Band 8 detectors are labeled A and B. Band 8 detectors are coupled to the telescope focal plane via germanium relay optics, the entrance pupil of which is also shown in Figure C-4. The light pipe array dimensions, physical arrangement and sampling process are directly related to mirror velocity and spacecraft motion. An understanding of this relationship is essential to the calculation of effective field of view as well as in understanding computer compatible tape (CCT) production.

The MSS mirror is driven at a frequency of 13.62 Hz derived by counting down the frequency of a crystal-controlled clock using a count-down factor of $135 \times 2^{13} = 1{,}105{,}920$. Thus the 13.62 Hz is derived from a frequency of 15.0626 MHz. This frequency is significant in that it represents the maximum bit rate that can be accommodated during detector sampling. Time per bit is 0.0664 microsecond. Each detector represents a channel of data and 25 such channels exist on the Landsat spacecraft (24 detectors plus one channel for multiplexed thermal band data). Each detector analog output is encoded as a six bit digital word, each word corresponding to one picture element (pixel). The word period is then 0.3983 microsecond (6 x 0.0664) which is the sampling time per detector. Because there are 25 channels, each detector (with the exception of band 8) is sampled once in every 9.958 microseconds.

Consider a ground scene composed of a single 79 x 79 meter object, imaged on Detector A, band 4 at a time t = 0. The active scan time during which video is acquired is 33 milliseconds. In the west to east active scan period, two auxiliary sensors determine the mirror angular position and initiate and terminate detector sampling. The two sensors insure that the cross-track optical scan is

185.2 km regardless of mirror scan non-linearity or other perturbations of mirror velocity. Cross-track image velocity is nominally 5.612 meters per microsecond. After 9.958 microseconds, the 79 x 79 meter image has moved 55.99 meters. The S1 sample taken at this instant represents 23 meters of previous information and 56 meters of new information. Therefore, in practice the "effective" IFOV of a detector in the cross-track direction must be considered to be 56 meters corresponding to a nominal pixel area of 56 x 79 meters (at nadir point). Use of the "effective" IFOV in area calculation therefore eliminates the overlap in area between adjacent samples (pixels).

Upon the completion of two complete sampling intervals, an elapsed time of 19.916 microseconds, plus one sequential sample time of 0.3983 microsecond, detector A of band 5 is sampled. In 20.314 microseconds the image of the ground has moved 114 meters. If the condition is imposed that the 79 x 79 ground object coincides with detector A, band 5, then bands 4 and 5 light pipes must be spaced by 35 meters equivalent ground distance. By imposing this same constraint for detector A in band 6 and band 7, Table C-2 can be derived.

Table C-2. Numerical Values for Light Pipe Array and Detector Sampling Sequence

No of Complete Sampling Sequences	No of Completed Samples in Next Sequence	Elapsed Time in Microseconds	Cross Track Image Motion in Meters	Image Position Det. X Band n
0	0	0	0	Det. A Band 4
2	1	20.314	114	Det. A Band 5
4	12	44.612	250	Det. A Band 6
6	13	64 926	364	Det. A Band 7

Average Image Velocity = 5612 m/μs

The numerical values in Table C-2 explain the array spacing in Figure C-3. In addition, note that band 4 data precedes band 7 data by 64.926 microseconds. Also, band 5 precedes band 7 data by 44.612 microseconds and band 6 precedes band 7 by 20.314 microseconds. This spatial misregistration is corrected by inserting the appropriate number of dummy bytes prior to the data in bands 4, 5 and 6 during CCT production. In using the term "byte", it is important to distinguish between "spacecraft" bytes and in-band bytes. For example, in band 4, detector A is sampled once every 9.958 microseconds so that one in-band byte of information is created in this time period. The number of bytes generated in all bands in this period is 25. The number of in-band bytes required to achieve spatial registration is illustrated in Figure C-4. Bands 4, 5, 6 and 7 are offset from each other by two in-band bytes.

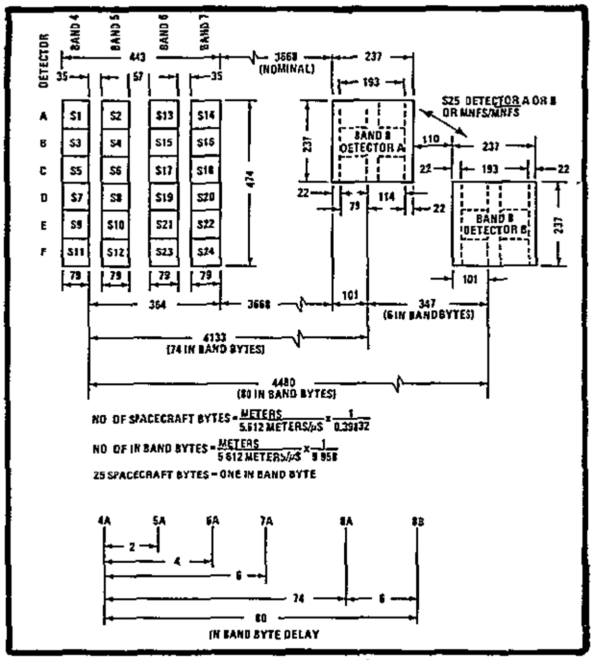


Figure C-4. Landsat-C Light Pipe Array Configuration

Within a spectral band there is also a time delay between the outputs of detector A and F of 3.98 microseconds or 22.3 meters (for a non-rotating earth) which is compensated for during the production of film imagery

The addition of band 8 on Landsat-C will be accomplished as follows. The 25th channel in Landsat 1 and 2 carries a signal known as minor frame synchronization (MNFS) and its digital complement ($\overline{MNFS}$). These digital codes are used during ground data demultiplexing to tag the beginning of the spacecraft sampling sequence and thereby keep track of the identification of each data byte. Detectors A and B of band 8 are alternately sampled and multiplexed into the 25th channel. Landsat-C spacecraft sampling sequence can be represented as follows:

25th Channel	Data Channels 1-24
MNFS	**1, 2, 3. . . . . .24**
Detector A, Band 8	**1, 2, 3. . . . . .24**
Detector B, Band 8	**1, 2, 3. . . . . .24**
$\overline{MNFS}$	**1, 2, 3. . . . . .24**
Detector A, Band 8	**1, 2, 3. . . . . .24**
Detector B, Band 8	**1, 2, 3. . . . . .24**

Each sequence (for example, MNFS, 1 . . . 24) represents 25 samples (spacecraft bytes) in a period of 9.958 microseconds. Note that detector A of band 8, is interrogated every 75th sample. Similarly, detector B of band 8 is interrogated every 75th sample. Bands 4 through 7 theoretically contain 3,314 samples/detector. That is, there are 3,314 periods of 9.958 microseconds duration in the 33 millisecond acquisition time (active portion of the mirror scan period). Band 8, detectors A and B, due to the reduced sampling rate, produce a maximum of 1,104 samples each within the 33 millisecond active mirror scan.

In some instances users will desire approximate registration of band 8 data with data from bands 4 through 7. The user can achieve the desired registration by the appropriate insertion of dummy bytes in bands 4 through 7 as follows. At t = 0, assume a 79 x 79 meter ground patch is coincident with the IFOV of detector A in band 4. From Figure C-4 it can be seen that the image of the ground patch must move 4,133 meters to be imaged in detector A of band 8. At a mirror velocity of 5.612 meters/microsecond, the image will have moved this distance in 736 microseconds. This corresponds to 74 in-band bytes. Similarly, band 4 detector D data precedes band 8 detector B data by 798 microsecond or 80 in-band bytes. An illustration of the in-band byte delays between all of the Landsat-C spectral bands is shown in Figure C-4. The precise number of dummy in-band bytes to achieve spatial registration must be determined experimentally because the exact separation between the entrance apertures of band 8 detectors A and B with respect to bands 4 through 7 light pipes is a nominal value ± 15%.

C.5 ANALOG SENSOR SIGNAL PROCESSING

The analog sensor samples are to be eventually digitized into a single 15.063 Mbps data stream; however, analog processing, including amplification, track and hold (boxcarring) and dc restoration are performed before A/D conversion. In addition, provision is made for linear amplification or non-linear amplification, which is selectable by ground issued spacecraft commands.

Signal compression, via four-segment quasi-logarithmic amplifiers, is generally employed to improve the signal-to-noise ratio in bands 4, 5 and 6. By compressing high radiance level signals, the quantization noise more nearly matches photomultiplier noise. Band 7 signals, derived from silicon photodiodes are never compressed because equivalent load resistor noise is best matched by linear quantization. The available ground commandable analog processing options are illustrated in Figure C-5. In the high gain mode applied to bands 4 and 5, amplifier gain is increased by a factor of 4. This allows greater use of system dynamic range for those scenes producing low sensor irradiance.

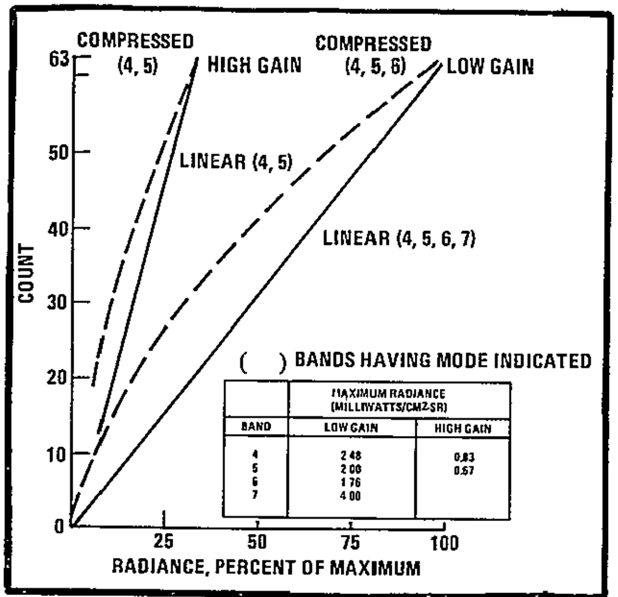


Figure C-5. MSS Output Count Vs. Radiance, Compressed and Linear Modes

There are two signal compression amplifiers in the spacecraft. One is used to process sensor data from bands 4 and 6 and the second is used exclusively for band 5 data. In subsequent processing, decompression of the signals is performed using separate decompression tables for bands 4 and 6 and for band 5. Calibration wedge signals from each band are decompressed through the same tables prior to data calibration.

Band 8 signals will be linearly amplified with eight commandable gain settings ranging from a minimum gain of 2.5 to a maximum of 10.05. Intermediate gains are related by a factor of 1.22. Predicted band 8 characteristics are shown in Table C-3.

Table C-3. Predicted MSS Band 8 Characteristics

Spectral band	10 4 to 12 6 micrometers
Dynamic range (scene apparent temp)	260^0 to 340^0K
Instantaneous field of view	237 x 237 meters (nominal)
Number of sensors	2
Information bandwidth	14 1 kHz
Effective aperture	308 cm^2
Lines/mirror scan	2
Swath width	100 nm
Detector material	Hg Cd Te
NE$\Delta\rho$ (noise equivalent radiance)	2.5 x 10^{-10} watts
Responsivity	3100V/watt (nom)
Detector operation temp	110^0K
NEΔT (noise equivalent temperature)	1.4^0K for 300 k scene
MTF min. (minimum modulation transfer function)	0.29 for 237 m bars
In flight calibration	a) Ambient black body b) Reflected detector
Cooling	Passive radiation

C.6 FORMATION OF THE SERIAL DIGITAL DATA STREAM

After analog processing of sensor data, all data are then encoded into six-bit (one byte) digital words representing sensor signal amplitudes in terms of 64 discrete steps, 0-1-2- . . . -63. Six-bit encoding is used regardless of whether the data was linearly processed or compressed. Additional data must be multiplexed into the digital data in order to allow proper identification and recovery of sensor data during ground processing. As an example, the start and end of each active mirror scan time must be indicated. A preamble is added to maintain mirror scan-to-mirror scan bit synchronization. A line length code is added that represents the number of pixels encoded from each detector during the mirror active scan time.

A vital addition to the sensor data is spacecraft time code. This is essential to identify when and thereby where the data were acquired. Time code is basic to framing MSS data to coincide with RBV image center points. In addition, scene identification, which is applied to all Landsat photographic and tape products, is derived from spacecraft time code (Greenwich Mean Time).

A typical data sequence may be described as follows. preamble maintains bit synchronization from scan to scan. As the mirror angular position arrives at the western edge of the area to be imaged, a line start code is produced. This code interrupts the detector sampling sequence and causes detector A, band 4 to be sampled. A minor frame synchronizing digital word, MNFS, is also produced (on Channel 25) and, each time it or its complement is generated, indicates that a new sequence of detector video, starting with detector A, band 4 is being produced. In this manner, data is tagged throughout each line scan.

At line start, and generation of the first MNFS, video is preempted to permit insertion of two bytes of spacecraft time code. The complete time code consists of a four-byte identifier followed by 44 bytes of time code data. The first mirror scan contains the four identifier bytes followed by 20 bytes of time code. The 24 bytes are distributed, one byte per sensor channel. The next line start (mirror scan) contains the remaining 24 bytes of time code. Therefore, the complete time code can be recovered from two consecutive mirror sweeps.

After time code insertion, detector video, MNFS and its complement $\overline{MNFS}$, are transmitted until an end of scan code is produced by a position sensor, which detects that the angular position of the scan mirror has reached the eastern edge of the imaged area. At this time, an end of line code is transmitted. A line length code (LLC) is then computed for each sensor channel. This code provides information on the number of bytes generated by each detector during active scan time. During ground processing, byte variations between sensors can be eliminated to equalize the line length through the introduction of dummy bytes of synthetic video.

After the LLC is completed, on every mirror retrace, calibration data is transmitted in digital form. Bands 4 through 7 calibration occurs on one mirror retrace whereas the next retrace contains band 8 calibration data. Precisely 6060 word periods after line start code, the preamble code preempts all data and the process repeats.

The 25 channels with all necessary codes are multiplexed into a 15 megabit/second digital stream and transmitted either to ground or stored in an on-board magnetic tape recorder for transmission at a time when the spacecraft is within range of a ground receiving station.

At the receiving station, the data is demultiplexed into 25 data channels and recorded on 25 channels of a 28 channel magnetic tape recorder (Ampex FR1928). Figure C-6 illustrates a typical channel of data as recorded at the receiving site.

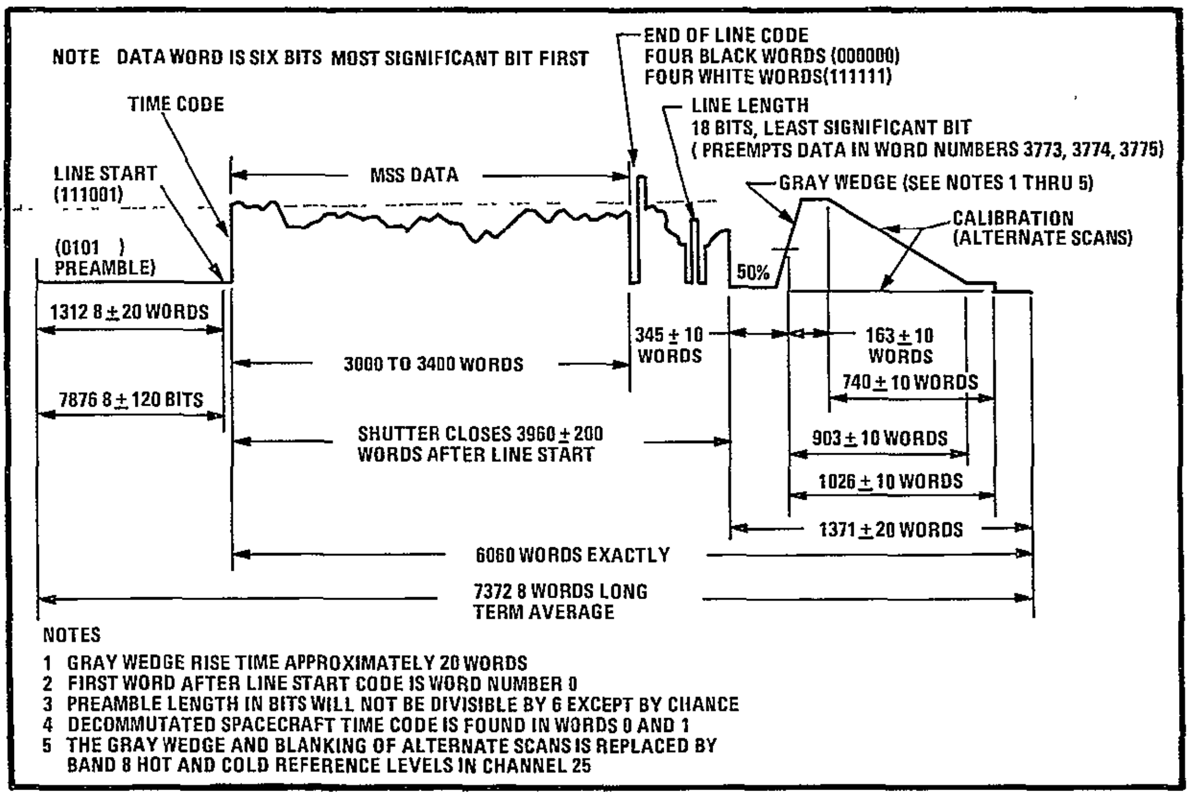


Figure C-6. MSS Tape Data Format From FR1928 (One Track - Typical)

APPENDIX D
MSS COMPUTER COMPATIBLE TAPE

D.1 INTRODUCTION

MSS data are acquired at a real-time rate of approximately 600 kilobits/second per channel on an Ampex FR1928 multi-track recorder. Conventional computer systems and peripherals operate in the range of 0.25 to 1 megabit/second. Computer compatible tape (CCT) products must therefore be recorded at substantially lower bit rates. This is accomplished by means of an off-line process in order to maintain the IPF information handling capacity at the 600 kilobits/channel rate for the generation of photographic film products.

As a first step in the off-line process, the MSS data are reproduced at the 600 kilobit/channel rate, reformatted and recorded on a high density digital tape recorder (HDTR). The resulting high density digital tape (HDT) is then reproduced at a substantially lower tape speed to achieve the necessary bit-rate reduction for CCT generation. This HDT is the principal data input to the IPF Digital Subsystem that generates CCT products of selected MSS scenes for the user community

In the original IPF configuration, MSS video tapes were reformatted and recorded on a Newell HDTR. This recorder and associated data reformatting equipment have been superseded by Ampex FR2014, 14-track recorders and new formatting and interface electronics that produce the exact equivalent of the Newell HDT. A block diagram of the previous and present configuration is illustrated in Figure D-1.

The Newell HDT format consists of four data tracks that are simultaneously accessible In all, 16 tracks are available, four at a time Each track, in a group of four, represents one spectral band of MSS data (for Landsat 1 and 2). Scan lines are in a sequential (series) format on each track. For Landsat-C, quarter scan lines of band 8 are interleaved after every three full scan lines in each track The serial scan line format permits simultaneous

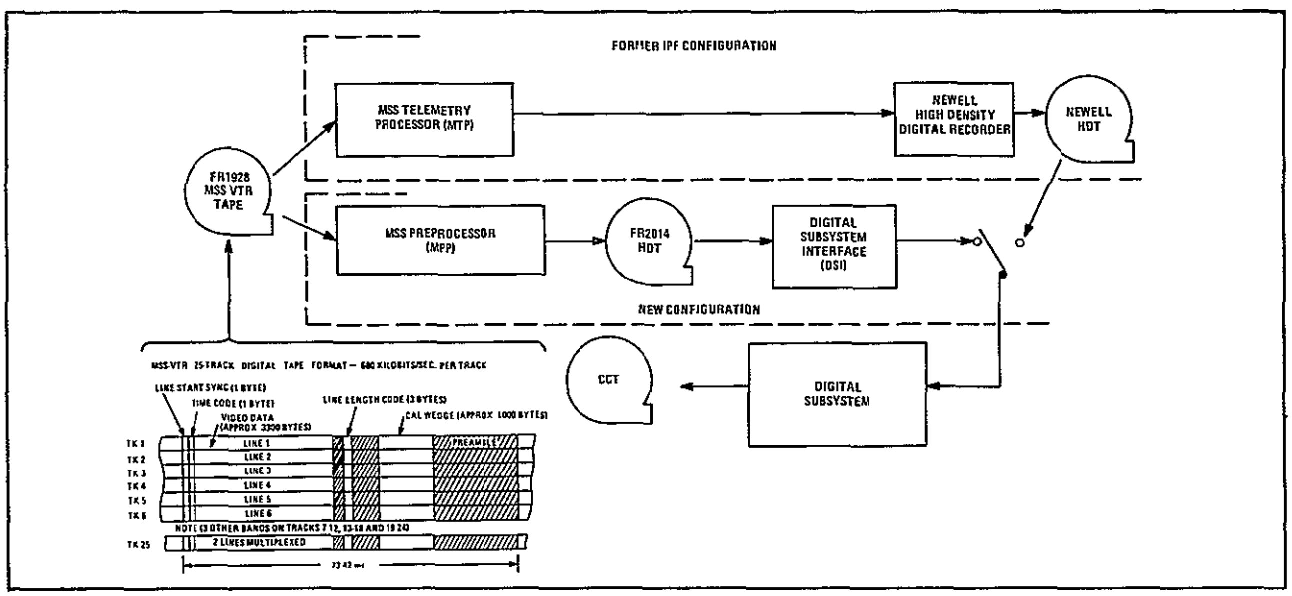


Figure D-1 Previous and Current Equipment Used to Produce Computer Compatible Tape Products access to picture elements in each of the four spectral bands as required to implement the spectral interleaving format of CCTs.

The Newell HDT format differs from the FR1928 format in a number of additional aspects. During the reformatting process, spacecraft time code is removed. In place of time code, a frame identification (Frame ID) is inserted at the beginning of each frame of data to uniquely identify the center point of the image and the time of imaging. Time code per se is no longer of interest because the "framing" of the MSS continuous strip image is performed in response to a specific user request. Each group of scan lines is also preceded by the appropriate six words of calibration coefficients and line length corrections prior to processing of the scan line data All pixels remain encoded as six-bit bytes (whether acquired in compressed, linear, high or low gain modes). Decompression (if required), calibration and line length correction remain to be accomplished within the Digital Subsystem. As recorded, the HDT MSS data also retain the data as acquired with spatial misregistration.

The Digital Preprocessor Subsystem (DPPS), FR2014 recorders and Digital Subsystem Interface (DSI) produce an output to the Digital Subsystem identical to that produced by the Newell HDT; however, the DPPS permits extensive quality control and data screening not possible in the earlier subsystem For example, detection of substandard scan line data automatically results in substitution of the previous scan line "Quick-look" assessment of digital imagery is also provided by means of a cathode-ray tube display and storage tube for image retention. Although the DPPS removes spatial misregistration and retains time code for high speed tape search, the output signals from the DSI are again spatially deregistered and stripped of time code to match the Newell format.

D.2 NEWELL HDT FORMAT STRUCTURE

To assist in understanding the production of CCTs, the Newell HDT format, now simulated by the FR2014 recorder and DSI as seen by the Digital Subsystem, is described.

An MSS scene is defined as an area of 185.2 x 185.2 km (100 x 100 nm) represented by four spectral bands of video data for Landsat 1 and 2 and by five bands of data for Landsat-C In digital terminology, spectral band and frame have become synonymous. The Newell HDT, or its equivalent, generally contains up to five scenes. Each spectral band or frame of the scene is made up of 390 successive spacecraft mirror sweeps. Each mirror sweep results in six scan lines of video per spectral band (Landsat 1 and 2) Therefore, each band or frame contains 2340 scan lines (390 x 6) For Landsat-C, bands 4, 5, 6 and 7 each contain 2340 scan lines. Band 8, using two detectors, is represented by two scan lines per mirror scan. Therefore, 780 scan lines of band 8 represent a 185.2 x 185.2 km area.

Previously, the spacecraft scan mirror frequency was stated to be 13.620 Hz/second. Nevertheless, the angular velocity of the mirror is subject to perturbations during the active scan period. This period was established by two angular position sensors that initiate and preempt detector sampling. The result is a slight variation in the number of bytes (samples or pixels) per scan line. Landsat 1 performance typically results in 3,216 ± 6 and Landsat 2 in 3,247 ± 5 bytes/scan line The digital systems within the IPF can accommodate up to 3800 bytes per band 4 through 7 scan line

For illustrative purposes, 3220 pixels (bytes or samples) will be chosen for use in the following HDT format discussion. Each band 8 detector, having one-third the resolution of band 4 through 7 detectors, will generate

1073 bytes per scan line Band 8 data are to be added into each track of the four track HDT in the form of one quarter scan line (QSL) which will therefore be composed of 268 bytes. The digital equipment was designed to accept up to 300 bytes per QSL Figures D-2A & D-2B show the encoding of one scan line of video data. If calibration data were acquired during the mirror scan that is associated with that scan line, six of the calibration wedge bytes precede the scan line If no calibration was present, six bytes of all zeros are substituted (Landsat 1 and 2) It is important to appreciate that each video scan line was generated from a specific spacecraft detector. During prelaunch calibration, six bytes of calibration wedge data were uniquely selected for that detector Therefore, the six bytes of calibration data preceding the scan line on the HDT are unique to that scan line (and subsequent scan lines derived from the same detector), however, when a defective scan line is replaced by the DPPS, incorrect calibration of that scan line will occur. Calibration bytes associated with band 8 are also listed as six bytes; however, only two levels corresponding to two temperatures, that of the cold (self-look) reference and the hot (shutter housing) reference, will be obtained.

Figure D-2A pertains to any scan line in bands 4 through 7 of Landsat 1 or 2. Figure D-2B details the format for a band 8 scan line.

The complexity of the scan line format can be explained as follows. Preamble A is present to permit byte synchronization prior to acquisition of line synchronization (LS). Line synchronizations 1, 2 and 3 establish that calibration data are about to be presented followed by line length code LLC. Gap A provides a time period during which computations can be performed to arrive at radiometric calibration gain and offset coefficients as well as a computation of the number of bytes to be permitted in the next scan line to be processed Preamble B again establishes byte synchronization and LS 1, 2 and 3 are precursors of data Using the value of 3220 bytes per scan line and the maximum design value of 3600 picture elements, there will be 3220 bytes of video followed by 380 bytes of fill code. (In practice, the number of bytes per scan line on the HDT is a variable that is to be subsequently given a fixed value during CCT generation). The 3600 bytes of video and fill code are followed by an End of Line

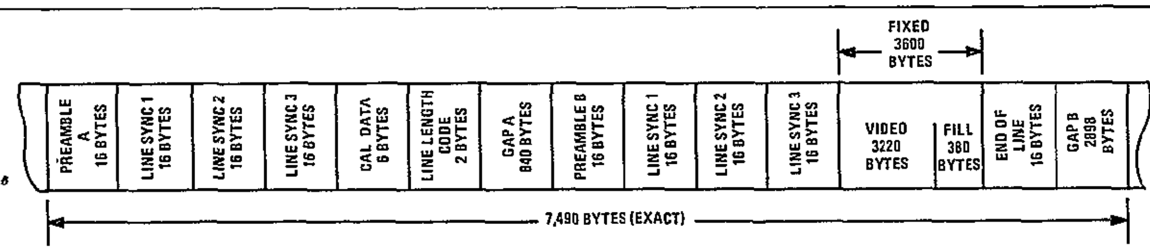


Figure D-2A Bands 4, 5, 6 & 7 Scan Line Format

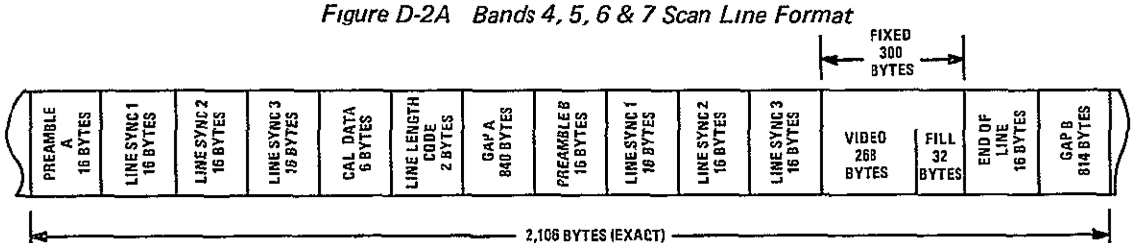


Figure D-2B. Band 8 Scan Line Format

PREAMBLE A 001010	CAL DATA 6 BIT BYTES	VIDEO 6 BIT BYTES
LINE SYNC 1 100001	LINE LENGTH CODE 6 BIT BYTES	FILL 011110
LINE SYNC 2 110111	GAP A 101010	END OF LINE 011110
LINE SYNC 3 000100	PREAMBLE B 001101	GAP B 101010

Figure D-2 MSS Scan Line Format on HDT

Code (ELC). Gap B, 2898 bytes of 101010 permits retention of byte synchronization prior to receipt of the next Preamble A. For Landsat 1 and 2 the total number of bytes per scan line, with necessary computer synchronizing codes and gaps, amounts to 7490 bytes/track (where four tracks represent the four spectral bands). For Landsat-C, band 8 video is multiplexed into the four data tracks. After every three full scan lines (bands 4 through 7), a quarter scan line of band 8 video is inserted. Because the resolution of the band 8 detectors is one-third that of detectors in bands 4 through 7, approximately 1073 samples (per detector) were acquired during one mirror scan. A QSL therefore contains about 268 bytes. These 268 bytes of video are followed by 32 bytes of fill. Again, the number of actual video bytes will vary with mirror velocity, as indicated by the line length code and will be set to a fixed value/mirror scan during CCT generation Detector A and detector B video for band 8 are alternated. That is, the first QSL will represent detector A data. After three full scan lines of bands 4 through 7 data, a QSL of detector B data in the format shown in Figure D-2B will be present. Each QSL of band 8 format will contain exactly 2106 bytes.

The four HDT data tracks are depicted in Figure D-3. Misregistration of the video data between spectral bands still exists but is not illustrated.

Figure D-4 depicts the HDT scene format. Each scene is preceded by a scene gap code that establishes synchronization of the computer at the bit level Scene synchronization establishes synchronization at the byte level. Scene ID identifies the image in terms of the time of acquisition measured from the day of spacecraft launch, in days since launch, hours, minutes and seconds, the spacecraft is also identified.

The 185.2 x 185.2 kilometer scene required 390 spacecraft mirror scans. Each mirror scan generated six scan lines in each of the four spectral bands, bands 4 through 7. Each of these scan lines is encoded as 7490 bytes. In band 8, two scan lines are produced per mirror scan. One quarter scan line is encoded as 2106 bytes. Therefore one track of video data on the HDT contains (390 x 6 x 7490 + 390 x 2 x 2106) = 19,169,280 bytes (exactly).

BYTES/TRACK	7490	7490	7490	2106	7490	7490	7490	2106
TRACK 1	SCAN LINE 1 BAND 4	SCAN LINE 2 BAND 4	SCAN LINE 3 BAND 4	1ST QSL DET A BAND 8	SCAN LINE 4 BAND 4	SCAN LINE 5 BAND 4	SCAN LINE 6 BAND 4	1ST QSL DET B BAND 8
TRACK 2	SCAN LINE 1 BAND 5	SCAN LINE 2 BAND 5	SCAN LINE 3 BAND 5	2ND QSL DET A BAND 8	SCAN LINE 4 BAND 5	SCAN LINE 5 BAND 5	SCAN LINE 6 BAND 5	2ND QSL DET B BAND 8
TRACK 3	SCAN LINE 1 BAND 6	SCAN LINE 2 BAND 6	SCAN LINE 3 BAND 6	3RD QSL DET A BAND 8	SCAN LINE 4 BAND 6	SCAN LINE 5 BAND 6	SCAN LINE 6 BAND 6	3RD QSL DET B BAND 8
TRACK 4	SCAN LINE 1 BAND 7	SCAN LINE 2 BAND 7	SCAN LINE 3 BAND 7	4TH QSL DET A BAND 8	SCAN LINE 4 BAND 7	SCAN LINE 5 BAND 7	SCAN LINE 6 BAND 7	4TH QSL DET B BAND 8

NOTES QSL = QUARTER SCAN LINE, 1 BYTE = 6 BITS = 1 PIXEL
SEE FIGURES D 2A, D 2B FOR SCAN LINE FORMAT

Figure D-3. Newell MSS HDT Format

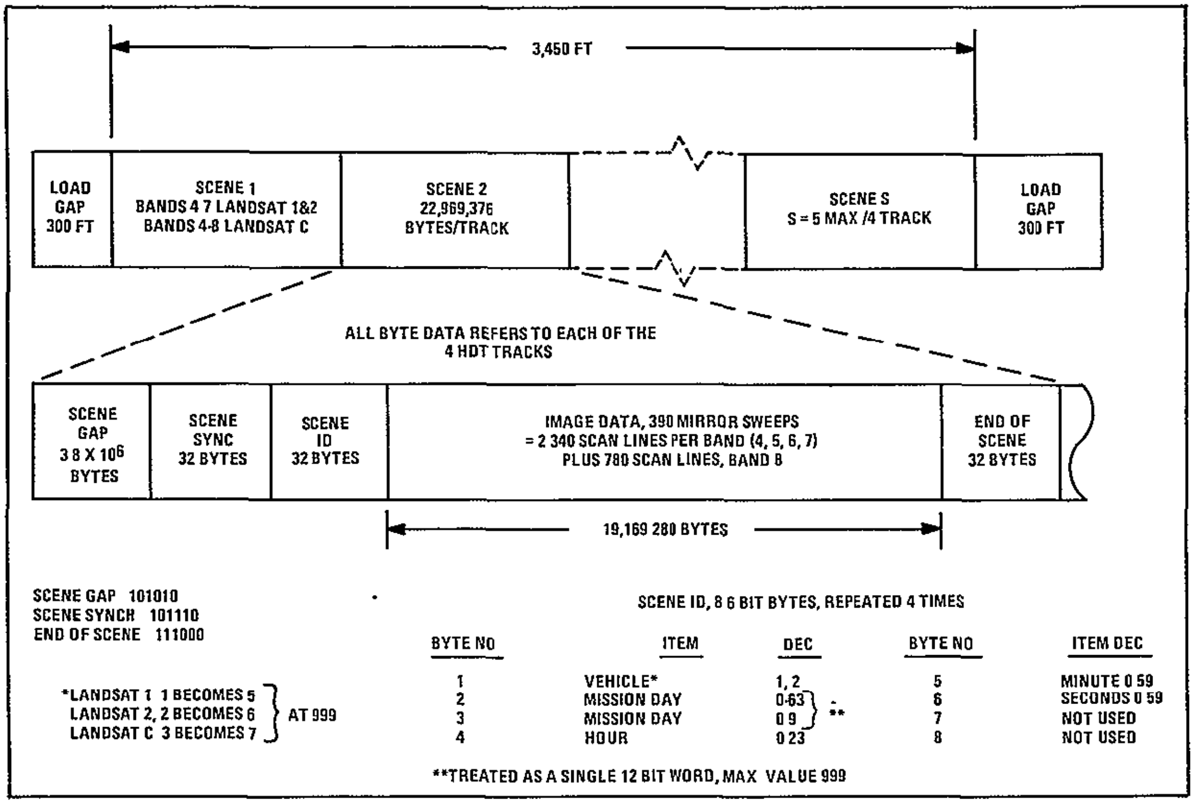


Figure D-4 MSS HDT Scene Format

The next step in CCT production is to use the HDT, or its equivalent, as the input to the Digital Subsystem with a playback tape speed such that the bit rate/track will be nominally 250,000 bits/second.

D.3 DIGITAL SUBSYSTEM

The Digital Subsystem processes selected MSS scene data into computer compatible tape (CCT) form. The MSS data input is either the Newell HDT or its equivalent from the MSS preprocessor (MPP) FR2014 as modified to the Newell format by the Digital Subsystem Interface Unit. Input bit rate is 250,000 bits/second/track, which is accomplished by reducing tape playback speed relative to recording speed.

The Digital Subsystem accomplishes the following:

1. Band-to-band spatial registration
2. Line length correction
3. Data decompression (if required) and subsequent radiometric correction
4. Interleaving of the spectral data
5. Annotation of each tape
6. Detection and printout of processing errors for CCT quality control

A block diagram of the Digital Subsystem is shown in Figure D-5 In addition to the MSS video input, other inputs include an auxiliary paper tape, punched cards, teletype instructions and an eight-track image annotation tape. Output consists of four computer compatible tapes per four-band input scene. Each output tape represents a 25 x 100 nautical mile area of the imaged scene and contains all spectral data associated with that image segment.

The auxiliary paper tape informs the Digital Subsystem of the number of bytes in the longest scan line in each scene to be process-

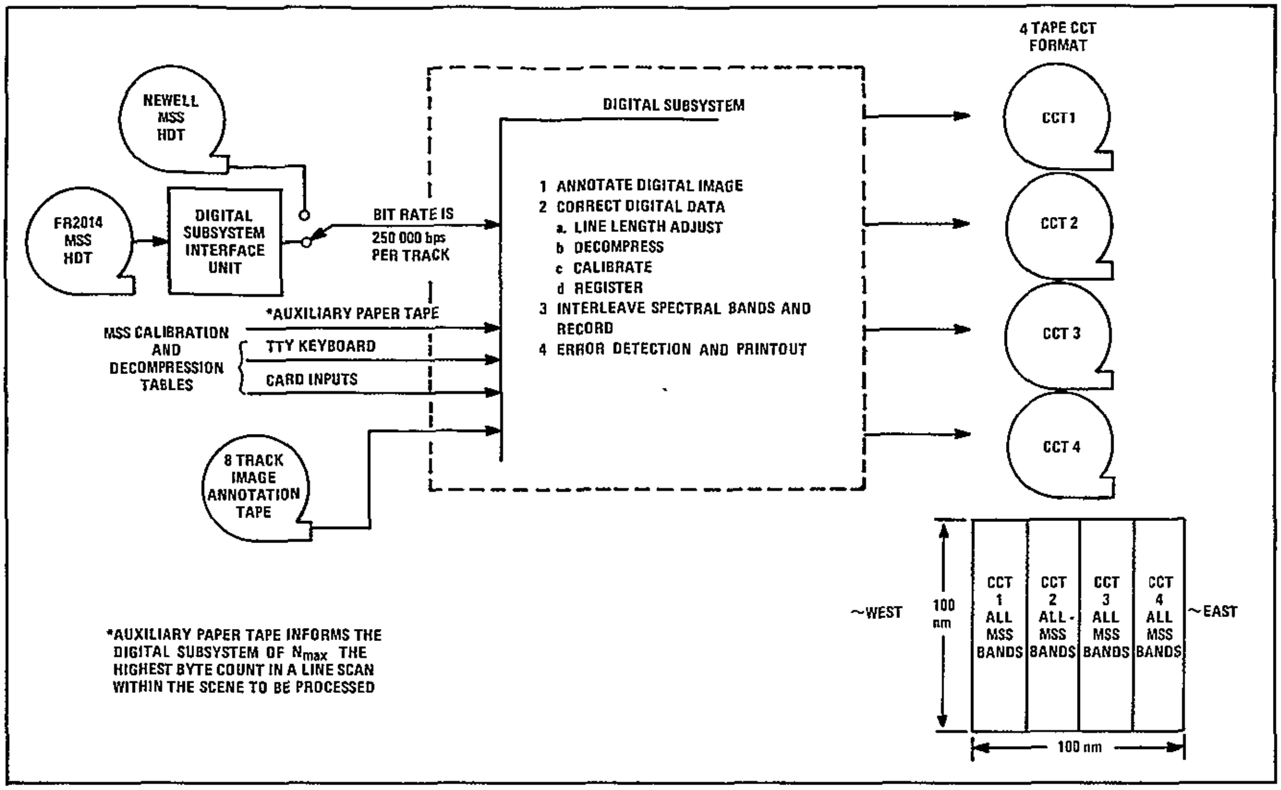


Figure D-5. Overview of Digital Subsystem

ed. Actual line length of each scan line is encoded on the HDT.

The teletype permits error printouts as well as being the means of entering non-standard processing instructions Both the teletype and punched card input can be used to load the subsystem with prelaunch and/or-modified sensor calibration data

The first step in processing the data is to extract calibration wedge and line length codes so that these data precede the scan line data to which they are to be applied.

D.3.1 Band-to-Band Spatial Registration

As previously described with regard to MSS sensor sampling, there is a two byte delay between data in adjacent spectral bands Consequently, band 4 data precede band 7 data by six bytes. Registration is re-established by inserting dummy bytes at the beginning and end of the scan line as illustrated in Figure D-6

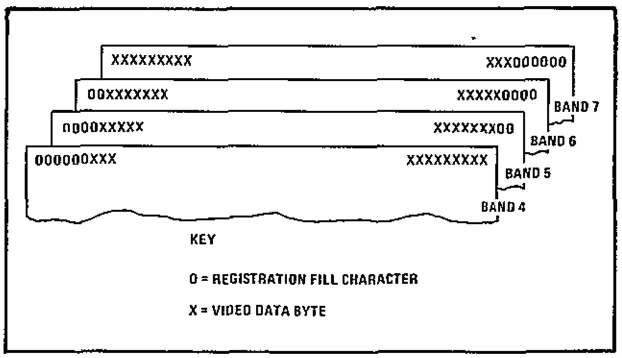


Figure D-6. Position of Registration Fill Characters in Spectral Bands

D.3.2 Line Length Correction

Line length correction is applied to each MSS scene as it is processed. During previous processing of the scene by the Initial Image Generation Subsystem, a determination was made of the greatest number of bytes associated with a scene scan line This number, N_{max}, which is supplied by the auxiliary paper tape input, is used as follows

N_{max} = Number of bytes in the longest scan line
LLC = Number of bytes in the scan line to be processed
CLL = Corrected line length

The corrected line length must be a multiple of eight because the output CCT format contains two bytes each from bands 4 through 7 interleaved as eight-byte groups. The CLL must also be a multiple of three because band 8 data have one-third the resolution of bands 4 through 7 data, and a quarter scan line of band 8 data is to be multiplexed into the output tape after every three full scan lines of bands 4 through 7 interleaved data (across four tapes). Therefore the CLL must be a multiple of 24.

After insertion of six dummy bytes, to restore band-to-band registration, the number of bytes in the longest scan line is $N_{max} + 6$.

The CLL is expressed as 24 times the largest integer in

$$\frac{N_{max} + 6 + (23)}{24}$$

where 23/24 provides high roundoff.

The correction to the individual scan lines is accomplished by the addition of synthetic video bytes at regular intervals within a line. The interval between bytes is the integer value of

$$\Delta = \frac{LLC}{CLL - (LLC + 6)}$$

The initial deltas must be adjusted to maintain spectral registration Let

$$\Delta_b = 14 - 2b$$

where b is the spectral band number (4, 5, 6 or 7) Then

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

The synthetic byte is inserted by repeating the preceding byte. Because the byte count, as determined by the mirror period, remains constant over many months, comparisons of multi-temporal data in user change detection processing will seldom if ever exhibit the presence of synthetic bytes.

D.3.3 Decompression

If data are acquired in the compressed mode, the inverse of the spacecraft compression is applied to both video and calibration wedge signals before calibration Regardless of whether the data were acquired in linear or compressed form, one byte contains six bits. Decompression is accomplished in the Digital Subsystem computer by means of a table look-up routine. The input byte, value 0-63, is output as 0-127. Two decompression tables are employed. One table serves band 4 and 6 data. The second table serves band 5 Both bands 7 and 8 are acquired linearly and do not require decompression.

To permit interleaving of spectral data, as eight-bit binary words, linear and decompressed data are represented as indicated below.

LINEAR

1	2	3	4	5	6	7	8
O	O	X	X	X	X	X	X

DECOMPRESSED

1	2	3	4	5	6	7	8
O	X	X	X	X	X	X	X

THE X'S REPRESENT THE VIDEO DATA BITS IN THE WORD THE BITS IN THE DIAGRAM WHICH CONTAIN THE O'S ARE USED TO INDICATE FLAGS (E G , 11111111 IS USED AS THE REGISTRATION FILL CHARACTER)

D.3.4 Calibration

From preflight calibration tests, during which the MSS detectors were used as transfer devices between a standard radiance source and the MSS internal calibration lamp, the radiance at selected calibration word counts and the maximum radiance to be assigned to each spectral band were determined. R_{cwi} is the internal calibration lamp radiance as modified by the calibration wedge at word count "i" R_{max} is the maximum radiance assigned to a specific spectral band and that value of radiance produces a digital count of 63 for linearly acquired data and a digital count of 127 for decompressed data.

The "best fit" straight line relating relative radiance R_{cwi}/R_{max}, at calibration wedge word "i" is determined by a six point regression analysis for each detector.

$$V_{cwi} = a + b\frac{R_{cwi}}{R_{max}}$$

$$b = \sum_{i=1}^{6} D_i V_{cwi} \text{ (gain coefficient)}$$

$$a = \sum_{i=1}^{6} C_i V_{cwi} \text{ (offset coefficient)}$$

where

$$D_i = \frac{6\frac{R_{cwi}}{R_{max}} - \sum_{i=1}^{6}\frac{R_{cwi}}{R_{max}}}{6\sum_{i=1}^{6}\left(\frac{R_{cwi}}{R_{max}}\right)^2 - \sum_{i=1}^{6}\left(\frac{R_{cwi}}{R_{max}}\right)^2}$$

$$C_i = \frac{\sum_{i=1}^{6}\left(\frac{R_{cwi}}{R_{max}}\right)^2 - \frac{R_{cwi}}{R_{max}}\sum_{i=1}^{6}\frac{R_{cwi}}{R_{max}}}{6\sum_{i=1}^{6}\left(\frac{R_{cwi}}{R_{max}}\right)^2 - \left(\sum_{i=1}^{6}\frac{R_{cwi}}{R_{max}}\right)^2}$$

Note that D_i and C_i are solely dependent on prelaunch determined radiance values. The C_i and D_i values can therefore be calculated and stored in table look-up form. For each of the 24 detectors there are six pairs of C_i and D_i values.

Due to the presence of noise on received calibration voltage values, the values of "a" and "b" are smoothed according to the following equations. "n" is the number of the estimate and corresponds to the number of calibration wedges that have been processed to the current position in the scene.

$\hat{a}_s(1) = a(1)$ = value of "a" computed from the first calibration wedge data encountered at scene processing initiation (n = 1).

$$\hat{a}_s(n) = \hat{a}_s(n-1) + 1/n\,[\,a(n) - \hat{a}_s(n-1)\,]$$
for $1 < n \leqslant 16$

$$\hat{a}_s(n) = \hat{a}_s(n-1) + 1/16\,[\,a(n) - \hat{a}_s(n-1)\,]$$
for $16 < n \leqslant 195$ (calibration wedges)

where $\hat{a}_s(n)$ = n th estimate of "a"

a (n) = calculation of "a" based solely on the n th set of calibration data received.

Up to and including n = 16, the successive values of $\hat{a}_s$ are the average of all the computed values of a(n). That is

$$\hat{a}_s(n) = \frac{a(1) + a(2) + \ldots + a(n)}{n}, \; n \leqslant 16$$

Similarly,

$\hat{b}_s$ (1) = b(1) = value of "b" computed encountered at scene processing initiation.

$$\hat{b}_s(n) = \hat{b}_s(n-1) + \frac{1}{n}\left[b(n) - \hat{b}_s(n-1)\right]$$

for $1 < n \leqslant 16$

$$\hat{b}_s(n) = \hat{b}_s(n-1) + 1/16\left[b(n) - \hat{b}_s(n-1)\right]$$

for $n \geqslant 16$

The best fit straight line is now expressed as

$$V_{cwi} = \left[\hat{a}_s(n) + \hat{b}_s(n)\frac{R_{cwi}}{R_{max}}\right]$$

Note that the values of $\hat{a}_s$ (n) and $\hat{b}_s$ (n) are constant if the calibration wedge voltages are absolutely constant. In practice, the presence of noise on the V_{cwi} will result in considerable variation in $\hat{a}_s$ (n) and $\hat{b}_s$ (n) until the filter has averaged over many V_{cwi} inputs. Therefore, one should not expect that radiometric corrections at the beginning of a scene will be similar to those in later portions of the scene. Whenever HDT processing is initialized, this effect will be observed. Adjacent scenes in the same orbit can exhibit this effect in start-up and overlap regions if processing of the southernmost scene required a change in input HDT.

The relation between V_{cwi} and R_{cwi}/R_{max} allows correction of actual scene data. Assuming linear system operation,

$$R_{cwi} = \frac{R_{max}}{\hat{b}_s(n)}\left[V_{cwi} - \hat{a}_s(n)\right]$$

or for scene radiance values R,

$$R = \frac{R_{max}}{\hat{b}_s(n)}\left[V_r - \hat{a}_s(n)\right]$$

where V_r is received scene voltage. The correct value of V_r, V_c, that should have been received in response to scene radiance R, is

$$V_c = K_o\frac{R}{R_{max}}$$

K_o = 63 for linearly acquired data and 127 for compressed data. Then

$$R = \frac{V_c\ R_{max}}{K_o}$$

Equating the two values of R

$$\frac{V_c\ R_{max}}{K_o} = \frac{R_{max}}{\hat{b}_s(n)}\left[V_r - \hat{a}_s(n)\right]$$

from which

$$V_c = \frac{K_o}{\hat{b}_s(n)}\left[V_r - \hat{a}_s(n)\right]$$

The Digital Subsystem performs the above correction on the output of each detector. If detector-to-detector striping is present, the C_i and D_i values must be slightly altered from the preflight calibration values.

D.3.5 Sun Calibration

Up to this point in the calibration process, it has been assumed that the internal MSS calibration lamp emits constant radiance for the life of the spacecraft. In practice, lamp radiance is likely to exhibit a long term drift. Provision has been made to monitor calibration lamp versus sun radiance on a once per orbit basis. In this technique, an image of the sun is recorded and the resulting detector voltages are observed. Any overall drift in detector voltages may be attributed to changes in internal calibration lamp radiance. The drift can be accommodated by altering the scale factor for scene voltage correction.

$$V_c = \frac{K_s\ K_o}{\hat{b}_s(n)}\left[V_r - \hat{a}_s(n)\right]$$

where K_S is computed from the sun calibration process. On Landsat 1, reliable sun calibration data could not be obtained because the sun imaging optics were apparently fogged by contaminants released from nearby spacecraft components. The problem was rectified on Landsat 2. Operational use of sun calibration data is anticipated for Landsat-C and may yet be activated on Landsat 2. For the present, $K_S = 1$.

D.4 FINAL PROCESSING STEPS TO CCT

The final steps in Landsat video to CCT processing are spectral interleaving, separating the resulting data streams into four adjacent geographical strips and producing the four CCTs. Each Landsat scene consists of 2340 scan lines containing an equal number of bytes. At the output of the Digital Subsystem, all video and calibration data are in eight-bit/byte form. Spectral interleaving is accomplished by selecting two successive bytes from each of the four spectral bands and forming an eight-byte serial group. This group then contains all of the spectral information associated with two adjacent scene picture elements (pixels). Interleaving is illustrated in Figure D-7 for any scan line "k". "m" is the group "G" index and the pixels associated with the group are numbers 2m-1 and 2m, from scan line "k"

Figure D-8 illustrates the CCT format for scan line "k" and the incorporation of calibration data associated with scan line "k" in the four bands The interleaved data is quartered and one quarter is placed on each of the CCTs. The total number of video bytes in scan line "k" is 24n. Interleaving the four bands results in 4 x 24n bytes associated with scene scan line "k". Since eight bytes form a group, the number of groups is $\frac{4 \times 24n}{8}$. The number of groups associated with a quarter scan line

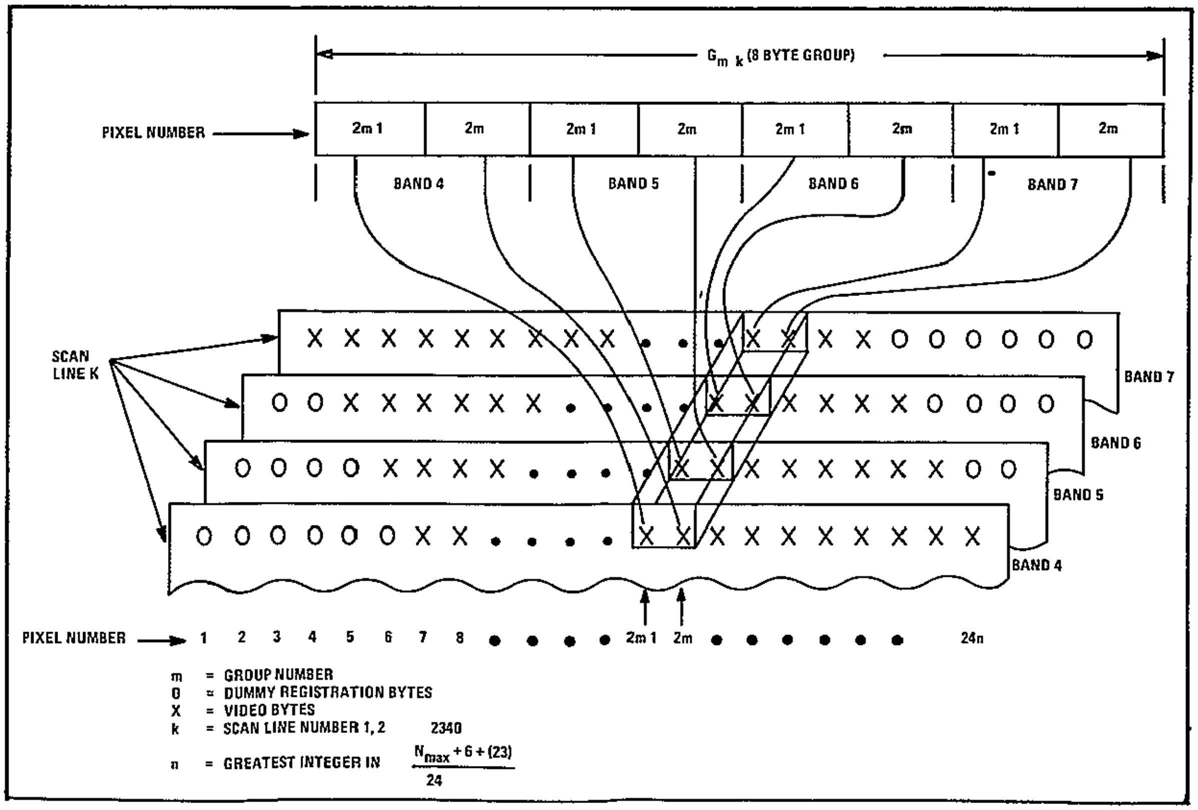


Figure D-7. Four-Band MSS Scan-to-Interleaved Byte Conversion

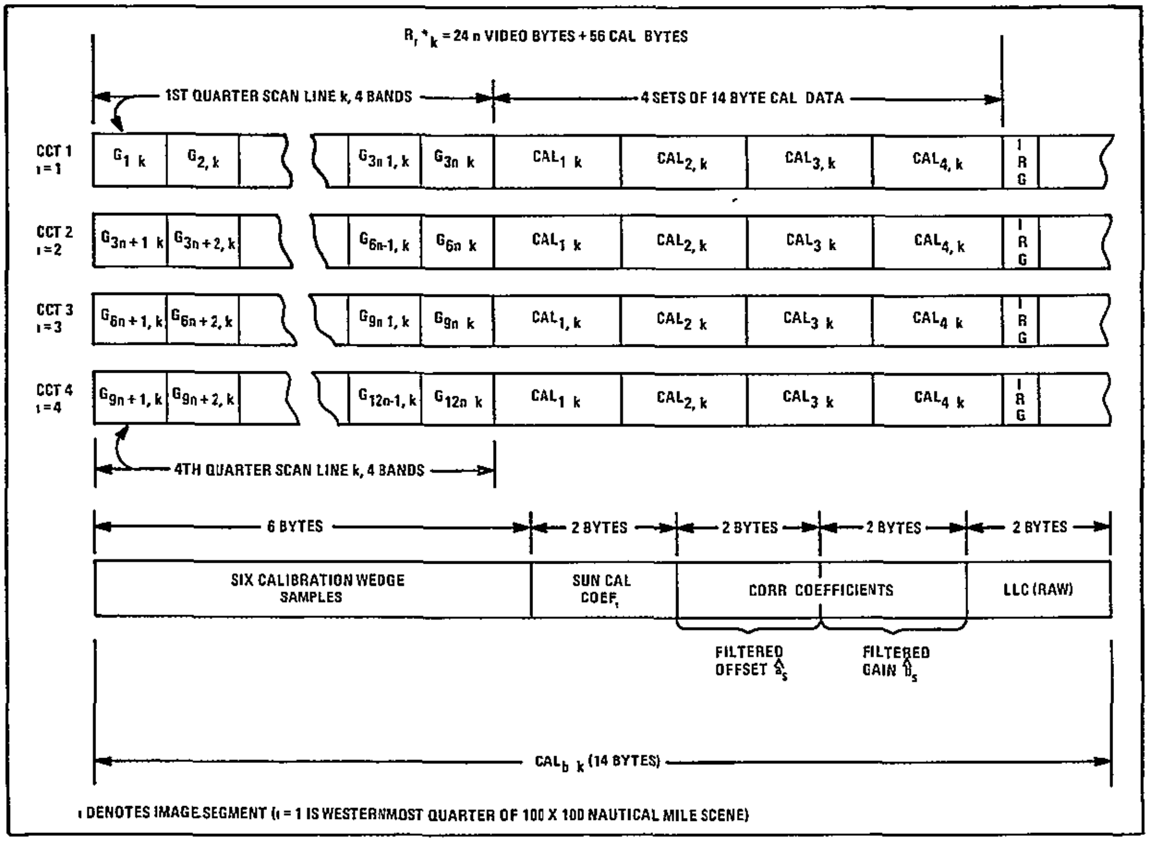


Figure D-8. MSS Full Scene Interleaved Record Format

is then 3n. CCT number 1 contains groups 1 through 3n. CCT number 2 contains groups 3n + 1 through 6n, etc. All of these groups are associated with scan line "k" Continuing this process for all scan lines results in the western-most 25 nautical mile north-to-south image segment being represented by CCT number 1. CCT number 4 represents the eastern-most 25 nautical mile strip. Strip length extends 100 nautical miles north and south.

The quarter scan line of four-band spectrally interleaved data plus four-band calibration data contains 24n video bytes and 56 calibration bytes. This data string is designated as a tape record $R_{i,k}$ "i" denotes the image segment (same as CCT number) and "k" designates the scan line number. Every record is separated from every other record by an inter-record gap (IRG).

D.5 ADDITION OF BAND 8 TO THE CCT FORMAT

Band 8 video and calibration are spatially registered and added as independent records. They are not spectrally interleaved with band 4 through 7 data. In a complete MSS scene of 390 mirror sweeps, 780 scan lines of band 8, 390 for detector A and 390 for detector B, are generated. These scan lines are adjusted to 24n - 3 = 8n video byte lengths. One quarter scan line, or 2n bytes, is added to each CCT after every three quarter-scan lines of interleaved spectral data from bands 4, 5, 6 and 7. The first band 8 record is from detector A. After three quarter-scan lines of interleaved spectral data from bands 4, 5, 6 and 7, a second band 8 record, representing the output of detector B, is added. Each band 8 record consists of 2n bytes of video plus 14 bytes of calibration data per CCT.

Format of the calibration data is the same as for the other bands; however, it is expected that there will be only two calibration word values repeated three times to fill the 6 bytes allocated for six calibration words. A typical band 8 record, either detector A or B, is illustrated in Figure D-9. "k" is the scan line. S_{8k1} . . .S_{8k2n} are the individual video bytes constituting one quarter of scan line "k".

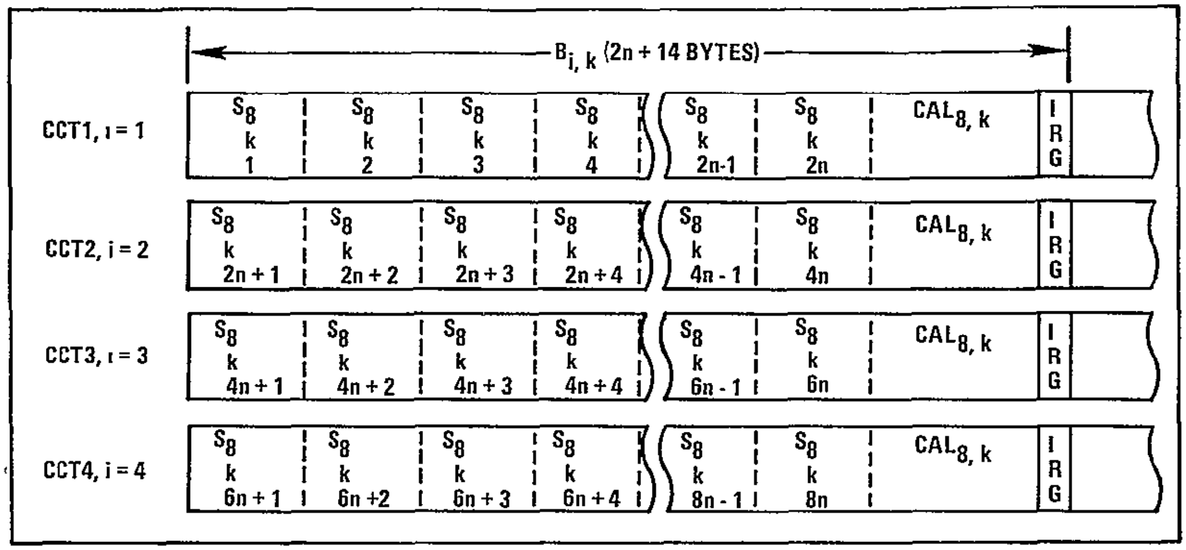


Figure D-9 Band 8 Format as Inserted Into the CCT Format

APPENDIX E
DATA COLLECTION SYSTEM

The Data Collection System (DCS) collects, transmits, and disseminates data from remotely located earth-based sensors As shown in Figure E-1, the system includes remote data collection platforms (DCPs), satellite relay equipment, ground receiving site equipment, and a ground data handling system

The DCP is connected to individual environmental sensors that are selected and provided by the investigator or user agency to satisfy their own particular needs Up to eight individual sensors may be connected to a single DCP. The sensors may provide digital or analog outputs to the DCP. The DCP transmits the sensor data to the satellite, which in turn relays the data to the ground receiving site through an on-board receiver/transmitter.

The ground receiving site equipment accepts the data and decodes and formats it for transmission to the Ground Data Handling System (GDHS) at Greenbelt, Maryland The data is received in the Operations Control Center (OCC) where it is reformatted and written on magnetic tape and then either transmitted direct to the user or passed on to the Image Processing Facility (IPF) for further processing and cataloging required for dissemination to the user agencies

The geometry involved in relaying DCS data is shown in Figure E-2. The satellite is at a nominal altitude of 920 kilometers (570 miles). The transmitting antenna of the DCP subtends an angle of ± 70 degrees from the vertical and the ground receiving site visibility is nominally ± 85 degrees from the vertical. When the satellite is in mutual view of a transmitting DCP and one or more of the ground receiving sites, the message from the DCP is relayed to the receiving site and transmitted over land lines to the OCC. The DCPs operate continuously, sampling the sensors period-

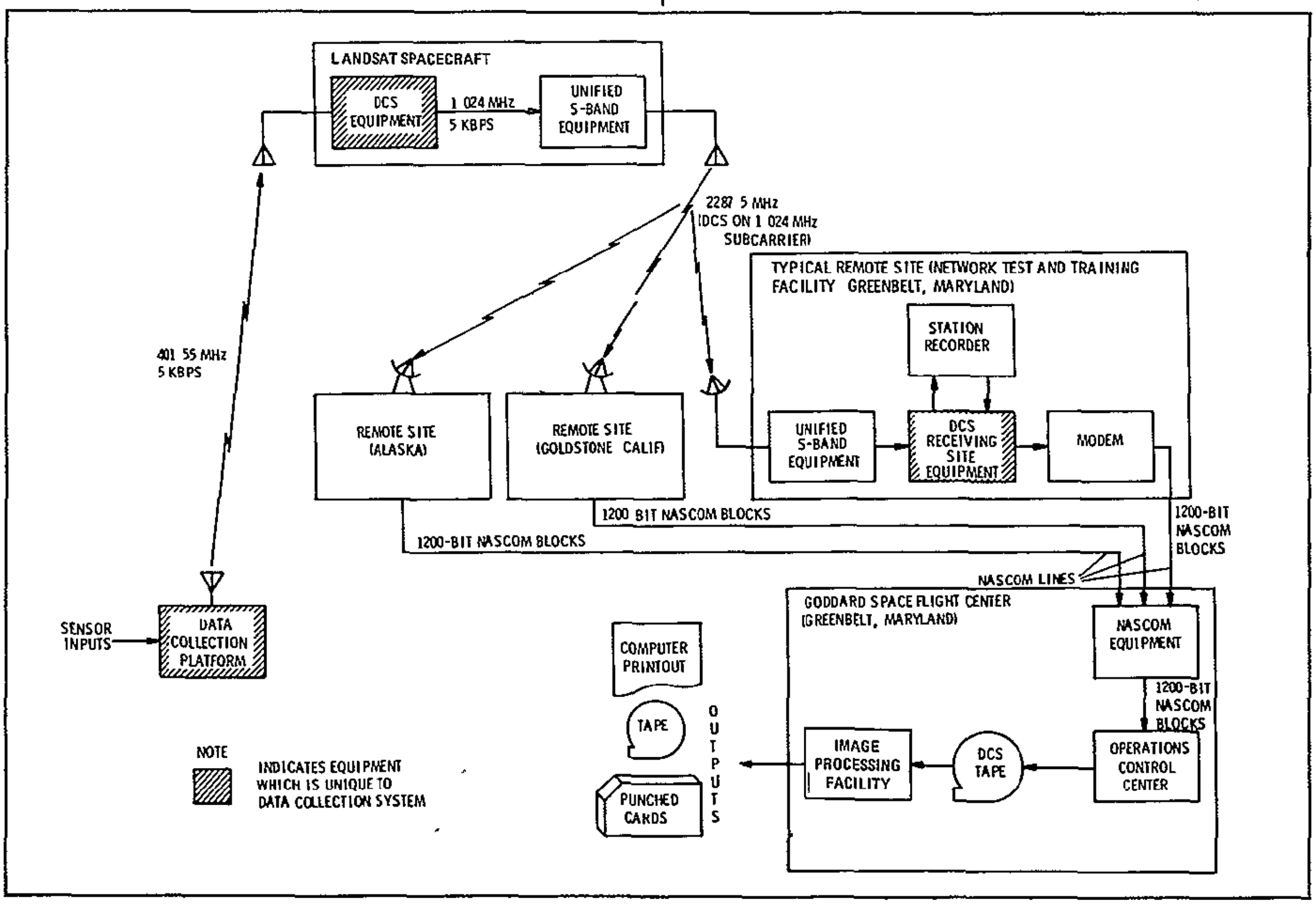


Figure E-1. Data Collection System Block Diagram

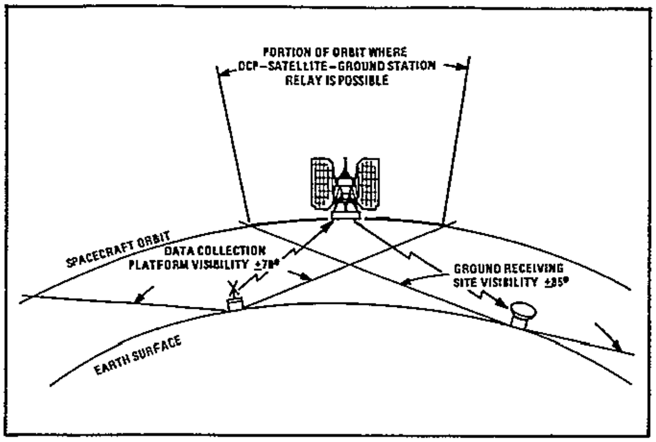


Figure E-2 DCS Data Relay Geometry

ically and transmitting a 38-millisecond burst of data containing all sensor channels at intervals of about every three minutes Note that the satellite acts as a simple real time relay with no' on-board storage The DCP transmissions are received at the ground receiving site immediately except for small propagation and fixed system time delays.

The orbit parameters (the orbital period is ~103 minutes) allow for up to 9 minutes of mutual visibility for some DCPs Figure E-3 shows the potential area of mutual visibility for one orbital pass. In these cases it is possible to receive up to three separate transmissions from a DCP for each orbital pass of the satellite The use of three receiving sites, Alaska, Goldstone and NTTF, provides nine active passes over the North American continent each day, of which five are daylight passes and four are night time passes.

For a particular DCP, the orbit parameters and the receiving site locations cause the spacecraft to be in mutual view of a platform located almost anywhere in North America and at least one of the three ground receiving sites during at least two orbits per day—one about 9:30 in the morning and the other about 9 30 in the evening At least one message is relayed from each platform every 12 hours

The Data Collection System is designed to assure that the probability of receiving at least one valid message from any DCP every 12 hours is at least 0.95 for as many as 1000 DCPs located throughout the United States.

Interference of signals from two or more DCPs transmitting simultaneously may cause incorrect or partial messages to be received. To minimize this possibility, the system uses error coding and other schemes to correct or identify messages containing errors and to identify incomplete messages. The probability of erroneously indicating that a given message is valid (i.e., stating that a message that contains an error does not) is less than 0.001.

In order to improve performance for locations where there is a relatively short period of mutual DCP-ground station visibility from the observatory, the average rate of DCP message bursts can be switched to a more rapid rate one message burst each 90 seconds. Using this feature, DCPs may be located anywhere in the continental U.S. or Alaska and achieve this performance DCPs may be deployed beyond these bounds, however, with degraded performance in terms of probability of receiving a valid message each 12 hours.

As shown in Figure E-1, operation of the Data Collection System requires three hardware subsystems the DCPs, the receiving and transmitting equipment in the satellite and special receiving and preprocessing equipment located at each of the three ground receiving sites. In addition, the system uses existing

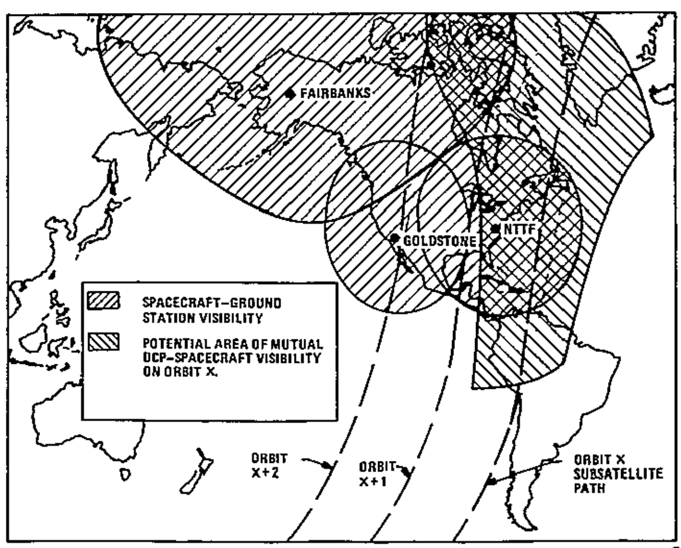


Figure E-3 Mutual DCP-Receiving Site Visibility ground communication facilities and the hardware/software capabilities of the OCC and IPF at GSFC. These facilities are described in the following sections.

E.1 DATA COLLECTION PLATFORM

The DCP collects, encodes, and transmits ground sensor data to the Landsat Observatory. A block diagram is shown in Figure E-4 and a sketch in Figure E-5.

The DCP will accept analog, serial-digital, or parallel-digital input data as well as combinations of those. Eight analog inputs or 64 bits of digital input can be accepted. Combined inputs are selected by individual analog inputs and groups of 8 bits of digital input up to a total equivalent of 64 bits.

Selection of the type of input is made by the switch positions on the front panel of the platforms. For all types of inputs the nominal signal amplitude range is from 0 to +5 Vdc. The source impedance must be less than 10,000 ohms resistitve and less than 1000 picofarads capacitive Input impedance is greater than 1 megohm.

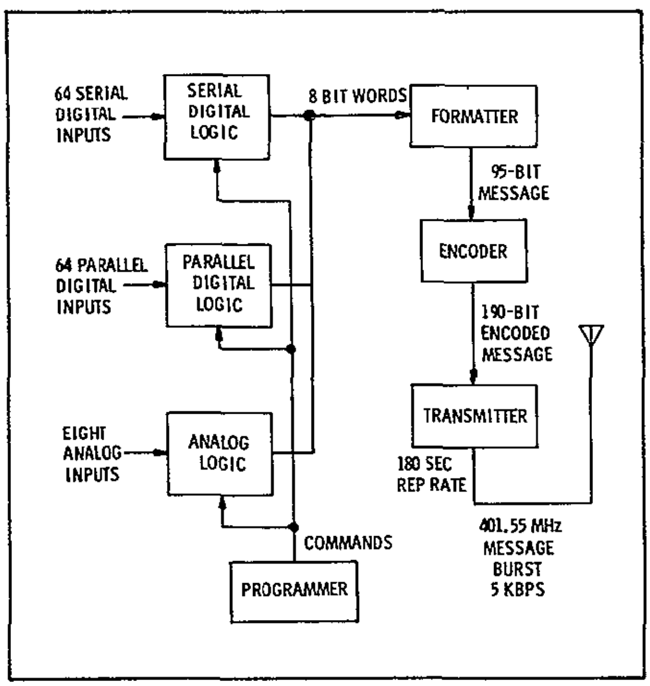


Figure E-4 Data Collection Platform Block Diagram

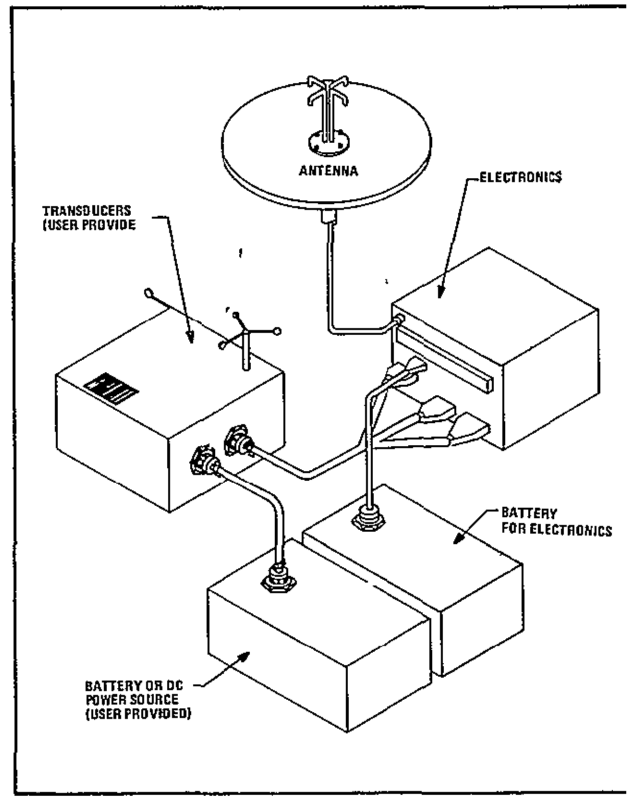


Figure E-5 Data Collection Platform

For analog inputs, the analog-to-digital converter converts the normal signal range of 0 to +5 Vdc into eight bits of binary with a resolution of 19.53 millivolts per bit; conversion error is less than one percent of full scale, including quantization.

Serial digital data (of up to 64 bits) are accepted as a single input. An enable command and a 2.5 kHz clock is supplied to enable the transfer of the serial digital data

Up to 64 parallel digital bits can be accepted by the DCP. These parallel bits are sampled in 8-bit groups in sequence during a 68-millisecond period corresponding to the entire platform "on" time (warm-up and message transmission) A data gate is provided during this period.

Format of a DCP message prior to encoding consists of 95 bits in the format shown in Table E-1.

Before transmission, each DCP message is encoded using a rate 1/2 constraint length five

Table E-1 DCP Message Format

Bits		
1-15	Preamble	
16-17	Synchronization	
18-27	Platform ID	
28-35	Data Word Number 1	Sensor 1 through 8 occupy 64 bits
36-43	Data Word Number 2	
44-51	Data Word Number 3	
52-59	Data Word Number 4	
60-67	Data Word Number 5	
68-75	Data Word Number 6	
76-83	Data Word Number 7	
84-91	Data Word Number 8	
92-95	Encoder run-out bits	

convolutional code, to produce a 190-bit message output. A message is sent every 90 or 180 seconds, depending on the setting of the time selection switch on the front panel of the DCP.

E.2 DCS SPACECRAFT EQUIPMENT

The spacecraft acts as a simple relay receiving, frequency translating and retransmitting the burst messages from the DCPs. No on-board recording, processing or decoding of the data is performed. A DCS unique UHF antenna and redundant receivers are provided. The output of the DCS receiver is applied to the premodulation processor where the DCS data are put on a subcarrier of the United S-band (USB) equipment. USB equipment, used for narrow band telemetry, is used to retransmit the DCP messages to the three primary receiving sites

E.3 TREATMENT OF DATA AT THE RECEIVING SITE

At the receiving site, the composite S-band signal is received and the DCS subcarrier is extracted and inputted to special DCS Receiving Site Equipment (DCS/RSE). The DCS/RSE performs a matched filter operation on each encoded bit received, and quantitizes the output of that operation to three bits. Each bit representation recovered from the DCP transmission is in the form of a four-bit byte; one bit, indicating the presence or lack of signal (squelch), and the three-bit quantization of the matched filter. When no signal is present, the output byte is set to all zeros. The quantized bits are decoded, and quality bits are assigned to each decoded bit and the overall message to indicate the decoding confidence level.

The DCS/RSE formats the decoded data with the quality indicators and a 30-bit site time code, which was converted from the NASA 36-bit time code. The data are buffered and formatted into a 1200-bit NASCOM block and outputted to a site modem in real time as messages are received. The DCS/RSE adds the NASCOM header and the filler and check bits, along with buffering the data and site-time information. In the event of equipment problems, the data are also recorded for post-pass playback. The NASCOM blocks are transmitted to the OCC by the modem.

E.4 TREATMENT OF DATA AT THE GDHS

The NASCOM data blocks are received at the OCC where the NASCOM header is stripped and DCS data messages are written, in the order received, on a magnetic tape. One magnetic tape may contain messages from one or more receiving sites. At the conclusion of one or more station passes, this tape is transferred to the IPF. The usual mode of operation involves the transfer of data to the IPF at the conclusion of each pass.

When the DCS tapes arrive at the IPF from the OCC, they are read, edited, reformatted, and the data are sorted according to platform identification and the time the data were received Redundant data resulting from overlapping station coverage are removed The criterion for determining redundant data is an exact match between the messages except for receiving site (station ID). An active data file is generated that maintains a record of the most recent 24-48 hours of DCS messages. This resides in random-access storage in the IPF computer.

The active data file contains the platform message data in addition to the results of the editing checks and certain identifying information. Four editing checks are performed. the station code is checked to assure that it is one of the three valid codes for Goldstone, Alaska, or NTTF, the platform ID is checked to assure that it matches a valid ID maintained in a platform ID file, a flag is set if any one of the quality bits associated with the platform ID is zero, a fourth check is made on the time of reception. If any part of the time code exceeds possible values for day, hour, minute, or seconds, a flag is set in the active data file These checks and flags do not cause any messages to be rejected.

An active data file entry is made for each platform message and consists of eight words as shown in Table E-2 The platform ID is a binary coded decimal from 1 to 1000. Each platform has a unique designator. The platform ID quality bits are those that were associated with the platform ID during transmission Words 5 and 6 contain the actual data bits in the order in which they were received. For convenience, the associated quality bits have been separated and put in words 7 and 8.

Table E-2 DCS Active Data File Entry

Word	Bits	Item	Mode	Format
1	0 15	Platform ID	Binary	XXXX
	16 23	Satellite ID	EBCDIC*	1/2(1 for Landsat 1 2 for Landsat 2)
	24 31	Station ID	EBCDIC	A/G/N (Alaska, Goldstone, NTTF)
2	0 15	Days (GMT)	Binary	1 366
	16 31	Days Since Launch	Binary	1 N
3	0 7	Hours (GMT)	Binary	0 23
	8 15	Minutes (GMT)	Binary	0 59
	16 23	Seconds (GMT)	Binary	0 59
	24 31	Year (GMT)	EBCDIC	0 9
4	0 5	Not Used	Binary	0
	6 15	Platform ID Quality	Binary	All Ones
	16 17	Not Used	Binary	0
	18 23	Error Flags		
		Invalid Station Code	Bit 18	(1 = set)
		Invalid Platform ID	Bit 19	(1 = set)
		Poor Platform ID Quality	Bit 20	(1 = set)
		Invalid Time Code	Bit 21	(1 = set)
		Duplicate Message	Bit 22	(1 = set)
		Redundant Message	Bit 23	(1 = set)
	24 28	Not Used		
	29 31	Message Quality	Binary	0 7
5	0 31	Data Bits	Binary	
6	0 31	Data Bits	Binary	
7	0 31	Quality Bits	Binary	
8	0 31	Quality Bits	Binary	

*Extended Binary Decimal Interchange Code

Available DCS products consist of magnetic tapes, punched cards or computer listings All products are limited to uncalibrated data, that is, data bits are disseminated to the user without conversion to engineering units. Magnetic tapes contain message data records ordered according to platform ID and time with ID, and in the same 8-word format as the active data file entry. The entries are blocked 60 to a tape record A tape header is included for identification The details of this tape format are contained in Figure 4-22 of Section 4.

The data card format for DCS products is shown in Figure 4-20 Entries for these cards are also given in Table E-3. The listing format is given in Figure 4-21. DCS data products may be requested in two ways A standing order may be permanently established with the IPF to require that all data from a set of

Table E-3. DCS Data Card Entries

Column	Item	Format
1 2	Card ID for Standing Requests for Variable Requests	SC VC
3 6	User ID	AAAA
7-10	Platform ID	1-1000
11	Satellite ID (1 for Landsat 1 2 for Landsat 2)	N
12	Year of Reception	1 9
13 21	Time Code (GMT)	DDDHHMMSS
22	Station ID	A/G/N
23,24	Encoded Error Flag 32 = Invalid Station ID 16 = Invalid Platform ID 8 = Poor Platform ID Quality 4 = Invalid Time Code 2 = Duplicate Message 1 = Redundant Message (Or any combination of the above, e g) 63 = All Conditions Exist	0 63
25	Message Quality Level 0 = Long or short message 1–7 indicates lowest to highest quality	0 7
26	Data Format Indicator O = Data in octal digits (22 columns) H = Data in hexadecimal digits (16 columns)	O/H
28/34 49	Data in Octal or Hexadecimal Digits	
51/57-72	Data Quality in Octal or Hexadecimal Digits	

NOTE If quality bits are included, they will be in the user format as the data bits Columns 51/57-72 are optional depending on the use of data quality bits platforms be sent to the user agency. The capability is provided in a standing request either to keep or eliminate the quality bits for card or listing outputs It is also possible for the investigator to designate the level of message quality that is acceptable to him.

A variable request allows the investigator to do retrospective searches. The capability is provided to search the archives based on user ID (all platforms listed for this user are retrieved), or individual platform ID. It is possible to qualify the search based on a given time period or geographical area All three product media are available and data can be qualified as to message quality.

APPENDIX F
ORBIT CONTROL, COVERAGE, OCC AND MISSION PLANNING

F.1 ORBIT CONTROL

Several significant characteristics of the Landsat orbit have been selected to minimize variations in observation conditions and provide a systematic process of imagery collection. Precise control of the orbital parameters is required to achieve and maintain the desired characteristics. Hence, the Landsat spacecraft include an orbit adjust capacity that is used to attain the orbit initially and maintain this orbit throughout the life of the mission.

The Orbit Adjust Subsystem is a monopropellant system consisting of three rocket engines fed by a common propellant/pressurant tank. The three thrusters are aligned to provide impulse along or opposed to the spacecraft velocity vector and also perpendicular to the orbital plane. Each thruster imparts a thrust of approximately one pound

F.1.1 Attainment of Required Orbit

The Delta launch vehicle injects the spacecraft into its final orbit to within the limits of the errors inherent in the launch vehicle system. Launch vehicle errors at injection are random and can be of magnitudes that impact the desired observation characteristics. The spacecraft orbit adjust capabilities are utilized after spacecraft separation to remove residual launch vehicle injection errors.

The orbital parameters most critical to providing the desired imagery characteristics are the semi-major axis (or equivalently the period of the orbit), the inclination, and the eccentricity. For Landsat, a unique combination of orbital period and inclination is required to establish the desired coverage pattern and sun synchronization. Errors in eccentricity also affect these characteristics. However, eccentricity errors have a negligible effect compared to the effects of inclination and period errors.

F.1.1.1 Period Errors

The maximum expected injection error in the orbital period exceeds by a wide margin the accuracy required for satisfactory systematic coverage and cross-track repeatability. For example, an injection period error of only one percent of the maximum (3σ) error would result in a 35 kilometer sidelap error in the second 18-day cycle relative to imagery from the corresponding revolutions in the first 18-day cycle. If not corrected this error would continue to expand with time until the relative error exceeded half the swath width.

F.1.1.2 Inclination Errors

Injection inclination errors cause a drift in the time of the descending node and also imagery sidelap errors. Without an orbit adjustment capability, the injection inclination error would result in a continually increasing sidelap error. These inclination effects can be compensated for by adjusting the orbital period.

F.1.1.3 Error Correction

Thus, injection period errors had to be removed and compensation provided for the inclination error. Period adjustments are accomplished by utilizing one of the two thrusters which impart impulse along the velocity vector. Because of the one pound force of these thrusters, the weight of the spacecraft, the magnitude of the period adjustment, and other scheduling criteria, the period adjustment process took several days from injection to completion.

F.1.2 Maintenance of Required Orbit

Several forces (such as. atmospheric drag, the gravitational attraction of the sun and moon, and the spacecraft's own attitude control mass explusion subsystem) act upon the spacecraft after the desired orbit has been attained. These forces cause changes to the orbit that compromise the desired coverage and repeatability characteristics. The orbit to which the injection error removal process was targeted had been selected to minimize the effects of these forces on the desired coverage characteristics. Nonetheless, orbit adjustment is occasionally required to compensate for these forces.

During the first several weeks of the mission, several small although significant perturbing factors (e.g., the force due to the attitude control system mass expulsion subsystem) were determined. These factors were then included in orbit planning operations to minimize the number of subsequent adjustments. Several small adjustments were necessary during this period to optimize the desired coverage characteristics. These adjustments were minor and were scheduled so as not to interfere with imaging operations.

Subsequent to the first several weeks of the mission, the requirements for adjustments became minimal, systematic, and predictable. The requirements for these adjustments result from the perturbing forces on the spacecraft which, over long periods of time, cause predictable perturbations to the orbit. The significant impact of these perturbations is a systematic cross-track drift of imagery from

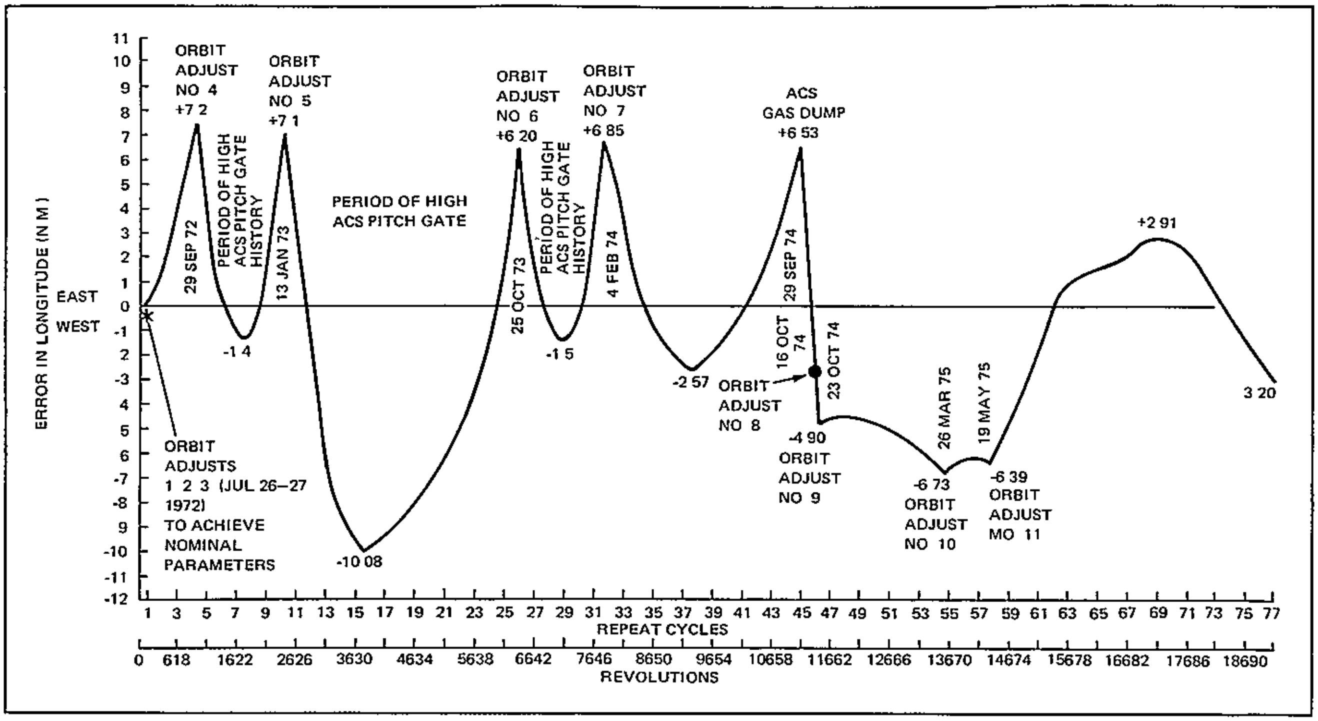


Figure F-1A. Cross Track Drift and Orbit Adjustments for Landsat 1.

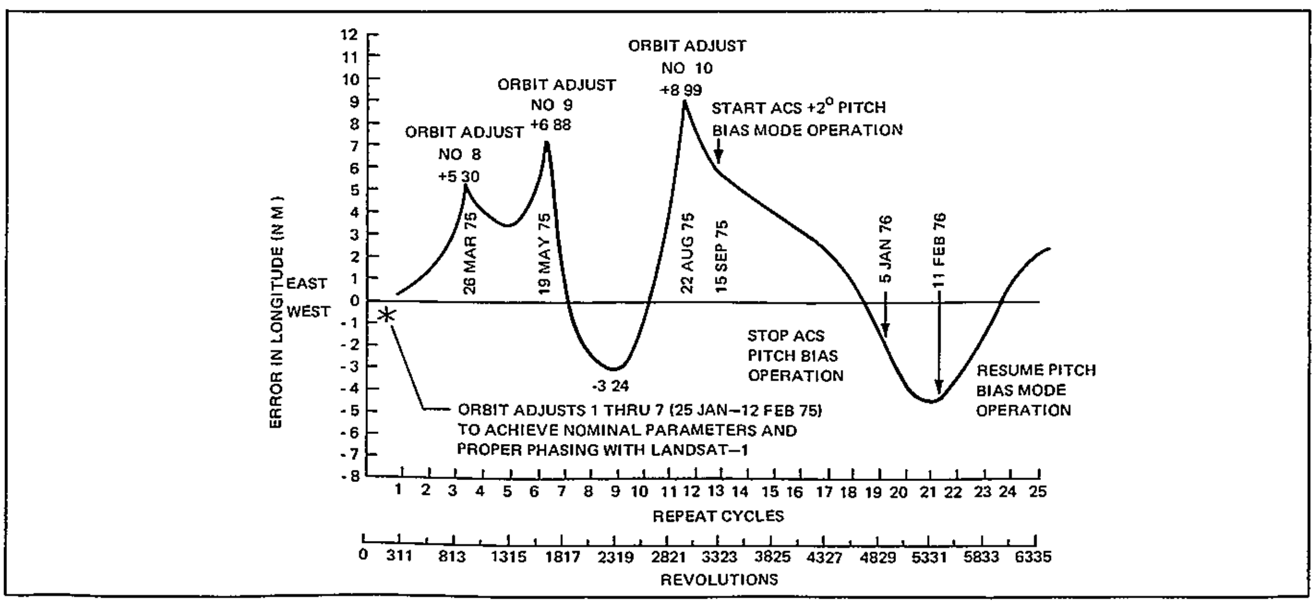


Figure F-1B. Cross Track Drift and Orbit Adjustments for Landsat 2.

revolutions of one 18-day, earth coverage cycle relative to imagery from corresponding revolutions of other 18-day cycles during the mission. Orbit adjustments are scheduled to limit this cross-track imagery drift to 37 kilometers during the entire mission. Figure F-1 shows the drift and adjustment profile for both Landsat spacecraft. Acceptable coverage can be maintained over a mission by several small orbital period adjustments. These adjustments are of several seconds duration only and are scheduled over Landsat ground stations so as not to interfere with imaging operations

F.2 ORBIT COVERAGE

Systematic, repetitive, global earth coverage under nearly constant observing conditions is required for maximum utility of the multi-spectral images collected by Landsat. Both Landsat 1 and 2 have been launched into circular sun-synchronous orbits with a nominal 9·30 a.m. descending node (equatorial crossing). The orbital parameters are given in Table F-1.

Table F-1. Landsat Orbit Parameters)
(September 1976)

Orbit Parameter	Spacecraft 1	Spacecraft 2
Semi major axis (km)	7285 438	7285 730
Inclination (deg)	98 906	99 015
Period (min)	103 143	103 149
Eccentricity	001070	001392
Time at descending node (equatorial crossing)	8 50 a m	9 20 a m
Coverage cycle duration	18 days (251 revs)	
Distance between adjacent ground tracks (at equator) (km)	159 38	

F.2.1 Earth Coverage

The ground coverage pattern selected for a Landsat spacecraft is shown in Figure F-2 for two orbits on two consecutive days. The orbital parameters cause the daily coverage swath to be shifted in longitude at the equator by 1.43 degrees, corresponding to 159 kilometers. The revolutions progress in a westwardly direction and the pattern continues until all the area between orbit N and orbit N+1 is covered. This constitutes one complete coverage cycle, consisting of 251 revolutions, taking exactly 18 days, and providing complete global coverage between 81 degrees north and 81 degrees south latitude On any given day, the satellite makes approximately 14 revolutions of the earth as shown by the typical ground trace in Figure F-3.

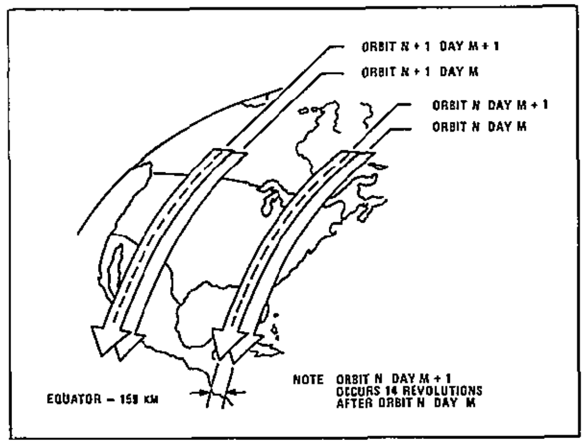


Figure F-2 Ground Coverage Pattern

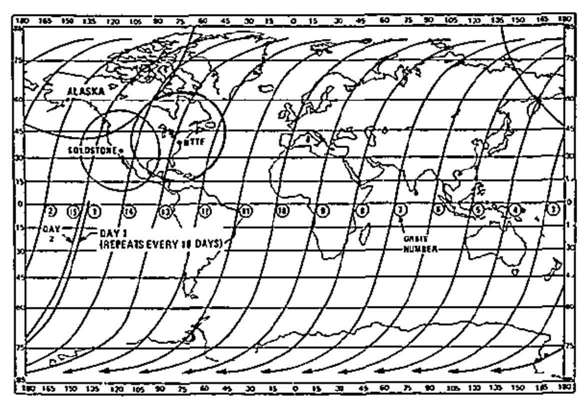


Figure F-3. Typical Landsat Ground Trace for One Day (Only Southbound Passes Shown)

Coverage over the continental United States is depicted in Figure F-4. The observatory proceeds along each swath from top to bottom in the illustration and the orbits proceed from right to left. The daily coverage of the U.S. is provided during two or three orbits. With the three ground stations, data covering the United States (including Alaska but excluding Hawaii) are obtained by a Landsat spacecraft in approximately 18 minutes of operation per day.

Table F-4. Landsat Orbit Paths

Cycle Day	Path Numbers
1	106, 124, 142, 160, 178, 196, 214, 232, 250, 17, 35, 53, 71, 89, 107
2	107, 125, 143, 161, 179, 197, 215, 233, 251, 18, 36, 54, 72, 90, 108
3	108, 126, 144, 162, 180, 198, 216, 234, 1, 19, 37, 55, 73, 91, 109
4	109, 127, 145, 163, 181, 199, 217, 235, 2, 20, 38, 56, 74, 92, 110
5	110, 128, 146, 164, 182, 200, 218, 236, 3, 21, 39, 57, 75, 93, 111
6	111, 129, 147, 165, 183, 201, 219, 237, 4, 22, 40, 58, 76, 94
7	94, 112, 130, 148, 166, 184, 202, 220, 238, 5, 23, 41, 59, 77, 95
8	95, 113, 131, 149, 167, 185, 203, 221, 239, 6, 24, 42, 60, 78, 96
9	96, 114, 132, 150, 168, 186, 204, 222, 240, 7, 25, 43, 61, 79, 97
10	97, 115, 133, 151, 169, 187, 205, 223, 241, 8, 26, 44, 62, 80, 98
11	98, 116, 134, 152, 170, 188, 206, 224, 242, 9, 27, 45, 63, 81, 99
12	99, 117, 135, 153, 171, 189, 207, 225, 243, 10, 28, 46, 64, 82, 100
13	100, 118, 136, 154, 172, 190, 208, 226, 244, 11, 29, 47, 65, 83, 101
14	101, 119, 137, 155, 173, 191, 209, 227, 245, 12, 30, 48, 66, 84, 102
15	102, 120, 138, 156, 174, 192, 210, 228, 246, 13, 31, 49, 67, 85, 103
16	103, 121, 139, 157, 175, 193, 211, 229, 247, 14, 32, 50, 68, 86, 104
17	104, 122, 140, 158, 176, 194, 212, 230, 248, 15, 33, 51, 69, 87, 105
18	105, 123, 141, 159, 177, 195, 213, 231, 249, 16, 34, 52, 70, 88, 106

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Table F-5A. Landsat 1 Orbit Calendar — 1972

Calendar Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Cycle Day											
1								1	14	8	3	15
2								2	15	9	4	16
3								3	16	10	5	17
4								4	17	11	6	18
5								5	18	12	7	1
6								6	1	13	8	2
7								7	2	14	9	3
8								8	3	15	10	4
9								9	4	16	11	5
10								10	5	17	12	6
11								11	6	18	13	7
12								12	7	1	14	8
13								13	8	2	15	9
14								14	9	3	16	10
15								15	10	4	17	11
16								16	11	5	18	12
17								17	12	6	1	13
18								18	13	7	2	14
19								1	14	8	3	15
20								2	15	9	4	16
21								3	16	10	5	17
22								4	17	11	6	18
23							11	5	18	12	7	1
24							12	6	1	13	8	2
25							13	7	2	14	9	3
26							13	8	3	15	10	4
27							14	9	4	16	11	5
28							15	10	5	17	12	6
29							16	11	6	18	13	7
30							17	12	7	1	14	8
31							18	13		2		9

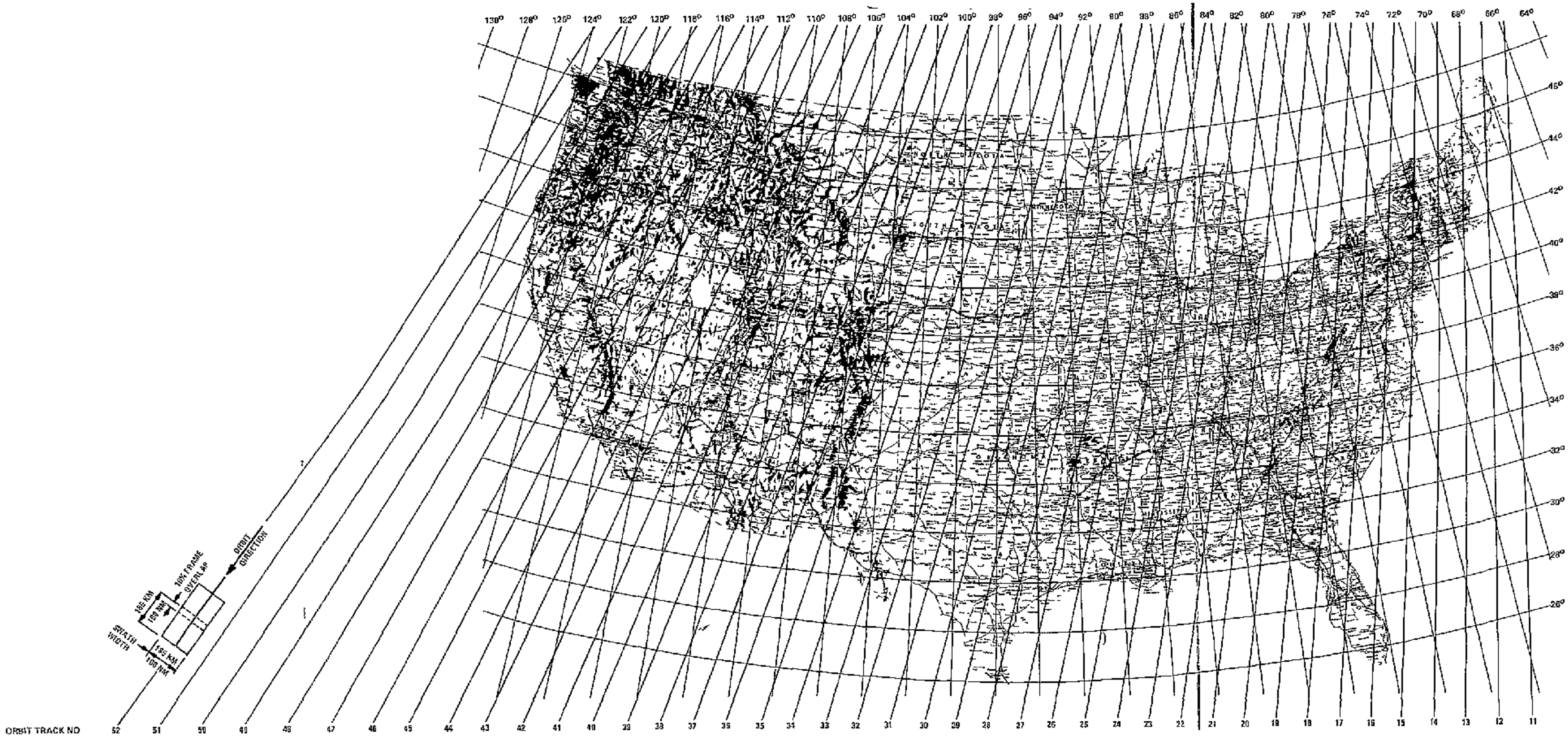

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Figure F-4. Landsat Coverage of the Continental United States

F.2.2 Imagery Sidelap

The coverage pattern provides 14 percent sidelap at the equator as shown in Figure F-5.

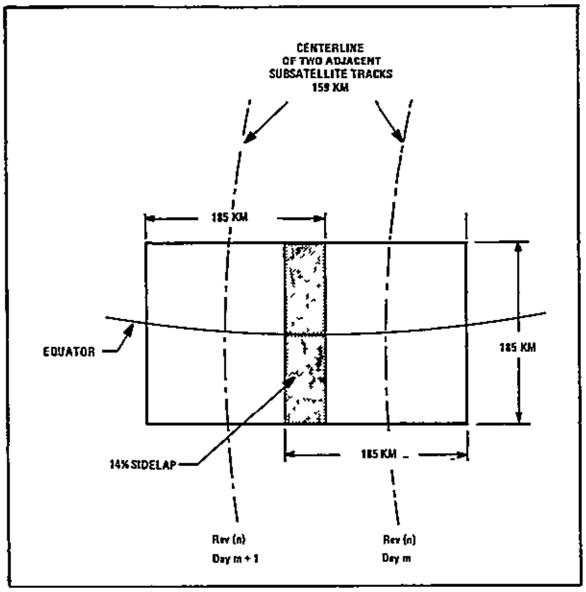

Figure F-5. Imagery Sidelap at the Equator

Table F-2 indicates the increase in sidelap of the swaths as higher latitudes are reached. At latitudes with greater than 50 percent sidelap, complete duplicate coverage is achieved on sequential days. The duplicate coverage affords the possibility of obtaining images of a given ground area via portions of images taken on days M-1 and M+1 even though an image was not obtained on day M (Figure F-6). At even greater sidelap percentage levels, portions of images taken as many as six days apart will provide complete ground coverage, as shown in Table F-3.

Table F-2. Sidelap of Adjacent Landsat Coverage Swaths

Latitude (deg)	Image Sidelap (%)
0	14 0
10	15 4
20	19 1
30	25 6
40	34 1
50	44 8
60	57 0
70	70 6
80	85 0

Table F-3. Coverage Redundancy Due To Imagery Sidelap

Latitude (Deg)	Image Sidelap (%)	Redundancy Factor*	Min Coverage Requirement
0 55	14 - 50	1	Every day
55 - 67	50 67	2	Every 2nd day
67 - 42	67 75	3	Every 3rd day
72 - 74	75 - 80	4	Every 4th day
74 - 76	80 - 85	5	Every 5th day
76 - 82	> 85	6	Every 6th day

*Number of adjoining ground tracks which provide coverage for a given location

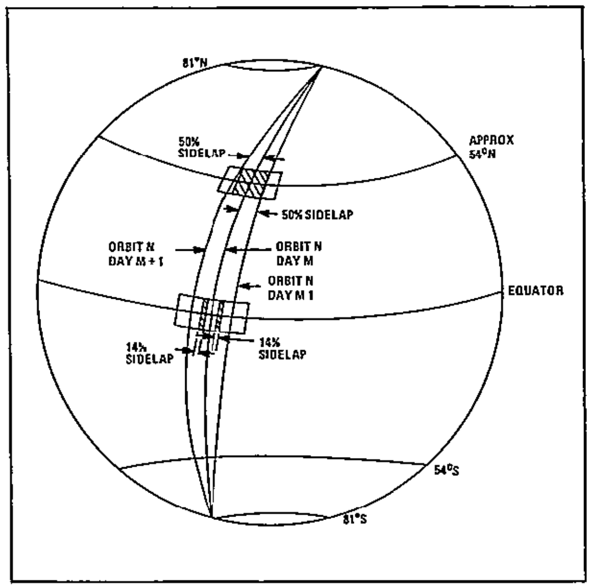

Figure F-6. Landsat Sidelapping Coverage

F.2.3 Repeatability

The Landsat orbit has also been designed so that the swaths viewed during one 18-day coverage cycle repeat or overlay the corresponding swaths viewed on all subsequent coverage cycles. This facilitates comparison of imagery of a given area collected during different coverage cycles. In addition, picture-taking sequences are scheduled so that centers of images taken every 18 days are aligned along the in-track direction. This is accomplished by referencing all payload operation to the equator as indicated in Figure F-7 For example, if imagery of Region A were desired

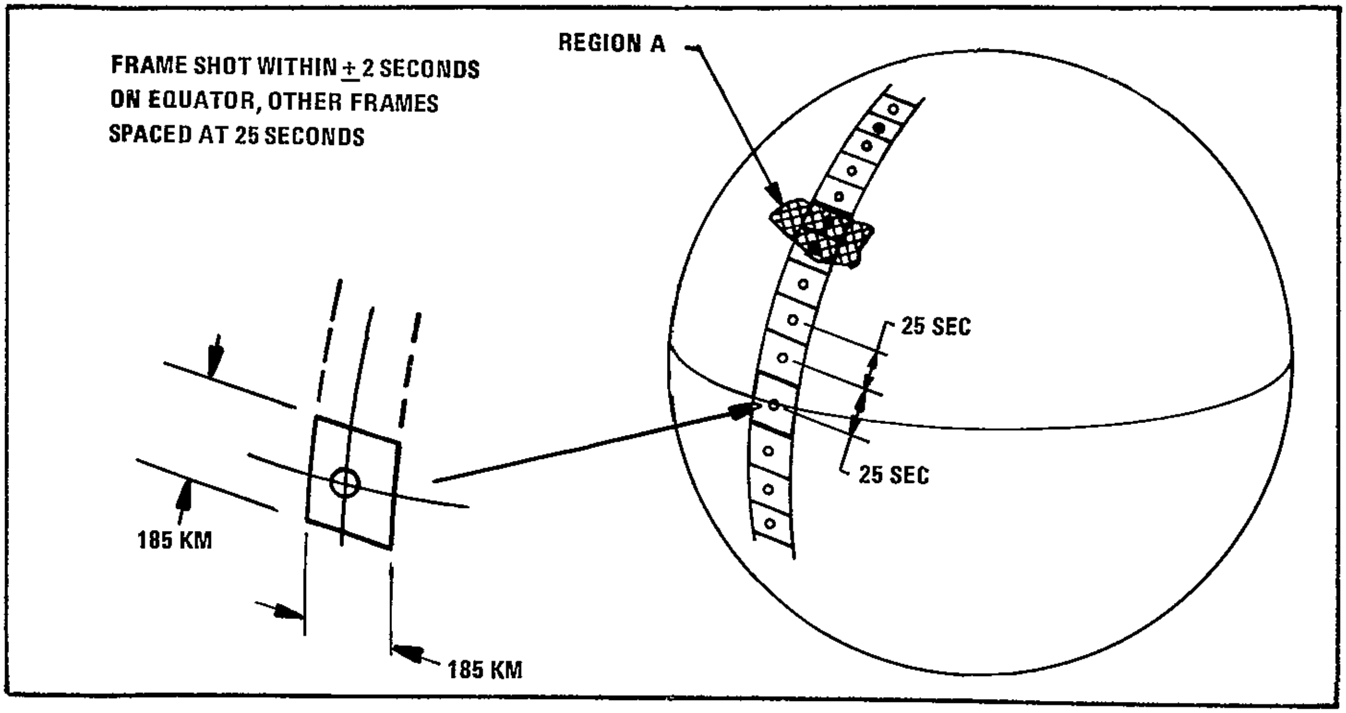

Figure F-7. In-Track Picture Scheduling

in the orbit shown in Figure F-7, it will not be obtained as one picture centered over the region, but will consist of two consecutive images formatted 25 seconds apart. The orbit is maintained such that no more than 37 kilometers cross-track picture-center variation will occur over the mission life. The in-track scheduling will assure that no more than 30 kilometers in-track picture-center variation will occur.

With two satellites operating simultaneously, the relative phasing of their orbits is nominally established to offset the 18-day repeat pattern of one spacecraft by 9 days with respect to the other. In this way, the spacecraft overfly a given area every 9 days. By maintaining both flight orbits to a common nominal repeat-orbit pattern, and by scheduling the operation of each spacecraft with reference to its equator-crossing point, imagery from the two satellites is framed consistently and a 9-day repeat coverage pattern is effectively established. To alleviate communications overlays, Landsat 1 will be moved, during the period October 1976 to February 1977, to a new orbit schedule 6 days behind Landsat 2, giving successive repeat cycles of 6 and 12 days.

F.2.4 Altitude Variations

Selection of a circular orbit minimizes the variations in the altitude of the spacecraft. However, even a pure circular orbit cannot maintain a constant altitude profile due both to the oblate characteristics (polar flattening) of the earth and to perturbing forces upon the satellite such as the gravitational effects of the earth, sun and moon. The combined effects of oblateness and perturbing forces will cause the altitude of the satellite to vary periodically within the range of 880 to 930 km throughout the mission life.

F.2.5 Mean Sun Time

The Landsat orbit is sun-synchronous, as shown in Figure F-8; hence, the geometric relationship between the orbit's descending node (southbound equatorial crossing) and the mean sun's projection into the equatorial plane will remain nearly constant throughout the mission. As a result, the *mean sun* time at each individual point in the orbit will remain fixed and, in fact, all points at a given latitude on descending passes will have the same mean sun time. For Landsat's 1 and 2 the mean sun times of the descending node were initially established at launch as 9 42 and 9 32 a.m., respectively.

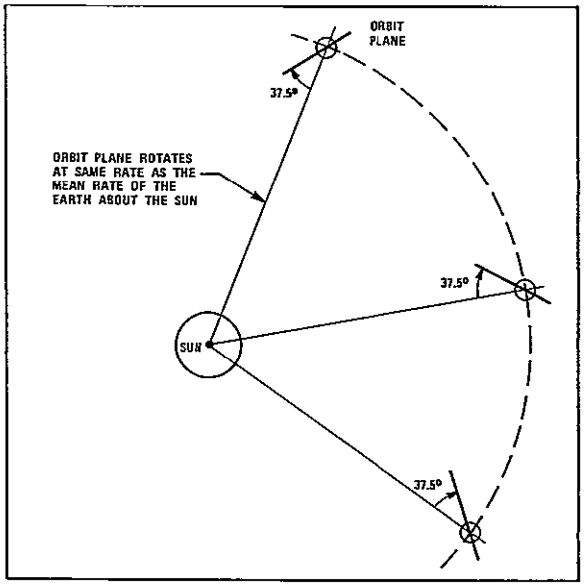

Figure F-8 Motion of Orbit Plane in Sun-Synchronous Orbit

A fixed mean sun time does not mean that the local clock time will remain fixed for all points at a given latitude, however, because discrete time zones are used to determine local time throughout the world. Figure F-9 illustrates a typical variation between mean sun time and local time for sequential satellite equatorial crossings.

The local time that the satellite crosses over a given point at latitudes other than at the equator will also vary due to: (1) the time the satellite takes relative to the equator to reach the given point (103 minutes is required for one complete revolution), and (2) the time zones crossed by the satellite relative to its equatorial crossing point.

Figure F-10 illustrates these effects on local clock time for various points in a typical orbit as a function of latitude.

F.2.6 Determination of Observation Dates

An arbitrary reference system has been established to identify nominal scenes imaged by Landsat. Each scene has been assigned a unique three-digit path number (or orbit number) and a three-digit row number. Figures F-11 through F-17 provide maps of the major earth land masses with Landsat paths and rows overprinted. These maps were prepared by the U.S. Department of the Interior — Geological Survey; the maps also provide cloud cover information on Landsat coverage from July 23, 1972 through July 23, 1974. The coverage symbols used indicate least cloud coverage for a nominal scene. There is at least one scene with the indicated cloud coverage. There may be several images with the same, or more, cloud cover. Symbol meanings are: ● 0%, □ 10%, Ⓐ 20 to 30%, ○ 40 to 50%, and X, 60 through 100% cloud cover

The 251 orbits or paths are repeated every 18 days Table F-4 indicates which orbit paths are flown on each of the 18 days in this cycle. Table F-5A provides a calendar for Landsat 1 and Table F-5B a calendar for Landsat 2, which relate the day of the month to the cycle day. Thus, to determine what orbits are being flown on a specific date, simply enter Table F-5A or 5B for that date and obtain the cycle day for that date. Using the cycle day obtained, enter Table F-4 to find the specific orbit paths for that day. Finally, using Figure F-11 through F-17, specific ground coverage for that day's orbit paths can be determined.

F.2.7 Landsat-C Orbit

Landsat-C will incorporate a fifth band on the MSS that will be sensitive to thermal infrared radiation and can thus be used at night The night orbit paths will be from south to north with a westward tilt such that they intersect daytime orbit paths at an angle of about 18°. Thus, 12-hour repeat coverage will be possible only at a few locations.

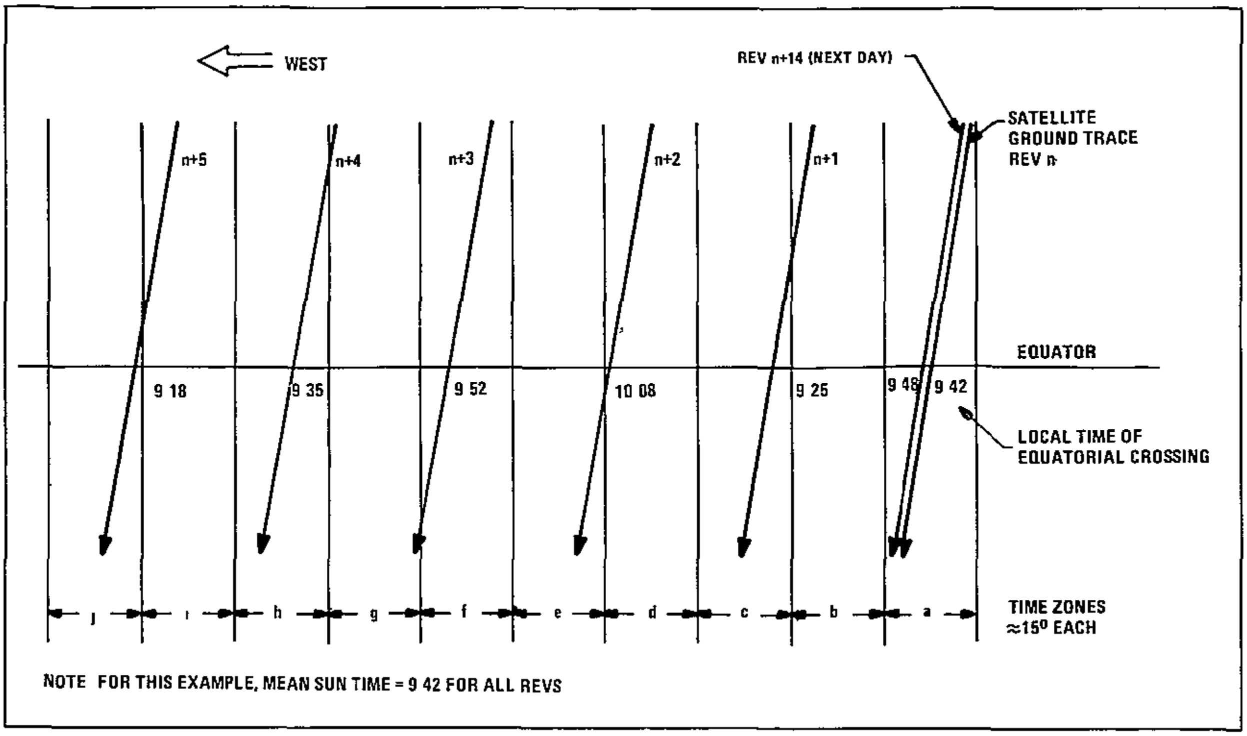

Figure F-9. Typical Variation in Local Time of Equatorial Crossing (Landsat-1)

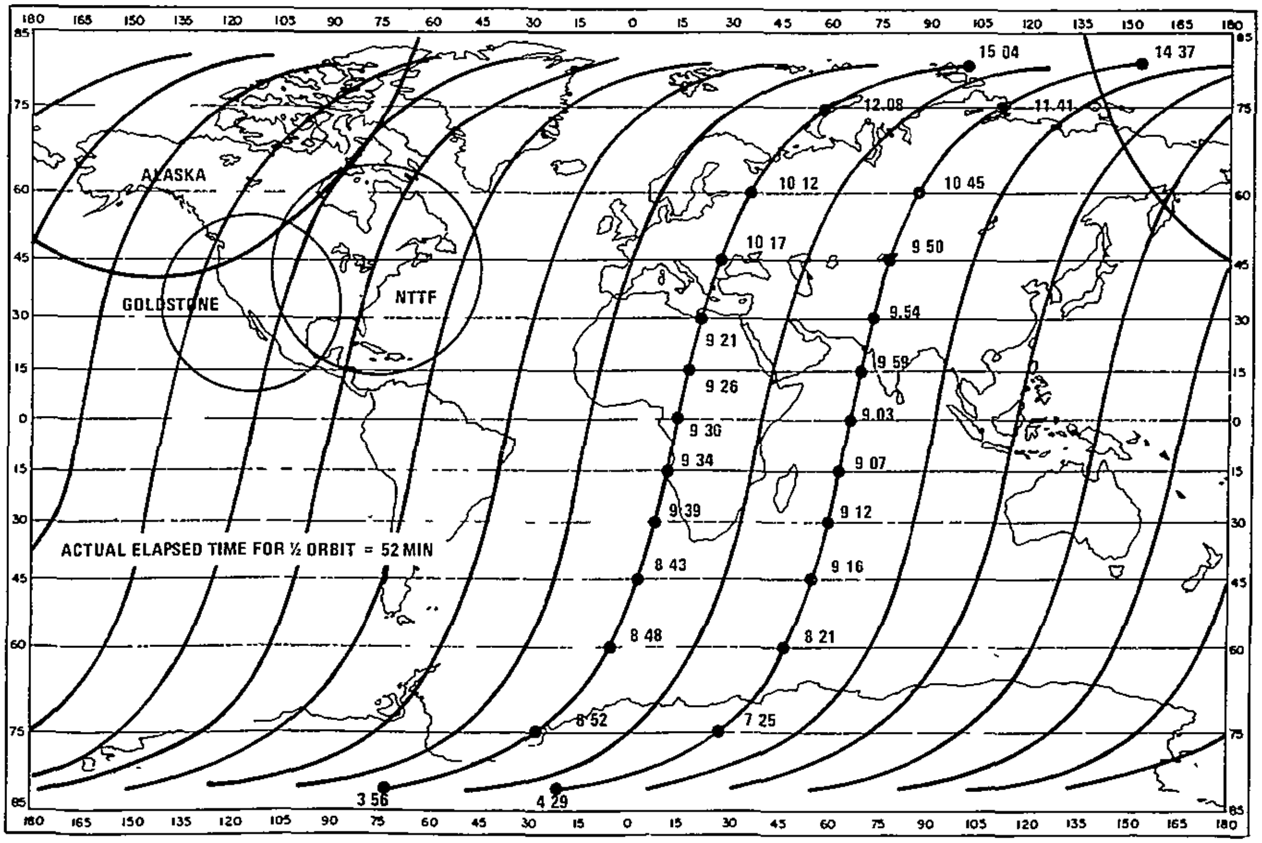

Figure F-10. Local Time — Variations Within an Orbit

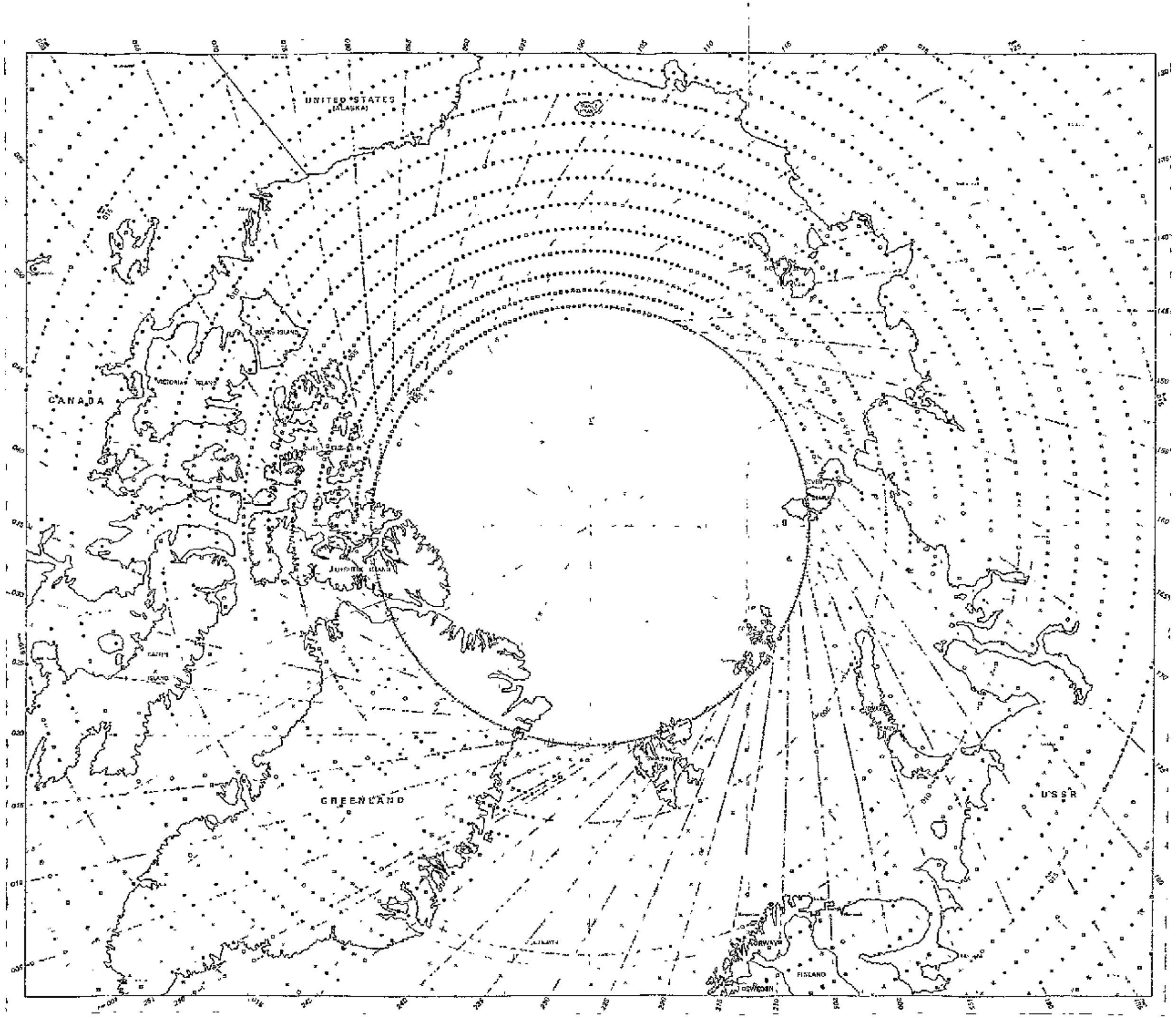

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Figure F-17. Landsat Coverage of the Arctic Ocean

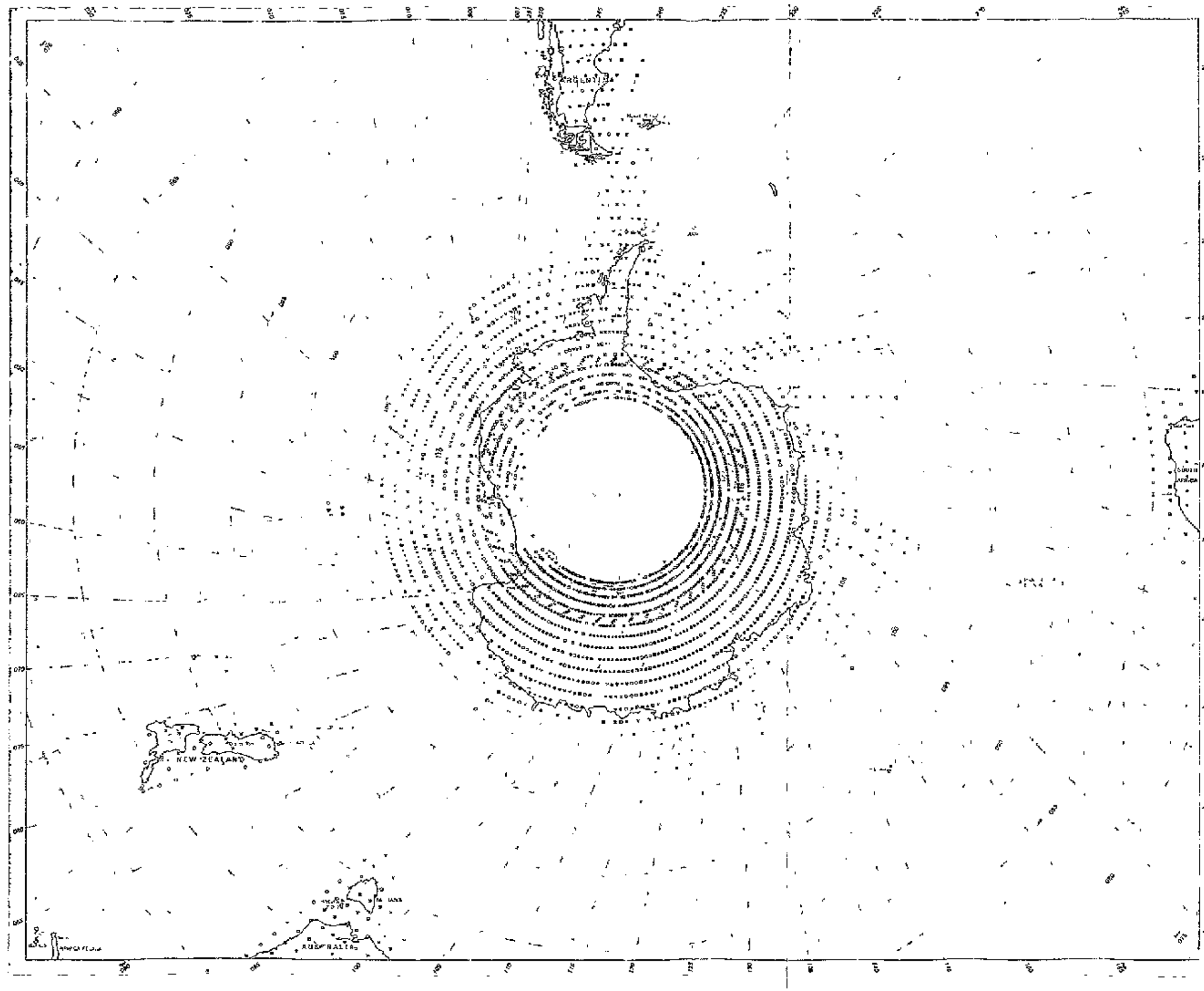

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Figure F-16 Landsat Coverage of Antarctica

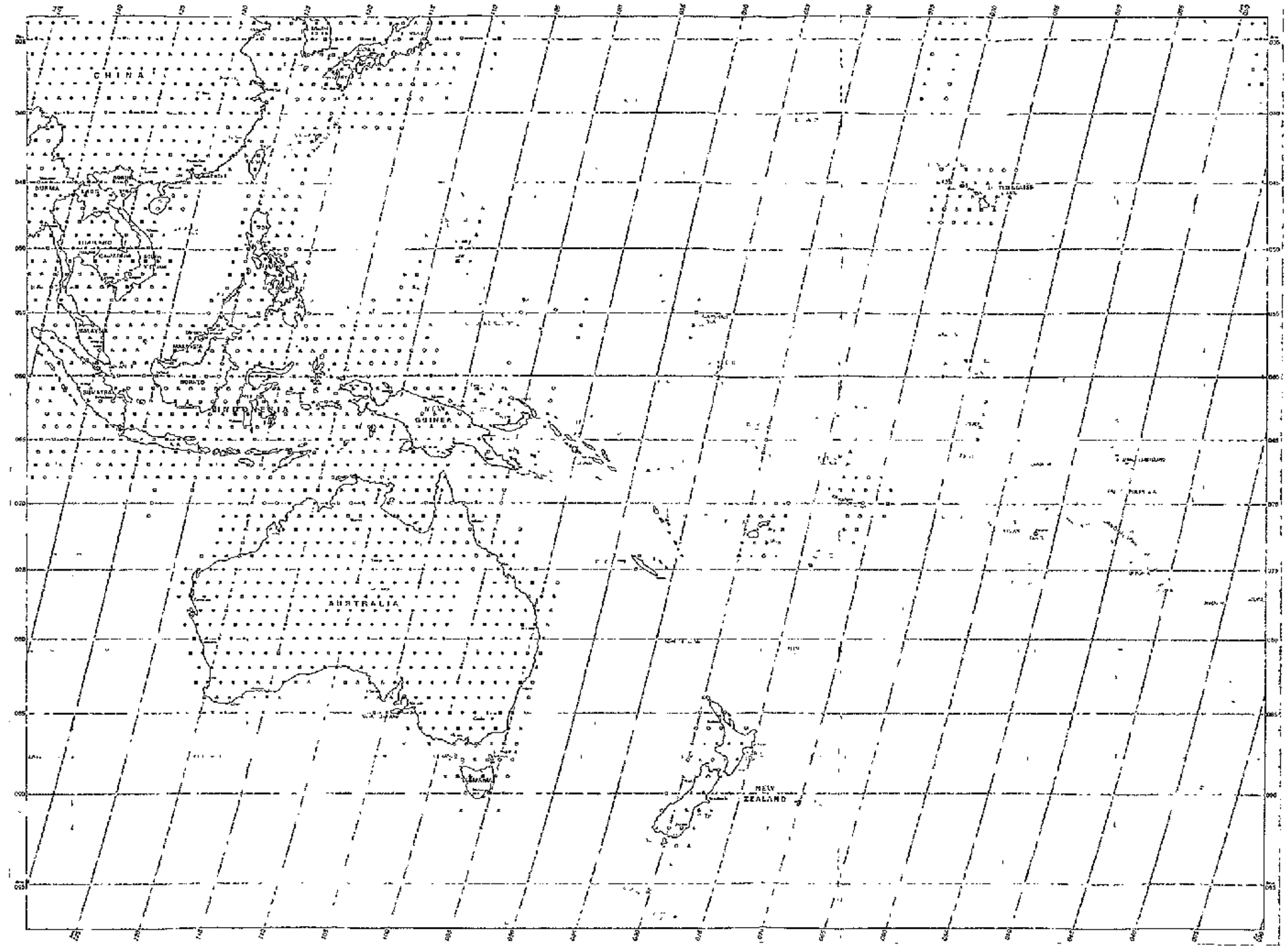

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Figure F-15 Landsat Coverage of Oceania

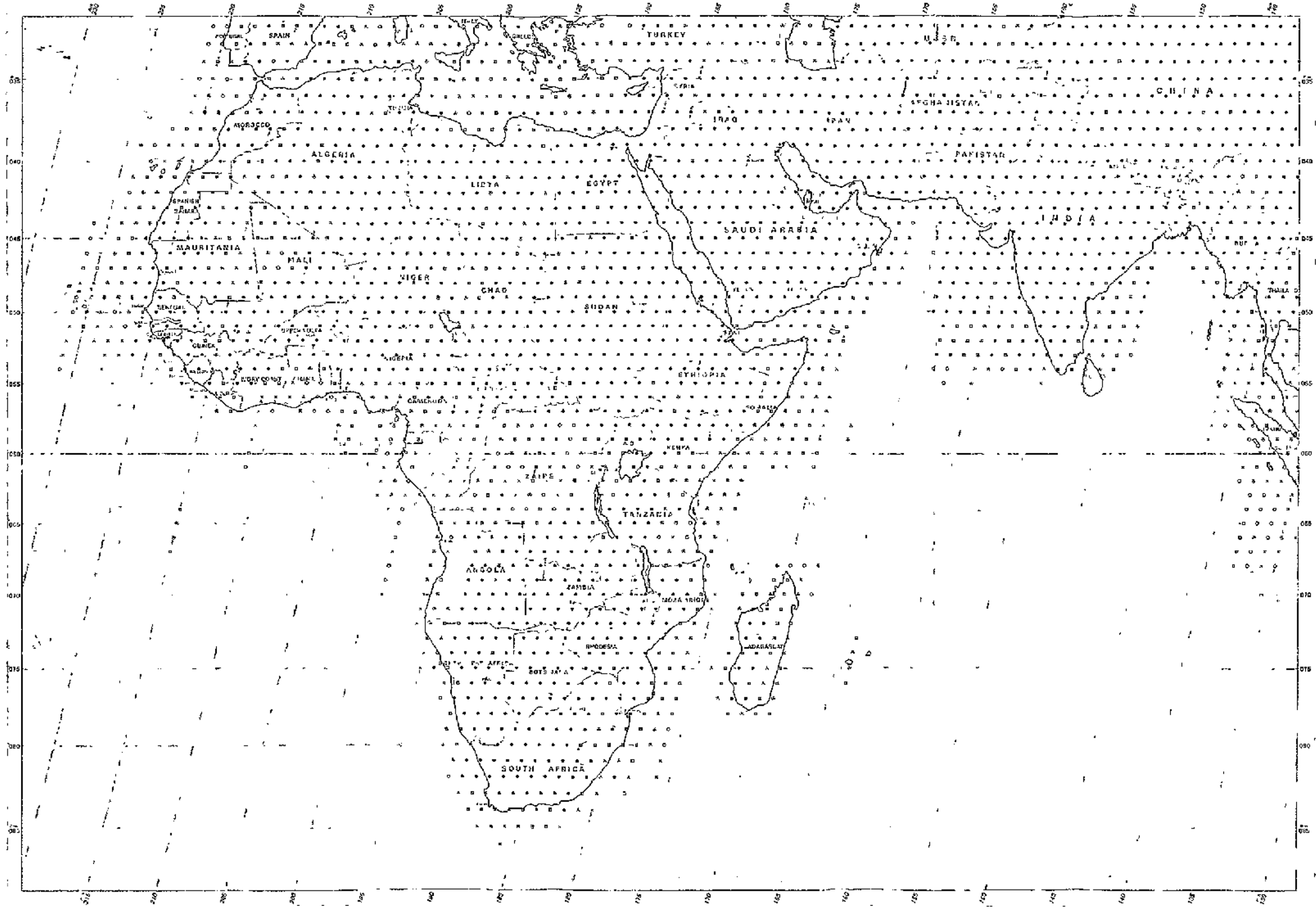

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Figure F-14. Landsat Coverage of Africa

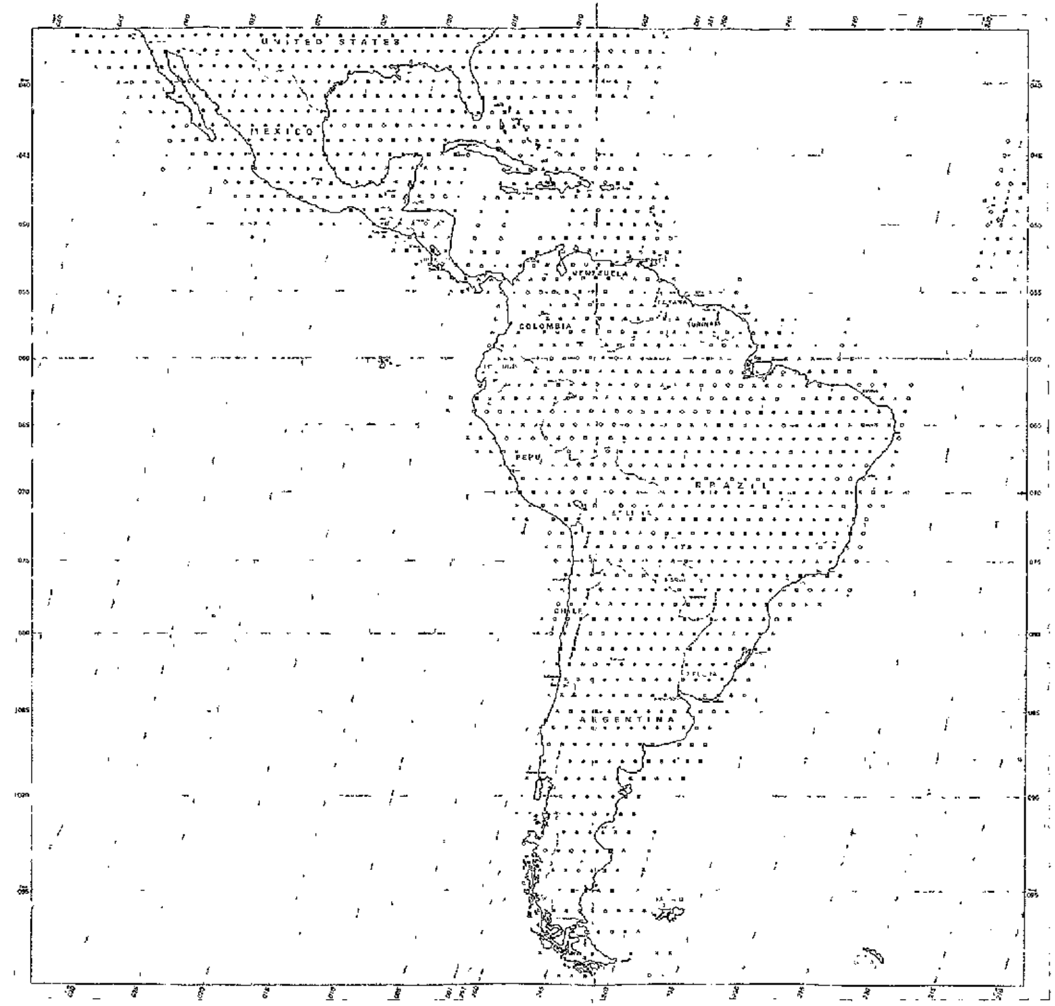

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Figure F-13. Landsat Coverage of South America

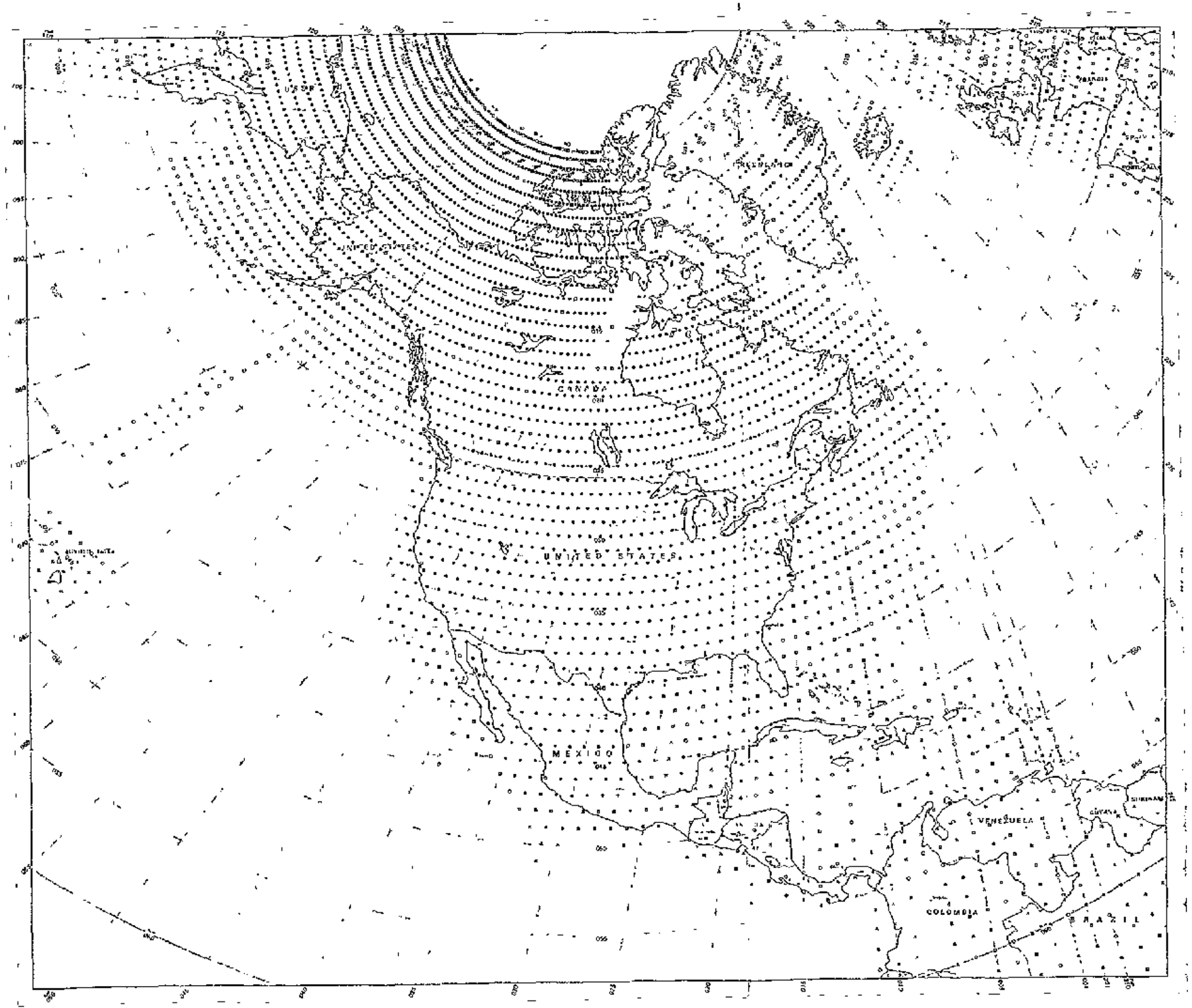

Figure F-12. Landsat Coverage of North America

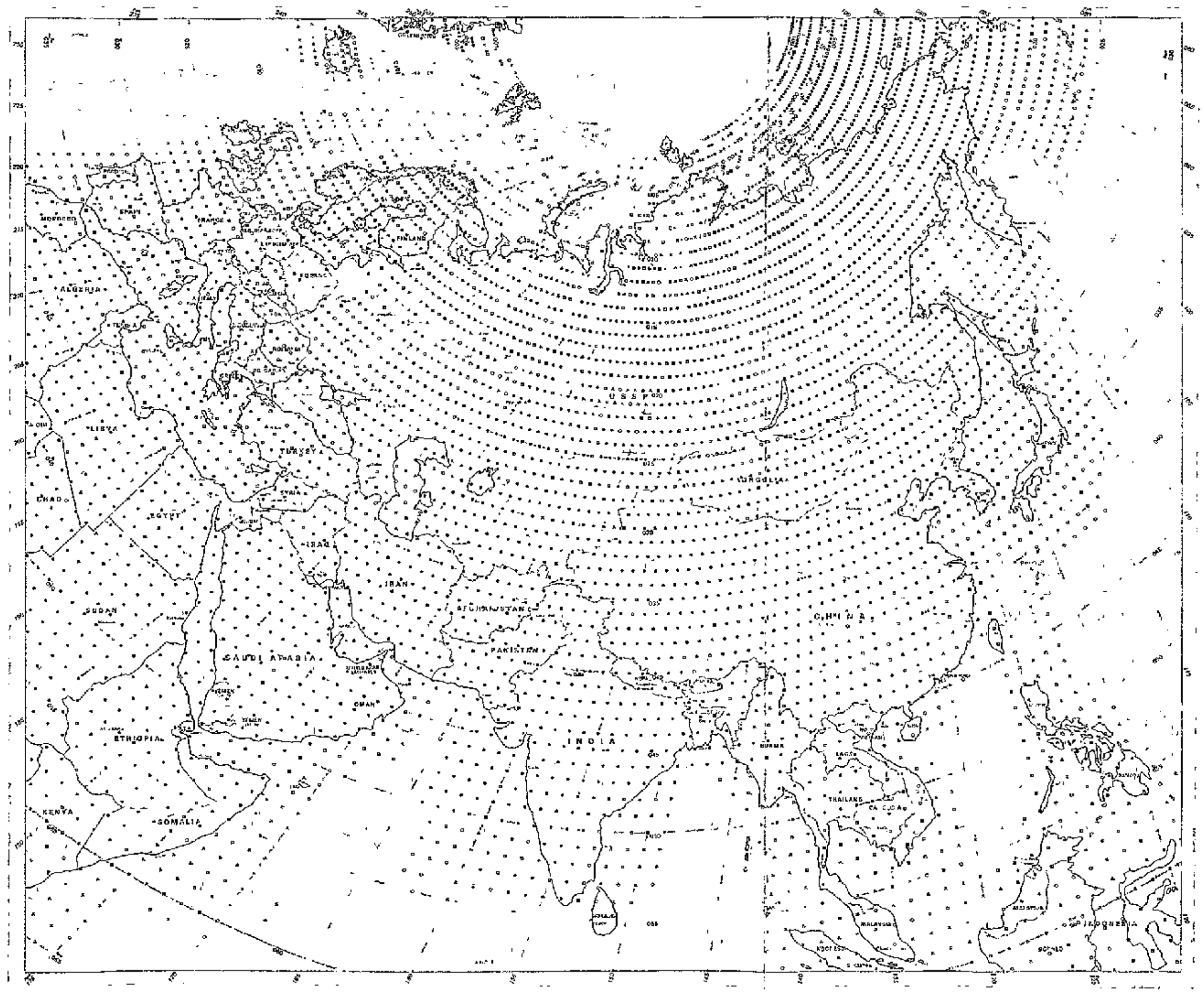

Figure F-11. Landsat Coverage of Eurasia

Table F-5A Landsat 1 Orbit Calendar — 1973

Calendar Date	Cycle Day Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	10	5	15	10	4	17	11	6	1	13	8	2
2	11	6	16	11	5	18	12	7	2	14	9	3
3	12	7	17	12	6	1	13	8	3	15	10	4
4	13	8	18	13	7	2	14	9	4	16	11	5
5	14	9	1	14	8	3	15	10	5	17	12	6
6	15	10	2	15	9	4	16	11	6	18	13	7
7	16	11	3	16	10	5	17	12	7	1	14	8
8	17	12	4	17	11	6	18	13	8	2	15	9
9	18	13	5	18	12	7	1	14	9	3	16	10
10	1	14	6	1	13	8	2	15	10	4	17	11
11	2	15	7	2	14	9	3	16	11	5	18	12
12	3	16	8	3	15	10	4	17	12	6	1	13
13	4	17	9	4	16	11	5	18	13	7	2	14
14	5	18	10	5	17	12	6	1	14	8	3	15
15	6	1	11	6	18	13	7	2	15	9	4	16
16	7	2	12	7	1	14	8	3	16	10	5	17
17	8	3	13	8	2	15	9	4	17	11	6	18
18	9	4	14	9	3	16	10	5	18	12	7	1
19	10	5	15	10	4	17	11	6	1	13	8	2
20	11	6	16	11	5	18	12	7	2	14	9	3
21	12	7	17	12	6	1	13	8	3	15	10	4
22	13	8	18	13	7	2	14	9	4	16	11	5
23	14	9	1	14	8	3	15	10	5	17	12	6
24	15	10	2	15	9	4	16	11	6	18	13	7
25	16	11	3	16	10	5	17	12	7	1	14	8
26	17	12	4	17	11	6	18	13	8	2	15	9
27	18	13	5	18	12	7	1	14	9	3	16	10
28	1	14	6	1	13	8	2	15	10	4	17	11
29	2		7	2	14	9	3	16	11	5	18	12
30	3		8	3	15	10	4	17	12	6	1	13
31	4		9		16		5	18		7		14

Table F-5A. Landsat 1 Orbit Calendar — 1974

Calendar Date	Cycle Day											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	15	10	2	15	9	4	16	11	6	18	13	7
2	16	11	3	16	10	5	17	12	7	1	14	8
3	17	12	4	17	11	6	18	13	8	2	15	9
4	18	13	5	18	12	7	1	14	9	3	16	10
5	1	14	6	1	13	8	2	15	10	4	17	11
6	2	15	7	2	14	9	3	16	11	5	18	12
7	3	16	8	3	15	10	4	17	12	6	1	13
8	4	17	9	4	16	11	5	18	13	7	2	14
9	5	18	10	5	17	12	6	1	14	8	3	15
10	6	1	11	6	18	13	7	2	15	9	4	16
11	7	2	12	7	1	14	8	3	16	10	5	17
12	8	3	13	8	2	15	9	4	17	11	6	18
13	9	4	14	9	3	16	10	5	18	12	7	1
14	10	5	15	10	4	17	11	6	1	13	8	2
15	11	6	16	11	5	18	12	7	2	14	9	3
16	12	7	17	12	6	1	13	8	3	15	10	4
17	13	8	18	13	7	2	14	9	4	16	11	5
18	14	9	1	14	8	3	15	10	5	17	12	6
19	15	10	2	15	9	4	16	11	6	18	13	7
20	16	11	3	16	10	5	17	12	7	1	14	8
21	17	12	4	17	11	6	18	13	8	2	15	9
22	18	13	5	18	12	7	1	14	9	3	16	10
23	1	14	6	1	13	8	2	15	10	4	17	11
24	2	15	7	2	14	9	3	16	11	5	18	12
25	3	16	8	3	15	10	4	17	12	6	1	13
26	4	17	9	4	16	11	5	18	13	7	2	14
27	5	18	10	5	17	12	6	1	14	8	3	15
28	6	1	11	6	18	13	7	2	15	9	4	16
29	7		12	7	1	14	8	3	16	10	5	17
30	8		13	8	2	15	9	4	17	11	6	18
31	9		14		3		10	5		12		1

Table F-5A. Landsat 1 Orbit Calendar — 1975

Calendar Date	Cycle Day Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2	15	7	2	14	9	3	16	11	5	18	12
2	3	16	8	3	15	10	4	17	12	6	1	13
3	4	17	9	4	16	11	5	18	13	7	2	14
4	5	18	10	5	17	12	6	1	14	8	3	15
5	6	1	11	6	18	13	7	2	15	9	4	16
6	7	2	12	7	1	14	8	3	16	10	5	17
7	8	3	13	8	2	15	9	4	17	11	6	18
8	9	4	14	9	3	16	10	5	18	12	7	1
9	10	5	15	10	4	17	11	6	1	13	8	2
10	11	6	16	11	5	18	12	7	2	14	9	3
11	12	7	17	12	6	1	13	8	3	15	10	4
12	13	8	18	13	7	2	14	9	4	16	11	5
13	14	9	1	14	8	3	15	10	5	17	12	6
14	15	10	2	15	9	4	16	11	6	18	13	7
15	16	11	3	16	10	5	17	12	7	1	14	8
16	17	12	4	17	11	6	18	13	8	2	15	9
17	18	13	5	18	12	7	1	14	9	3	16	10
18	1	14	6	1	13	8	2	15	10	4	17	11
19	2	15	7	2	14	9	3	16	11	5	18	12
20	3	16	8	3	15	10	4	17	12	6	1	13
21	4	17	9	4	16	11	5	18	13	7	2	14
22	5	18	10	5	17	12	6	1	14	8	3	15
23	6	1	11	6	18	13	7	2	15	9	4	16
24	7	2	12	7	1	14	8	3	16	10	5	17
25	8	3	13	8	2	15	9	4	17	11	6	18
26	9	4	14	9	3	16	10	5	18	12	7	1
27	10	5	15	10	4	17	11	6	1	13	8	2
28	11	6	16	11	5	18	12	7	2	14	9	3
29	12		17	12	6	1	13	8	3	15	10	4
30	13		18	13	7	2	14	9	4	16	11	5
31	14		1		8		15	10		17		6

Table F-5A. Landsat 1 Orbit Calendar – 1976

Calendar Date	Cycle Day											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	7	2	13	8	2	15	9	4	17	11		
2	8	3	14	9	3	16	10	5	18	12		
3	9	4	15	10	4	17	11	6	1	13		
4	10	5	16	11	5	18	12	7	2	14		
5	11	6	17	12	6	1	13	8	3	15	SPACECRAFT DEACTIVATED	SPACECRAFT DEACTIVATED
6	12	7	18	13	7	2	14	9	4	16		
7	13	8	1	14	8	3	15	10	5	17		
8	14	9	2	15	9	4	16	11	6	18		
9	15	10	3	16	10	5	17	12	7	1		
10	16	11	4	17	11	6	18	13	8	2		
11	17	12	5	18	12	7	1	14	9	3		
12	18	13	6	1	13	8	2	15	10	4		
13	1	14	7	2	14	9	3	16	11	5		
14	2	15	8	3	15	10	4	17	12	6		
15	3	16	9	4	16	11	5	18	13	7		
16	4	17	10	5	17	12	6	1	14	8		
17	5	18	11	6	18	13	7	2	15	9		
18	6	1	12	7	1	14	8	3	16	10		
19	7	2	13	8	2	15	9	4	17	11		
20	8	3	14	9	3	16	10	5	18	SPACECRAFT DEACTIVATED		
21	9	4	15	10	4	17	11	6	1			
22	10	5	16	11	5	18	12	7	2			
23	11	6	17	12	6	1	13	8	3			
24	12	7	18	13	7	2	14	9	4			
25	13	8	1	14	8	3	15	10	5			
26	14	9	2	15	9	4	16	11	6			
27	15	10	3	16	10	5	17	12	7			
28	16	11	4	17	11	6	18	13	8			
29	17	12	5	18	12	7	1	14	9			
30	18		6	1	13	8	2	15	10			
31	1		7		14		3	16				

Table F-5A Landsat 1 Orbit Calendar – 1977

Calendar	Cycle Day											
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	S	11	3	16	10	5	17	12	7	1	14	8
2	P	12	4	17	11	6	18	13	8	2	15	9
3	A	13	5	18	12	7	1	14	9	3	16	10
4	C	14	6	1	13	8	2	15	10	4	17	11
5	E	15	7	2	14	9	3	16	11	5	18	12
6	C	16	8	3	15	10	4	17	12	6	1	13
7	R	17	9	4	16	11	5	18	13	7	2	14
8	A	18	10	5	17	12	6	1	14	8	3	15
9	F	1	11	6	18	13	7	2	15	9	4	16
10	T	2	12	7	1	14	8	3	16	10	5	17
11		3	13	8	2	15	9	4	17	11	6	18
12	D	4	14	9	3	16	10	5	18	12	7	1
13	E	5	15	10	4	17	11	6	1	13	8	2
14	A	6	16	11	5	18	12	7	2	14	9	3
15	C	7	17	12	6	1	13	8	3	15	10	4
16	T	8	18	13	7	2	14	9	4	16	11	5
17	I	9	1	14	8	3	15	10	5	17	12	6
18	V	10	2	15	9	4	16	11	6	18	13	7
19	A	11	3	16	10	5	17	12	7	1	14	8
20	T	12	4	17	11	6	18	13	8	2	15	9
21	E	13	5	18	12	7	1	14	9	3	16	10
22	D	14	6	1	13	8	2	15	10	4	17	11
23		15	7	2	14	9	3	16	11	5	18	12
24		16	8	3	15	10	4	17	12	6	1	13
25		17	9	4	16	11	5	18	13	7	2	14
26		18	10	5	17	12	6	1	14	8	3	15
27		1	11	6	18	13	7	2	15	9	4	16
28		2	12	7	1	14	8	3	16	10	5	17
29			13	8	2	15	9	4	17	11	6	18
30			14	9	3	16	10	5	18	12	7	1
31			15		4		11	6		13		2

Table F-5A Landsat 1 Orbit Calendar — 1978

Calendar Date	Cycle Day Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	16	8	3	15	10	4	17	12	6	1	13
2	4	17	9	4	16	11	5	18	13	7	2	14
3	5	18	10	5	17	12	6	1	14	8	3	15
4	6	1	11	6	18	13	7	2	15	9	4	16
5	7	2	12	7	1	14	8	3	16	10	5	17
6	8	3	13	8	2	15	9	4	17	11	6	18
7	9	4	14	9	3	16	10	5	18	12	7	1
8	10	5	15	10	4	17	11	6	1	13	8	2
9	11	6	16	11	5	18	12	7	2	14	9	3
10	12	7	17	12	6	1	13	8	3	15	10	4
11	13	8	18	13	7	2	14	9	4	16	11	5
12	14	9	1	14	8	3	15	10	5	17	12	6
13	15	10	2	15	9	4	16	11	6	18	13	7
14	16	11	3	16	10	5	17	12	7	1	14	8
15	17	12	4	17	11	6	18	13	8	2	15	9
16	18	13	5	18	12	7	1	14	9	3	16	10
17	1	14	6	1	13	8	2	15	10	4	17	11
18	2	15	7	2	14	9	3	16	11	5	18	12
19	3	16	8	3	15	10	4	17	12	6	1	13
20	4	17	9	4	16	11	5	18	13	7	2	14
21	5	18	10	5	17	12	6	1	14	8	3	15
22	6	1	11	6	18	13	7	2	15	9	4	16
23	7	2	12	7	1	14	8	3	16	10	5	17
24	8	3	13	8	2	15	9	4	17	11	6	18
25	9	4	14	9	3	16	10	5	18	12	7	1
26	10	5	15	10	4	17	11	6	1	13	8	2
27	11	6	16	11	5	18	12	7	2	14	9	3
28	12	7	17	12	6	1	13	8	3	15	10	4
29	13		18	13	7	2	14	9	4	16	11	5
30	14		1	14	8	3	15	10	5	17	12	6
31	15		2		9		16	11		18		7

Table F-5A. Landsat 1 Orbit Calendar — 1979

Calendar Date	Cycle Day Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	8	3	13	8	2	15	9	4	17	11	6	18
2	9	4	14	9	3	16	10	5	18	12	7	1
3	10	5	15	10	4	17	11	6	1	13	8	2
4	11	6	16	11	5	18	12	7	2	14	9	3
5	12	7	17	12	6	1	13	8	3	15	10	4
6	13	8	18	13	7	2	14	9	4	16	11	5
7	14	9	1	14	8	3	15	10	5	17	12	6
8	15	10	2	15	9	4	16	11	6	18	13	7
9	16	11	3	16	10	5	17	12	7	1	14	8
10	17	12	4	17	11	6	18	13	8	2	15	9
11	18	13	5	18	12	7	1	14	9	3	16	10
12	1	14	6	1	13	8	2	15	10	4	17	11
13	2	15	7	2	14	9	3	16	11	5	18	12
14	3	16	8	3	15	10	4	17	12	6	1	13
15	4	17	9	4	16	11	5	18	13	7	2	14
16	5	18	10	5	17	12	6	1	14	8	3	15
17	6	1	11	6	18	13	7	2	15	9	4	16
18	7	2	12	7	1	14	8	3	16	10	5	17
19	8	3	13	8	2	15	9	4	17	11	6	18
20	9	4	14	9	3	16	10	5	18	12	7	1
21	10	5	15	10	4	17	11	6	1	13	8	2
22	11	6	16	11	5	18	12	7	2	14	9	3
23	12	7	17	12	6	1	13	8	3	15	10	4
24	13	8	18	13	7	2	14	9	4	16	11	5
25	14	9	1	14	8	3	15	10	5	17	12	6
26	15	10	2	15	9	4	16	11	6	18	13	7
27	16	11	3	16	10	5	17	12	7	1	14	8
28	17	12	4	17	11	6	18	13	8	2	15	9
29	18		5	18	12	7	1	14	9	3	16	10
30	1		6	1	13	8	2	15	10	4	17	11
31	2		7		14		3	16		5		12

Table F-5A. Landsat 1 Orbit Calendar – 1980

Calendar Date	Cycle Day Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	13	8	1	14	8	3	15	10	5	17	12	6
2	14	9	2	15	9	4	16	11	6	18	13	7
3	15	10	3	16	10	5	17	12	7	1	14	8
4	16	11	4	17	11	6	18	13	8	2	15	9
5	17	12	5	18	12	7	1	14	9	3	16	10
6	18	13	6	1	13	8	2	15	10	4	17	11
7	1	14	7	2	14	9	3	16	11	5	18	12
8	2	15	8	3	15	10	4	17	12	6	1	13
9	3	16	9	4	16	11	5	18	13	7	2	14
10	4	17	10	5	17	12	6	1	14	8	3	15
11	5	18	11	6	18	13	7	2	15	9	4	16
12	6	1	12	7	1	14	8	3	16	10	5	17
13	7	2	13	8	2	15	9	4	17	11	6	18
14	8	3	14	9	3	16	10	5	18	12	7	1
15	9	4	15	10	4	17	11	6	1	13	8	2
16	10	5	16	11	5	18	12	7	2	14	9	3
17	11	6	17	12	6	1	13	8	3	15	10	4
18	12	7	18	13	7	2	14	9	4	16	11	5
19	13	8	1	14	8	3	15	10	5	17	12	6
20	14	9	2	15	9	4	16	11	6	18	13	7
21	15	10	3	16	10	5	17	12	7	1	14	8
22	16	11	4	17	11	6	18	13	8	2	15	9
23	17	12	5	18	12	7	1	14	9	3	16	10
24	18	13	6	1	13	8	2	15	10	4	17	11
25	1	14	7	2	14	9	3	16	11	5	18	12
26	2	15	8	3	15	10	4	17	12	6	1	13
27	3	16	9	4	16	11	5	18	13	7	2	14
28	4	17	10	5	17	12	6	1	14	8	3	15
29	5	18	11	6	18	13	7	2	15	9	4	16
30	6		12	7	1	14	8	3	16	10	5	17
31	7		13		2		9	4		11		18

Table F-5B. Landsat 2 Orbit Calendar — 1975

Calendar Date	Cycle Day											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		6	16	11	5	18	12	7	2	14	9	3
2		7	17	12	6	1	13	8	3	15	10	4
3		8	18	13	7	2	14	9	4	16	11	5
4		9	1	14	8	3	15	10	5	17	12	6
5		10	2	15	9	4	16	11	6	18	13	7
6		11	3	16	10	5	17	12	7	1	14	8
7		12	4	17	11	6	18	13	8	2	15	9
8		13	5	18	12	7	1	14	9	3	16	10
9		14	6	1	13	8	2	15	10	4	17	11
10		15	7	2	14	9	3	16	11	5	18	12
11		16	8	3	15	10	4	17	12	6	1	13
12		17	9	4	16	11	5	18	13	7	2	14
13		18	10	5	17	12	6	1	14	8	3	15
14		1	11	6	18	13	7	2	15	9	4	16
15		2	12	7	1	14	8	3	16	10	5	17
16		3	13	8	2	15	9	4	17	11	6	18
17		4	14	9	3	16	10	5	18	12	7	1
18		5	15	10	4	17	11	6	1	13	8	2
19		6	16	11	5	18	12	7	2	14	9	3
20		7	17	12	6	1	13	8	3	15	10	4
21	13	8	18	13	7	2	14	9	4	16	11	5
22	14	9	1	14	8	3	15	10	5	17	12	6
23	15	10	2	15	9	4	16	11	6	18	13	7
24	16	11	3	16	10	5	17	12	7	1	14	8
25	17	12	4	17	11	6	18	13	8	2	15	9
26	18	13	5	18	12	7	1	14	9	3	16	10
27	1	14	6	1	13	8	2	15	10	4	17	11
28	2	15	7	2	14	9	3	16	11	5	18	12
29	3		8	3	15	10	4	17	12	6	1	13
30	4		9	4	16	11	5	18	13	7	2	14
31	5		10		17		6	1		8		15

Table F-5B. Landsat 2 Orbit Calendar – 1976

Calendar Date	Cycle Day Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	16	11	4	17	11	6	18	13	8	2	15	9
2	17	12	5	18	12	7	1	14	9	3	16	10
3	18	13	6	1	13	8	2	15	10	4	17	11
4	1	14	7	2	14	9	3	16	11	5	18	12
5	2	15	8	3	15	10	4	17	12	6	1	13
6	3	16	9	4	16	11	5	18	13	7	2	14
7	4	17	10	5	17	12	6	1	14	8	3	15
8	5	18	11	6	18	13	7	2	15	9	4	16
9	6	1	12	7	1	14	8	3	16	10	5	17
10	7	2	13	8	2	15	9	4	17	11	6	18
11	8	3	14	9	3	16	10	5	18	12	7	1
12	9	4	15	10	4	17	11	6	1	13	8	2
13	10	5	16	11	5	18	12	7	2	14	9	3
14	11	6	17	12	6	1	13	8	3	15	10	4
15	12	7	18	13	7	2	14	9	4	16	11	5
16	13	8	1	14	8	3	15	10	5	17	12	6
17	14	9	2	15	9	4	16	11	6	18	13	7
18	15	10	3	16	10	5	17	12	7	1	14	8
19	16	11	4	17	11	6	18	13	8	2	15	9
20	17	12	5	18	12	7	1	14	9	3	16	10
21	18	13	6	1	13	8	2	15	10	4	17	11
22	1	14	7	2	14	9	3	16	11	5	18	12
23	2	15	8	3	15	10	4	17	12	6	1	13
24	3	16	9	4	16	11	5	18	13	7	2	14
25	4	17	10	5	17	12	6	1	14	8	3	15
26	5	18	11	6	18	13	7	2	15	9	4	16
27	6	1	12	7	1	14	8	3	16	10	5	17
28	7	2	13	8	2	15	9	4	17	11	6	18
29	8	3	14	9	3	16	10	5	18	12	7	1
30	9		15	10	4	17	11	6	1	13	8	2
31	10		16		5		12	7		14		3

Table F-5B Landsat 2 Orbit Calendar — 1977

Calendar Date	Cycle Day											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	4	17	9	4	16	11	5	18	13	7	2	14
2	5	18	10	5	17	12	6	1	14	8	3	15
3	6	1	11	6	18	13	7	2	15	9	4	16
4	7	2	12	7	1	14	8	3	16	10	5	17
5	8	3	13	8	2	15	9	4	17	11	6	18
6	9	4	14	9	3	16	10	5	18	12	7	1
7	10	5	15	10	4	17	11	6	1	13	8	2
8	11	6	16	11	5	18	12	7	2	14	9	3
9	12	7	17	12	6	1	13	8	3	15	10	4
10	13	8	18	13	7	2	14	9	4	16	11	5
11	14	9	1	14	8	3	15	10	5	17	12	6
12	15	10	2	15	9	4	16	11	6	18	13	7
13	16	11	3	16	10	5	17	12	7	1	14	8
14	17	12	4	17	11	6	18	13	8	2	15	9
15	18	13	5	18	12	7	1	14	9	3	16	10
16	1	14	6	1	13	8	2	15	10	4	17	11
17	2	15	7	2	14	9	3	16	11	5	18	12
18	3	16	8	3	15	10	4	17	12	6	1	13
19	4	17	9	4	16	11	5	18	13	7	2	14
20	5	18	10	5	17	12	6	1	14	8	3	15
21	6	1	11	6	18	13	7	2	15	9	4	16
22	7	2	12	7	1	14	8	3	16	10	5	17
23	8	3	13	8	2	15	9	4	17	11	6	18
24	9	4	14	9	3	16	10	5	18	12	7	1
25	10	5	15	10	4	17	11	6	1	13	8	2
26	11	6	16	11	5	18	12	7	2	14	9	3
27	12	7	17	12	6	1	13	8	3	15	10	4
28	13	8	18	13	7	2	14	9	4	16	11	5
29	14		1	14	8	3	15	10	5	17	12	6
30	15		2	15	9	4	16	11	6	18	13	7
31	16		3		10		17	12		1		8

Table F-5B. Landsat 2 Orbit Calendar — 1978

Calendar Date	Cycle Day											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	9	4	14	9	3	16	10	5	18	12	7	1
2	10	5	15	10	4	17	11	6	1	13	8	2
3	11	6	16	11	5	18	12	7	2	14	9	3
4	12	7	17	12	6	1	13	8	3	15	10	4
5	13	8	18	13	7	2	14	9	4	16	11	5
6	14	9	1	14	8	3	15	10	5	17	12	6
7	15	10	2	15	9	4	16	11	6	18	13	7
8	16	11	3	16	10	5	17	12	7	1	14	8
9	17	12	4	17	11	6	18	13	8	2	15	9
10	18	13	5	18	12	7	1	14	9	3	16	10
11	1	14	6	1	13	8	2	15	10	4	17	11
12	2	15	7	2	14	9	3	16	11	5	18	12
13	3	16	8	3	15	10	4	17	12	6	1	13
14	4	17	9	4	16	11	5	18	13	7	2	14
15	5	18	10	5	17	12	6	1	14	8	3	15
16	6	1	11	6	18	13	7	2	15	9	4	16
17	7	2	12	7	1	14	8	3	16	10	5	17
18	8	3	13	8	2	15	9	4	17	11	6	18
19	9	4	14	9	3	16	10	5	18	12	7	1
20	10	5	15	10	4	17	11	6	1	13	8	2
21	11	6	16	11	5	18	12	7	2	14	9	3
22	12	7	17	12	6	1	13	8	3	15	10	4
23	13	8	18	13	7	2	14	9	4	16	11	5
24	14	9	1	14	8	3	15	10	5	17	12	6
25	15	10	2	15	9	4	16	11	6	18	13	7
26	16	11	3	16	10	5	17	12	7	1	14	8
27	17	12	4	17	11	6	18	13	8	2	15	9
28	18	13	5	18	12	7	1	14	9	3	16	10
29	1		6	1	13	8	2	15	10	4	17	11
30	2		7	2	14	9	3	16	11	5	18	12
31	3		8		15		4	17		6		13

Table F-5B. Landsat 2 Orbit Calendar — 1979

Calendar Date	Cycle Day											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	14	9	1	14	8	3	15	10	5	17	12	6
2	15	10	2	15	9	4	16	11	6	18	13	7
3	16	11	3	16	10	5	17	12	7	1	14	8
4	17	12	4	17	11	6	18	13	8	2	15	9
5	18	13	5	18	12	7	1	14	9	3	16	10
6	1	14	6	1	13	8	2	15	10	4	17	11
7	2	15	7	2	14	9	3	16	11	5	18	12
8	3	16	8	3	15	10	4	17	12	6	1	13
9	4	17	9	4	16	11	5	18	13	7	2	14
10	5	18	10	5	17	12	6	1	14	8	3	15
11	6	1	11	6	18	13	7	2	15	9	4	16
12	7	2	12	7	1	14	8	3	16	10	5	17
13	8	3	13	8	2	15	9	4	17	11	6	18
14	9	4	14	9	3	16	10	5	18	12	7	1
15	10	5	15	10	4	17	11	6	1	13	8	2
16	11	6	16	11	5	18	12	7	2	14	9	3
17	12	7	17	12	6	1	13	8	3	15	10	4
18	13	8	18	13	7	2	14	9	4	16	11	5
19	14	9	1	14	8	3	15	10	5	17	12	6
20	15	10	2	15	9	4	16	11	6	18	13	7
21	16	11	3	16	10	5	17	12	7	1	14	8
22	17	12	4	17	11	6	18	13	8	2	15	9
23	18	13	5	18	12	7	1	14	9	3	16	10
24	1	14	6	1	13	8	2	15	10	4	17	11
25	2	15	7	2	14	9	3	16	11	5	18	12
26	3	16	8	3	15	10	4	17	12	6	1	13
27	4	17	9	4	16	11	5	18	13	7	2	14
28	5	18	10	5	17	12	6	1	14	8	3	15
29	6		11	6	18	13	7	2	15	9	4	16
30	7		12	7	1	14	8	3	16	10	5	17
31	8		13		2		9	4		11		18

Table F-5B. Landsat 2 Orbit Calendar — 1980

Calendar Date	Cycle Day											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	14	7	2	14	9	3	16	11	5	18	12
2	2	15	8	3	15	10	4	17	12	6	1	13
3	3	16	9	4	16	11	5	18	13	7	2	14
4	4	17	10	5	17	12	6	1	14	8	3	15
5	5	18	11	6	18	13	7	2	15	9	4	16
6	6	1	12	7	1	14	8	3	16	10	5	17
7	7	2	13	8	2	15	9	4	17	11	6	18
8	8	3	14	9	3	16	10	5	18	12	7	1
9	9	4	15	10	4	17	11	6	1	13	8	2
10	10	5	16	11	5	18	12	7	2	14	9	3
11	11	6	17	12	6	1	13	8	3	15	10	4
12	12	7	18	13	7	2	14	9	4	16	11	5
13	13	8	1	14	8	3	15	10	5	17	12	6
14	14	9	2	15	9	4	16	11	6	18	13	7
15	15	10	3	16	10	5	17	12	7	1	14	8
16	16	11	4	17	11	6	18	13	8	2	15	9
17	17	12	5	18	12	7	1	14	9	3	16	10
18	18	13	6	1	13	8	2	15	10	4	17	11
19	1	14	7	2	14	9	3	16	11	5	18	12
20	2	15	8	3	15	10	4	17	12	6	1	13
21	3	16	9	4	16	11	5	18	13	7	2	14
22	4	17	10	5	17	12	6	1	14	8	3	15
23	5	18	11	6	18	13	7	2	15	9	4	16
24	6	1	12	7	1	14	8	3	16	10	5	17
25	7	2	13	8	2	15	9	4	17	11	6	18
26	8	3	14	9	3	16	10	5	18	12	7	1
27	9	4	15	10	4	17	11	6	1	13	8	2
28	10	5	16	11	5	18	12	7	2	14	9	3
29	11	6	17	12	6	1	13	8	3	15	10	4
30	12		18	13	7	2	14	9	4	16	11	5
31	13		1		8		15	10		17		6

Table F-5B Landsat 2 Orbit Calendar — 1981

Calendar Date	Cycle Day											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	7	2	12	7	1	14	8	3	16	10	5	17
2	8	3	13	8	2	15	9	4	17	11	6	18
3	9	4	14	9	3	16	10	5	18	12	7	1
4	10	5	15	10	4	17	11	6	1	13	8	2
5	11	6	16	11	5	18	12	7	2	14	9	3
6	12	7	17	12	6	1	13	8	3	15	10	4
7	13	8	18	13	7	2	14	9	4	16	11	5
8	14	9	1	14	8	3	15	10	5	17	12	6
9	15	10	2	15	9	4	16	11	6	18	13	7
10	16	11	3	16	10	5	17	12	7	1	14	8
11	17	12	4	17	11	6	18	13	8	2	15	9
12	18	13	5	18	12	7	1	14	9	3	16	10
13	1	14	6	1	13	8	2	15	10	4	17	11
14	2	15	7	2	14	9	3	16	11	5	18	12
15	3	16	8	3	15	10	4	17	12	6	1	13
16	4	17	9	4	16	11	5	18	13	7	2	14
17	5	18	10	5	17	12	6	1	14	8	3	15
18	6	1	11	6	18	13	7	2	15	9	4	16
19	7	2	12	7	1	14	8	3	16	10	5	17
20	8	3	13	8	2	15	9	4	17	11	6	18
21	9	4	14	9	3	16	10	5	18	12	7	1
22	10	5	15	10	4	17	11	6	1	13	8	2
23	11	6	16	11	5	18	12	7	2	14	9	3
24	12	7	17	12	6	1	13	8	3	15	10	4
25	13	8	18	13	7	2	14	9	4	16	11	5
26	14	9	1	14	8	3	15	10	5	17	12	6
27	15	10	2	15	9	4	16	11	6	18	13	7
28	16	11	3	16	10	5	17	12	7	1	14	8
29	17		4	17	11	6	18	13	8	2	15	9
30	18		5	18	12	7	1	14	9	3	16	10
31	1		6		13		2	15		4		11

Table F-5B Landsat 2 Orbit Calendar – 1982

Calendar Date	Cycle Day Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	12	7	17	12	6	1	13	8	3	15	10	4
2	13	8	18	13	7	2	14	9	4	16	11	5
3	14	9	1	14	8	3	15	10	5	17	12	6
4	15	10	2	15	9	4	16	11	6	18	13	7
5	16	11	3	16	10	5	17	12	7	1	14	8
6	17	12	4	17	11	6	18	13	8	2	15	9
7	18	13	5	18	12	7	1	14	9	3	16	10
8	1	14	6	1	13	8	2	15	10	4	17	11
9	2	15	7	2	14	9	3	16	11	5	18	12
10	3	16	8	3	15	10	4	17	12	6	1	13
11	4	17	9	4	16	11	5	18	13	7	2	14
12	5	18	10	5	17	12	6	1	14	8	3	15
13	6	1	11	6	18	13	7	2	15	9	4	16
14	7	2	12	7	1	14	8	3	16	10	5	17
15	8	3	13	8	2	15	9	4	17	11	6	18
16	9	4	14	9	3	16	10	5	18	12	7	1
17	10	5	15	10	4	17	11	6	1	13	8	2
18	11	6	16	11	5	18	12	7	2	14	9	3
19	12	7	17	12	6	1	13	8	3	15	10	4
20	13	8	18	13	7	2	14	9	4	16	11	5
21	14	9	1	14	8	3	15	10	5	17	12	6
22	15	10	2	15	9	4	16	11	6	18	13	7
23	16	11	3	16	10	5	17	12	7	1	14	8
24	17	12	4	17	11	6	18	13	8	2	15	9
25	18	13	5	18	12	7	1	14	9	3	16	10
26	1	14	6	1	13	8	2	15	10	4	17	11
27	2	15	7	2	14	9	3	16	11	5	18	12
28	3	16	8	3	15	10	4	17	12	6	1	13
29	4		9	4	16	11	5	18	13	7	2	14
30	5		10	5	17	12	6	1	14	8	3	15
31	6		11		18		7	2		9		16

Table F-5B. Landsat 2 Orbit Calendar — 1983

Calendar Date	Cycle Day											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	17	12	4	17	11	6	18	13	8	2	15	9
2	18	13	5	18	12	7	1	14	9	3	16	10
3	1	14	6	1	13	8	2	15	10	4	17	11
4	2	15	7	2	14	9	3	16	11	5	18	12
5	3	16	8	3	15	10	4	17	12	6	1	13
6	4	17	9	4	16	11	5	18	13	7	2	14
7	5	18	10	5	17	12	6	1	14	8	3	15
8	6	1	11	6	18	13	7	2	15	9	4	16
9	7	2	12	7	1	14	8	3	16	10	5	17
10	8	3	13	8	2	15	9	4	17	11	6	18
11	9	4	14	9	3	16	10	5	18	12	7	1
12	10	5	15	10	4	17	11	6	1	13	8	2
13	11	6	16	11	5	18	12	7	2	14	9	3
14	12	7	17	12	6	1	13	8	3	15	10	4
15	13	8	18	13	7	2	14	9	4	16	11	5
16	14	9	1	14	8	3	15	10	5	17	12	6
17	15	10	2	15	9	4	16	11	6	18	13	7
18	16	11	3	16	10	5	17	12	7	1	14	8
19	17	12	4	17	11	6	18	13	8	2	15	9
20	18	13	5	18	12	7	1	14	9	3	16	10
21	1	14	6	1	13	8	2	15	10	4	17	11
22	2	15	7	2	14	9	3	16	11	5	18	12
23	3	16	8	3	15	10	4	17	12	6	1	13
24	4	17	9	4	16	11	5	18	13	7	2	14
25	5	18	10	5	17	12	6	1	14	8	3	15
26	6	1	11	6	18	13	7	2	15	9	4	16
27	7	2	12	7	1	14	8	3	16	10	5	17
28	8	3	13	8	2	15	9	4	17	11	6	18
29	9		14	9	3	16	10	5	18	12	7	1
30	10		15	10	4	17	11	6	1	13	8	2
31	11		16		5		12	7		14		3

F.3 OPERATIONS CONTROL CENTER

The Operations Control Center (OCC) at GSFC is the focal point of all communications with both Landsat spacecraft. All spacecraft and operations scheduling, commanding and spacecraft related data evaluation for the Landsat missions are controlled by the OCC. Its 24-hour-a-day activities are geared to the operational timeline dictated by the orbit and ground station coverage capabilities. The major elements of the OCC are shown in Figure F-18.

F.3.1 System Scheduling

At the beginning of each spacecraft day the activity plans for that day are generated by the OCC for each orbit's operation, based on sensor coverage requirements, spacecraft and payload status, network availability and the current cloud-cover predictions. Priorities are assigned to coverage requirements for selecting the data to be collected over various geographic locations as described in Section F.4. Sensor operations, including real-time and remote coverage, and calibrations are scheduled. Current spacecraft and payload status are examined to ensure effective utilization of observatory capabilities. Tracking and orbit adjust requirements are obtained from the NASA Orbit Determination Group when required and are integrated with coverage planning. Scheduling is coordinated with the network operations center and station availability is determined for both routine contact operations and orbit-adjust maneuvers. After integration of all the required data sources and support activities, a final activity plan is issued. This plan is the integrated, time-ordered sequence of events defining the spacecraft, payload, and ground system operations for each orbit, and serves as the basis for the compilation of spacecraft command lists.

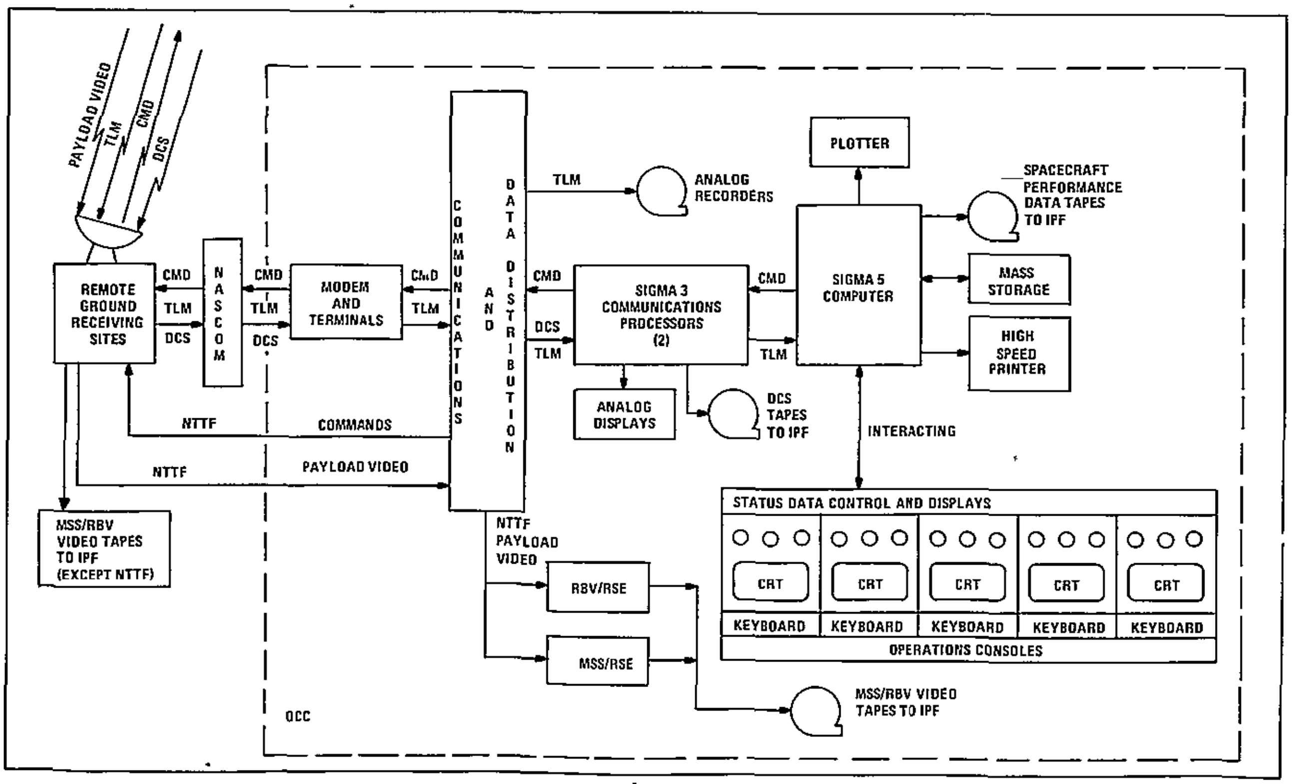

Figure F-18. Major Elements of Operations Control Center

F.3.2 Data Acquisition

After acquisition of telemetry signals from the spacecraft, the narrowband housekeeping data (real time and playback) and Data Collection System (DCS) information are routed via the NASA Communication (NASCOM) network to the OCC. The real-time spacecraft data are then displayed on five operations consoles where computer-driven status lights and CRT displays provide the spacecraft evaluators with a complete on-line determination of vehicle and payload status, performance, and health, as well as command verification DCS data are also processed in the OCC on-pass and placed on magnetic tape. These tapes are available immediately post-pass for continued processing in the NASA Image Processing Facility (IPF).

In-depth spacecraft evaluation and image annotation information are derived from the data stored on the narrowband tape recorders. These data contain all the satellite telemetry for the entire orbit, including all remote areas. Playback data are received during the station post-pass to produce detailed spacecraft evaluation parameters and trends. The Spacecraft Performance Data Tape is also generated from this playback data and given to the IPF for use in generation of image annotation parameters.

Video data received during Network Test and Training Facility (NTTF) station passes are relayed directly to the OCC where they are processed in the identical manner as at other remote sites as outlined in Appendix D. The video tapes generated in the OCC are hand-carried to the IPF for image processing.

F.3.3 Command Generation

The Landsat spacecraft are commanded by an operator at either of two operations consoles located in the OCC. All commands are checked and then routed by the OCC computer system to the remote receiving site that is in contact with the satellite. At the site, an "as transmitted" command check is performed and command acknowledgements are relayed back to the OCC. Final command verification is made through analysis of telemetry data

F.4 MISSION PLANNING

Each spacecraft has access to all global areas between 81 degrees north and 81 degrees south latitude every 18 days. However, due to constraining factors both within and external to the Landsat system, not all of this area can be imaged all the time. The constraints include:

1. On-board tape recorder capacity of 30 minutes maximum
2. On-board command memory capability for switching sensors on and off
3. Ground station availability and contact time duration
4. Global landmass distribution
5. Ground scene illumination conditions
6. Cloud cover

The purpose of the mission planning function is to define the sequence of spacecraft and ground-station operations to maximize the imagery yield while operating within these constraints. The output is a time-ordered sequence of events that define all sensor, wideband tape recorder, and assorted routine spacecraft functions. This sequence of events is then used to define the specific commands for operating the spacecraft. In addition, the mission planning function defines the events that are to occur during every spacecraft/ground station contact.

The bulk of the mission planning operation is done once a day and results in activity plans for that day's operation. These plans are updated on an orbit-by-orbit basis as required to account for any last-minute anomalous occurrences such as ground station outages.

Figure F-3 illustrates the coverage for a typical day's operation for Landsat. Each spacecraft will normally be scheduled to send real-time (direct) data whenever it is concurrently over an area of interest and is within view of a ground station that can receive Landsat data. The three primary Landsat stations shown in Figure F-3 (NTTF, Goldstone, and Alaska) provide coverage of most of North America and real-time imagery transmission is normally scheduled during this time. Data recovery over the rest of the globe is performed by recording the data on the on-board wideband video tape recorders and playing back during subsequent ground station contacts.

During remote operations the spacecraft has access to much more coverage area than can be accommodated by the wideband tape recorders. Therefore, a selection process is required to determine which areas are to be recorded during any given remote operation. To assist in this selection process, a system of priorities is used for all coverage areas of the world. By scheduling payload operations based on these priorities, coverage of the areas of greatest investigator interest is assured.

In order to establish the priorities, several factors must be considered. These include:

1. Scientific importance of the area — is there investigator interest in a given area and how often need it be imaged?
2. Season of the year — when is imagery of that area most/least desirable?
3. Lighting conditions — image quality varies with scene contrast and brightness which in turn varies with local sun angle; what lighting conditions are required for the given scene?
4. Time since the area was last imaged — how recent is the imagery for that area; was it obscured by clouds?

The priorities in the system are quite dynamic in that they must be periodically updated to reflect changes in the desirability of imaging the various areas. The investigator's requests for data provide information to the Landsat Project to assist in defining the various areas of interest and priorities.

Predicted cloud cover data is used in mission planning to minimize the number of obscured images. Prediction data is received from the National Oceanographic & Atmospheric Administration (NOAA) on a periodic basis and the spacecraft schedule is updated as near as possible to the upcoming data pass to include the most recent cloud information. Due to spacecraft command constraints, the sensors and recorders can be switched on and off only a limited number of times; hence, some imagery of fully cloud-covered areas may be taken.

The decision not to schedule sensor operation over a given area depends both on the percentage of cloud cover expected and the degree of investigator interest in that particular area. Areas of very high investigator interest are normally scheduled even though a fairly high percentage of cloud cover is predicted. Areas of low, or no investigator interest tend not to be scheduled even for a lesser percentage of cloud cover. The objective is to maximize the number of cloud-free images while at the same time making every attempt to image the areas of greatest interest.

The possibility of cloud obscured scenes has one major implication to investigators who require periodic repeating coverage. Since the satellites have access to a given scene only once every 9 days (except for higher latitudes), cloud cover could result in the repeat coverage being interrupted for periods of 18, 27, or more days for any particular scene.

APPENDIX G
GROUND STATIONS AND GROUND COMMUNICATIONS

G.1 GENERAL DESCRIPTION

Communications between the spacecraft and the ground are handled via ground stations that are part of NASA's Space Tracking and Data Network (STDN). The NASA Communications (NASCOM) network provides the necessary communication of data between these ground stations and the Ground Data Handling System (GDHS) located at Goddard Space Flight Center (Figure G-1)

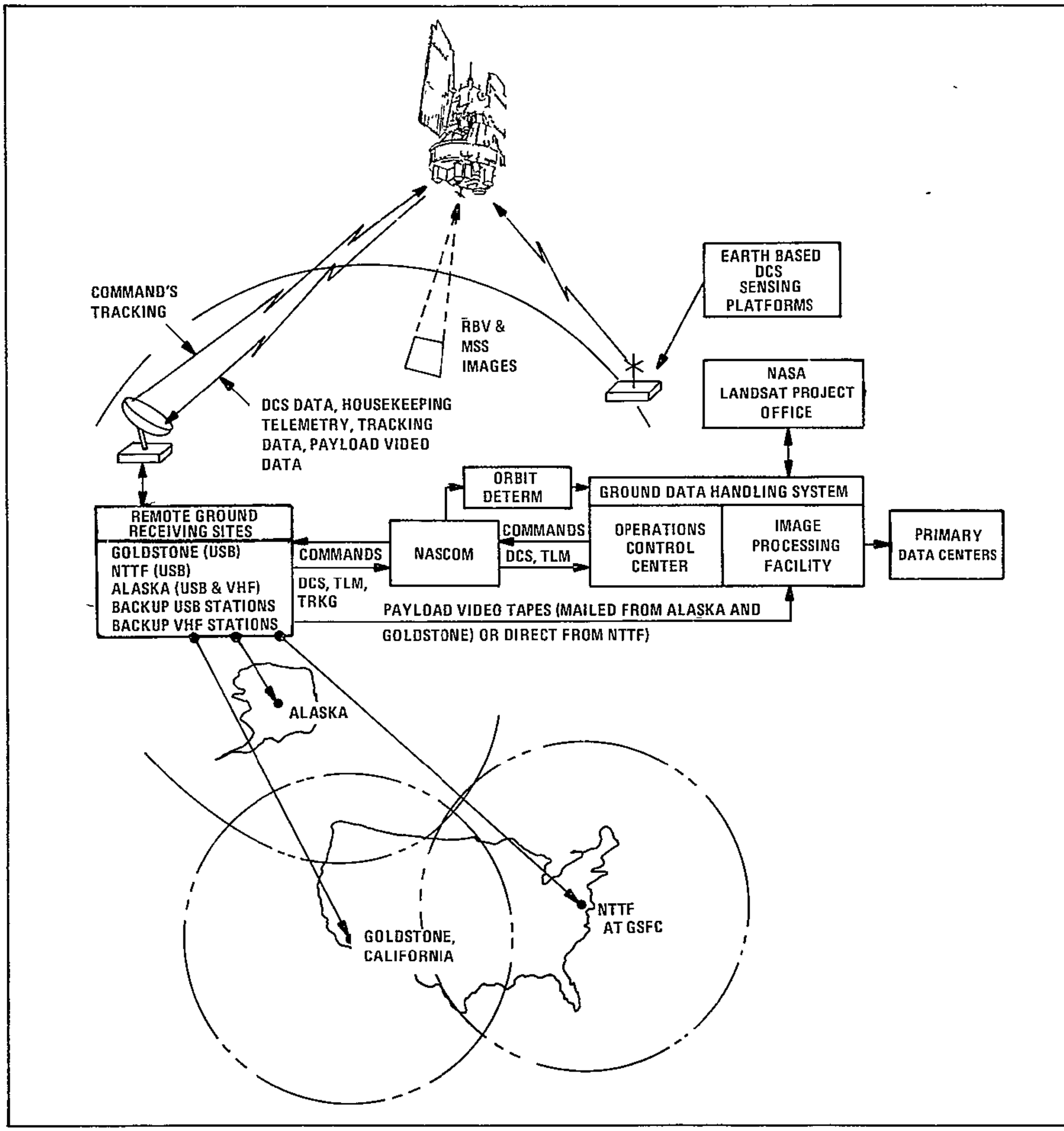

Figure G-1. Communications and Data Flow Configuration

Three primary ground stations accomplish all of the necessary communications in support of the mission in the United States (Table G-1).

Table G-1. Landsat Ground Stations.

STATION	COMMAND AND TELEMETRY RF CAPABILITY
Goldstone (Calif)	Unified S Band (USB)
NASA Test and Training Facility (NTTF)	USB
Alaska	Very high Frequency (VHF) and USB

These are the only sites equipped to receive the Multispectral Scanner (MSS), Return Beam Vidicon (RBV), and Data Collection System (DCS) data, and perform all narrowband telemetry, tracking and command functions Other STDN stations are used as a backup for narrowband telemetry, tracking or command functions only.

Figure G-2 summarizes the various spacecraft to ground communications links and Table G-2 lists the capabilities of the ground stations to receive and transfer the various types of data

Table G-2. Spacecraft/Ground Communications Summary

CAPABILITY	STATION				
	Goldstone	Alaska	NTTF	Backup USB	Backup VHF
Payload Data					
Receive RBV/MSS Video	X	X	X		
Receive DCS Data (USB)	X	X	X		
Transfer RBV/MSS Video To OCC			X		
Mail RBV/MSS Video Tapes to NDPF	X	X			
Transfer DCS Data to OCC	X	X	X		
Command Data					
USB Command	X			X	
VHF Command		X	X		X
Computer Controlled Commands	X	X	X	X	
Manual Commands		X			X
Housekeeping Telemetry Data (Narrowband)					
Receive USB PCM	X	X	X	X	
Receive VHF PCM		X			X
Transfer Real Time PCM to OCC	X	X	X	X	X
Transfer Playback PCM to OCC		X	X		
Tracking Data					
USB Tracking	X		X*	X	
Minitrack Tracking		X			X

*Receive Only

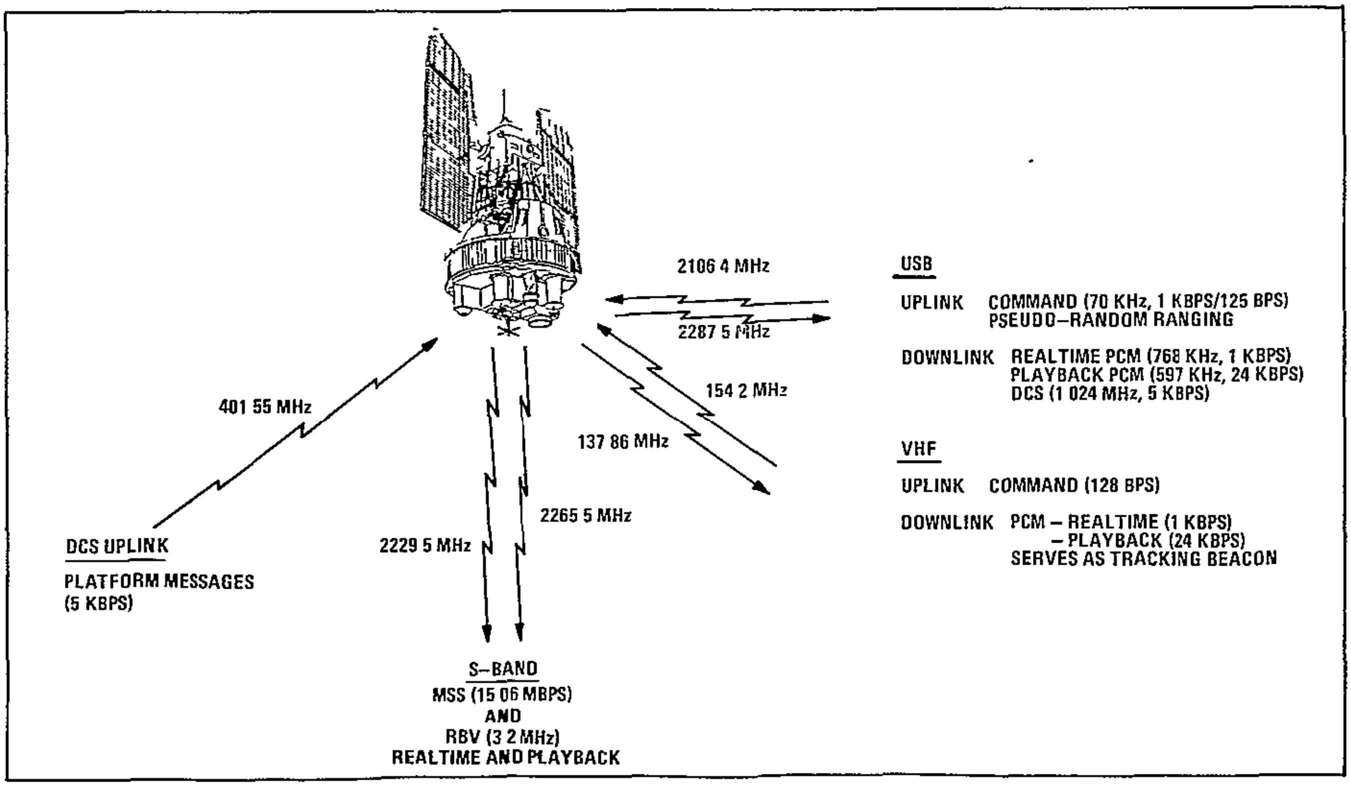

Figure G-2. Spacecraft/Ground Communication Links

G.2 PAYLOAD WIDEBAND COMMUNICATIONS

G.2.1 Spacecraft-to-Ground Communication

RBV and MSS wideband data are normally telemetered simultaneously to one of the three prime ground stations over two S-band links operating at center frequencies of 2229.5 MHz and 2265.5 MHz. The RBV camera has a video bandwidth of 3 2 MHz and is used to frequency modulate the carrier within an RF bandwidth of 20 MHz The MSS output is a single Pulse Code Modulation-Non-Return to Zero Level (PCM-NRZL) encoded bit stream at a bit rate of 15 06 Mbps This PCM signal Frequency Shift Key (FSK) modulates the carrier

Both RF links contribute a small degradation to the data. For the RBV the degradation in signal-to-noise ratio is less then 1 dB. The MSS bit error rate is less than 1 in 10^5. These are worst-case values expected at the 2^o elevation limit of the three primary ground station viewing cones

G.2.2. Ground Receiving and Recordings

Figure G-3 illustrates the flow of the wideband data as they are received and recorded At the Alaska and Goldstone stations the data are received and demodulated and then hardwired into special Remote Site Equipment where they are processed and recorded. For the NTTF station at GSFC, the Receiving Site Equipment is physically located in the Operations Control Center rather than at the station. This permits operations personnel to directly monitor the display equipment during data reception from NTTF

The Receiving Site Equipment for the RBV includes equipment to resynchronize and reclamp the video, a video display CRT, and various test equipment This equipment monitors the data as they are received and supplies the necessary timing and control signals to the video tape recorder The recorder records the composite video signal on tape for physical transfer to the IPF

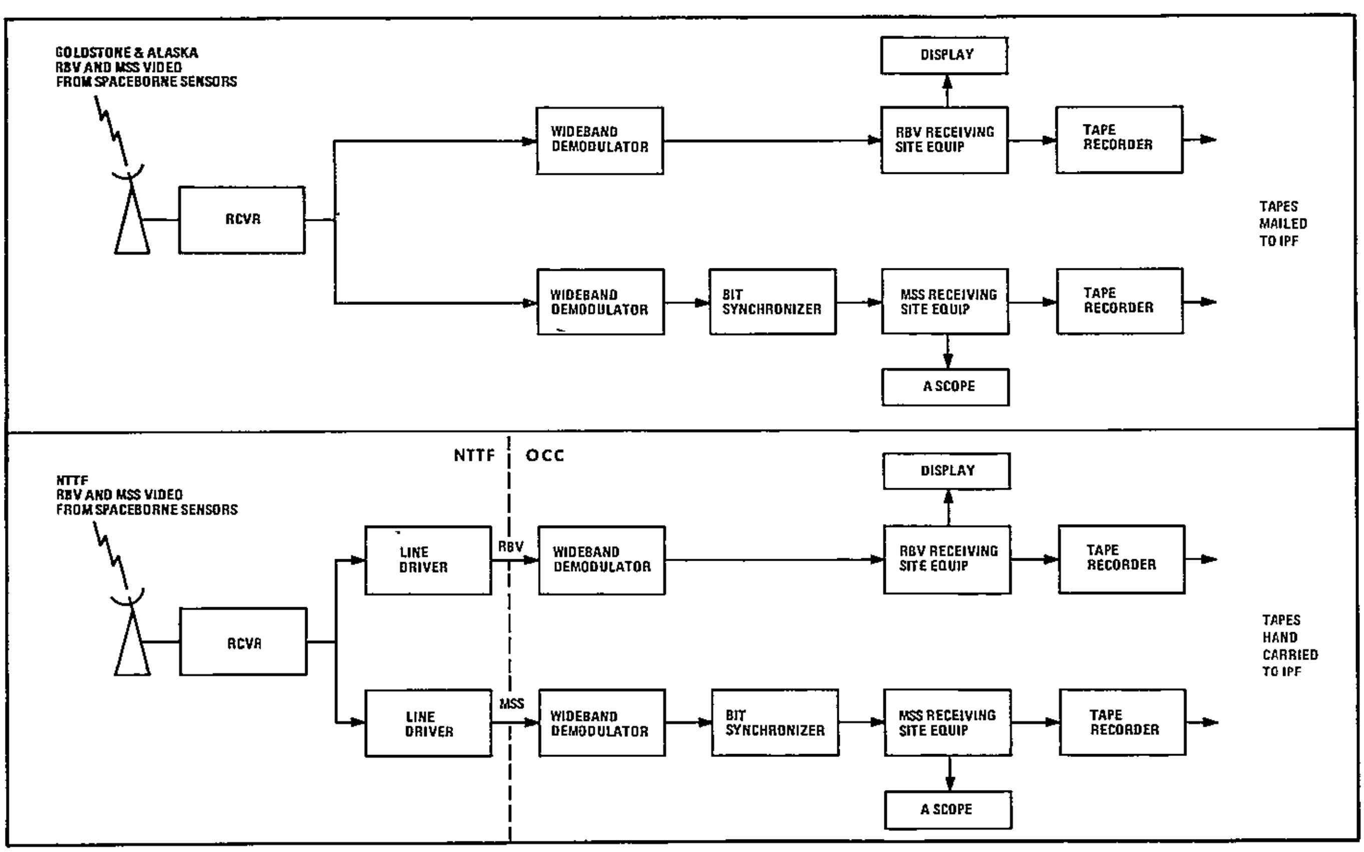

Figure G-3. Wideband Video Data Flow

The Receiving Site Equipment for the MSS demultiplexes the serial bit stream into individual data channels corresponding to each of the detectors in the sensor. It adds a preamble, line start code, line length code, and other data to each channel, and outputs the digital data on parallel lines for recording on a tape recorder. An A-scope provides the capability to monitor one of the output channels after demultiplexing.

G.3 TELEMETRY, TRACKING AND COMMAND DATA HANDLING

The spacecraft telemetry, tracking and command equipment operates with either the USB or VHF type stations. The stations and the NASA ground communication facilities provide the link for the transfer of these data between the spacecraft and the Operations Control Center at GSFC.

G.3.1 Telemetry Data

The spacecraft transmits real-time telemetry data at 1 kbps, using the VHF downlink to VHF stations or a subcarrier of the USB downlink to USB stations. These data are received whenever the spacecraft is in view of one of the three prime ground stations, and are directly relayed to the OCC.

The spacecraft also continuously records telemetry data on one of two on-board narrowband tape recorders These data are played back at 24 kbps using another of the USB subcarriers (or VHF backup donwlink) These data are normally received during station contacts at Alaska or NTTF and are transferred in real time to the OCC. Stored data provide a continuous history of the spacecraft and sensor status.

G.3.2 Command Data

Normally all commands are generated in the OCC and relayed to the spacecraft from one of the three prime stations. These commands may be real-time commands executed immediately upon receipt, or time-tagged commands that are stored for execution later at a prescribed time. In emergency situations commands may be sent from other stations. Commands from USB stations are transmitted on a subcarrier of the USB link and from VHF type stations on the VHF link

G.3.3 Tracking Data

Primary tracking data are obtained using the USB range/range rate system. Tracking data are processed at the ground stations to determine range, velocity and direction parameters. These are then transmitted by teletype to GSFC where the orbital parameters and spacecraft ephemeris are computed.

Secondary tracking can be provided by the VHF minitrack interferometer tracking system located at VHF stations.

G.3.4 DCS Data

Data from individual Data Collection Platforms are transmitted up to the spacecraft at UHF where they are received, frequency translated, and retransmitted over the USB downlink to one of the three prime stations. Special DCS receiving site equipment at these stations decodes and processes the data as they are received and reformats them for transmission to the OCC. (Refer to Appendix E for a more complete discussion of the Data Collection System)

APPENDIX H
IMAGE PROCESSING FACILITY
AND
FILM AND DEVELOPER CHARACTERISTICS

H.1 IMAGE PROCESSING FACILITY

The Image Processing Facility (IPF) processes and stores all sensor data and disseminates large quantities of these data to distributing agencies in the form of film imagery, computer compatible tapes, and Data Collection System (DCS) cards, and listings. To accomplish these functions, the IPF utilizes the following subsystems

- Initial Image Generation Subsystem (IIGS)
- Multispectral Scanner Preprocessor (MPP)
- General Purpose Image Processor (GPIP)
- Digital Subsystem (DS)
- Photographic Processing Subsystem (PPS)
- Quality Control Subsystem
- Data Services Laboratory
- Support Services

Figure H-1 illustrates the flow of image and DCS data through the IPF, and their relationship to the various subsystems.

The Initial Image Generation Subsystem (IIGS) processes all image data received at the IPF Data are accepted in the form of video tapes and converted to film imagery using an electron beam recorder (EBR). Image annotation tapes provide descriptive and positional data.

Latent images from the IIGS are developed and transferred to the Photographic Processing Subsystem where multiple copies are made for distribution to Federal distributing agencies and a limited number of special project users The wideband video tapes are screened for data quality and user selected scenes are converted to high density tapes (HDTs) within the Multispectral Scanner Preprocessor (MPP).

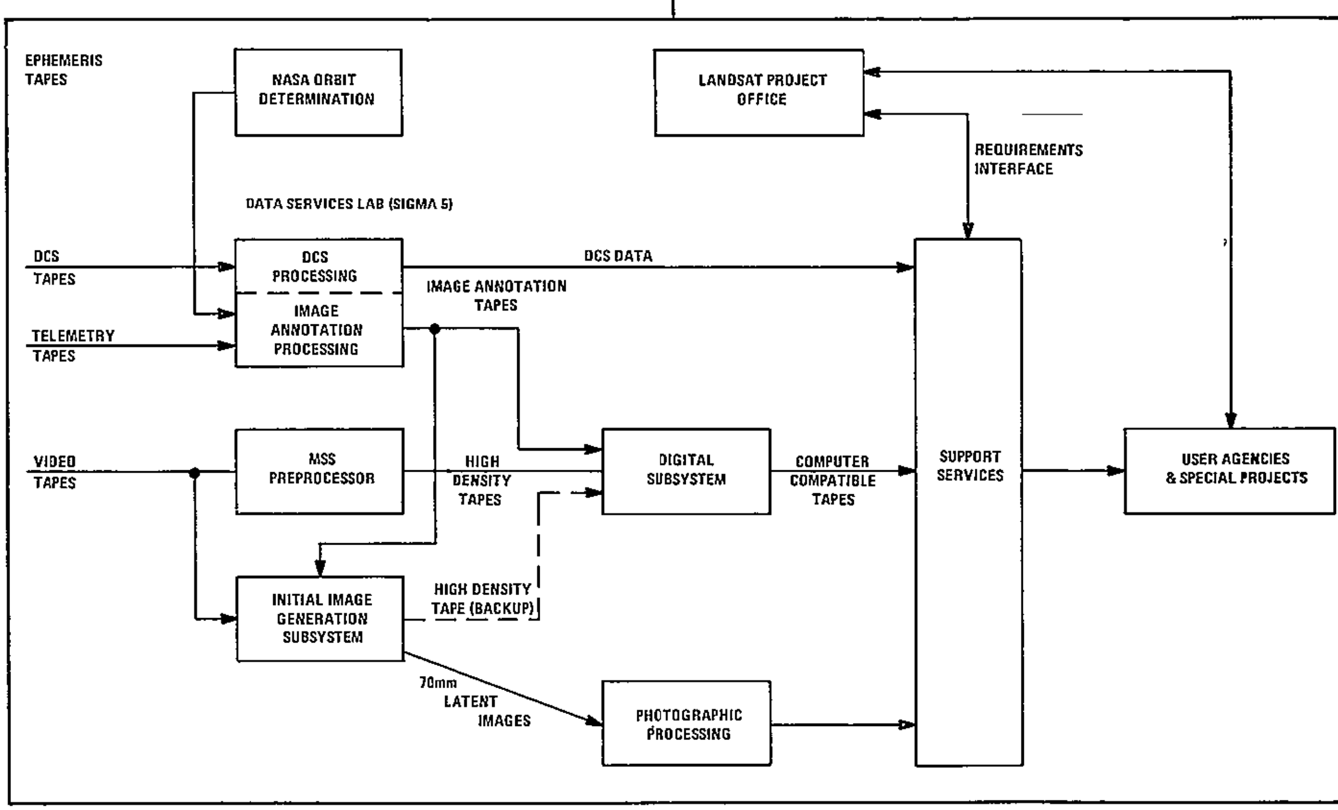

Figure H-1. IPF Functions

These HDTs are subsequently processed within the Digital Subsystem and computer computer compatible tapes (CCTs) are produced in limited numbers for users. Production Support Services determines and controls the process flow throughout the system by means of work orders The IIGS also provides a backup capability to the MSS Preprocessor in writing image data on HDTs.

Processing of DCS information in the IPF consists of editing and storing the data on magnetic tape, and reformatting them into computer cards and listings for distribution to investigators. This process is completely independent of image acquisition and processing.

H.1.1 Initial Image Generation Subsystem

The IIGS, shown in Figure H-2, produces latent images on 70mm film from the data received for each spectral band of the RBV and MSS sensors. The data can also be digitized, reformatted, and placed on high density tape in a backup capacity to the MSS Preprocessor

The corrections that are applied to the data during this operation include

- Geometric correction for spacecraft platform instabilities (Note· Digital tapes are not geometrically corrected)
- Reduction of systematic errors caused by RBV camera distortion and image generation
- Radiometric correction for each RBV and MSS spectral band
- Framing of MSS data to be spatially coincident with RBV data

Operation of the IIGS equipment is controlled by a process control computer that provides control and timing of all hardware in the IIGS, formatting of annotation data, and computation of geometric corrections to be applied to the imagery. The high-resolution EBR is used to expose the images on 70mm film. The recorder has a continuous film transport to minimize degradations at the corners of the image and to allow dynamic framing of the MSS data Its functional parameters and performance data are given in Tables H-1 and H-2.

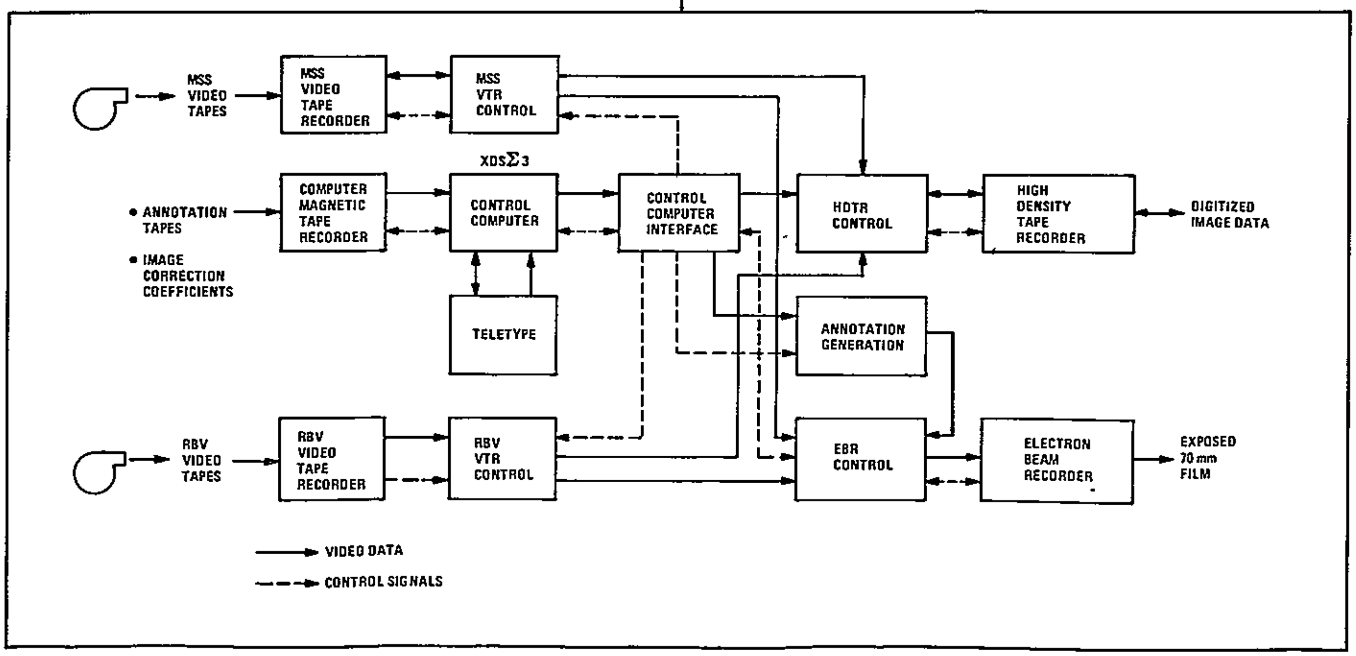

Figure H-2. IIGS Equipment Configuration

H.1.1.1 MSS Video Processing

The MSS data are entered into the IIGS via the MSS video tape recorder (VTR). The MSS VTR control unit decommutates both image and calibration data, time, line length, and frame identification (ID) codes and performs calibration and digital-to-analog (D/A) conversion of the MSS data Examples of the MSS ID record organization, annotation record organization, annotation record information sequence and the MSS calibration group detail are shown in Figures H-3, H-4, and H-5 The IIGS then outputs the video data in analog form to the EBR control unit The MSS VTR control unit also outputs reformatted digital data to the high density tape recorder (HDTR) control unit. However, the MSS data on the HDT are not corrected or calibrated by the IIGS. All calibration and correction of the MSS digital data are performed later in the Digital Subsystem.

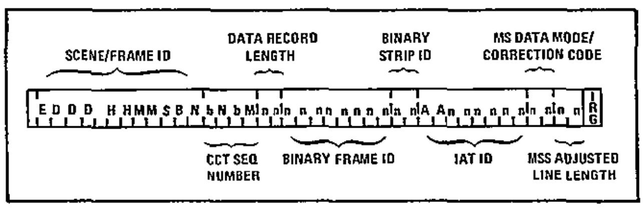

Figure H-3. MSS ID Record Organization.

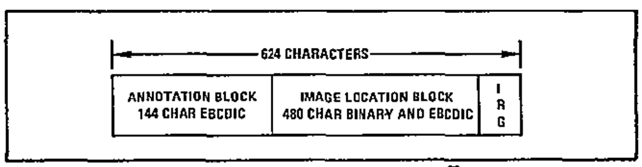

Figure H-4 Annotation Record Information Sequence

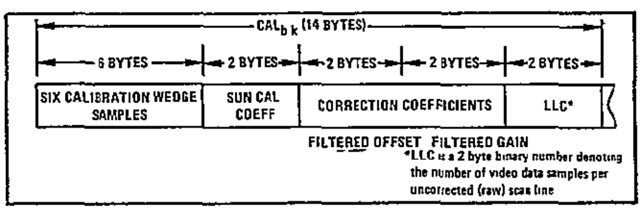

Figure H-5 MSS Calibration Group Detail

Table H-2 Electron Beam Recorder Performance Data

Parameter	Performance
Video Bandwidth	0 to 8MHz at -3dB
Video Filter	RBV. passband 0 to 3.5MHz at -1dB MSS passband 0 to 1.0MHz at -1dB
Line Scan Rate	RBV 1250 lines/sec MSS 326 lines/sec
Dynamic Writing Area	63 x 16 mm
Horizontal center Frequency edge Response	8000 TV lines at 50% response 7200 TVL at 50% response
Vertical Lines per frame	RBV. 4125 (55 mm frame) MSS 4512 (53 mm frame, after line doubling
Density Range	0 1 to 2 1
Transmission Range	100 1
Field Flatness	Max density variation <1% of D_{max}
Scan Jitter	peak-to-peak variation <0 01% of 63 mm
Film Transport Jitter	rms variations line-to-line (non-cumulative) <20% raster pitch
Repeatability	Peak error <0 03 mm

Table H-1 Electron Beam Recorder Functional Parameters

Mode	Lines Per Frame	Line Rate (lines/sec)	Cells Per Line	Active Line Time (μsec)	X Sweep Speed (μsec/mm)	Band Width (MHz)	Active Writing Time Per Frame (sec)	Framing Time (sec)	Film Speed (mm/sec)	Image Writing Speed (mm/sec)	Y Sweep Speed (mm/sec)	Aperture Scanned (mm)	Spot Wobble (μm)
RBV VFC	4125	1250	4003	720	13 09	3 50	3 3	3 5	18 286	16.667	1 619	5 344 10 344 MAX	13.3
MSS-VFC	4512	326	3300 ± 300 ± 30	2160	39 27	1 00	27 6	25	2.380	1 918	466	12 86 15 36 MAX	11 7

VFC = Video Data To Film Conversion

H.1.1.2 RBV Video Processing

The RBV data are entered into the IIGS via the RBV VTR The IIGS accepts the analog RBV data, performs necessary signal conditioning and error signal generation, and outputs the data through the EBR control unit During RBV data processing, geometric and radiometric corrections are applied to the video data. These corrections are derived from measurements of actual RBV imagery and from preflight calibration data stored in the General Purpose Image Processor. They correct for systematic RBV camera non-linearities, alignment errors, and shading errors, as well as EBR internal errors. The correction coefficients are transferred to the IIGS on computer-readable tape, stored in the control computer, and used to control EBR writing beam position and intensity during image generation

H.1.1.3 Framing

Framing of the RBV images is inherent in the simultaneous shuttering action of the three cameras; the centers of the RBV images are nominally identical. There are, however, slight offsets between the image centers due to misalignments between the cameras During IIGS processing, the correction data developed within the General Purpose Image Processor (GPIP) are used to adjust for these alignment differences and to position each image within the writing area so that the latitude and longitude identified in the annotation block represent the format center Format center is the intersection of the diagonals between the four registration marks.

During the sensor ON periods, RBV shutter action occurs every 25 seconds In this interval, the satellite ground track and sensor "coverage area" advance approximately 163 kilometers (88 nm). (These values are nominal, depending on orbit parameters.) This results in approximately 22 kilometers (12 nm) of overlap at the top and bottom of each RBV image as illustrated in Figure H-6A.

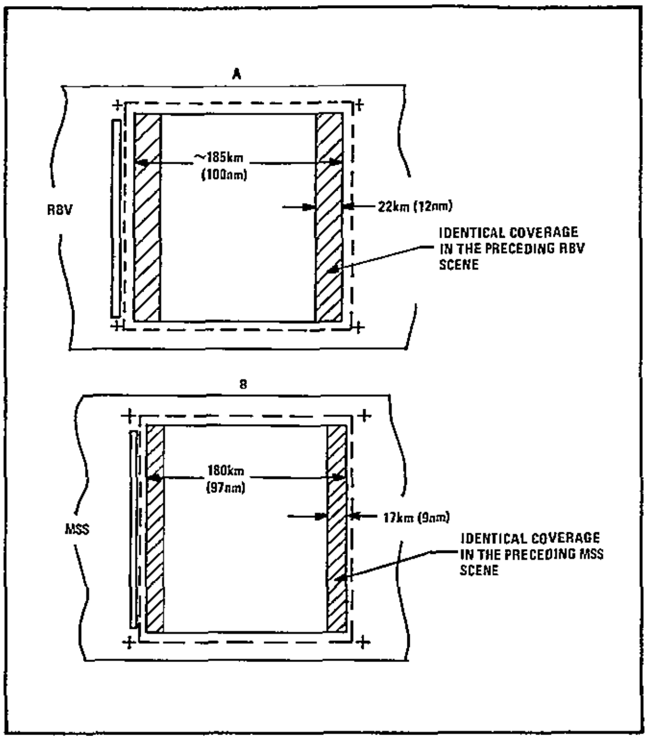

Figure H-6 RBV and MSS Overlap Area Between Consecutive Scenes

For determining temporal changes in ground scenes, the RBV frames are scheduled in order to overlay, as closely as possible, previous frames of the same area This pattern is referenced by a frame centered on the equator (Ref. Figure F-6 in Appendix F). The equatorial frame is centered to within ± 2 seconds and all other frames, in that orbit, are referenced either forward or backward from this frame at 25-second intervals.

The MSS, on the other hand, is a continuous scanning device; images are constructed by "cutting" this continuous record into 25-second pieces corresponding to the RBV frames. In this technique, the spacecraft time code of the exposure for the RBV shutters is used as the reference time to compute the MSS frame centers. Using this time and "counting back" the number of scan lines equivalent to one-half a frame, the MSS imagery is framed to correspond to RBV imagery. Framing is coincident to within 10 milliseconds of actual time of occurrence of the midpoint RBV exposure. When the RBV is not being used, the MSS frame centers are still determined from a frame centered on the equator with other frames spaced at multiples of 25 seconds from it.

Imagery overlap between MSS frames is also provided as shown in Figure H-6B. The overlap corresponds to approximately 17 kilometers (9 nm) on the ground and is made possible by writing MSS scan lines twice — once on each of two adjacent frames as illustrated in Figure H-7. The MSS overlap is limited by the beam deflection aperture of the EBR.

H.1.2 Multispectral Scanner Preprocessor

The Multispectral Scanner Preprocessor (MPP), shown in Figure H-8, performs a quality screening function of MSS wideband video tapes (WBVTs) Other functions performed include inputting scenes from WBVTs, reformatting, and recording selected scenes on high density tape (HDT). Radiometric calibration data are extracted and recorded on the HDT but not applied to the data. Since neither geometric nor radiometric corrections are applied during the process, the basic function performed by the MPP is the reformatting of raw telemetry data onto high density tape in a format compatible for processing in the Digital Subsystem

The MPP and the Digital Subsystem combined as a processing system are referred to as the Digital Image Preprocessing System (DPPS). An overall system configuration of the DPPS is shown in Figure H-9.

H.1.3 General Purpose Image Processor

A key feature of the GPIP is the use of ground control points to measure positional errors in the MSS and RBV images. The ground control points used for precision location of imagery are objects having a known position on the earth's surface that can be identified in an image Data obtained from measurements of these control points are used in the IIGS for systematic error removal.

The GPIP consists of a viewer/scanner assembly that receives the 70 mm film input from the IIGS and associated control/interface circuits that tie the viewer/scanner to the control computer Figure H-10 shows the major hardware components of the GPIP.

The image measurement functions are performed using the viewer/scanner This instrument is basically a precision, two-stage image comparator with automatic and manual image-matching and coordinate-measuring capability. The operator station includes a data entry device, binocular viewing optics, X-Y handwheels and a video monitor.

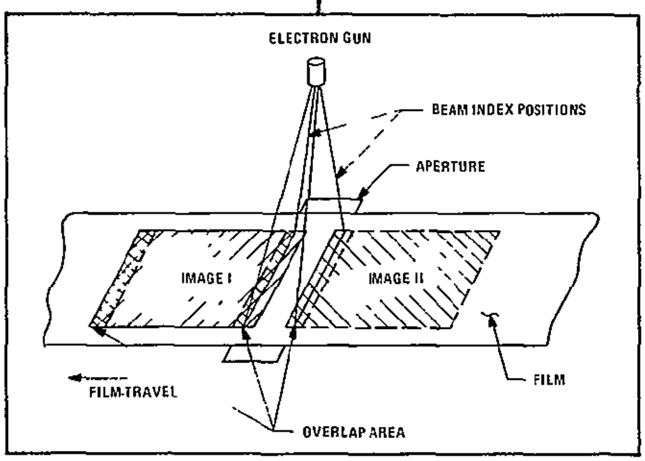

Figure H-7. MSS Dynamic Framing Technique

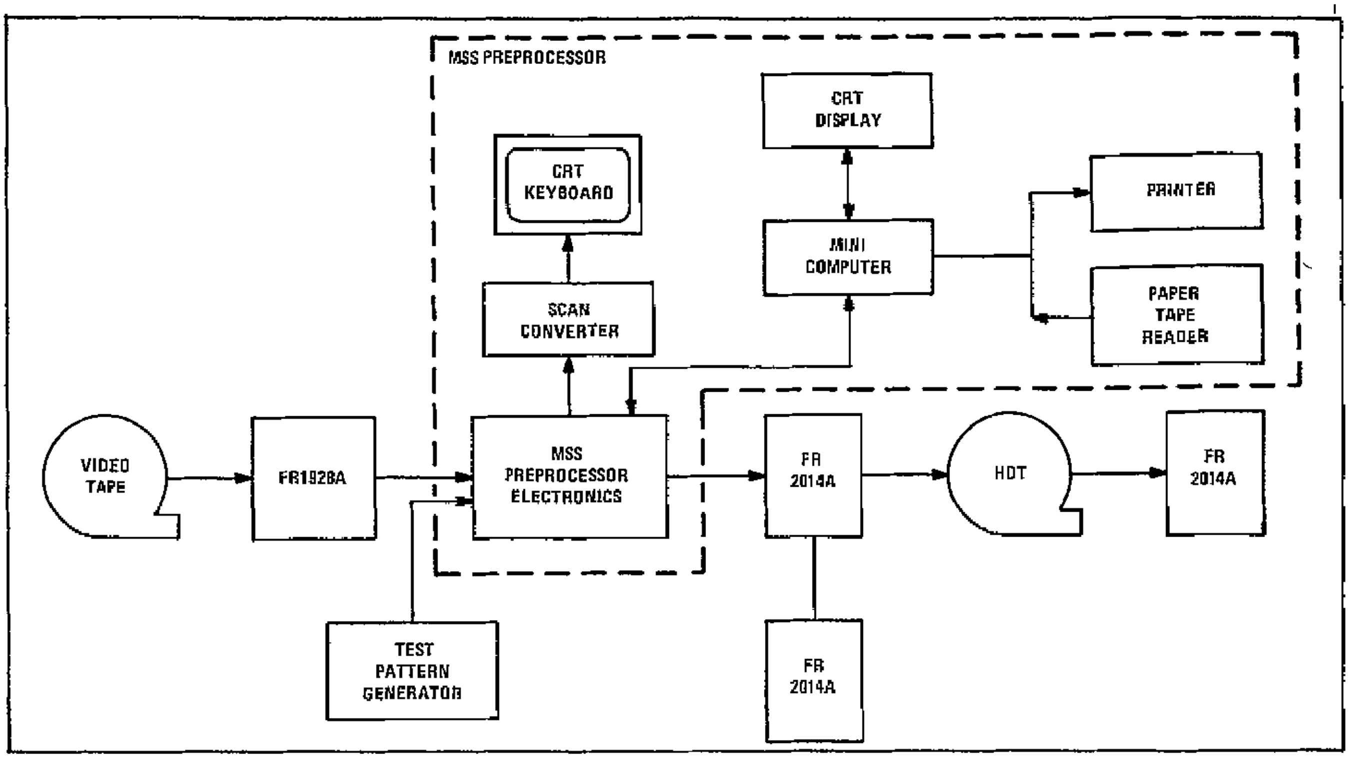

Figure H-8 Multispectral Scanner Preprocessor

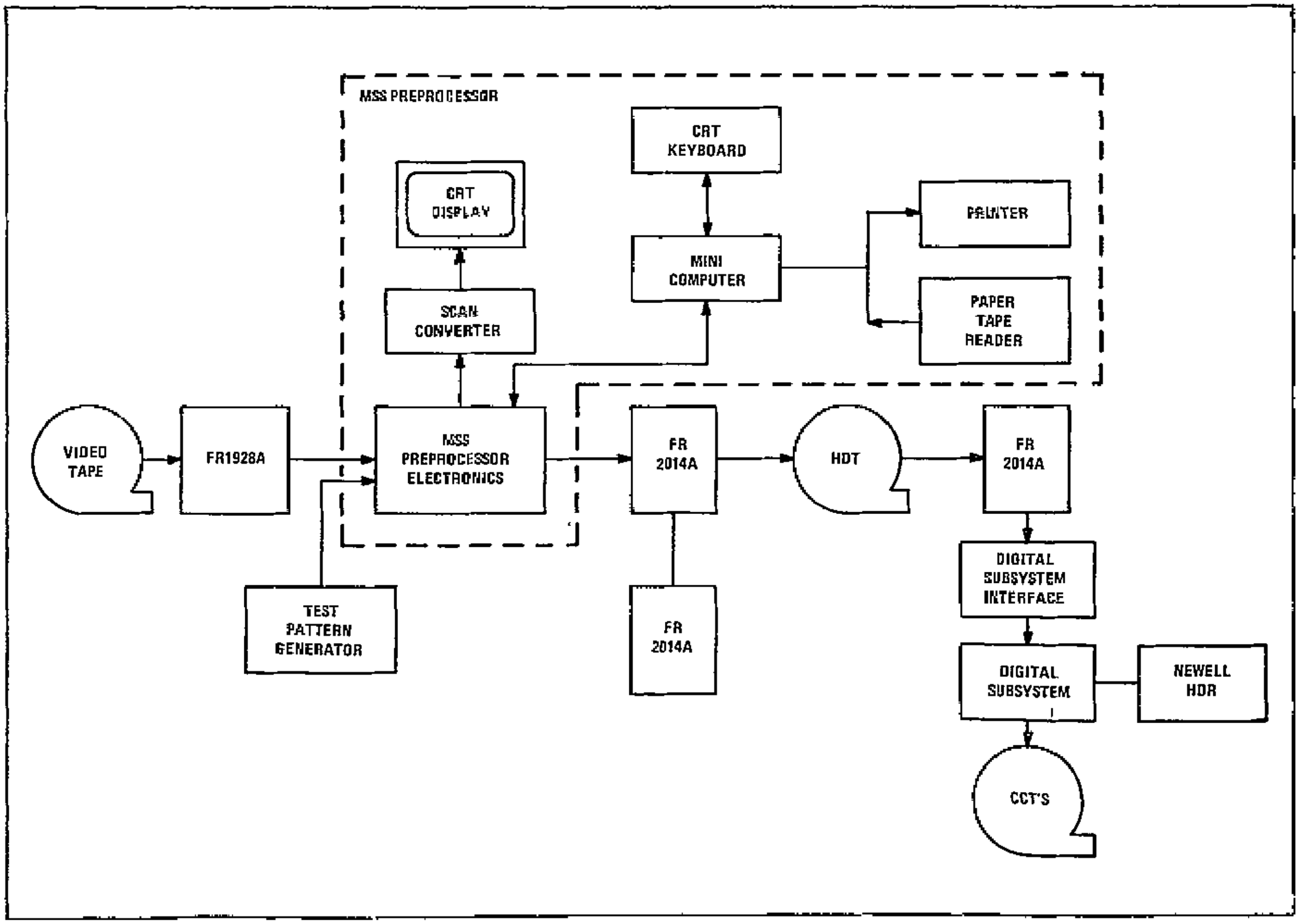

Figure H-9. Digital Image Preprocessing System (DPPS) Overall System Configuration

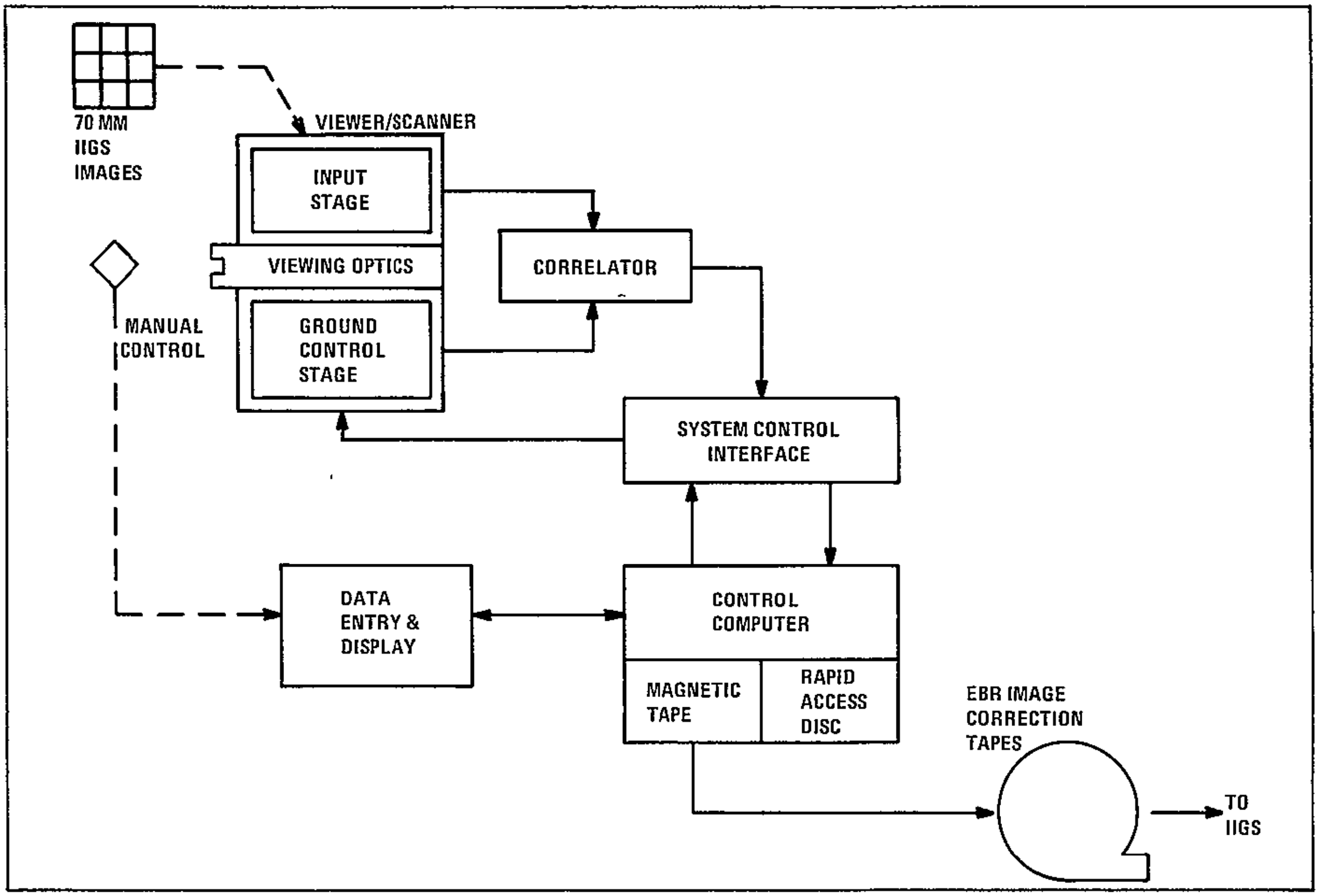

Figure H-10. General Purpose Image Processor Equipment Configuration

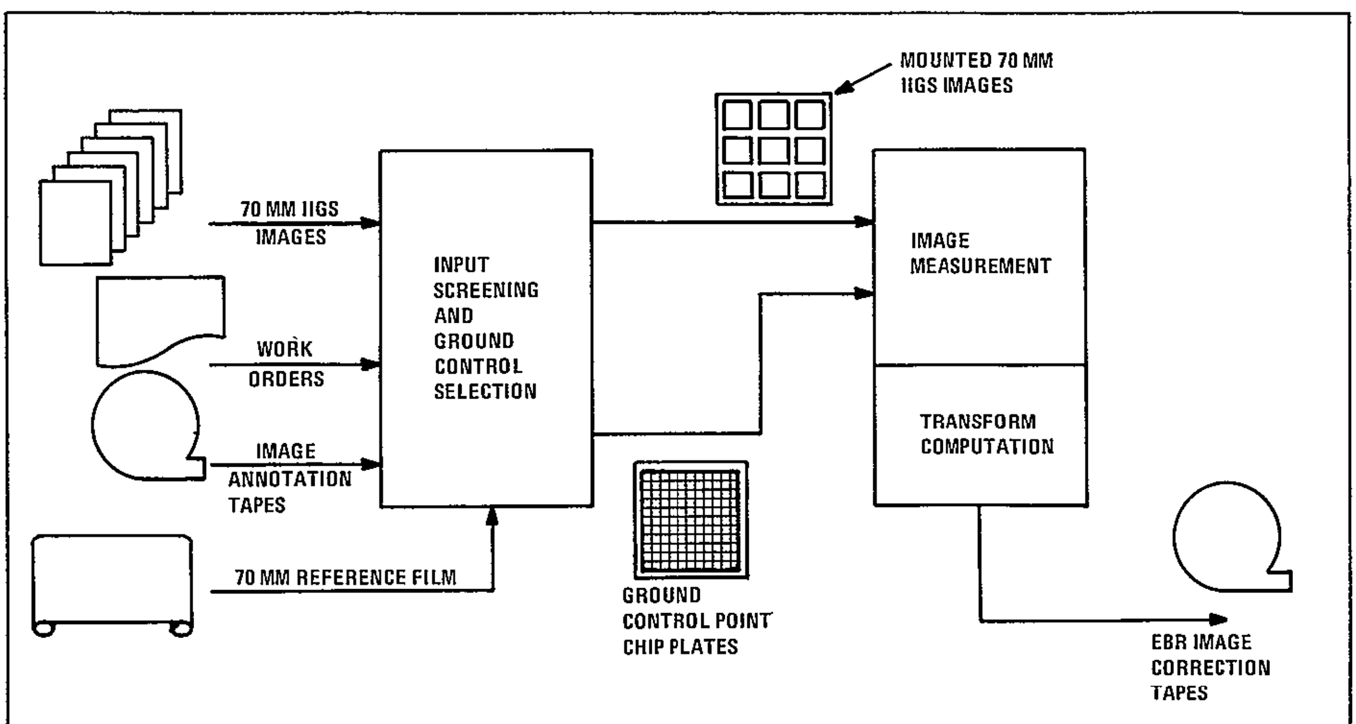

Figure H-11. General Purpose Image Processor Operation

The computer operates as a real time control computer for image measurement and EBR image correction tape generation. The computer, with associated magnetic tape unit and rapid access disc memory, also functions as a data processor for other system operations

Figure H-11 shows the major internal functions of the GPIP and their relation to the system inputs and outputs. The normal throughput path is from IIGS processed RBV and/or MSS image inputs to EBR image correction tape output.

H.1.4 Digital Subsystem

The Digital Subsystem (DS) provides transformation of selected digitized data to a computer compatible tape (CCT) format. The DS equipment consists of a process control computer, seven magnetic tape units, a data controller/corrector, two CRT monitors and an HDTR. These items and the DS relationship to the IIGS and MPP are shown in Figure H-12.

The high density tape (HDT) and associated HDTR are essential to the efficient flow of data within the IPF. The HDTR provides high bit packing density and transfer rates during processing, along with playback at lower speeds to retain compatibility with the average recording rate on the DS computer compatible tapes.

The control computer is used in a process-control mode whereby the digital image data are transferred to the memory modules and the main frame computer performs the data correction computation. As shown in Figure H-13, the subsystem reads data into the control computer memory, accepts manual instruction inputs, operates on the stored data to correct, edit, reformat, and annotate them, and records the processed data onto CCTs

For MSS data, selected corrections are performed by the special data controller/corrector consisting of line length adjust, radiometric calibration and decompression

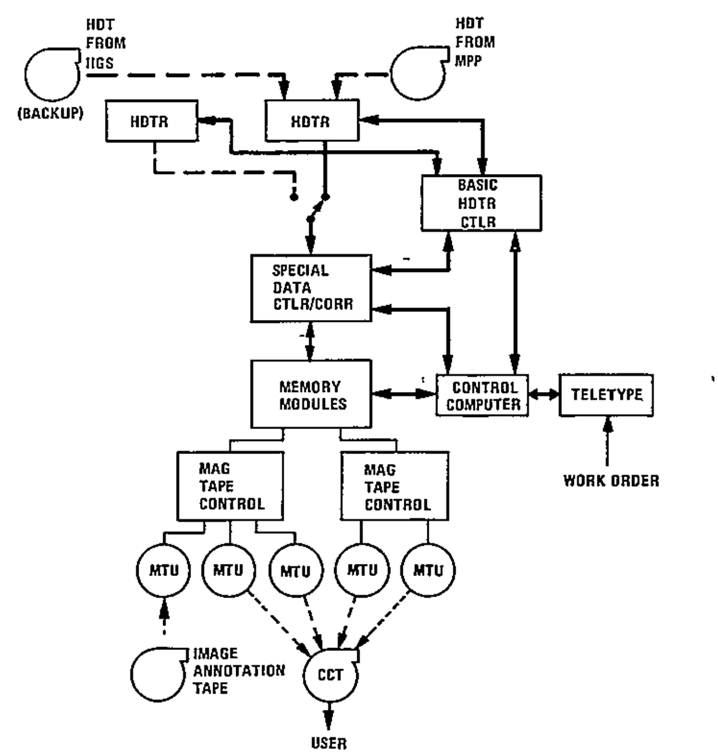

Figure H-12 Digital Subsystem Equipment Configuration

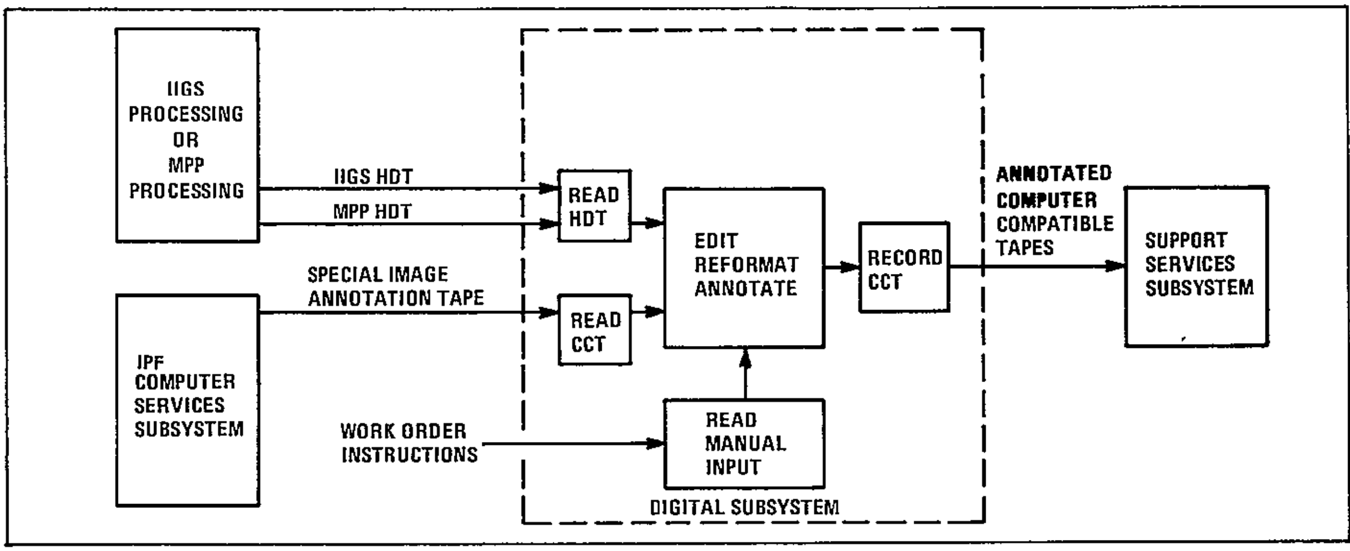

Figure H-13. Digital Subsystem Operation

H.1.5 Photographic Processing Subsystem

The Photographic Processing Subsystem (PPS) accepts the IIGS produced latent images and produces whole roll or cut film products The PPS is capable of producing 70mm and 9 5-inch black and white imagery, 9.5-inch color imagery and 16mm microfilm. Equipment used includes continuous tone automatic black and white processors, automatic color film and paper processors, high speed strip printers, and step-and-repeat contact printers. Specialized equipment includes a photographic enlarger modified to a fixed focus enlargement of 3.37, a precision punch, a color composite printer, and microfilm copying, processing and duplicating equipment.

The PPS also includes a centralized chemical mixing and storage facility incorporating a pollution abatement system consisting of electrolytic silver recovery units, black and white fixer recirculation, and color bleach regeneration and recirculation

Inputs to the PPS are latent film from IIGS processing, stored imagery from Support Services, and computer generated work orders. The orders specify images to be reproduced and type and quantity of products required.

Black and white processing includes the following activities as illustrated in Figure H-14:

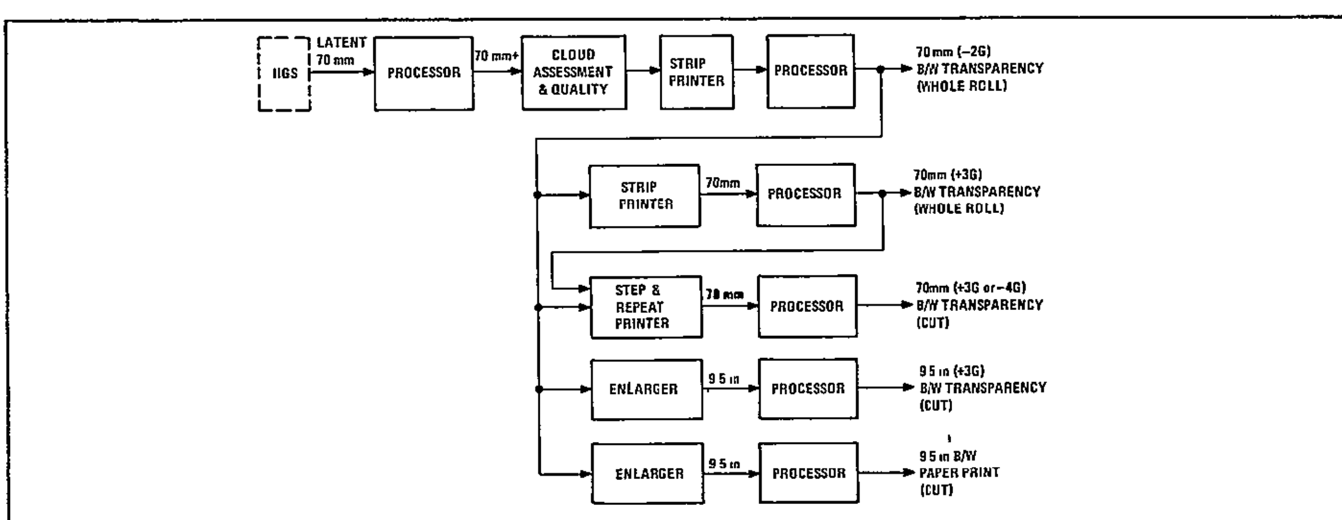

Figure H-14. Black and White Processing

- Processing of 70mm latent image from IIGS
- Enlargement and processing of 9.5-inch positive transparencies and paper prints
- Printing and processing of 70mm inter-negatives and interpositives
- Printing and processing of 9.5-inch triplet sets used for generation of color composite negatives
- Duplicating and processing 70mm negative and positive transparencies.

Color processing as shown in Figure H-15 includes the following activities

- Punching of registration points in black and white triplet sets
- Generation of color composite negatives from black and white triplet sets
- Printing and processing 9.5-inch color transparencies and color paper prints for users

Figure H-16 shows the flow of microfilm preparation and processing. Each frame is copied to produce an archival film negative Inventory is updated by denoting the identifiers contained on the roll and the roll number. The archival negative is processed, analyzed for quality and spot checked to assure that the images are in proper order Negative masters are converted to positive copies that are then shipped to the data distribution centers and other users.

A detailed discussion of the characteristics of the film and developing techniques used in the PPS is presented in Paragraph H.2.

H.1.6 Quality Control

Process control testing and process independent testing are performed in the IPF photographic facility. The basic tool used to monitor process activities is a quality control strip containing four 21-step wedges, each with a different orientation. The strip measures "within frame" variability as well as gamma, film speed and base plus fog. The wedge is used every half hour, or after each 500 square feet of film is processed. When a processor is in control testing a go/no-go sample of three steps in each wedge is used to assess quality. Quality control is also exercised through incoming material and mixed chemistry tests, archival evaluation, and printing master evaluation.

The quality control procedures for printers consist of observations, tests and preparation of control charts once each shift for:

- Light source intensity and exposure duration
- Evenness of illumination
- Printer operating speed
- Resolving power
- Physical characteristics

The successful image development of archival film and the printing of masters and user products is predicated on rigid control of the

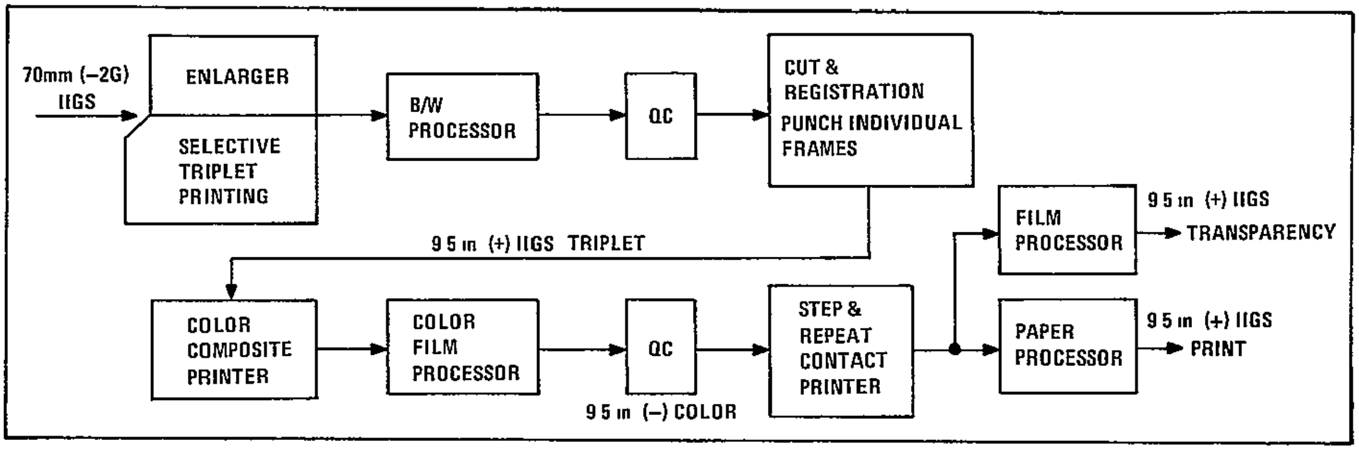

Figure H-15 Color Processing

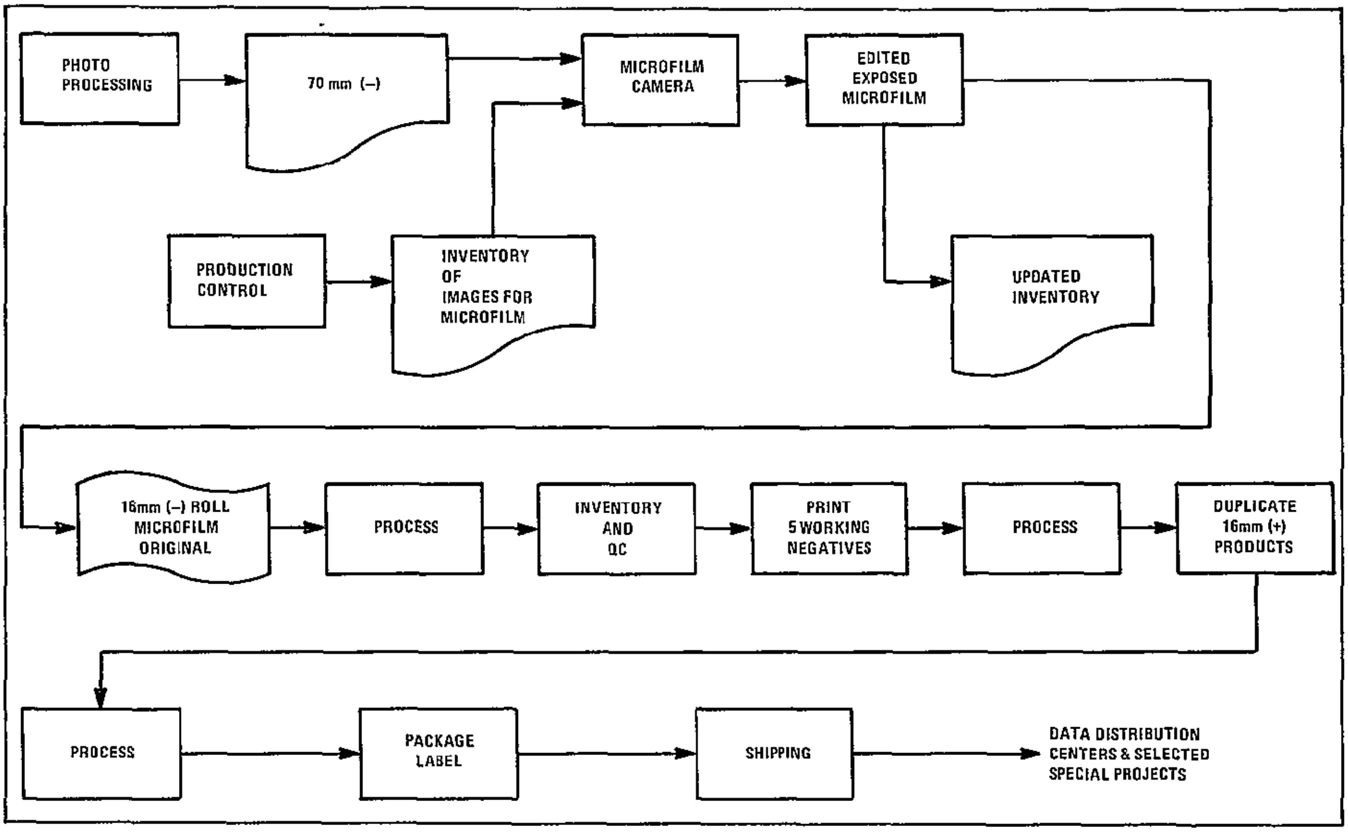

Figure H-16. Microfilm Processing

processing equipment. It is necessary to monitor variables encountered in the processing equipment operation frequently Those factors requiring frequent monitoring are:

- Processor operating speed
- Processor solution temperature
- Solution replenishment flow rate
- Sensitometric response
- Physical characteristics

Processing chemistry is prepared from standard commercial package mixes. To maintain quality control standards, a fraction of each incoming lot of chemicals is evaluated to determine that its action is within limits prescribed by previous testing of individual developers.

H.1.7 Data Services Laboratory

A central computer system, designated the Data Services Laboratory (DSL), that uses a comprehensive data base and information storage and retrieval capability provides control of IPF operations. The IPF information system utilizes a dedicated Xerox Sigma-5 computer and provides the capability for production control, management reporting, data storage and retrieval, service to users and preparation of digital products.

The information system, illustrated in Figure H-17, is built around a central data base providing support for computation and production control functions. It provides accurate accounting and storage of all data pertaining to observations, production schedules and management control All phases of operation are entered into the data base, including data received at the IPF, conditions under which the observations were made, results of image quality assessment, results of cloud assessment, status of production and status of shipment All data are readily available for general searches, in addition to being available to satisfy the more specific requirements of production control. The various reports and catalogs generated in the IPF are prepared by

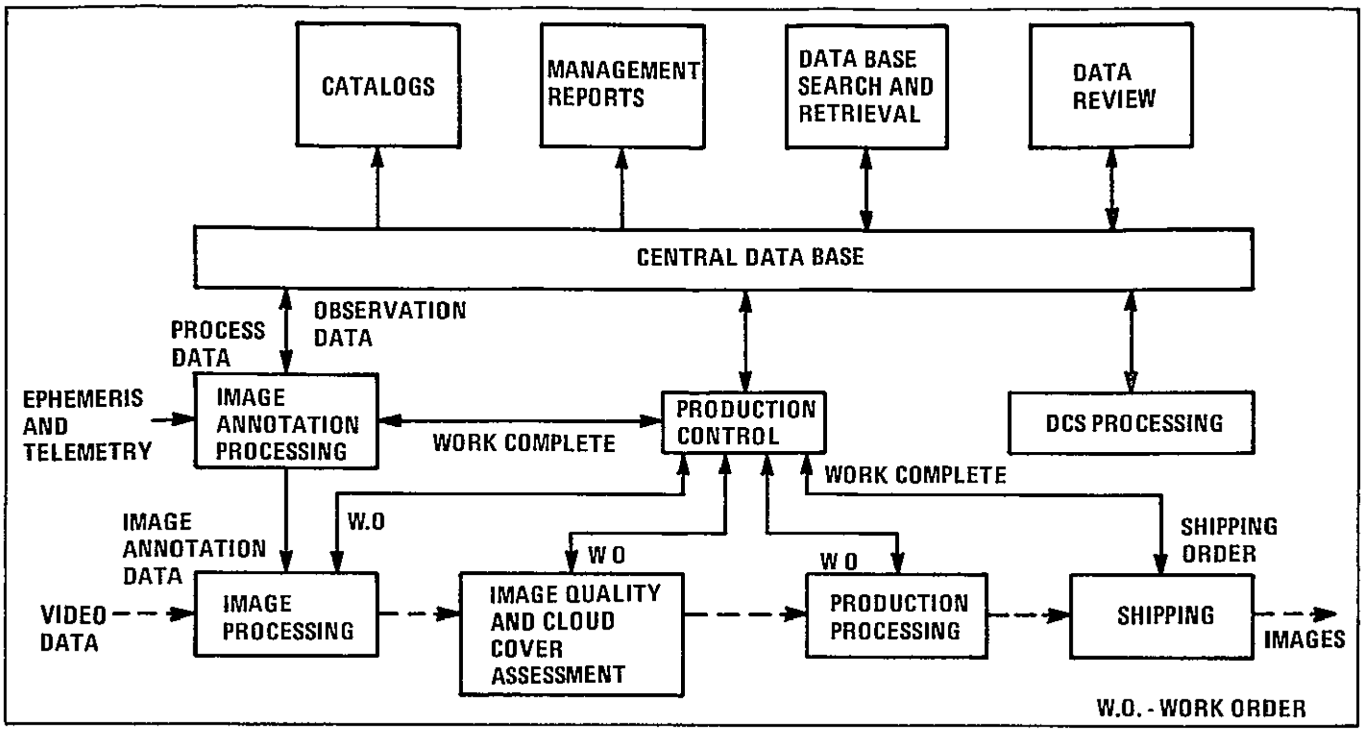

Figure H-17. IPF Information System

this system. In addition, two specific types of processing are performed that are associated directly with the payload data DCS processing and image annotation processing.

H.1.7.1 DCS Processing

DCS data transmissions are relayed by land lines from receiving stations to the Operations Control Center where the data are recorded on the Data Collection System Tape (DCST) The DCST is forwarded to the IPF where the data are edited, reformatted and stored on disc for up to 48 hours. At the end of each 24-hour period, the preceding 24 hours of collected data are placed on a permanent archive tape This transfer allows for retrieval of data at any time in the future, while permitting quick access to current (the most recent 24-48 hours) data.

DCS processing also prepares the platform data products for the DCS investigators Capability is provided to produce listings and punched cards containing a selected subset of available, uncalibrated platform data Means are also provided to accumulate and print summary data suitable for the DCS catalog.

H 1.7.2 Image Annotation Processing

Image annotation processing requires ephemeris and spacecraft performance data and generates the correlative data required for annotation and geometric correction of the imagery The annotation and computational data are passed to the image processing subsystems in the form of an Image Annotation Tape (IAT) This tape also contains processing instructions and supplements the work orders generated by Production Control. IATs are generated for the Initial Image Generation Subsystem and Digital Subsystem.

H.1.8 User Support Services

The IPF information system provides computer support for the User Support Services section of the IPF. This section services users in a timely and selective manner by providing a range of activities including catalogs, a comprehensive data retrieval system, microfilm services and dissemination of DCS data A detailed discussion of these services is contained in Section 5

H.1.9 IPF Improvements for Landsat—C

A number of improvements and additions to the IPF will be made for the handling of Landsat-C data. The most significant change will be that all video data from the RBV and MSS will be converted to high density tapes (HDTs) and then copies of the HDT's will be supplied to the Federal data distribution centers for additional processing and user product generation. Prime payload video processing flow is illustrated in Figure H-18 The following paragraphs describe the planned IPF elements. Expected performance of the overall system is shown in Table H-3

H.1.9.1 Multispectral Scanner Preprocessor

The MSS preprocessor, shown in Figure H-19, inputs MSS video tapes and work orders and converts the video data intervals specified on the work orders to formatted uncalibrated high density tape (HDT_F) Measurement of the

Table H-3 IPF System Performance for Landsat—C

Radiometric Calibration Accuracy	2 quantum levels over full range
Geometric Correction Accuracy	
1 Nominal Conditions with GCP	1 Pixel* (99% of the time)
2. Without GCP	Commensurate with S/C and sensor performance data
Temporal Registration	0 5 Pixel** (99% of the time)
Map Projections	Space Oblique Mercator (SOM), UTM, Polar Stereo
Resampling	Cubic convolution, nearest neighbor

* Without terrain
* Without Terrain Elevation Correction
** For RBV Data, <0.5 MSS Pixel Accuracy

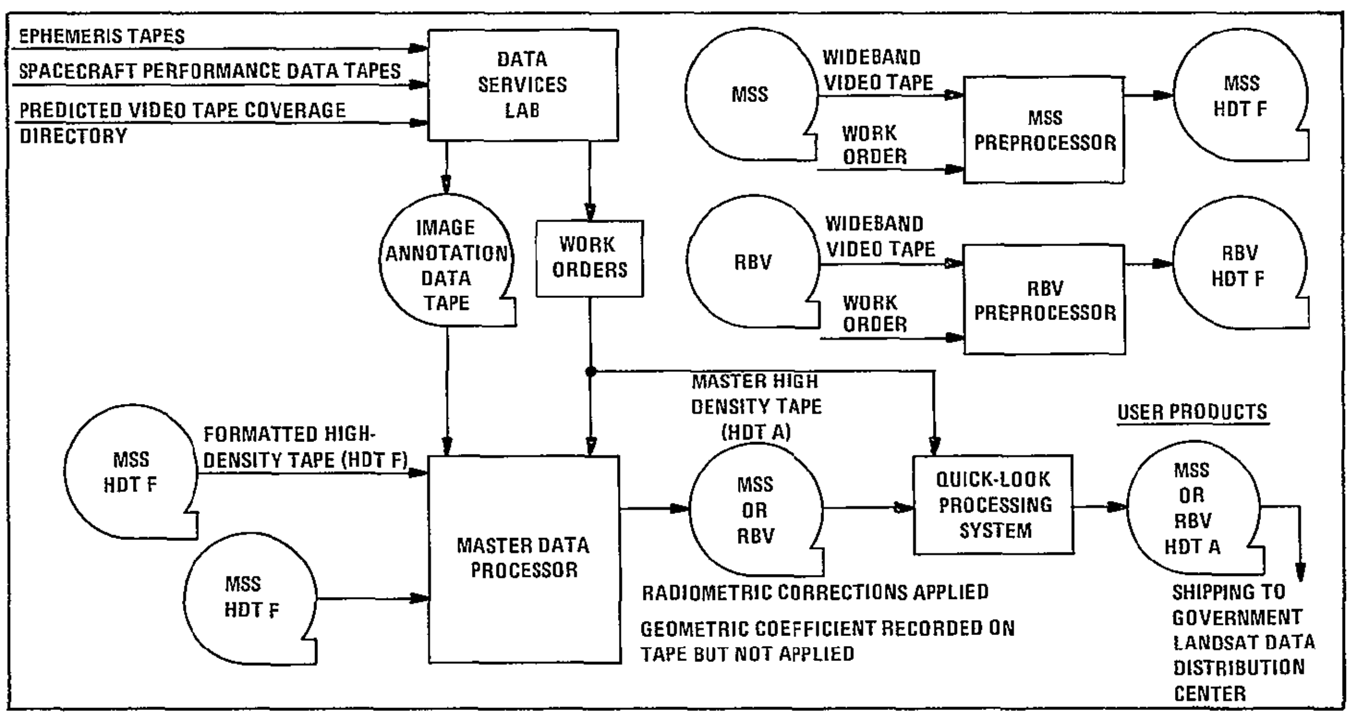

Figure H-18. Prime Payload Video Processing Flow

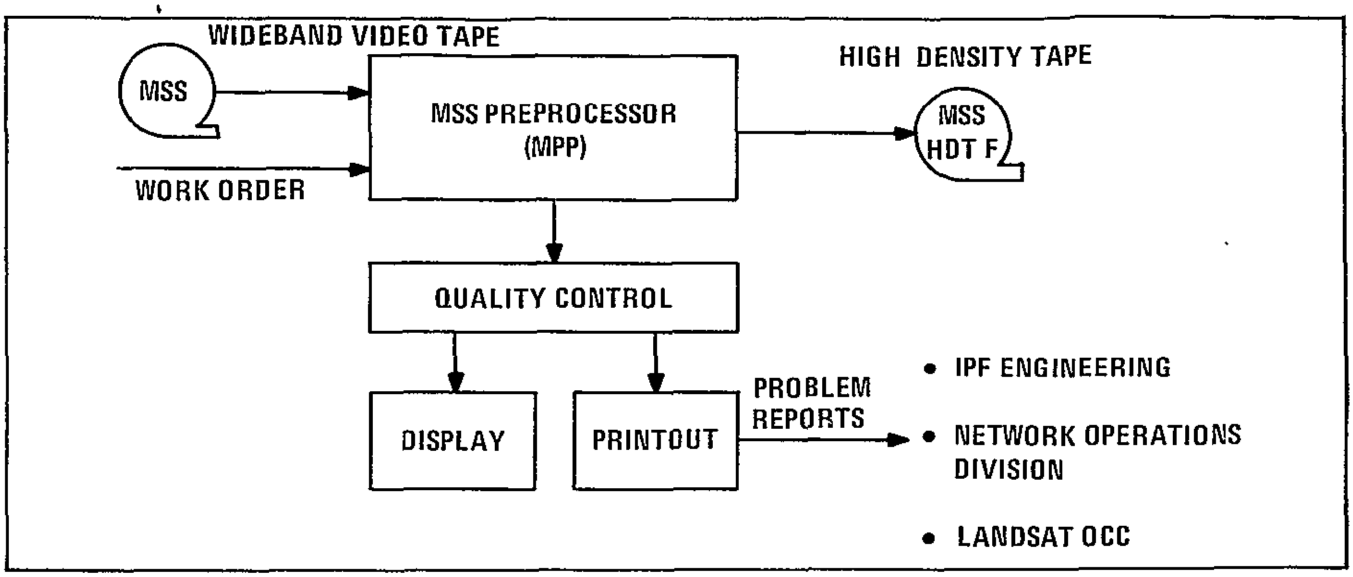

Figure H-19. Multispectral Scanner Preprocessor

quality of the MSS video data is also carried out in the MSS preprocessor, and any problems detected with the recorded video are fed back to the Landsat OCC and the Network Operations Division for corrective action

H.1.9.2 Return Beam Vidicon Preprocessor

The RBV preprocessor, functionally identical to the MSS preprocessor, inputs RBV video tapes and work orders and converts the video data intervals specified on the work order to high density tapes (HDT_F). Measurement of the quality of RBV video data is also carried out in the RBV preprocessor, and any problems detected with the recorded video are fed back to the Landsat OCC and the Network Operations Division for corrective action

H.1.9.3 Master Data Processor

As shown in Figure H-20, the master data processor (MDP) inputs are the formatted uncalibrated HDT produced on the MSS or RBV preprocessor, the work order produced by DSL, the image annotation tape produced by the DSL, and ground control point data. These data inputs are processed in the MDP and a standard uncorrected high density tape (HDT_A) is produced with radiometric corrections applied and geometric error coefficients added to the header but not applied to the data. The user can perform custom geometric corrections to this tape A fully radiometrically and geometrically corrected high density tape (HDT_P) will be supplied on a limited special-order basis to those users who do not perform their own geometric corrections

Ground control point data are entered into the system and filed for reference by the MDP in performing resampling of the uncorrected video to remove geometric errors

H.1.9.4 Quick-Look Processing System

The quick-look processing system (QLPS) consists of a general-purpose capability to edit, format and produce copies of selected HDT scenes in high density tape, computer compatible tape, 9.5-inch black and white and color film, or paper formats. The QLPS contains a quick-look processor, high resolution film recorder and photo processing laboratory. Flow diagrams of these three functional elements are shown in Figure H-21.

The quick-look processor inputs an HDT produced on the master data processor and generates edited/reformatted copies of user-selected scenes in HDT or computer-compatible tape format. Special tasks can receive band

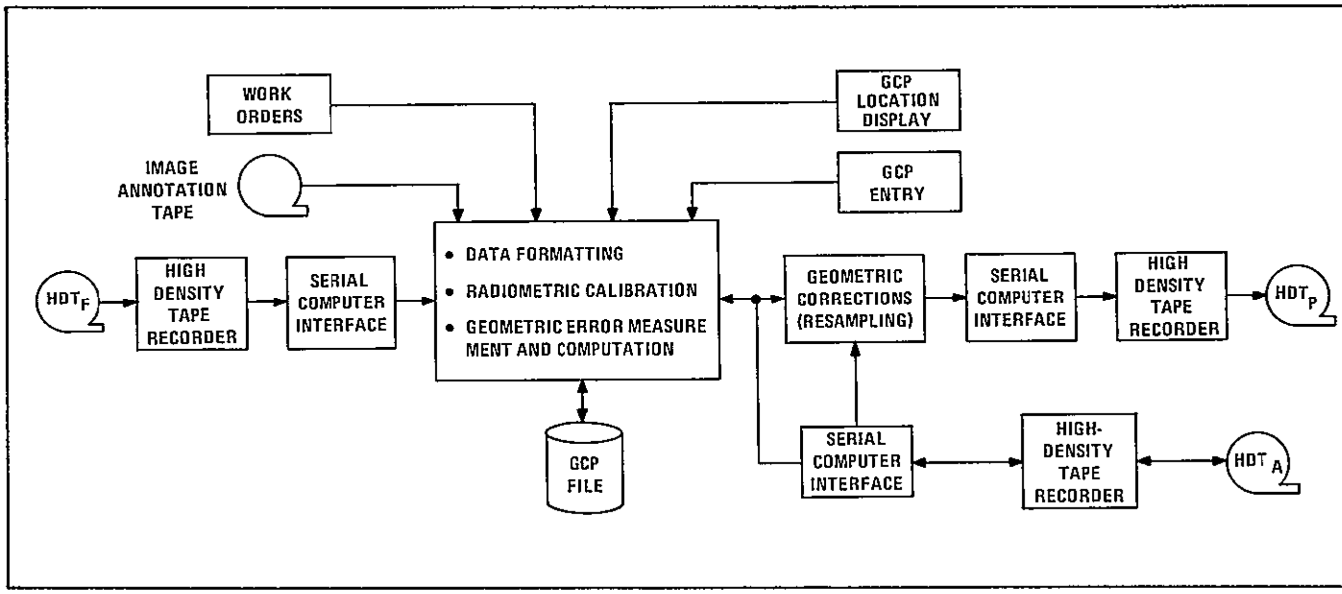

Figure H-20. Master Data Processor

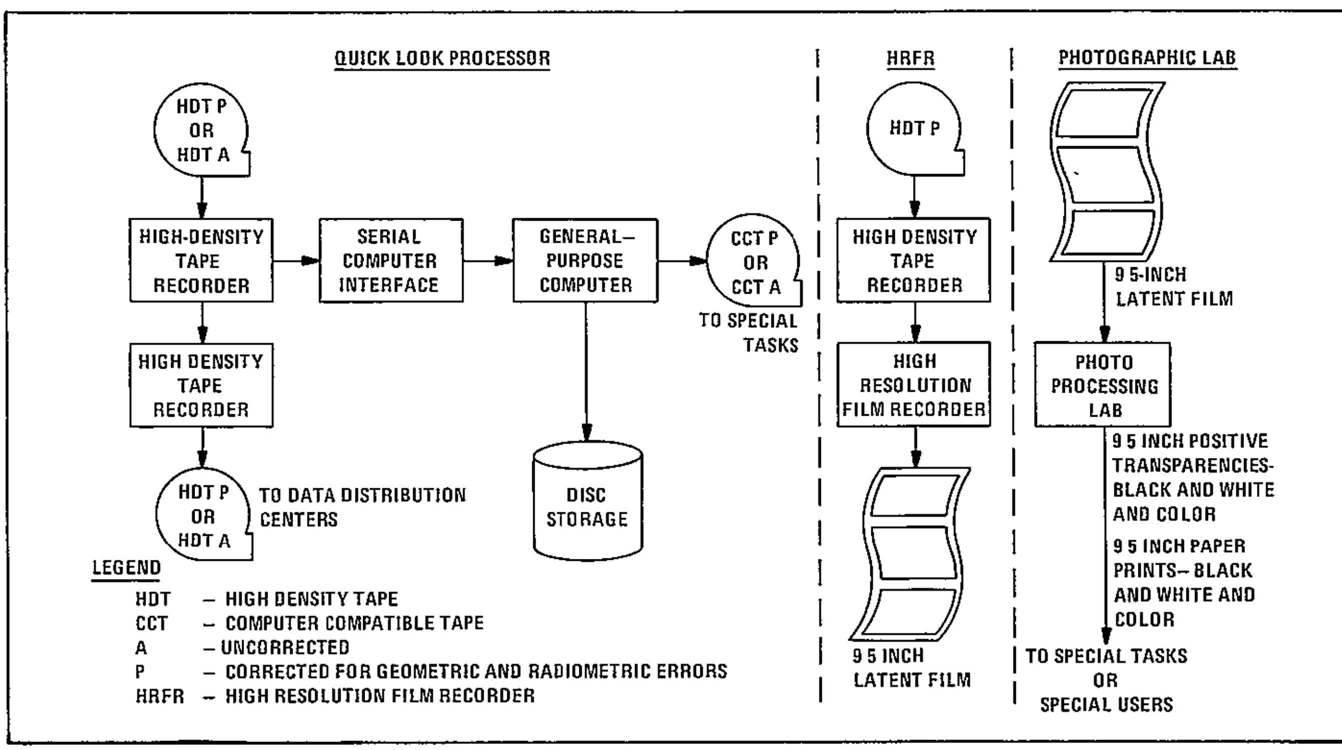

Figure H-21. Quick-Look Processing System

sequential HDTs and/or CCTs in pixel interleaved or line interleaved form. Computer tapes will be supplied in 9-track 800- or 1600-bpi densities only. The high resolution film recorder (HRFR) inputs a fully corrected HDT and converts selected user-requested scenes to 9 5-inch latent imagery

The photographic lab inputs 9.5-inch latent imagery generated on the HRFR, processes the imagery, and produces black and white or color products in support of a limited number of special tasks.

H.2 FILM AND DEVELOPER CHARACTERISTICS

H.2.1 PPS Description

As previously described, the PPS receives exposed 70mm positive roll film from the EBR and produces whole roll or cut film or paper products Selected 9 5-inch black and white film images from different spectral bands of the same scene are combined through filters to produce "false" color transparencies or paper prints. Figure H-22 is a block diagram of the PPS showing the flow of data through the various equipment

The latent image from the EBR is processed in a Versamat processor and, after screening for cloud cover and quality, the selected first generation images are copied using a strip printer to produce second generation 70mm negatives. After another copy stage using a strip printer, the third generation 70mm positive user product is produced. The second generation negative is also enlarged to produce 9.5-inch third generation film and paper prints. Certain of the film triplets are selected for production of color film and paper prints

Three 9.5-inch black and white positive transparencies representing the different spectral

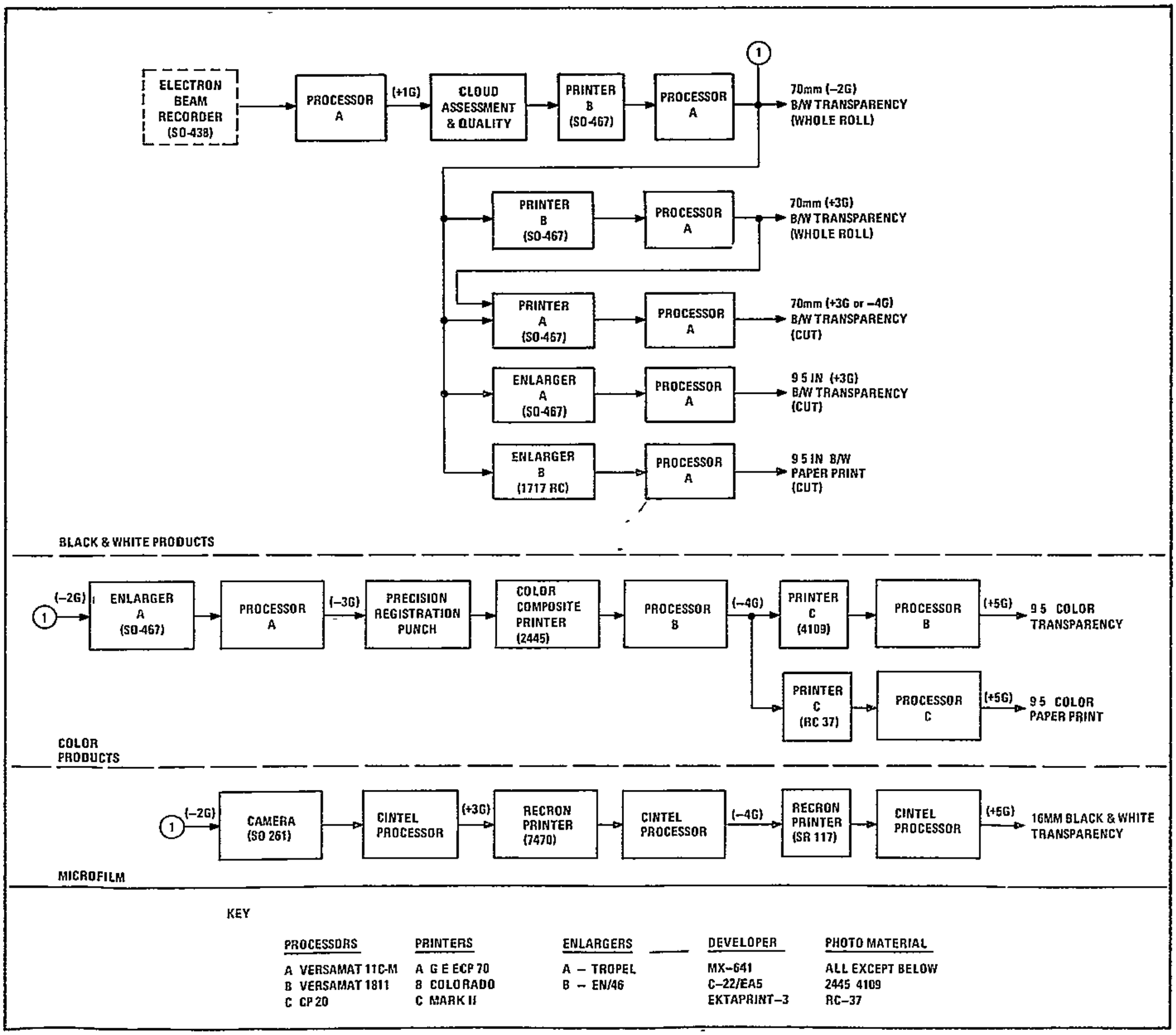

Figure H-22. Product Flow Through PPS

images of a scene are precision punched to insure registration and then printed using appropriate color filters as the individual spectral images are exposed. Both the RBV and MSS sensors have responses beyond the visible region into the infrared. In order to reproduce infrared on film it is assigned a visible color, usually red. Therefore, the band which is nominally designated as red is reproduced as green and the nominally green band is reproduced as blue.

Sixteen mm microfilm transparencies are made from a single spectral band of each scene of RBV and MSS imagery. The 70mm black and white negatives for bands 2 (RBV) and 5 (MSS) are used as inputs to the microfilm camera. For Landsat-C, it is planned to use band 5 for daytime coverage and band 8 for nighttime coverage.

Table H-4. False-Color Reproductions

Scene Color		Print Thru Filter	Negative Image Layer	Positive Image Layers
RBV	MSS			
Green	Green	Blue	Yellow	Mag + Cyan = Blue
Red	Red	Green	Magenta	Cyan + Yellow = Green
Near IR	Near IR or IR	Red	Cyan	Mag + Yellow = Red

Table H-4 illustrates the color representation in the Landset system. Since the MSS has two infrared bands, either of these may be chosen to make a color print along with the red and green bands. Band 7 is usually used. The black and white positive transparencies are contact printed using the red, green and blue filters listed in the third column of the table. The fourth column gives the dye-forming layer exposed in the Kodak Type 2445 color negative film by light of the color given in the previous column. The color negative is contact printed onto Type 4109 color negative film and a positive image is produced. Cyan light from the negative exposed the magenta and yellow layers in the positive. Magenta and yellow in combination produce red. The formation of green and blue is also described in the table.

The alphanumeric annotation on the image shows which spectral bands were used to make any color composite. Since these numbers are black in the positives and are spatially offset, they appear in the color positive as the complement of the color of the filter used (i.e., band 1 annotation printed through a blue filter appears yellow in a color positive).

H.2.2 PPS Transfer Function

As each image of data is exposed in the EBR, an electronically generated gray scale, correlated with reference points in the RBV or MSS data, is added. This annotation gray scale provides a means of maintaining a radiometric reference with each image as it is processed. The electrical signals for the video data as well as for the annotation gray scale pass through film and gun gamma correctors. The gun gamma corrector compensates for non-linearities in the input-voltage/electron exposure characteristic of the EBR. The film gamma corrector reduces the slope of the D-log E curve to the proper value and straightens the toe. (Without a film gamma corrector, the gamma measured on the SO-467 film is about 2 and the characteristic curve has a long toe.) After gamma correction, there is a linear relation between film transmission and RBV voltage or MSS count, namely:

$$T_x = \frac{V_x}{V_R} T_R + T_{min}$$

where

T_x = Transmission of film corresponding to voltage V_x.

V_x = Corrected sensor voltage

V_R = Sensor voltage range

T_R = Range of film transmission ($T_{max} - T_{min}$)

T_{min} = Minimum film transmission

If T_{min} is neglected, it can be seen that the slope of the density versus log sensor voltage (or count) curve can be equal to one anywhere in the range ($\gamma = 1$). But the effect of T_{min} not being zero is to cause the D-log voltage curve to deviate from the slope of 1 at high densities corresponding to low transmission. This has the effect of lowering the contrast on a positive in darker parts of a scene. Table H-5 gives the gradient or local slope of the D-log voltage curve as a function of the percent of sensor voltage range.

Succeeding generations after the first have a D-log E Curve with $\gamma = 1$ and the images are recorded on the linear portion. Therefore, Table H-5 also applies to all generations of black and white positive film products.

Table H-5. Gradient of First Generation D-Log Voltage

Sensor Output (% of Max.)	Gradient (Slope)
2 0	0 75
3.2	0 8
5.0	0.85
8.0	0.9
12.7	0.95
20 & higher	1.0

H.2.3 Photographic Image Quality

Photographic image quality is mainly dependent upon the choice of film, although the developer is sometimes significant. Generally, films of high light sensitivity have relatively inferior image quality while films of low light sensitivity have relatively high image quality. Aerial duplicating films used in the Landsat PPS are all of low light sensitivity and consequently have good image quality characteristics.

Image quality is broadly defined by four parameters:

1. Tone reproduction
2. Modulation Transfer Function (MTF) or resolution
3. Granularity or graininess
4. Spatial non-uniformity

These parameters were originally used as criteria to select the films used in the PPS and are described in the following paragraphs.

H.2.3.1 Tone Reproduction

Tone reproduction is the generation of photographic records by the modulation of the input exposure source. The exposure for the first generation is a time-modulated electron beam and for succeeding generations a spatially-modulated film transparency.

Tone reproduction is performed to standards established by requirements placed upon the photographic system. These requirements and the methods by which they are controlled are discussed in the following paragraphs. The requirements and controls for production of the first generation or master image are discussed first, followed by those for production of succeeding generations.

H.2.3.1.1 Master Image Generation

The photographic transfer function combined with the gamma corrector transfer function are required to maintain a linear relationship between film transmission and sensor voltage or count. Further, the maximum and minimum film transmissions (or density) are controlled within absolute tolerances. The nominal transfer function and allowable tolerances are shown in Figure H-23. Nominally, the film

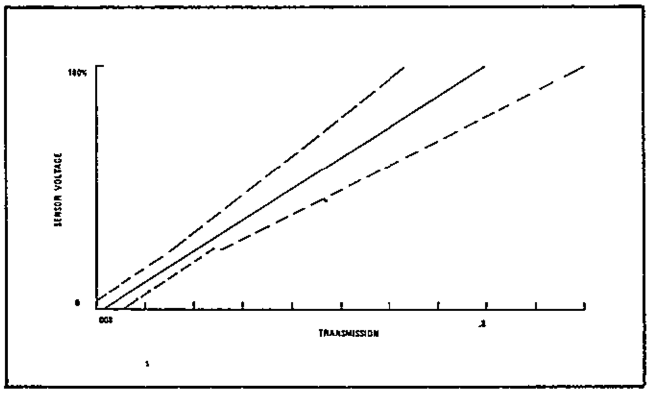

Figure H-23. Transfer Function for First Generation Positive

density corresponding to 0% sensor voltage is 2.1D (.0079T) and that corresponding to 100% sensor voltage is 0.1D (.794T) The linearity limits with respect to sensor voltage are ±0.1D between 0.1 and 0.70 (.794 and .195T). Between 0.7 and 2.1D (.195 and .0079T) the linearity limits are ±0.04T Figure H-24 provides the conversion between transmission and density for convenience.

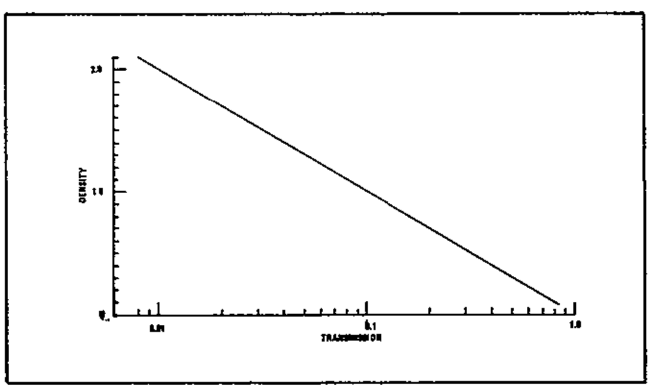

Figure H-24. Density-Transmission Conversion

Tone reproduction in the first generation is monitored by processing a video tape through initial image generation that contains voltages or counts representing a gray scale. The gray scale has 17 levels (i.e., the distance between steps is 1/16 of the count or voltage range). An electron beam recording is made of the gray scale and after processing the density of each level in the image is measured with a densitometer. The image density is plotted against the input step number to verify the linearity.

H.2.3.1.2 Subsequent Image Processing

Succeeding generations of photographic products are also required to maintain the linear sensor voltage to transmission relationship. The nominal maximum and minimum density values, however, are shifted upward to 2.4D and 0.4D, respectively, to allow use of the linear portion of the D-log E curve of the duplicating film. The density range of 2.0 is maintained. This tone reproduction process is shown in Figure H-25.

The tolerance on the maximum and minimum density for the second generation is ±0.06 and for the second and third generations combined is ±0.12 about the 2.4D and 0.4D points.

Tone reproduction in photo generations after the first is monitored by computing gamma between the maximum and minimum density limits maintaining the average gamma between these density limits at 1 ±0.1. The computation is done by determining the best (least squares) straight line fit to density and log E measurements. Log E is the density measured on a step of a gray scale that is printed onto the film being monitored. Thus, tone reproduction control is involved with not only the film characteristics but also the effect of the exposing device—contact printer or enlarger

Density measurements on all black and white transparencies are visible diffuse measured using a Macbeth TD-102 densitometer with the blackened aperture modification. A 1mm aperture is used on 70mm products and 3mm on 9.5-inch products.

H.2.3.1.3 Paper and Color Products.

Black and white paper prints are processed to $\gamma = 1$. The tonal range between saturation on

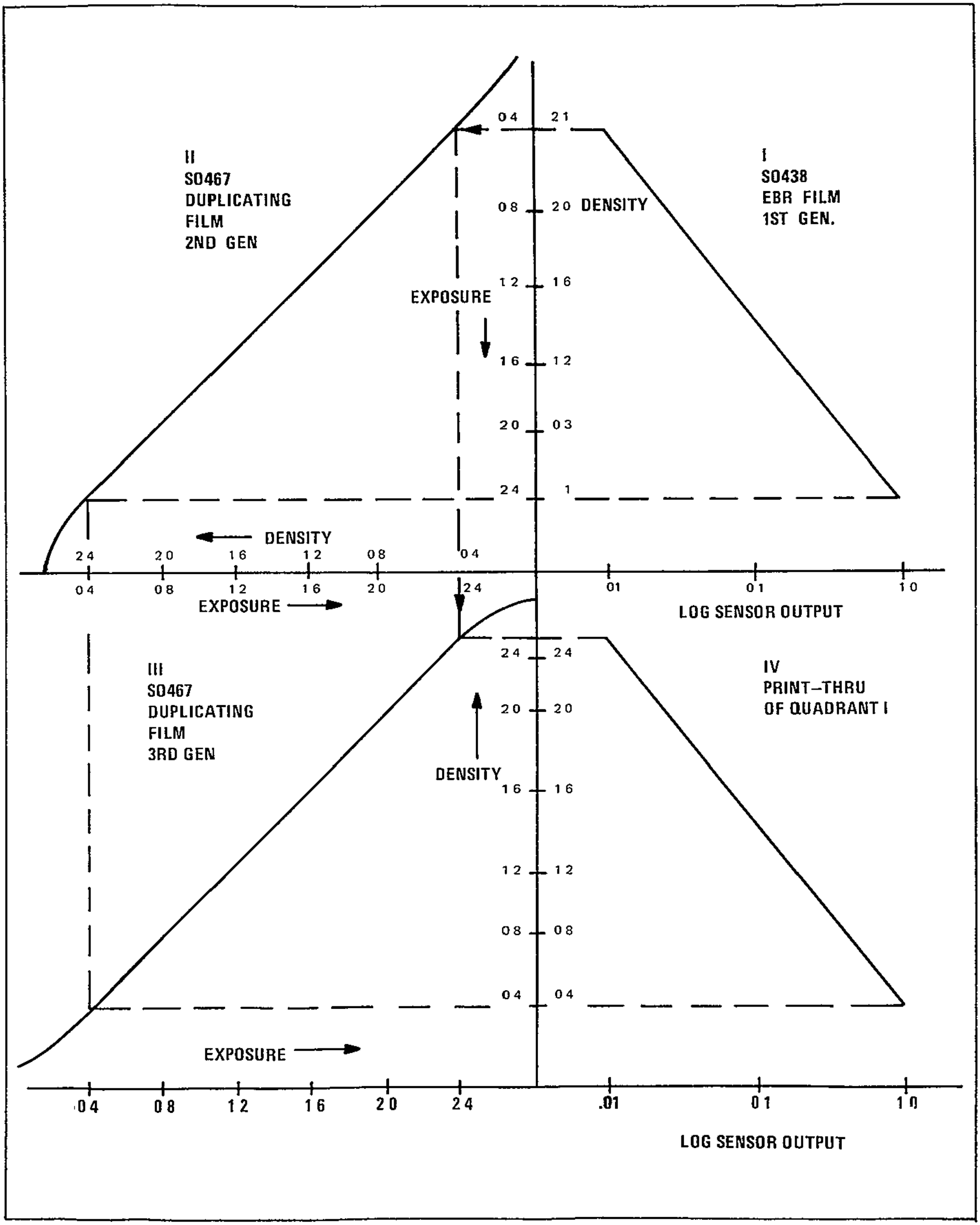

Figure H-25. Tone Reproduction Characteristics of Photo Processing Subsystem these prints is about 1.6 density units (40:1 sensor output) and the linear portion of this range is about 1.2 density units (16:1 sensor output).

Color transparencies have a gamma of approximately 1, a tonal range between saturation of about 1.8 density units (60 1 sensor output) and a linear portion that is about 1.2 density units for red.

Color prints have a gamma close to 2 and a tonal range that allows 14 of the 15 gray steps to be discerned. Current practice in the photographic facility for products that do not cover a 2.0 density range is to expose them so that saturation occurs at the second darkest step of the gray scale.

H.2.3.2 Modulation Transfer Function

Modulation Transfer Function (MTF) is the response to a sine wave at frequency f after image processing relative to the amplitude of the sine wave previous to processing The MTF of the PPS is determined by contact printing a sine wave target onto film, processing, and then measuring the transmission of the film using a microdensitometer.

The sine wave target is a film transparency that has transmission varying sinusoidally as a function of distance The target contains frequencies including the range from 1.5 to 42 cycles per mm. The modulation of the target equals·

$$\frac{T_{max} - T_{min}}{T_{max} + T_{min}}$$

where T_{max} and T_{min} are the transmissions at the peak of the sine wave. The target modulation is 0.6. This modulation is measured using the same microdensitometer as the film being tested and the reported modulation divided by the target modulation. The photographic system MTF includes the effect of printers in addition to the film emulsion.

MTF is measured using a microdensitometer having a slit of small width and large height The width is in the scanning direction The large height is used to make the effect of film grain insignificant An aperture size of 2 x 275 μm is used in measuring the MTF of the photographic system.

The magnitude of the modulation on the film affects both resolving power and radiometry. Modulation affects resolving power because detectability is a function of the contrast threshold of the eye or the modulation-to-noise ratio. Radiometric errors occur since the MTF falls off as the size of an object in the scene decreases The decreased modulation means that the image of the object will have lesser or greater density than the image of the same type of object in a larger size.

The MTF of the 70mm third generation positive is given in Figure H-26. The response

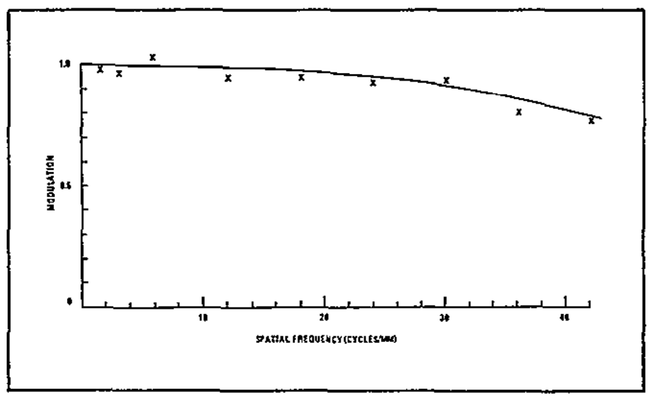

Figure H-26. Sine Wave Response, Third Generation 70 MM

is relatively flat over the frequency range. At 40 cycles per mm the photographic system MTF is about four times the sensor MTF and thus is not the limiting factor in resolving power or radiometric errors For enlarged products the photographic system MTF has even less effect because of the larger format, however, the enlarger MTF must be considered. Tests of the enlarger MTF indicate its response to be about 2.5 times that of the sensors at 40 cycles per mm Thus the photographic system MTF will have little effect on 9.5-inch products

H.2.3.3 Granularity

Film granularity is the rms density variation about a mean density level as measured with a specified microdensitometer aperture. Granularity is the integrated film noise from a spatial frequency close to zero up to a frequency corresponding to the diameter of the scanning aperture. Very low frequency noise is removed from the granularity measurements and reported separately as spatial non-uniformity. Granularity is given as 1000 times the measured value.

In a single photographic generation, granularity increases in proportion to the square root of density, but this proportionality does not apply in a multi-generation photo system. High granularity in the first generation results in a low granularity in the second generation because of the density reversal in going from a positive to a negative. Also, the resultant granularity is a function of the MTF of printers and emulsion and the gradient of the density-log exposure curve.

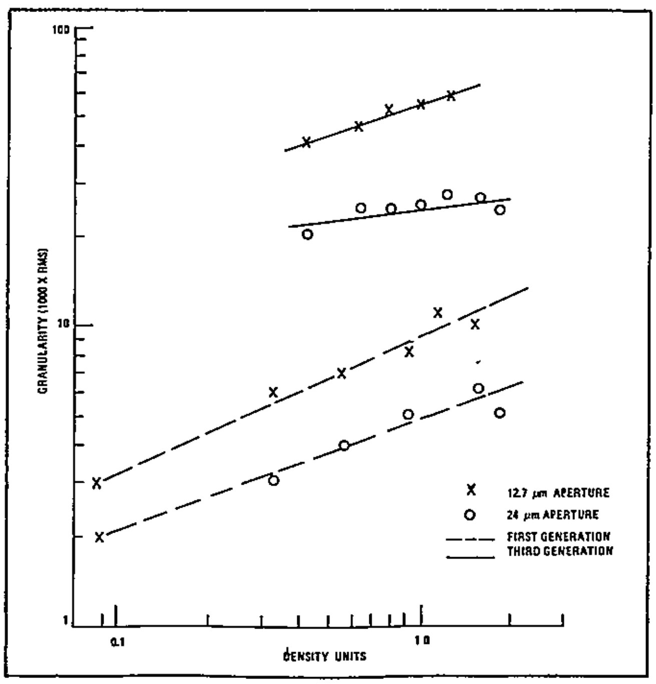

Figure H-27. Granularity for First and Third Generation Film

Measured rms granularity is given in Figure H-27. The data is given for the first and third generation 70mm film for two aperture sizes.

The film noise increases five to six times in going from the first to the third generation and is approximately inversely proportional to the aperture diameter within a film generation.

H.2.3.4 Spatial Uniformity

Spatial non-uniformity is the rms variation in density over the image area of the processed film exposed with a uniform level of gray. Spatial non-uniformity introduces an error in relating density measurements within the image or between points in the image and the annotation gray scale.

Spatial uniformity is measured using a densitometer with a 1 mm aperture on 70mm film and a 3mm aperture on 9.5-inch film. The film is exposed using a point light source to obtain uniform exposure. After processing to the appropriate generation, density measurements are made over the image area and the rms value computed.

Given spatial non-uniformity measured in density units, the transmission error is:

$$\Delta T = \frac{\Delta D\ (T)}{0.434}.$$

where,

ΔD = Spatial non-uniformity

T = Transmission level, percent

Spatial uniformity tests have been made for both 70mm third generation and enlarged 9.5-inch third generation transparencies. Typically ΔD ranges from 0.04 to 0.08 for 70mm products and from 0.06 to 0.10 for 9.5-inch products including the effects of the enlarger.

H.2.4 Dimensional Stability

All films used in the IPF have 0.004-inch Estar polyester film bases, which are relatively insensitive to dimensional changes. However, polyester bases do exhibit minor size changes due to three independent factors.

1. Thermal changes

2. Humidity changes

3. Processing

Eastman Kodak's Handbook of Physical Properties gives the following dimensional stability characteristics for this film. The dimension of the film exhibits a hysteresis effect when the humidity is allowed to reach a value of about 80% RH. The aging shrinkage is the result of storage at 120° F and 20% RH for seven days. Storage for a year at 78° F and 60% RH results in negligible shrinkage beyond that allowed for processing.

Thermal Coefficient of Linear Expansion (% per ° F)	+0.0015
Humidity Coefficient of Linear Expansion (% per 1% RH)	+0 0025
Humidity Bias for Expansion Beyond 80% RH (%)	−0 05
Processing Plus Aging Shrinkage (%)	−0.04
Processing Shrinkage (%)	−0.03

The first generation film is exposed under the following environmental conditions:

Temperature	72 ± 2° F
Humidity	50 ± 5% RH

In order to obtain an estimate of the effect of the environment on relative measurement accuracy, a case was used in which the measurement was made under relatively cool (60° F), dry (20% RH) conditions, causing all dimensional changes to be of the same polarity. (If the third generation film is measured within the image at a temperature and humidity higher than these values, it is likely that the relative error will be quite small due to cancellation of expansion and shrinkage effects) It was assumed that at some time previous to measurement the humidity had reached 80% The errors are then

Temperature	— 0.015%
Humidity	— 0.075%
Humidity Bias	— 0.05%
2nd Gen. Processing	— 0 03%
3rd Gen Processing & Aging	— 0.04%
TOTAL	— 0.21%

The effect of this shrinkage is a photographic scale change that will cause two objects 10 statute miles apart to be measured 33 meters closer than actual

The use of the tick marks in measurement will eliminate the effect of dimensional changes due to the causes given above

Random dimensional changes of 5 μm have been reported in the literature. Using an RSS summation and using a 3.385 enlargement ratio, this change is 24 μm over three generations For comparison with the stability figures given above, this is equivalent to 0.013 percent of the image size on the 9.5-inch third generation.

APPENDIX I
SUN ELEVATION EFFECTS

The unique orbit of Landsat causes the spacecraft to pass over the same point on the earth at essentially the same local time every 18 days. However, even though the local time remains essentially the same, changes in solar elevation angle, as defined in Figure I-1, cause variations in the lighting conditions under which imagery is obtained These changes are due primarily to the north/south seasonal motion of the Sun

Formulas for the calculation of solar elevation angle for any latitude, time of day and time of year are as follows

$$a = \arc\sin(\sin\delta\ \sin\phi + \cos\delta\ \cos h \cos\phi)$$

a = Solar elevation angle
δ = Solar declination
h = Hour angle (deg) to sun
ϕ = Latitude

Calculation of δ

Exact values of the Sun's declination can be obtained from the American Ephemeris and Nautical Almanac A close approximation is given by the following formula

$$\sin\delta = \sin i \sin\lambda$$

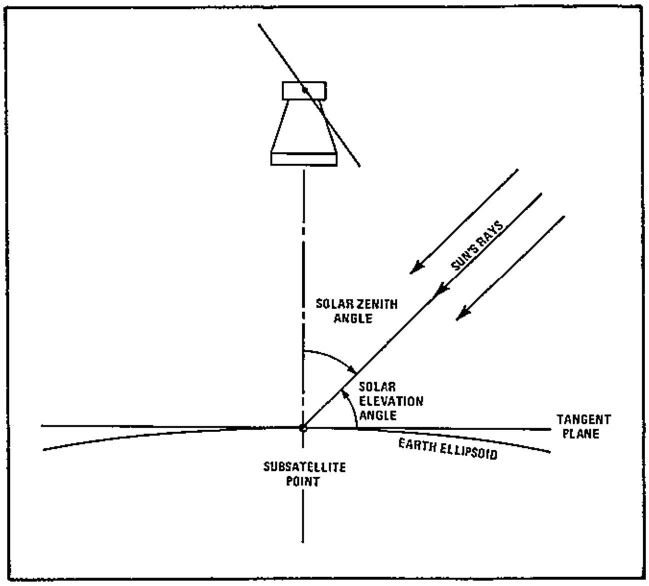

Figure I-1. Solar Elevation Angle

i = Inclination to ecliptic = 23.44°
λ = Sun's apparent position (0° at vernal equinox)
d = Days past vernal equinox (≈21 March)
δ = Arc sin [0 3978 sin (0 986° d)]

Calculation of h

1. Find the difference in hours and decimal hours, from 1200 (local standard time) to time of interest.

2 Change (1) to degrees by multiplying by 15°

3. Using longitude of interest find difference in degrees to center longitude for respective time zone. (75°, 90°, 105°, or 120° for conterminous U.S.)

4 Add (3) to (2) if longitude of interest is to the East (of center longitude) and afternoon, or West and morning Subtract (3) from (2) for opposite conditions. The final value is h.

Note h is in error (slightly) by not accounting for the equation of time. This correction can be obtained from the American Ephemeris and Nautical Almanac From the Table of the Sun, find ephemeris transit time for date of interest and use instead of 1200 in step (1) above.

The change in irradiance of the sensor is influenced by the change of solar elevation angle, by the change in intrinsic reflectance of the ground scene and by the change in atmospheric effects due to length and composition. Exposure time of the RBV may be varied by ground commands to accommodate the changing illumination levels. At certain times of the year imagery is not obtained in the high latitude regions (north and south) of the Earth due to inadequate scene illumination.

The actual effect of changing solar elevation angle on a given scene is very dependent on the scene itself. For example, the intrinsic reflectance of sand is significantly more sensitive to changing solar elevation angle than are most types of vegetation. Due to this scene dependence, each type of scene must be evaluated individually to determine the range of solar elevation angles over which useful imagery will be obtained.

Figure I-2 shows the solar elevation angle as a function of time of year and latitude. This family of curves is for a 9:30 a.m descending node time, which is the nominal time of equatorial crossing for the satellites. By draw-

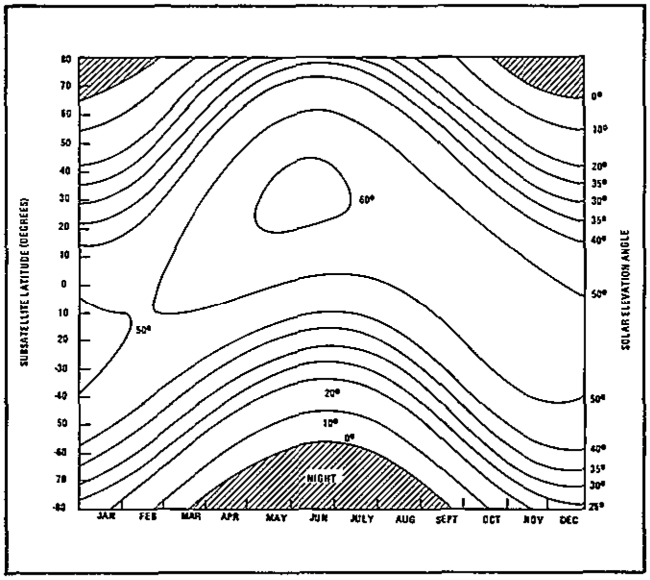

Figure I-2 Solar Elevation Angle History as a Function of Subsatellite Latitude – Descending Node at 9.30 a.m

ing a horizontal line for a given latitude, the solar elevation angle can be determined for any time of year. Portions of the data have been transferred to the global maps in Figure I-3 These maps show the range of possible sensor operation (i.e., daylight) for the various seasons Depending on the scene, it may or may not be possible to obtain useful imagery at the lower solar elevation angles At solar elevation angles greater than 30 degrees, it is expected that all scenes can be satisfactorily imaged Normally, no attempt is made to obtain imagery for solar elevation angles less than 10°.

Two other parameters affect the local solar elevation angle. These are the Landsat launch window and perturbations to the orbit. The

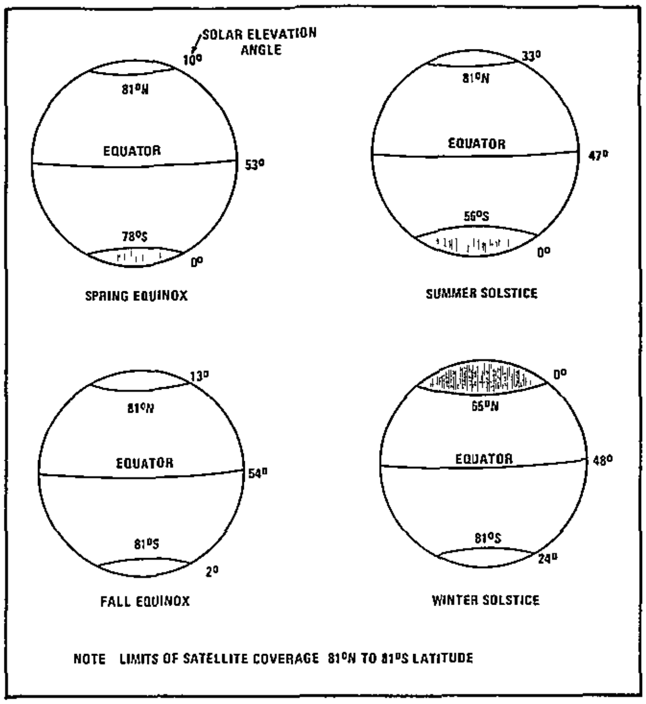

Figure I-3. Seasonal Variations in Solar Elevation Angle – 9·30 a.m. Descending Node

launch window (allowable launch time variation) was plus 30 and minus zero minutes, which resulted in a possible descending node time anywhere in the range of 9.30 to 10:00 a.m. The effects of launch time variations on solar elevation angle are shown in Figures I-4 through I-6 for various latitudes.

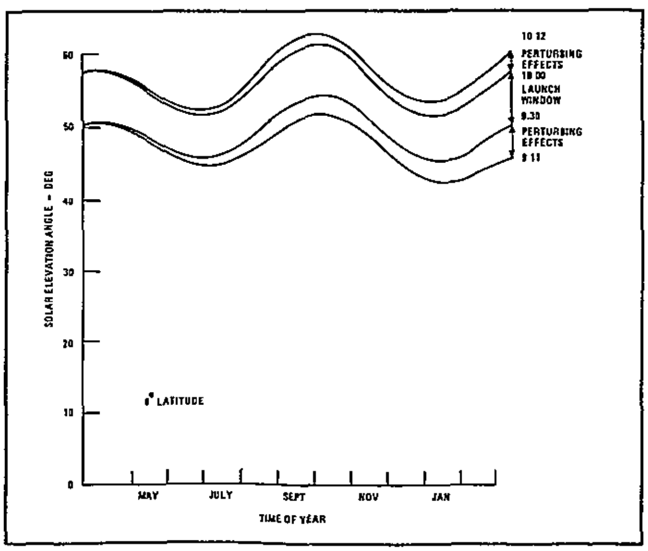

Figure I-4. Launch Window and Orbit Perturbing Effects on Solar Elevation Angle at 0 Degrees Latitude

After spacecraft launch, the local times would then remain fixed throughout the mission were it not for perturbing forces to the orbit These forces, such as atmospheric drag and the Sun's gravity, will shift the time of descending node throughout the year, resulting in changes to the nominal solar elevation angle. The changes due to these perturbing effects are also shown in Figures I-4 through I-6 Actual equatorial crossing times for Landsats 1 and 2 are shown in Figure F-9, Appendix F.

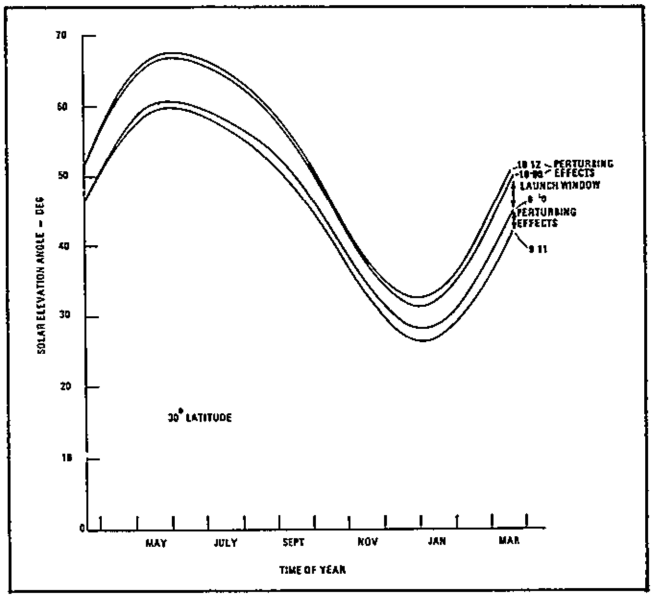

Figure I-5. Launch Window and Orbit Perturbing Effects on Solar Elevation Angle at 30 Degrees North Latitude

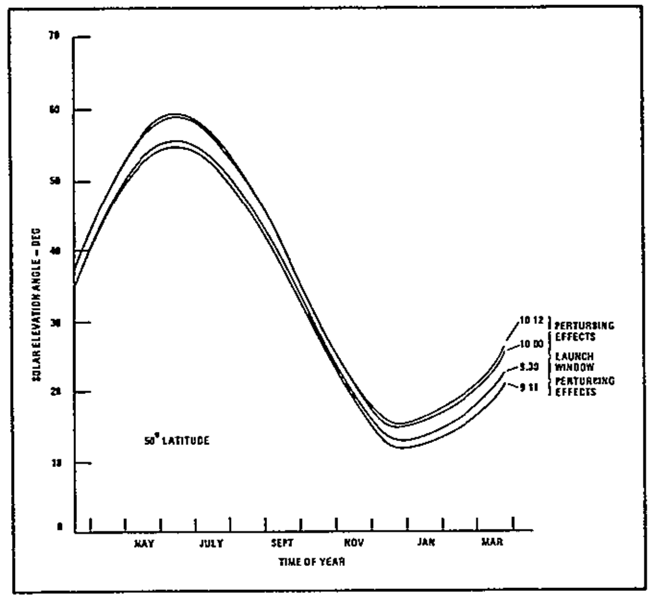

Figure I-6. Launch Window and Orbit Perturbing Effects on Solar Elevation Angle at 50 Degrees North Latitude

APPENDIX J

LIST OF NASA PRINCIPAL INVESTIGATORS

A comprehensive list of investigators is given in this appendix for both Landsat 1 and Landsat Follow-On Investigation Programs. Names of investigators are grouped by primary disciplines, along with their address, title of their investigation, telephone number, and identifying number assigned by NASA/GSFC. Landsat 1 investigators are identified by a GSFC ID No. beginning with a "1", and Landsat Follow-On investigators by a GSFC ID No. beginning with a "2".

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GSFC ID 1101A-UN02A-C -A000
PHONE 603-646-3523
TITLE LAND USE OF NORTHERN 1/3 OF MEGALOPOLIS & CREATE APPROPRIATE MAPS & DATA BANK

(PRIMARY DISCIPLINE)

PD: 2. LAND USE SURVEY AND MAPPING

NAME COOK,JOHN P.,DR.
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FAIRBANKS, ALASKA 99701

GSFC ID 1110N-UN02F-C -A000
PHONE 907-479-7288
TITLE FEASIBILITY STUDY FOR LOCATING ARCHAEOLOGICAL VILLAGE SITES BY SATELLITE REMOTE SENSING TECHNIQUES

NAME EDSON,DEAN T.
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NAT'L.CENTER,RM.2A300
MAIL STOP 524
RESTON, VA 22092

GSFC ID 1116A-IN02C-C -A000
PHONE 703-860-6301
TITLE INVESTIGATION ERTS-A IMAGERY FOR APPLICATION TO THERMATIC MAPPING

NAME ENRIQUEZ,ALBERTO,DR.
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427825 CARACAS
VENEZUELA

GSFC ID 1117A-FO02A-C -0000
PHONE 417564-427825
TITLE INVESTIGATION OR URBAN-REGIONAL PLANNING IN VENEZUELA

NAME RAJE, SURENDRA ANANT
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VALLEY FORGE STC, U-3230
P. O. BOX 8555
PHILADELPHIA, PA 19101

GSFC ID 1124A-PR02A-C -A000
PHONE 215-962-1177
TITLE URBAN DEVELOPMENT AND REGIONAL PLANNING FOR LOS ANGELES COUNTY

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RESTON, VA 22092

GSFC ID 1125A-IN02A-C -A000
PHONE 703-860-6345
TITLE CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE

NAME MCEWEN,ROBERT B.
ADDRESS TOPOGRAPHIC DIV.,U.S.G.S.
NAT'L.CENTER,RM.2A225
MAIL STOP 510
RESTON, VA 22092

GSFC ID 1150A-IN02C-C -0000
PHONE 703-860-6271
TITLE CARTOGRAPHIC EVALUATION OF ERTS ORBIT & ATTITUDE DATA

NAME REHDER,JOHN B.
ADDRESS DEPT. OF GEOGRAPHY
UNIV. OF TENN.
KNOXVILLE, TENN. 37916

GSFC ID 1162C-UN02A-C -A000
PHONE 615-974-2418
TITLE GEOGRAPHIC APPLIC. TO RURAL LANDSCAPE CHANGE

NAME PLACE,JOHN L.,DR.
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RESTON, VA 22092

GSFC ID 1186A-IN02A-C -A000
PHONE 703-860-6345
TITLE INTERPRET ERTS IMAGES TO PRODUCE A LAND USE MAP & COMPUTER MODEL OF PHOENIX QUADRANGLE.

(PRIMARY DISCIPLINE)

PD: 2. LAND USE SURVEY AND MAPPING

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P.O. BOX 1496
TITUSVILLE, FLA. 32780

GSFC ID 1196A-ST02A-C -A000 PHONE 305-269-8362

TITLE URBAN & REGIONAL PLANNING

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GSFC ID 1211A-IN02H-C -R000 PHONE 703-860-6271

TITLE INVESTIGATION OF ERTS RBV & MSS IMAGERY FOR PHOTOMAPPING OF THE USA

NAME HARTING, WILLIAM
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100 CHURCH STREET
NEW YORK, N.Y. 10007

GSFC ID 1219A-ST02A-C -A000 PHONE 212-433-5212

TITLE TO DETECT AND IDENTIFY DEVELOPMENT OR CHANGES IN LAND USE PATTERNS FOR
REGIONAL PLANNING PURPOSES

NAME COLVOCORESSES,ALDEN P.
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NAT'L.CENTER,RM.2A318
MAIL STOP 522
RESTON, VA 22092

GSFC ID 1233A-IN02B-C -R000 PHONE 703-860-6285

TITLE EVALUATION OF ERTS IMAGERY FOR CARTOGRAPHIC APPLICATION

NAME SMEDES,HARRY W.
ADDRESS U.S. GEOLOGICAL SURVEY
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DENVER, COLORADO 80225

GSFC ID 1236A-IN02C-C -R000 PHONE 303-234-3940

TITLE COMPUTER MAPPING OF TERRAIN USING MULTISPECTRAL DATA FROM ERTS-A FOR
YELLOWSTONE NATL. PARK

NAME KOSCO,WILLIAM J.
ADDRESS TOPOGRAPHIC DIV.U.S.G.S.
NAT'L.CENTER,RM.2A223
MAIL STOP 510
RESTON, VA 22092

GSFC ID 1237A-IN02B-C -D000 PHONE 703-860-6271

TITLE MAN-MADE CULTURE INTERPRETATION & CULTURE REVISION OF SMALL-SCALE MAPS

NAME THOMAS,EDWIN L.
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BALTIMORE, MD. 21201

GSFC ID 1261A-ST02A-C -A000 PHONE 301-383-2455

TITLE APPLICATION OF ERTS-A DATA TO INTEGRATED STATE PLANNING IN MD.

NAME WRAY,JAMES R.
ADDRESS U.S.G.S. GEOGRAPHIC APPL.PROG.
NAT'L.CENTER,RM.2722
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RESTON, VA 22092

GSFC ID 1273A-IN02F-C -A000 PHONE 703-860-6345

TITLE CENSUS CITIES EXPERIMENT IN URBAN CHANGE DETECTION

(PRIMARY DISCIPLINE)

PD: 2. LAND USE SURVEY AND MAPPING

NAME SIZER, JOSEPH E.
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802 CAPITOL SQUARE BLDG.
ST. PAUL, MINN. 55101
GSFC ID 1283A-ST02A-C -A000
PHONE 612-296-3985
TITLE LAND MANAGEMENT IN MINN.

NAME LINTZ JR., DR. JOSEPH
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UNIVERSITY OF NEVADA
RENO, NEV. 89507
GSFC ID 1289A-UN02C-C -A000
PHONE 702-784-6050
TITLE COMPILATION OF TWO PHOTO MAPS OF NEVADA

NAME COLWELL, ROBERT N., DR.
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UNIVERSITY OF CALIFORNIA
BERKELEY, CALIF. 94720
GSFC ID 1317E-UN02A-C -A000
PHONE 415-642-2395
TITLE USE OF ERTS-A TO ASSESS & MONITOR CHANGE IN SAN JOAQUIN VALLEY & CENT. COASTAL ZONE OF CALIF.

NAME SIMONSON, GERALD H., DR.
ADDRESS DEPT. OF SOILS
OREGON STATE UNIV.
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GSFC ID 1345A-UN02A-C -A000
PHONE 503-754-2441
TITLE COMPARATIVE EVAL. OF IMAGERY FOR RESOURCE INVENTORY IN LAND-USE PLANNING & COMMUNITY DEVELOPMENT

NAME HARDY, ERNEST E.
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FERROW HALL
CORNELL UNIVERSITY
ITHACA, NEW YORK 14850
GSFC ID 1358A-UN02A-C -A000
PHONE 607-256-2162
TITLE APPLICATION OF ERTS(A) IMAGERY TO INVENTORYING LAND USE AND NATURAL RESOURCES

NAME LANGER, BERILO
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DNPM-PROJECT RADAM
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RIO DE JANEIRO, BRAZIL
GSFC ID 1370A-FO02A-C -0000
PHONE 266-5901
TITLE ANALYSIS OF EARTH RESOURCES & FACTORS GOVERNING ENVIRONMENTAL QUALITY IN AMAZON REGION

NAME SAA, RENE
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DE RECURSOS NATURALES
CASILLA 14.995
SANTIAGO, CHILE
GSFC ID 1372A-FO02A-C -0000
PHONE 69369-67690
TITLE CHANGES IN RURAL LAND USE IN CENTRAL & NORTH CHILE

NAME BUSUEGO, FERNANDO
ADDRESS DIRECTOR, BUREAU OF MINES
HERRAN STREET
MANILA, PHILIPPINES
GSFC ID 1612A-FO02A-C -0000
PHONE
TITLE USE ERTS-A IMAGES FOR NATURAL RESOURCES INVESTIGATION IN PHILIPPI

PD: 2. LAND USE SURVEY AND MAPPING

NAME TORIBIO,FRANCISCO J. ARZATE — GSFC ID 1631B-F002G-C -0000 — PHONE 5-19-79-39
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AVS. XOLA Y UNIVERSIDAD
MEXICO 12,D.F., MEXICO
TITLE INVESTIGATION OF LONG SCOPE FOR HIGHWAY ENGINEERING PURPOSES

NAME WILSON,JOE F. — GSFC ID 1677A-C002B-C -X000 — PHONE 301-496-8881
ADDRESS NOAA, NATIONAL OCEAN SURVEY
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TITLE EVALUATE ERTS IMAGERY AS SOURCE MATERIAL FOR MAPPING AND CHARTING

NAME VACA,JORGE F. — GSFC ID 19540-F002A-P02-0YJ0 — PHONE 5-78-62-00 — 116
ADDRESS COMMISSION OF MEXICAN STUDIES
SAN ANTONIO ABAD NO.124
MEXICO 8,D.F.,MEXICO
TITLE COMPREHENSIVE STUDY OF LEON-QUERETARO AREA

(PRIMARY DISCIPLINE)

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

NAME WEECKSTEEN, GUY
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B. P. 6009
45 ORLEANS (02), FRANCE

GSFC ID 1003A-F003K-C -0000 PHONE 38-66-06-60

TITLE RESEARCH TO DETECT VARIOUS SIZED LINEAMENTS, TO GIVE CHRONOLOGY IN GEOLOGICAL UNITS, & TO FIND STRUCTURAL UNITS

NAME WEECKSTEEN, GUY
ADDRESS BUREAU DE REC.GEO.ET MIN.
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GSFC ID 1003B-F003J-C -0000 PHONE 38-66-06-60

TITLE RESEARCH ON SPACECRAFT PHOTOGRAPH ABILITY TO GIVE COMPREHENSIVE CHRONOLOGY IN COMPLEX GEOLOGICAL UNITS

NAME WEECKSTEEN, GUY
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TITLE OBTAIN COMPREHENSIVE CHRONOLOGY OF COMPLEX GEOLOGICAL UNITS IN DAHOMEY

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TITLE RESEARCH ON SPACECRAFT PHOTOGRAPHS ABILITY TO POINT OUT STRUCTURAL UNITS

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92-RUEIL-MALMAISON
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GSFC ID 1009C-F003K-C -A000 PHONE 967-11-10

TITLE STUDY GEOMORPHOLOGY, PAST & PRESENT, LINEAR TRENCH, TECTONICS RELATIONSHIP BETWEEN PYRENEES & ALPS

NAME KNEPPER JR., DANIEL H.
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TITLE GEOLOGIC AND MINERAL AND WATER RESOURCES INVESTIGATIONS IN WESTERN COLORADO USING ERTS-A DATA

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GSFC ID 1036A-F003M-C -0000 PHONE

TITLE GEOLOGICAL RESEARCH PROGRAM IN ETHIOPIA

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TITLE STRUCTURAL AND LITHOLOGIC STUDY OF NORTHERN COAST RANGE AND SACRAMENTO VALLEY, CALIFORNIA

(PRIMARY DISCIPLINE)

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

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PHONE 805-498-4545 (192)
TITLE IDENTIFICATION AND INTERPRETATION OF TECTONIC FEATURES FROM ERTS-A IMAGERY

NAME VINCENT, ROBERT K.
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ANN ARBOR, MICHIGAN 48107
GSFC ID 1075A-OT03A-C -A000
PHONE 313-483-0500 346
TITLE MAPPING OF EXPOSED FERRIC AND FERROUS COMPOUNDS

NAME SAUNDERS, DONALD F., DR.
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TEXAS INSTRUMENTS, INC.
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DALLAS, TEXAS 75222
GSFC ID 1083A-PR03A-C -A000
PHONE 214-238-2813
TITLE EVAL.OF COMMERCIAL UTILITY OF ERTS-A IMAGERY IN STRUCTURAL RECONNAISSANCE FOR MINERALS & PETROLEUM

NAME BECHTOLD, IRA C.
ADDRESS ARGUS EXPLORATION COMPANY
555 S. FLOWER ST., SUITE 3700
LOS ANGELES, CALIF. 90071
GSFC ID 1103A-PR03K-C -A000
PHONE 213-489-3700
TITLE A RECON. SPACE SENSING INVEST.OF CRUSTAL STRUC.FOR STRIP FROM E.SIERRA TO COLO. PLATEAU

NAME GEDNEY, LARRY D.
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GSFC ID 1110L-UN03E-C -A000
PHONE 907-479-7197
TITLE EVALUATION OF FEASIBILITY OF MAPPING SEISMICALLY ACTIVE FAULTS IN ALASKA

NAME BENSON, CARL S., DR.
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FAIRBANKS, ALASKA 99701
GSFC ID 1110M-UN03C-C -A000
PHONE 907-479-7565
TITLE GLACIOLOGICAL & VOLCANOLOGICAL STUDIES OF WRANGELL MTS., ALASKA & MT.EREBUS, ANTARCTICA

NAME ROMERO, ADOLFO C., DR.
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EDF. CAMEJO
CENTRO SIMON BOLIVAR
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GSFC ID 1120A-FO03I-C -0000
PHONE 45-27-87
TITLE VENEZUELA DEVELOPMENT OF TECHNIQUES TO INVESTIGATE & ESTIMATE NATURAL RESOURCES IN REMOTE AREAS

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GSFC ID 1131A-IN03I-C -A000
PHONE 303-234-4109
TITLE A STUDY OF MORPHOLOGY, PROVENANCE, AND MOVEMENT OF DESERT SAND OF SAND SEAS IN AFRICA, ASIA, AND AUST

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

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GSFC ID 1141A-PR03K-C -A000 PHONE 202-223-8115

TITLE EXPLOITATION OF ERTS IMAGERY USING SNOW ENHANCEMENT TECHNIQUES

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GSFC ID 1145A-IN03C-C -A000 PHONE 415-323-2520

TITLE PROTOTYPE VOLCANO SURVEILLANCE NETWORK: INSTALLATION, TESTING, AND EVALUATION

NAME GLOVER III,LYNN
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VA. POLYTECHNIC INST.
BLACKSBURG, VA. 24061

GSFC ID 1160A-UN03I-C -A000 PHONE 703-951-6969

TITLE GEOLOGICAL LANDFORM ANALYSIS IN CENTRAL PIEDMONT

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ROLLA,MISSOURI 65401

GSFC ID 1168A-ST03M-C -A000 PHONE 314-364-1752 (34)

TITLE ENVIRONMENTAL GEOLOGY AND LAND-USE PLANNING IN THE ST. LOUIS-KANSAS CITY CORRIDOR IN MISSOURI

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5225 N. SHARTEL AVE.
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GSFC ID 1173A-PR03B-C -A000 PHONE 405-842-3333

TITLE AN EVALUATION OF THE SUITABILITY OF ERTS DATA FOR THE PURPOSES OF PETROLEUM EXPLORATION

NAME LATHRAM,ERNEST H.
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GSFC ID 1180A-IN03K-C -A000 PHONE 415-323-2348

TITLE IDENT.GEOSTRUCTURES OF CONTINENTAL CRUST PARTICULARLY AS RELATED TO MINERAL RESOURCE EVALUATION

NAME SCHMIDT,ROBERT G.
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GSFC ID 1181A-IN03A-C -A000 PHONE 703-860-7358

TITLE ANALYSIS STUDY OF MULTISPECTRAL DATA FROM ERTS-A IN W.PAKISTAN

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GSFC ID 1182A-IN03H-C -A000 PHONE 303-234-4111

TITLE ERTS APPL.TO ACCELERATED EROSION & TO MONITOR FUTURE EROSIONAL CHANGES IN ARIZONA REGION

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

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GSFC ID 1189A-IN03M-C -A000 PHONE 703-860-7872

TITLE GEOLOGIC MAPPING,STRUCTURAL ANALYSIS & MINERAL RESOURCE INVENTORY OF SOUTH AMERICA

NAME SMEDES,HARRY W.
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GSFC ID 1194A-IN03J-C -A000 PHONE 303-234-3940

TITLE EFFECTS OF ATMOSPHERE ON MULTISPECTRAL MAPPING OF ROCK TYPE BY COMPUTER,CRIPPLE CREEK-CANON CITY

NAME KRINSLEY,DANIEL B.
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GSFC ID 1195A-IN03I-C -A000 PHONE 703-860-6414

TITLE DELINEATION OF SEASONAL SURFICIAL PLAYA ENVIRONMENTS FOR ECONOMIC UTILIZATION & ENGINEERING DEVELOPMENT

NAME WOODMAN, RAYMOND G.
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GSFC ID 1204A-ST03I-C -A000 PHONE 207-942-4868

TITLE TO MAP THE DISTRIBUTION OF GLACIOFLUVIAL DEPOSITS AND ASSOCIATED GLACIAL LANDFORMS

NAME FERRIANS JR.,OSCAR J.
ADDRESS ALASKAN MINERAL RESOURCES BR.
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345 MIDDLEFIELD RD.
MENLO PARK,CALIF. 94025

GSFC ID 1207A-IN03C-C -A000 PHONE 415-323-2247

TITLE REMOTE SENSING OF PERMAFROST & GEOLOGIC HAZARDS IN ALASKA

NAME MORRISON,ROGER B.,DR.
ADDRESS U.S. GEOLOGICAL SURVEY
FEDERAL CENTER
BLDG. 53
DENVER,COLORADO 80225

GSFC ID 1238A-IN03I-C -A000 PHONE 303-234-4111

TITLE DETECTING AND MAPPING PLEISTOCENE GLACIAL MORAINES, FORMER RIVER VALLEYS,AND RIVER TERRACES

NAME WILSON,JOHN C.,DR.
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GEOLOGIC RESEARCH DIV.
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SALT LAKE CITY, UTAH 84104

GSFC ID 1241A-PR03A-C -A000 PHONE 801-486-6911

TITLE RECOGNITION OF GEOLOGIC FRAMEWORK OF PORPHYRY COPPER DEPOSITS ON ERTS-1 IMAGERY

NAME FRIEDMAN,JULES,DR.
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GSFC ID 1251A-IN03C-C -A000 PHONE 303-234-4898

TITLE THERMAL INVESTIGATION OF ACTIVE VOLCANOES USING ERTS-A DCS

(PRIMARY DISCIPLINE)

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

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GSFC ID 1256A-UN03K-C -A000 PHONE 319-353-4448
TITLE UTILIZING ERTS-A IMAGERY FOR TECTONIC ANALYSIS THROUGH STUDY OF BIG HORN MTS. REGION

NAME KOTTLOWSKI,FRANK E.,DR.
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MINES & MINERAL RESOURCES
SOCORRO,NEW MEXICO 87801

GSFC ID 1262A-ST03K-C -A000 PHONE 505-835-5302
TITLE GEOLOGIC ANALYSIS & EVALUATION OF ERTS-A IMAGERY FOR THE STATE OF NEW MEXICO

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GSFC ID 1294A-UN03M-C -A000 PHONE 307-766-3386
TITLE COOPERATIVE PROP. TO STUDY GEOLOGY OF A TEST SITE IN ICE-FREE VALLEYS OF ANTARCTICA

NAME ERSKINE,MELVIN G.,DR.
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GSFC ID 1297A-PR03K-C -A000 PHONE 415-845-5140
TITLE EVALUATION OF POTENTIAL ERTS-A DATA FOR MINERAL EXPLORATION

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GEOPHYSICAL SCIENCES
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SALT LAKE CITY, UTAH 84112

GSFC ID 1307A-UN03A-C -A000 PHONE 801-581-7231
TITLE GEOLOGY OF UTAH AND NEVADA BY ERTS IMAGERY

NAME MOHR, PAUL, DR.
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GSFC ID 1320A-OT03K-C -A000 PHONE 617-864-7910 (408)
TITLE MAPPING OF THE MAJOR STRUCTURES OF THE AFRICAN RIFT SYSTEM

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611 N. WALNUT GROVE
BLOOMINGTON, IND. 47401

GSFC ID 1325A-ST03L-C -A000 PHONE 812-337-7785
TITLE APPL. OF ERTS-A IMAGERY TO FRACTURE-RELATED MINE SAFETY HAZARDS IN COAL MINING

NAME AMARAL,GILBERTO,DR.
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SAO PAULO SB, BRAZIL

GSFC ID 1326B-FO03A-C -0000 PHONE 4866
TITLE REGIONAL GEOLOGICAL & MINERAL RESOURCES SURVEY

(PRIMARY DISCIPLINE)

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

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DER UNIVERSITAT MUNCHEN
8 MUNCHEN 2
LUISENSTRASSE 37, WEST GERMANY

GSFC ID 1332A-F003K-C -0000
PHONE 5203-222
TITLE REG. TECTONIC EVOLUTION OF THE TUSCAN APPENIN, VULCANISM, THERMAL ANOMALIES & RELATION TO STRUCTURAL UNITS

NAME ISACHSEN, YNGVAR W.
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SCIENCE SERVICE
ALBANY, NEW YORK 12224

GSFC ID 1343A-ST03M-C -A000
PHONE 518-474-5819
TITLE TO EVALUATE ERTS-A DATA FOR USEFULNESS AS GEOLOGICAL SENSOR

NAME LIST, FRANZ K., DR.
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LEHRSTUHL FUR ANGEWANDTE GEO.
1 BERLIN 33, WICHERNSTR. 16
GERMANY

GSFC ID 1349A-F003M-C -0000
PHONE 0311-76902158
TITLE IDENT. OF DIFFERENT LITHOLOGICAL & STRUCTURAL UNITS, COMPARISON WITH AERIAL PHOTOGRAPHY & GROUND INVESTIGATION.

NAME KRONBERG, PETER, DR.
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3392 CLAUSTHAL
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TITLE MAPPING OF LITHOLOGIC & STRUCTURAL UNITS USING MULTISPECTRAL IMAGERY

NAME WEIDMAN, ROBERT M., DR.
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GSFC ID 1354A-UN03K-C -A000
PHONE 406-243-5251
TITLE APPLICABILITY OF ERTS-A TO MONTANA GEOLOGY

NAME BARKEY, HENRI
ADDRESS NORGES GEOLOGISKI UNDEROKELSI
P.O. BOX 3006
7001 TRONDHEIM, NORWAY

GSFC ID 1377A-F003K-C -0000
PHONE TR 20166
TITLE GEOLOGICAL STUDY, PHOTOGEOLOGICAL WORK IN OTHER AREAS

NAME WEAVER, KENNETH, DR.
ADDRESS MARYLAND GEOLOGICAL SURVEY
214 LATROBE HALL
JOHNS HOPKINS UNIVERSITY
BALTIMORE, MD. 21218

GSFC ID 1401A-UN03M-C -A000
PHONE 301-235-0771
TITLE RESEARCH & INVESTIGATION OF GEOLOGY, MINERAL & WATER RESOURCES OF MD.

NAME HOUSTON, ROBERT S.
ADDRESS GEOLOGY DEPT.
UNIVERSITY OF WYOMING
LARAMIE, WYO. 82070

GSFC ID 1434A-UN03I-C -D000
PHONE 307-766-2330
TITLE ANALYSIS OF ERTS-A IMAGERY OF WYOMING & EVAL. OF NATURAL RESOURCES

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

NAME BODENLOS, ALFRED J. GSFC ID 1480A-IN03K-C -D000 PHONE 202-282-7267
ADDRESS U.S. GEOLOGICAL SURVEY
BLDG. 10, NBS
WASHINGTON, DC 20242
TITLE STUDY OF MSS IMAGERY ERTS-A, NW SAUDI ARABIA

NAME DOEHRING, DONALD, DR. GSFC ID 1555A-UN03I-C -D000 PHONE 413-545-2285
ADDRESS UNIV. OF MASS
DEPT. OF GEOLOGY
AMHERST, MASS. 01002
TITLE MAPPING OF SAND DUNE FIELDS IN INACCESSIBLE REGIONS

NAME MOHR, HENRI VAN DER MEER GSFC ID 1569C-F003M-C -0000 PHONE 01730-42740
ADDRESS INTER. INST. FOR AERIAL
SURVEY & EARTH SCIENCE
P. O. BOX 6
ENSCHEDE, THE NETHERLANDS
TITLE GEOLOGICAL MAPPING IN CONJUNCTION WITH LONG-TERM AERIAL SURVEYING

NAME LEE, JOUNG HWAN, DR. GSFC ID 1570A-F003M-C -0000 PHONE
ADDRESS GEOLOGICAL & MINERAL INSTITUTE
219-5, KARIBONG-DONG
YONGDONGPO-KU, SEOUL
REPUBLIC OF KOREA
TITLE INVESTIGATIONS OF GEOLOGIC & STRUCTURAL FEATURES OF KOREAN PENINSULA

NAME BROCKMANN, CARLOS GSFC ID 1571A-F003A-C -0000 PHONE
ADDRESS MANAGER'S OFFICE
STATES' OIL ENTERPRISE (YPFB)
CASILLA 2729
LA PAZ, BOLIVIA
TITLE MAPPING & EVALUATION OF BASIC RESOURCES OF BOLIVIA

NAME TUDDENHAM, W. GSFC ID 1572A-F003A-C -0000 PHONE
ADDRESS UNIV. OF MELBOURNE
PARKVILLE, VICTORIA
AUSTRALIA
TITLE GEO-BOTANICAL SURVEYS; WOODLAND & FOREST VEGETATION

NAME TUOMINEN, H. V., DR. GSFC ID 1580B-F003K-C -A000 PHONE .
ADDRESS DEPT. OF GEOLOGY
UNIVERSITY OF HELSINKI
SNELLMANINKATU 5
00170 HELSINKI 17, FINLAND
TITLE MAJOR CRUSTAL FRACTURES IN BALTIC SHIELD

NAME ROQUERO, CARLOS, DR. GSFC ID 1621A-F003H-C -0000 PHONE 2444-807 27 + 3
ADDRESS ESCUELA TECNICA SUPERIOR
DE INGENIEROS AGRONOMOS
UNIV. POLITECHNICA DE MADRID
MADRID, SPAIN
TITLE AGRICULTURE/GEOGRAPHY/GEOLOGY/SOIL SURVEY LAND USE - THEMATIC MAPPING - LAND FORM ANALYSIS IN SPAIN

(PRIMARY DISCIPLINE)

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

NAME SVENSSON, NILS-BERTIL ADDRESS NORRLANDSFONDEN SMEDJEGATAN 17 S-951 00 LULEA, SWEDEN	GSFC ID 1630A-F003K-C -A000	TITLE RELATIONSHIP BETWEEN LINEAMENT SYSTEMS & MINERAL DEPOSITS IN SWEDEN	PHONE 0920/207 80
NAME SALAS, GUILLERMO P. ADDRESS CONSEJO DE RECURSOS NATURALES NO RENOVABLES NINOS HEROES #139 MEXICO 7, D.F., MEXICO	GSFC ID 1631A-F003I-C -0000	TITLE GEOMORPHOLOGICAL FEATURES & LOCATION OF MINERAL & NONMINERAL-BEARING FAULT SYSTEMS	PHONE 588-08-55
NAME GONZALEZ, ARTURO SALAZAR ADDRESS COMM. FEDERAL DE ELECTRICIDAD RODANO 14-9 PISO MEXICO D.F., MEXICO	GSFC ID 1631C-F003F-C -0000	TITLE LOCATE THE GEOTHERMAL PLACES AND DETERMINE THE PRINCIPAL GEOLOGICAL STRUCTURES.	PHONE 514-06-65 25-06
NAME NERI-ESPANA, F. ADDRESS DEPART.GEOFISICO IMEPET NAT'L.POLYTECHNIC INST. AV. 100 METROS #500 MEXICO 14, D.F., MEXICO	GSFC ID 1631F-F003M-C -0000	TITLE GEOLOGICAL STUDIES AND GEOPHYSICAL SURVEYS OF THE LOS TUXTLA MASSIF, THE MALPASO DAM, AND THE SALINA AREA	PHONE
NAME CASTILLO-TEJERO, CARLOS ADDRESS INST. MEXICANO DEL PETROLEO AV. CIEN METROS #500 MEXICO 14, D.F., MEXICO	GSFC ID 1631I-F003K-C -0000	TITLE STUDY OF STRUCTURAL CONDITIONS IN OUTCROPPING FORMATIONS.	PHONE 567-29-17
NAME DEL CASTILLO, LUIS ADDRESS UNIV. NAL. AUT. DE MEXICO INSTITUTO DE GEOFISICA CD. UNIVERSITARIA MEXICO 20, D.F., MEXICO	GSFC ID 1631J-F003K-C -0000	TITLE ESTABLISH RELATIONSHIP BETWEEN REMOTE SENSING SPECTRAL TECHNIQUES AND DEEP STRUCTURAL PATTERNS.	PHONE 548-65-60 147
NAME ROWAN, LAWRENCE C., DR. ADDRESS U.S. GEOLOGICAL SURVEY MAIL STOP 906 NATIONAL CENTER, RM.3155 RESTON, VA 22092	GSFC ID 1648A-IN03A-C -A000	TITLE IRON-ABSORPTION BAND ANALYSIS FOR DISCRIMINATION OF IRON-RICH ZONES	PHONE 703-860-6581
NAME WILLIAMS, RICHARD S., DR. ADDRESS EROS PROGRAM, U.S.G.S. 1925 NEWTON SQ., E., RM.134 MAIL STOP 506 RESTON, VA 22092	GSFC ID 1651A-IN03F-C -A000	TITLE GEOLOGICAL AND GEOPHYSICAL REMOTE SENSING OF ICELAND	PHONE 703-860-7873

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

NAME CASSINIS,ROBERTO, PROF.
ADDRESS LAB PER LA GEO.DELLA LITOSFERA
GEOLAB, MARIO BIANCO 9
20133 MILANO, ITALY

GSFC ID 1659A-F003C-C -0000
PHONE 284-0227
TITLE INTERACTIVE CONTROL OF THERMAL ANOMALIES & VOLCANIC ACTIVITY & RELATIONSHIP TO REGIONAL TECTONIC CHARACTERISTI

NAME MORETTI,ATTILIO
ADDRESS SERVIZIO GEOLOGICO D'ITALIA
LARGO SANTA SUSANNA, 13
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GSFC ID 1674A-F003I-C -0000
PHONE 48
TITLE INVESTIGATION OF GEOLOGIC,GEOMORPHOLOGIC & OCEANOGRAPHIC PROCESSES IN VICINITY OF ELBA ISLAND

NAME NIXON,PETER, DR.
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P.O. BOX 750
MASERU, LESOTHO

GSFC ID 1681A-F003I-C -A000
PHONE 3750
TITLE ASSESS THE VALUE OF ERTS IMAGERY IN ACCELERATING AGRICULTURAL & MINERAL RESOURCE DEVELOPMENT IN LESOTHO

NAME GEDNEY,LARRY D.
ADDRESS GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS,ALASKA,99701

GSFC ID 1951O-UN03E-PB3-OYJO
PHONE 907-479-7426
TITLE TECTONIC STRUCTURE OF ALASKA AS EVIDENCED BY ERTS IMAGERY AND ONGOING

(PRIMARY DISCIPLINE)

PD: 4. WATER RESOURCES

NAME BLANCHARD, BRUCE
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WATERSHED RESEARCH CENTER
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CHICKASHA, OKLAHOMA 73018

GSFC ID 1011A-AG04A-C -A000
PHONE 405-224-7393
TITLE USE OF SPACE DATA IN WATERSHED HYDROLOGY

NAME YARGER, HAROLD L.
ADDRESS SUBSURFACE GEOLOGY SECTION
KANSAS GEOLOGICAL SURVEY
UNIVERSITY OF KANSAS
LAWRENCE, KANSAS 66044

GSFC ID 1060G-ST04J-C -A000
PHONE 913-864-4014
TITLE STUDY OF MONITORING FRESH WATER RESOURCES

NAME BRYAN, M. L.
ADDRESS ENVIRONMENTAL RESEARCH INST.
P. O. BOX 618
ANN ARBOR, MICHIGAN 48107

GSFC ID 1072A-OT04I-C -A000
PHONE 313-483-0500 204
TITLE APPLICATION OF ERTS(A)IMAGERY TO LAKE ICE SURVEY

NAME COOPER, SAUL
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U.S.A. CORPS OF ENGR
424 TRAPELO RAOD
WALTHAM, MASS. 02154

GSFC ID 1089A-DE04J-C -A000
PHONE 617-894-2627
TITLE THE USE OF ERTS IMAGERY IN RESERVOIR MANAGEMENT AND OPERATIONS

NAME WIESNET, DONALD R.
ADDRESS NOAA/NESS S-33
SUITLAND, MD 20233

GSFC ID 1109A-CO04D-C -A000
PHONE 301-763-5981
TITLE EVALUATION OF ERTS DATA FOR CERTAIN HYDROLOGICAL USES

NAME WELLER, GUNTER, DR.
ADDRESS C/DR. CARL BENSON
GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA 99701

GSFC ID 1110D-UN04G-C -A000
PHONE 907-479-7371
TITLE SURVEY OF THE SEASONAL SNOW COVER OF ALASKA

NAME CARLSON, ROBERT F., DR.
ADDRESS INST. OF WATER RESOURCES
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA 99701

GSFC ID 1110E-UN04A-C -A000
PHONE 907-479-7776
TITLE BREAK-UP CHARACTERISTICS OF CHENA RIVER BASIN

NAME JELACIC, ALLAN, DR.
ADDRESS WOLF R&D CORP.
6801 KENILWORTH AVE.
RIVERDALE, MD. 20840

GSFC ID 1113A-PR04I-C -A000
PHONE 301-973-7447
TITLE THE INTERDEPENDENCE OF LAKE ICE & CLIMATE IN CENTRAL NORTH AMERICA

(PRIMARY DISCIPLINE)

PD: 4. WATER RESOURCES

NAME ANDERSON, RICHARD R., DR.
ADDRESS AMERICAN UNIVERSITY
DEPT. OF BIOLOGY, HURST HALL
WASHINGTON, D.C. 20016

GSFC ID 1140A-UN04C-C -A000
PHONE 202-686-2177
TITLE WETLANDS MAPPING & MONITORING WITH ERTS

NAME MACDONALD, WILLIAM R.
ADDRESS TOPOGRAPHIC DIV., U.S.G.S.
NAT'L. CENTER, RM. 2A420
MAIL STOP 515
RESTON, VA 22092

GSFC ID 1149A-IN04H-C -A000
PHONE 703-860-6244
TITLE CARTOGRAPHIC APPLICATION OF ERTS/RBV IMAGERY IN POLAR REGIONS

NAME SCHUMANN, HERBERT H.
ADDRESS U.S. GEOLOGICAL SURVEY
RM. 5017 FEDERAL BLDG.
230 N. FIRST AVE.
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GSFC ID 1184A-IN04F-C -A000
PHONE 602-261-3188
TITLE APPLICATIONS OF THE ERTS DATA COLLECTION SYSTEM IN THE ARETS

NAME PAULSON, RICHARD W.
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WATER RESOURCES DIVISION
U.S. GEOLOGICAL SURVEY
HARRISBURG, PA. 17108

GSFC ID 1190A-IN04A-C -A000
PHONE 717-782-3420
TITLE NEAR REAL-TIME WATER RESOURCES DATA FOR RIVER BASIN MANAGEMENT

NAME BARNES, JAMES C.
ADDRESS ENVIRONMENTAL RES. & TECHNOLOGY
429 MARRETT ROAD
LEXINGTON, MASS. 02173

GSFC ID 1201A-PR04G-C -A000
PHONE 617-861-1490
TITLE TO EVALUATE THE APPLICATION OF ERTS(A) DATA FOR DETECTING AND MAPPING SNOW COVER

NAME STOECKELER, ERNEST G.
ADDRESS MAINE STATE HIGHWAY DEPT.
BOX 1208
BANGOR, MAINE 04401

GSFC ID 1203A-ST04A-C -A000
PHONE 207-942-4868
TITLE DEVELOP A LAND USE-PEAK RUNOFF CLASSIFICATION SYSTEM FOR HIGHWAY ENGINEERING PURPOSES

NAME CAST, LARRY D.
ADDRESS U.S. BUREAU OF RECLAMATION
REGIONAL GEOLOGY BR. (MP-250)
2800 COTTAGE WAY
SACRAMENTO, CA 94401

GSFC ID 1208A-IN04J-C -R000
PHONE 915-484-4373
TITLE REMOTE SENSING OF RECLAMATION PROJECTS

NAME SHOWN, LYNN M.
ADDRESS U.S. GEOLOGICAL SURVEY
FEDERAL CENTER
BLDG. 25, RM. 1818
DENVER, COLO. 80225

GSFC ID 1234A-IN04A-C -A000
PHONE 303-234-4175
TITLE DETERMINE UTILITY OF IMAGERY IN PREPARATION OF HYDROLOGIC ATLASES OF ARIDLAND WATERSHED

(PRIMARY DISCIPLINE)

PD: 4. WATER RESOURCES

NAME HIGER, AARON L.
ADDRESS WATER RESOURCES DIV. U.S.G.S.
901 S. MIAMI AVENUE
MIAMI, FL 33130

GSFC ID 1272A-IN04F-C -D000
PHONE 305-350-5382
TITLE DEVELOP DATA RELAY SYSTEM FOR MONITORING HYDROLOGIC CONDITIONS IN SOUTH & CENTRAL FLORIDA

NAME BERG, DENNIS W.
ADDRESS ENGR. DEVELOPMENT DIV.
ARMY COASTAL ENG'G. RES.CTR.
5201 LITTLE FALLS RD., N.W.
WASHINGTON, D.C. 20015

GSFC ID 1293A-DE04C-C -0000
PHONE 202-325-7127
TITLE ESTUARY AND BARRIER ISLAND STUDY

NAME LUDWICK, JOHN C., DR.
ADDRESS OLD DOMINION UNIVERSITY
RESEARCH FOUNDATION
NORFOLK, VA. 23508

GSFC ID 1299B-UN04C-C -A000
PHONE 703-489-8000 (455)
TITLE TO RELATE THE CHLOROPHYLL & SUSPENDED SEDIMENT CONTENT IN THE LOWER CHESAPEAKE BAY TO ERTS IMAGERY

NAME POMALAZA, JOSE C.
ADDRESS INSTITUTO GEOFISICO DEL PERU
701 AREQUIPA AVE.
LIMA, PERU

GSFC ID 1302A-FO04A-C -0000
PHONE 247-722
TITLE STUDY OF SANTA RIVER BASIN

NAME COLWELL, ROBERT N., DR.
ADDRESS SPACE SCIENCES LAB
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIF. 94720

GSFC ID 1317B-UN04L-C -A000
PHONE 415-642-2396
TITLE USE OF ERTS-A TO AID IN SOLVING WATER RESOURCE MANAGEMENT PROBLEMS IN CALIF.

NAME COLWELL, ROBERT N., DR.
ADDRESS SPACE SCIENCE LAB
UNIVERSITY OF CALIFORNIA
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GSFC ID 1317D-UN04K-C -A000
PHONE 415-642-2396
TITLE ANALYSIS OF RIVER MEANDERS FROM ERTS-A IMAGERY

NAME HAEFNER, HAROLD, DR.
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BLUEMLISALPSTRASSE 10
8006 ZURICH, SWITZERLAND

GSFC ID 1323A-FO04G-C -A000
PHONE 01-289632
TITLE SNOW SURVEY & VEGETATION GROWTH IN SWISS ALPS

NAME BANNERT, DIETER, DR.
ADDRESS GEOLOGICAL SURVEY OF F.R.G.
ALFRED-BENTZ-HAUS
POSTFACH 4
3 HANNOVER-BUCHHLOZ, GERMANY

GSFC ID 1330A-FO04A-C -0000
PHONE 0511-6468-396
TITLE HYDROGEOLOGICAL INVESTIGATIONS IN THE PAMPA OF ARGENTINA

(PRIMARY DISCIPLINE)

PD: 4. WATER RESOURCES

NAME REEVES, C. C.
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P. O. BOX 4109
LUBBOCK, TEXAS 79409

GSFC ID 1342C-UN04D-C -A000 PHONE 806-742-7261

TITLE WATER BUDGET OF TEX. HIGH PLAINS PLAZA LAKES

NAME PLUHOWSKI,EDWARD J.
ADDRESS U.S.G.S. W.R.D.
NAT'L.CENTER,RM.5B304
MAIL STOP 432
RESTON, VA 22092

GSFC ID 1342D-IN04D-C -A000 PHONE 703-860-6958

TITLE DYNAMICS OF SUSPENDED SEDIMENT PLUMES IN LAKE ONTARIO

NAME HOLLYDAY,ESTE F.
ADDRESS U.S.G.S., W.R.D.
144 FEDERAL OFFICE BLDG.
NASHVILLE, TENN. 37203

GSFC ID 1342F-IN04A-C -D000 PHONE 615-749-5424

TITLE BASIN CHARACTERISTICS EXTRACTED FROM ERTS DATA FOR IMPROVING REGRESSION EST. OF STREAMFLOW

NAME MEIER,MARK F.,DR.
ADDRESS U.S.GEOLOGICAL SURVEY
1305 TACOMA AVE. SO.
TACOMA, WASH. 98402

GSFC ID 1342G-IN04G-C -A000 PHONE 205-593-6502

TITLE EVALUATE ERTS IMAGERY FOR MAPPING & DETECTION OF CHANGE OF SNOWCOVER ON LAND & ON GLACIERS

NAME LIND, A. O. ,DR.
ADDRESS UNIV. OF VERMONT
DEPT. OF GEOGRAPHY
BURLINGTON, VERMONT 05401

GSFC ID 1347A-UN04C-C -A000 PHONE 802-656-3060

TITLE ENVIRONMENTAL STUDY OF ERTS-A IMAGERY, LAKE CHAMPLAIN BASIN

NAME MACLEOD,NORMAN H.,DR.
ADDRESS BIOLOGY DEPT.
AMERICAN UNIVERSITY
MASS. & NEB. AVES.,N.W.
WASHINGTON, D.C. 20016

GSFC ID 1368A-UN04A-C -A000 PHONE 202-686-2177

TITLE OBSERVATIONS OF PLANT GROWTH & ANNUAL FLOODING IN THE INLAND DELTA OF THE NIGER RIVER, W.AFRICA

NAME ODEGAARD,HELGE
ADDRESS STATE POWER BOARD
P.BOX 5091, MAJORSTUA
OSLO 3, NORWAY

GSFC ID 1375A-F004G-C -A000 PHONE 46-98-00

TITLE SNOW SURVEYING TO ASSESS RISK OF SPRING FLOOD & SNOW STORAGE IN AREAS OF HYDRO-POWER STATIONS

NAME OSTREM,GUNNAR,DR.
ADDRESS NORWEGIAN WATER RES.& ELEC.BD
P.O.BOX 5091
OSLO 3, NORWAY

GSFC ID 1376A-F004G-C -0000 PHONE 46-98-00

TITLE EVALUATE GLACIER MASS BALANCE BY VARIATIONS IN TRANSIENT SNOW-LINE POSITIONS

(PRIMARY DISCIPLINE)

PD: 4. WATER RESOURCES

NAME KRJUS, JAAN, DR. ADDRESS WATER RESOURCES BR. ENVIRONMENT CANADA OTTAWA KIA 0E7, CANADA	GSFC ID 1532B-F004K-C -A000 TITLE WATER RESOURCE MONITORING PLATFORM	PHONE 613-994-9895
NAME LANE, ROBERT K., DR. ADDRESS DEPT. OF FISHERIES & FORESTRY P.O. BOX 5050 BURLINGTON, ONTARIO CANADA	GSFC ID 1532C-F004K-C -A000 TITLE ACCESS DCS DATA FROM RIDEAU RIVER, OTTAWA	PHONE 416-632-1940
NAME MAC PHAIL, HARRY W. ADDRESS CENTER FOR INLAND WATERS 867 LAKESHORE ROAD P. O. BOX 5050 BURLINGTON, ONTARIO, CANADA	GSFC ID 1532D-F004D-C -A000 TITLE PROPOSAL TO ACQUIRE CAPABILITIES & ASSESS DATA USING DCS	PHONE 416-637-4214
NAME VOCKEROTH, R. E. ADDRESS ATMOSPHERIC ENVIRON. SERVICE 4905 DUFFERIN STREET DOWNSVIEW, ONTARIO, CANADA	GSFC ID 1532E-F004D-C -A000 TITLE LAKE ONTARIO HYDROLOGY STUDY	PHONE
NAME HALLIDAY, R. A. ADDRESS SPEC.SERVICES 8C SURVEYS SEC. APPLIED HYDROLOGY DIV. DEPT.OF THE ENVIRONMENT OTTAWA, ONT., KIA 0E7 CANADA	GSFC ID 1532G-F004D-C -A000 TITLE APPLICATION FOR USE OF ERTS-A FOR RETRANSMISSION OF WATER RESOURCES DATA	PHONE 613-994-5114
NAME TAVERNIER, RENE ADDRESS GEOLOGICAL INST. STATE UNIVERSITY ROZIER 44 B-9000 GHENT, BELGIUM	GSFC ID 1576A-F004G-C -0000 TITLE RELATIONSHIP BETWEEN SNOW COVER & DISCHARGE & WATER QUALITY OF WATERSHEDS	PHONE 09/25-76-11
NAME PALOSUO, ERKKI, DR. ADDRESS INSTITUTE FOR MARINE RESEARCH TAHITORNINKATU 2 HELSINKI 14, FINLAND	GSFC ID 1580C-F004A-C -0000 TITLE APPLICATION OF SATELLITE DATA TO HYDROLOGY & ICE SURVEY	PHONE 635-092
NAME VAN DER OORD, W. J. ADDRESS MEKONG SECRETARIAT C/O ECAFE BANGKOK, THAILAND	GSFC ID 1605A-F004A-C -A000 TITLE APPLICATIONS OF ERTS-A DATA TO RESOURCES MANAGEMENT OF THE LOWER MEKONG BASIN	PHONE 817422

(PRIMARY DISCIPLINE)

PD: 4. WATER RESOURCES

NAME GONZALEZ, ALVARO FLETCHER, DR.
ADDRESS C.I.A.F.
APARTADO NACIONAL 762
CHAPINERO
BOGOTA, COLOMBIA

GSFC ID 1624A-F004F-C -0000
PHONE
TITLE ERTS APPLICATION PROGRAM FOR LOWER MAGDALENA & CASCA VALLEYS

NAME GARCIA, F. SIMO
ADDRESS SEC. DE RECURSOS HIDRAULICOS
DIRECCION DE ESTUDIOS
VERSALLES 19, 2 PISO
MEXICO 1, D.F., MEXICO

GSFC ID 1631H-F004A-C -0000
PHONE 591-10-37
TITLE TO STUDY THE BEST TECHNICAL SOLUTIONS FOR THE IRRIGATION PROBLEMS OF THE ZONE.

NAME FOSTER, KENNITH E., DR.
ADDRESS OALS-UNIV. OF ARIZONA
1201 E. SPEEDWAY BLVD.
TUCSON, AZ. 87519

GSFC ID 19530-UN04A-PA0-0N00
PHONE 602-884-1955
TITLE ERTS-B AND SUPPORTING DATA FOR TECHNOLOGY TRANSFER TO LOCAL AGENCIES.

PD: 5. MARINE RESOURCES AND OCEAN SURVEYS

NAME SCOLARI, M. ADDRESS BUREAU DE REC.GEO.ET MIN. SERVICE GEOLOGIQUE NATIONAL B. P. 6009 45 ORLEANS (02), FRANCE	GSFC ID 1003E-F005B-C -0000 TITLE LOCATING THERMAL BOUNDARIES AND BIOLOGICALLY RICH AREAS	PHONE 38-66-06-60
NAME GUY, MAX, PROF. ADDRESS INSTITUT FRANCAIS DU PETROLE 4, AVENUE DE BOIS PREAU 92 -RUEIL-MALMAISON, FRANCE	GSFC ID 1009A-F005B-C -A000 TITLE DYNAMIC BEHAVIOUR OF COASTAL SEDIMENTATION IN THE LIONS GULF	PHONE 967-11-10
NAME VERGER,FERNAND ADDRESS ECOLE PRATIQUE DES HAUTES ETUDES 61, RUE BUFFON 75 - PARIS, FRANCE	GSFC ID 1031A-F005H-C -0000 TITLE MARSHES & TURBID WATERS	PHONE 707-38-13
NAME HULT, DR. JOHN L. ADDRESS THE RAND CORPORATION 1700 MAIN ST. SANTA MONICA,CALIF. 90406	GSFC ID 1059A-PR05E-C -A000 TITLE APPLICABILITY OF ERTS FOR SURVEYING ANTARCTIC ICEBERG RESOURCES	PHONE (213) 393-0411
NAME POLCYN, FABIAN C. ADDRESS ENVIRONMENTAL RESEARCH INST. P. O. BOX 618 ANN ARBOR, MICHIGAN 48107	GSFC ID 1063A-OT05G-C -A000 TITLE TO USE SPACE ACQUIRED IMAGERY FOR THE MEASURMENT OF WATER DEPTH	PHONE 313-483-0500 216
NAME ANIKOUCHINE,WILLIAM A.,DR. ADDRESS OCEANOGRAPHIC SERVICES, INC. 135 EAST ORTEGA ST. SANTA BARBARA, CALIF. 93101	GSFC ID 1066A-PR05H-C -A000 TITLE ACQUISITION & ANALYSIS OF COASTAL GROUND TRUTH DATA FOR CORRELATION WITH ERTS-A IMAGERY	PHONE 805-965-6575
NAME PIRIE,DOUGLAS M. ADDRESS SAN FRANCISCO DISTRICT U.S. ARMY CORPS OF ENGINEERS 100 MCALLISTER STREET SAN FRANCISCO, CALIF. 94102	GSFC ID 1088A-DE05H-C -A000 TITLE CALIFORNIA COAST NEARSHORE PROCESSES STUDY	PHONE 415-556-5370
NAME HENDRICKSON,J.R.,DR. ADDRESS THE UNIVERSITY OF ARIZONA BIOLOGICAL SCIENCES DEPARTMENT TUCSON, ARIZONA 85721	GSFC ID 1102A-UN05J-C -A000 TITLE THE STUDY OF THE MARINE ENVIRONMENT OF NORTH GULF OF CALIFORNIA	PHONE 602-884-1889

(PRIMARY DISCIPLINE)

PD: 5. MARINE RESOURCES AND OCEAN SURVEYS

NAME / ADDRESS	GSFC ID / TITLE	PHONE
NAME STRONG, ALAN E., DR. ADDRESS NOAA(NESS), CODE S-33 3737 BRANCH AVE., S.E. WASHINGTON, D.C. 20031	GSFC ID 1106A-C005H-C -A000 TITLE EVALUATION OF ERTS DATA FOR CERTAIN OCEANOGRAPHIC USES	PHONE 301-763-5842
NAME HANSON, KIRBY J. ADDRESS NOAA/AOML, RF 205 SEA AIR INTERACTION LAB 15 RICKENBACKER CAUSEWAY MIAMI, FLA. 33149	GSFC ID 1107A-C005B-C -A000 TITLE REMOTE DETECTION OF OCEANIC EDDIES IN THE LESSER ANTILLES USING ERTS-A DATA	PHONE 305-361-5761
NAME MAUL, GEORGE A. ADDRESS NOAA/AOML 15 RICKENBACKER CAUSWAY MIAMI, FLA. 33149	GSFC ID 1108A-C005B-C -A000 TITLE REMOTE SENSING OF OCEAN CURRENTS	PHONE 305-361-3361
NAME SHARMA, G.D. ADDRESS INST. OF MARINE SCIENCE UNIVERSITY OF ALASKA FAIRBANKS, ALASKA 99701	GSFC ID 1110H-UN05H-C -A000 TITLE SEA ICE & SURFACE WATER CIRCULATION, ALASKAN CONTINENTAL SHELF	PHONE 907-279-8528
NAME MUENCH, ROBIN D., DR. ADDRESS INST. OF MARINE SCIENCE UNIVERSITY OF ALASKA FAIRBANKS, ALASKA 99701	GSFC ID 1110I-UN05H-C -A000 TITLE CIRCULATION OF PRINCE WILLIAM SOUND	PHONE 907-479-7745
NAME BARNES, JAMES C. ADDRESS ENVIRONMENTAL RES.& TECHNOLOGY 429 MARRETT ROAD LEXINGTON, MASS. 02173	GSFC ID 1126A-PR05E-C -A000 TITLE TO EVALUATE THE APPLICATION OF ERTS(A) DATA FOR DETECTING AND MAPPING SEA ICE.	PHONE 617-861-1490
NAME SZEKIELDA, KARL-HEINZ, DR. ADDRESS COLLEGE OF MARINE STUDIES ROBINSON HALL UNIVERSITY OF DELAWARE NEWARK, DELAWARE 19711	GSFC ID 1172A-UN05A-C -A000 TITLE DYNAMICS OF PLANKTON POPULATIONS IN UPWELLING AREAS	PHONE 302-738-1212
NAME HUNTER, RALPH E. ADDRESS U.S. GEOLOGICAL SURVEY 345 MIDDLEFIELD RD. MENLO PARK, CA 94025	GSFC ID 1183A-IN05H-C -D000 TITLE MONITORING CHANGING GEOLOGIC FEATURES ALONG THE TEXAS GULF COAST	PHONE 415-323-2508

(PRIMARY DISCIPLINE)

PD: 5. MARINE RESOURCES AND OCEAN SURVEYS

NAME REIMNITZ, ERK — GSFC ID 1206A-IN05H-C -A000 — PHONE 415-323-2695
ADDRESS U.S.GEOLOGICAL SURVEY
345 MIDDLEFIELD RD.
MENLO PARK, CALIF. 94025
TITLE STUDIES OF INNER SHELF & COASTAL SEDIMENTATION ENVIRONMENT OF BEAUFORT SEA FROM ERTS-A

NAME CARLSON, PAUL R. — GSFC ID 1209A-IN05F-C -A000 — PHONE 415-323-2612
ADDRESS U.S.GEOLOGICAL SURVEY
345 MIDDLEFIELD RD.
MENLO PARK, CALIF. 94025
TITLE SOURCES & DISPERSAL PATTERNS OF PART. MATTER IN NEARSHORE WATERS OF NE PAC. OCEAN & HAWAIIAN ISLANDS

NAME STEVENSON, WILLIAM H. — GSFC ID 1240A-CO05A-C -A000 — PHONE 601-688-3650
ADDRESS NAT'L.MARINE FISHERIES SERVICE
MISSISSIPPI TEST FACILITY
BAY ST.LOUIS, MISS. 39520
TITLE INVESTIGATIONS USING DATA FROM ERTS TO DEVELOP AND IMPLEMENT UTILIZATION OF LIVING MARINE RESOURCES

NAME KEE, ROBERT — GSFC ID 1248A-DE05B-C -D000 — PHONE 202-433-3752
ADDRESS DEVELOPMENT ENGINEERING DIV.
U.S.NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390
TITLE DEVELOP IMPROVED TECHNIQUES FOR ACCURATE PREDICTION OF OCEAN CURRENTS

NAME MAUGHAN, PAUL M., DR. — GSFC ID 1258A-PR05A-C -A000 — PHONE 202-223-8112
ADDRESS EARTH SATELLITE CORP.
1747 PENNSYLVANIA AVE., N.W.
WASHINGTON, D.C. 20006
TITLE IMPROVE MENHADEN FISHERY DETECTION & PREDICTION USING ERTS-A

NAME GRABAU, WARREN E. — GSFC ID 1281A-DE05H-C -A000 — PHONE 601-636-3111 (3320)
ADDRESS U.S.ARMY ENGINEER
WATERWAYS EXP. STATION
P.O.BOX 631
VICKSBURG, MISS. 39180
TITLE SEDIMENT PATTERN CORRELATIONS WITH INFLOW & TIDAL ACTION

NAME MARSHALL, HAROLD, DR. — GSFC ID 1299C-UN05A-C -A000 — PHONE 703-489-8000 (413)
ADDRESS OLD DOMINION UNIVERSITY
RESEARCH FOUNDATION
NORFOLK, VA. 23508
TITLE USE OF ERTS TO MORE FULLY UTILIZE & APPLY MARINE STATION DATA

NAME GAMA, EMMANUEL DE ALMEIDA — GSFC ID 1326C-FO05G-C -0000 — PHONE 4866
ADDRESS COMISSAO NAT'L.DE ATIVIDADES
ESPACIAIS C.P. 515
SAO JOSE DOS CAMPOS
SAO PAULO, BRAZIL
TITLE DEVELOP METHOD OF BATHYMETRIC STUDIES FROM SATELLITE IMAGERY

PD: 5. MARINE RESOURCES AND OCEAN SURVEYS

NAME GIERLOFF-EMDEN,H.G.,DR.
ADDRESS GEOGRAPHISCHEN INSTITUT
UNIVERSITAT MUNCHEN
8000 MUNCHEN 2,LUISENSTR.37
WEST GERMANY

GSFC ID 1331A-F005H-C -0000 PHONE 0811-5203-322

TITLE OCEANOGRAPHY OF NORTH & BALTIC SEAS,GEOMORPHOLOGY OF BISCAYA & AFRICA, SUBMARINE TOPOGRAPHY

NAME RUGGLES,FRED H.
ADDRESS U.S.G.S.,W.R.D.
P. O. BOX 715
HARTFORD, CT 06101

GSFC ID 1342E-IN05F-C -A000 PHONE 203-244-2528

TITLE ESTUARINE & COASTAL WATER DYNAMICS CONTROLLING SEDIMENT MOVEMENT + PLUME DEVELOPMENT IN LONG ISLAND

NAME BREMNES,OLE H.
ADDRESS NORWEGIAN METEOROLOGICAL INST.
OSLO, NORWAY

GSFC ID 1374A-F005E-C -0000 PHONE 60-50-90

TITLE STUDIES OF SEA ICE IN SPITZBERGEN AREA, FORMATION OF CONVECTION CLOUDS

NAME ZUBRYCKY,WALTER
ADDRESS DEPT. OF FISHERIES & FORESTRY
NO. 8 TEMPORARY BUILDING
CARLING AVENUE
OTTAWA, CANADA

GSFC ID 1532A-F005F-C -A000 PHONE 613-994-9122

TITLE EVALUATION OF SUITABILITY OF ERTS DATA FOR THE INVESTIGATOR'S REQUIREMENTS

NAME VAZQUEZ,LT. A.M. DE LA CERDA
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SENALAMIENTO MARITIMO
HERMOSILLO #16
MEXICO 7, D.F., MEXICO

GSFC ID 1631D-F005H-C -0000 PHONE 533-32-13

TITLE QUANTIFICATION OF SEASONAL VARIATIONS IN THE MARINE ENVIRONMENT OF THE VERACRUZ-COATZACOAL AREA.

NAME KLEMAS,V., DR.
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UNIVERSITY OF DELAWARE
NEWARK, DELAWARE 19711

GSFC ID 1654A-UN05H-C -A000 PHONE 302-738-1212

TITLE APPLICATION OF ECOLOGICAL,GEOLOGICAL & OCEANOGRAPHIC ERTS-A IMAGERY TO DELAWARE'S COASTAL RESOURCES PLANNING

NAME STRINGER,WILLIAM J.,DR.
ADDRESS UNIV. OF ALASKA
GEOPHYSICAL INST.
FAIRBANKS, ALASKA 99701

GSFC ID 1952O-UN05E-P45-ONJO PHONE 907-479-7455

TITLE ERTS SURVEY OF NEAR-SHORE ICE CONDITIONS ALONG THE ARCTIC COAST OF ALASKA

(PRIMARY DISCIPLINE)

PD: 6. METEOROLOGY

NAME TSUCHIYA,KIYOSHI
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LOS ANGELES, CA 90014

GSFC ID 1022A-F005A-C -0000
PHONE
TITLE STUDY OF MESOSCALE PHENOMENA, WINTER MONSOON

NAME LYONS,WALTER A. DR.
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MINNEAPOLIS, MN 55414

GSFC ID 1220A-UN05A-C -A000
PHONE 612-645-2724
TITLE THE USE OF ERTS-A SATELLITE DATA IN GREAT LAKES MESOMETEOROLOGICAL STUDIES

NAME PERRIER,RAYMOND
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METEOROLOGICAL SERVICE
1640 BOULEVARD DE L'ENTENTE
QUEBEC 6, P.Q., CANADA

GSFC ID 1532F-F005F-C -A000
PHONE 418-643-4588
TITLE USE OF DCS TO OPERATE A NETWORK OF REMOTE HYDROLOGICAL AND CLIMATOLOGICAL STATIONS

NAME KAHAN,ARCHIE M.,DR.
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BUREAU OF RECLAMATION
DENVER FEDERAL CENTER BLDG. 67
DENVER, COLO. 80225

GSFC ID 1642A-IN05C-C -R000
PHONE 303-234-2056
TITLE MONITOR WEATHER CONDITIONS FOR CLOUD SEEDING CONTROL

(PRIMARY DISCIPLINE)

PD: 7. ENVIRONMENT

NAME FONTANEL, ANDRE
ADDRESS INSTITUT FRANCAIS DU PETROLE
4 AVENUE DE BOIS-PREAU
92 RUEIL-MALMAISON
FRANCE
GSFC ID 1009B-F007D-C -A000
PHONE 967-11-10
TITLE OIL SLICKS DETECTION, STUDY OF POLLUTANTS

NAME MARUYASU, TAKAKAZU
ADDRESS INST OF INDUSTRIAL SCIENCE
UNIVERSITY OF TOKYO
7-22-1 ROPPONGI, MINATO-KU
TOKYO, JAPAN
GSFC ID 1021A-F007H-C -0000
PHONE
TITLE INVESTIGATION OF THE ENVIRONMENTAL CHANGE PATTERN OF JAPAN

NAME PEDGLEY, D.E.
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COLLEGE HOUSE
WRIGHTS LANE
LONDON W8 5SJ, ENGLAND
GSFC ID 1032A-F007H-C -0000
PHONE 01-937-8191
TITLE DETECTION OF POTENTIAL LOCUST BREEDING SITES

NAME YOST, EDWARD, DR.
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C.W. POST CENTER
LONG ISLAND UNIVERSITY
GREENVALE, N.Y. 11548
GSFC ID 1070A-UN07D-C -A000
PHONE 516-299-2292, 93
TITLE SPATIAL & TEMPERATURE MONITORING OF COASTAL WATER ENVIRONMENT OF NEW YORK

NAME HORVATH, ROBERT
ADDRESS ENVIRONMENTAL RESEARCH INST.
P. O. BOX 618
ANN ARBOR, MICHIGAN 48107
GSFC ID 1079A-OT07D-C -D000
PHONE 313-483-0500 (346)
TITLE OIL POLLUTION DETECTION, MONITORING AND LAW ENFORCEMENT

NAME WEZERNAK, DR. C.T.
ADDRESS ENVIRONMENTAL RESEARCH INST.
P. O. BOX 618
ANN ARBOR, MICHIGAN 48107
GSFC ID 1081A-OT07D-C -A000
PHONE 313-483-0500 216
TITLE APPLICATION OF REMOTE SENSING TO WATER QUALITY MONITORING

NAME ANDERSON, JAMES H., DR.
ADDRESS INST. OF ARCTIC BIOLOGY
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA 99701
GSFC ID 1110C-UN07H-C -A000
PHONE 907-479-7160
TITLE IDENTIFICATION, DEFINITION & MAPPING OF TERRESTRIAL ECOSYSTEMS IN INTERIOR

NAME LENT, PETER C., DR.
ADDRESS ALASKA COOP WILDLIFE RES. UNIT
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA 99701
GSFC ID 1110G-UN07H-C -A000
PHONE 907-479-7673
TITLE APPL. OF ERTS-A IMAGERY TO STUDY CARIBOU MOVEMENTS & WINTER DISPERSAL IN RELATION TO PREVAILING SNOWCOVER

PD: 7. ENVIRONMENT

NAME POLCYN,FABIAN C.
ADDRESS ENVIRONMENTAL RESEARCH INST.
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ANN ARBOR, MICHIGAN 48107

GSFC ID 1114A-OT07M-C -A000 PHONE 313-483-0500 (216)

TITLE HYDROLOGIC PROBLEMS OF LAKE ONTARIO BASIN FOR IFYGL

NAME DEUTSCHMAN, DR. W.A.
ADDRESS SMITHSONIAN ASTROPHYSICAL
OBSERVATORY
60 GARDEN STREET
CAMBRIDGE, MASS. 02138

GSFC ID 1128A-OT07M- -A000 PHONE 617-864-7910

TITLE PROGRAM FOR STUDIES OF IMAGES OF SHORT LIVED EVENTS

NAME WARD,E. A.
ADDRESS THE MITRE CORP.
WESTGATE RESEARCH PARK
1820 DOLLEY MADISON BLVD.
MCLEAN, VA. 22101

GSFC-ID 1200A-PR07A-C -A000 PHONE 703-893-3500 (2771)

TITLE NATIONWIDE ENVIRONMENTAL INDICES FROM ERTS

NAME STOECKELER,ERNEST G.
ADDRESS MAINE STATE HIGHWAY DEPT.
BOX 1208
BANGOR, MAINE 04401

GSFC ID 1205A-ST07B-C -A000 PHONE 207-942-4868

TITLE DETECTION AND MONITORING VEGETATION DAMAGE ASSOCIATED WITH HIGHWAYS AND HIGHWAY FACILITIES

NAME ROGERS, DR. ERNEST H.
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GSFC ID 1230A-PR07A-C -A000 PHONE (213) 648-7244

TITLE REMOTE HAZE DETECTION

NAME ABEGGLEN,CARL E.
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BUR.OF FISHERIES & WILDLIFE
813 D STREET
ANCHORAGE, AK 99501

GSFC ID 1235A-IN07K-C -A000 PHONE 907-265-2898

TITLE EVALUATION OF SPACE ACQUIRED DATA AS A TOOL FOR MGMT. OF WILDLIFE HABITS IN ALASKA

NAME GRIGGS,MICHAEL,DR.
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1250 PROSPECT STREET
P.O.BOX 2351
LA JOLLA, CALIF. 92037

GSFC ID 1245A-PR07A-C -A000 PHONE 714-459-0211

TITLE DETERMINATION OF AEROSOL CONTENT IN THE ATMOSPHERE FROM ERTS-A DATA

NAME MCGINNIES,WILLIAM G.
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UNIVERSITY OF ARIZONA
1201 E. SPEEDWAY
TUCSON, ARIZONA 85721

GSFC ID 1250A-UN07A-C -A000 PHONE 602-884-1955

TITLE A STUDY TO EXPLORE THE USE OF ORBITAL REMOTE SENSING TO DETERMINE NATIVE ARID PLANT DISTRIBUTION

PD: 7. ENVIRONMENT

NAME NELSON,HARVEY K.
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NO.PRAIRIE WILDLIFE RES. CTR.
P. O. BOX 1747
JAMESTOWN, N.D. 58401

GSFC ID 1255A-IN07K-C -A000 PHONE 701-252-6152

TITLE UTILIZATION OF ERTS-A SYSTEM FOR APPRAISING CHANGES IN CONTINENTAL MIGRATORY BIRD HABITAT

NAME HIDALGO,JOHN U.
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6823 ST.CHARLES AVE.
NEW ORLEANS, LA. 70118

GSFC ID 1295A-UN07C-C -A000 PHONE 504-865-4183

TITLE PRELIM. STUDY OF LAKE PONTCHARTRAIN & VICINTY USING REMOTELY SENSED DATA FROM ERTS

NAME ANDERSON, DR. DUWAYNE M.
ADDRESS OFFICE OF POLAR PROGRAMS
NAT'L SCIENCE FOUNDATION
1800 G STREET, N.W.
WASHINGTON, D.C. 20550

GSFC ID 1298A-DE07M-C -A000 PHONE 603-643-3200 294-8

TITLE ARCTIC & SUBARCTIC ENVIRONMENTAL ANALYSIS UTILIZING ERTS-A IMAGERY

NAME COPELAND,G. E.,DR.
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RESEARCH FOUNDATION
DEPT. OF GEOPHYSICAL SCIENCES
NORFOLK, VA. 23508

GSFC ID 1299A-UN07A-C -A000 PHONE 703-489-8000 (413)

TITLE CORRELATION OF SATELLITE & GROUND DATA IN AIR POLLUTION STUDIES

NAME YUNGHANS,R.
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TRENTON, NEW JERSEY 08625

GSFC ID 1304A-ST07I-C -A000 PHONE 609-292-2938

TITLE TIDAL & OCEAN CURRENT DATA FOR MANAGEMENT & PLANNING OF N.J. DEPT. OF ENVIR. PROTECTION

NAME ROGERS,ROBERT H.,DR.
ADDRESS BENDIX AEROSPACE SYS. DIV.
3300 PLYMOUTH ROAD
ANN ARBOR, MICHIGAN 48107

GSFC ID 1309A-PR07B-C -A000 PHONE 313-665-7766

TITLE DETERMINE UTILITY OF ERTS TO DETECT & MONITOR AREA STRIP MINING & RECLAMATION

NAME LOWE,CHARLES H.,DR.
ADDRESS DEPT.OF BIOLOGICAL SCIENCES
UNIVERSITY OF ARIZONA
TUCSON, ARIZ. 85721

GSFC ID 1327A-UN07H-C -A000 PHONE 602-884-3187

TITLE DESERT PLANT SPECIES IDENTIFICATION BY SPECTRAL SIGNATURES

NAME JAIN, R. K., DR.
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RESEARCH LABORATORY
P.O. BOX 4005
CHAMPAIGN, ILLINOIS 61820

GSFC ID 1341A-DE07E-C -A000 PHONE 217-352-6511

TITLE EVALUATE EFFECTS OF CONSTRUCTION & STAGED FILLING OF RESERVOIRS ON ENVIRONMENT & ECOLOGY

(PRIMARY DISCIPLINE)

PD: 7. ENVIRONMENT

NAME GULLENTOPS, F., PROF.
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REDINGSTRAAT 16 BIS
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GSFC ID 1407C-F007D-C -0000
PHONE 015/31254
TITLE STUDY OF NORTH SEA

NAME MACLEOD,NORMAN
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AMERICAN UNIVERSITY
MASS. & NEB. AVES.,N.W.
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GSFC ID 1502A-UN07M-C -A000
PHONE 202-686-2177
TITLE ERTS INFORMATION SYSTEM DEVELOPMENT FOR POTOMAC RIVER BASIN NATURAL RESOURCE MANAGEMENT

NAME GILBERTSON,B. P.
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P.O. BOX 2
RANDFONTEIN
SOUTH AFRICA

GSFC ID 1577A-F007E-C -R000
PHONE 663-2211
TITLE MONITER GROWTH OR DECLINE OF VEGETATION ON MINE DUMPS

NAME COULBOURN, W.C.
ADDRESS GRUMMAN ECOSYSTEMS CORPORATION
BETHPAGE, NEW YORK 11714

GSFC ID 1589A-PR07D-C -A000
PHONE 516-575-2473
TITLE DETERMINE THE BOUNDARIES OF A/C & S/C DATA WITHIN WHICH USEFUL WATER QUALITY INFO CAN BE EXTRACTED

NAME ROGERS,ROBERT H.,DR.
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BENDIX AEROSPACE SYS. DIV.
ANN ARBOR, MICH. 48107

GSFC ID 1598A-PR07C-C -A000
PHONE 313-665-7765
TITLE UTILIZATION OF ERTS(A) DATA TO MONITOR AND CLASSIFY EUTROPHICATION OF INLAND LAKES

(PRIMARY DISCIPLINE)

PD: 8. INTERPRETATION TECHNIQUES DEVELOPMENT

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92 RUEIL-MALMAISON
FRANCE
GSFC ID 1009D-F008A-C -A000
PHONE
TITLE ANALOG AND DIGITAL INFORMATION EXTRACTION TECHNIQUES

NAME BICKMORE, DAVID P., DR.
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GSFC ID 1033A-F008A-C -0000
PHONE 01-589-0026
TITLE PATTERNS IN GEO-SCIENCE & ENVIRONMENTAL DATA

NAME CLAYTON, KEITH M.
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NORWICH NOR 88C, ENGLAND
GSFC ID 1035A-F008G-C -0000
PHONE NOR-56161
TITLE COMPUTER SYSTEM TO MONITOR & GENERALIZE, BY AREAS, DATA ON PRECISION IMAGERY

NAME HOFFER, ROGER, DR.
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WEST LAFAYETTE, IND. 47906
GSFC ID 1040A-UN08G-C -A000
PHONE 317-749-2052
TITLE INTERDISCIPLINARY EVALUATION OF ERTS FOR COLO. MTN. ENVIRONMENTS USING ADP TECHNIQUES

NAME HARALICK, ROBERT M.
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IRVING HILL RD., WEST CAMPUS
LAWRENCE, KANSAS 66044
GSFC ID 1060A-UN08G-C -A000
PHONE 913-864-3542
TITLE USE OF FEATURE EXTRACTION TECHNIQUES FOR THE TEXTURE AND CONTEXT INFORMATION IN ERTS IMAGERY

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LAWRENCE, KANSAS 66044
GSFC ID 1060B-UN08A-C -A000
PHONE 913-354-3542
TITLE INTERPRETATION AND AUTOMATIC IMAGE ENHANCEMENT PROCESSING FACILIT

NAME DAVIS, JOHN C.
ADDRESS KANSAS GEOLOGICAL SURVEY
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LAWRENCE, KAN. 66044
GSFC ID 1060H-UN08A-C -A000
PHONE 913-864-4991
TITLE CONSTRUCT A MAP OF SURFICIAL GEOLOGY TO SEARCH FOR LARGE-SCALE SPATIAL GROUND PATTERNS

NAME YOST, DR. EDWARD
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C.W. POST CENTER
LONG ISLAND UNIV.
GREENVALE, N.Y. 11548
GSFC ID 1069A-UN08E-C -A000
PHONE 516-299-2292, 3
TITLE CORRELATE IN SITU REFLECTANCE SPECTRA WITH AGRI. LAND USE DATA & CORRELATE BOTH WITH SPACE ACQUIRED IMAGERY

(PRIMARY DISCIPLINE)

PD: 8. INTERPRETATION TECHNIQUES DEVELOPMENT

NAME GRAMENOPOULOS,NICHOLAS ADDRESS ITEK CORP. 10 MAGUIRE ROAD LEXINGTON, MASS. 02173	GSFC ID 1074A-PR03A-C -A000 TITLE AUTOMATED THEMATIC MAPPING AND CHANGE DETECTION OF ERTS-A IMAGES	PHONE 617-276-3435
NAME GRYBECK,DONALD,DR. ADDRESS DEPT. OF GEOLOGY UNIVERSITY OF ALASKA FAIRBANKS, ALASKA 99701	GSFC ID 1110K-UN03G-C -A000 TITLE ERTS DATA AS A TEACHING & RESEARCH TOOL IN THE DEPT. OF GEOLOGY	PHONE 907-479-7565
NAME MALILA, W.A. ADDRESS ENVIRONMENTAL RESEARCH INST. P. O. BOX 618 ANN ARBOR, MICHIGAN 48107	GSFC ID 1136A-OT03A-C -A000 TITLE IMAGE ENHANCEMENT & ADVANCED INFORMATION EXTRACTION TECHNIQUES FOR SATELLITE MSS DATA	PHONE 313-483-0500 317
NAME THOMSON, FRED J. ADDRESS ENVIRONMENTAL RESEARCH INST. P. O. BOX 618 ANN ARBOR, MICHIGAN 48107	GSFC ID 1137A-OT03F-C -D000 TITLE DETERMINATION OF ATMOSPHERIC EFFECTS ON THE PERFORMANCE OF SPECTRAL PATTERN RECOGNITION DEVICES	PHONE 313-483-0500 216
NAME SPENCER,DONALD J.,DR. ADDRESS TRW SYSTEMS GROUP ONE SPACE PARK REDONDO BEACH, CALIF. 90278	GSFC ID 1153A-PR08D-C -A000 TITLE ERTS IMAGE DATA COMPRESSION TECHNIQUE EVALUATION	PHONE 213-536-1407
NAME TABER,JOHN E. ADDRESS TRW SYSTEMS GROUP 1SPACE PARK REDONDO BEACH,CALIF. 90278	GSFC ID 1154A-PR08B-C -A000 TITLE EVALUATION OF DIGITAL CORRECTION TECHNIQUES FOR ERTS IMAGES	PHONE 213-536-2335
NAME BERNSTEIN,RALPH ADDRESS FEDERAL SYS. DIV. IBM CORP. 18100 FREDERICK PIKE GAITHERSBURG, MD. 20760	GSFC ID 1161A-PR08A-C -A000 TITLE ALL-DIGITAL PROCESSING OF ERTS IMAGES	PHONE 301-840-7043
NAME BODENHEIMER,ROBERT E.,DR. ADDRESS UNIV. OF TENNESSEE KNOXVILLE, TENN. 37915	GSFC ID 1162F-UN03G-C -A000 TITLE ERTS-A IMAGERY INTERPRETATION TECHS. IN TENN. VALLEY	PHONE 615-974-2294

(PRIMARY DISCIPLINE)

PD: 8. INTERPRETATION TECHNIQUES DEVELOPMENT

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TITLE AUTOMATIC PHOTOINTERPRETATION FOR LAND USE MANAGEMENT IN MINNESOTA

NAME GOETZ,A.F.H.,DR.
ADDRESS 183-501
JET PROPULSION LAB
PASADENA, CALIF. 91103

GSFC ID 1308A-PR03G-C -A000 PHONE 213-354-3254

TITLE APPL.OF ERTS & EREP IMAGES TO GEOL.INVEST.OF BASIN & RANGE-COLO.PLATEAU BOUNDARY IN ARIZ.

NAME COLWELL,ROBERT N.,DR.
ADDRESS SPACE SCIENCE LAB
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIF. 94720

GSFC ID 1317G-UN03A-C -A000 PHONE 415-642-2395

TITLE DIGITAL HANDLING & PROCESSING OF ERTS-A DATA

NAME SEREBRENY,SIDNEY M.
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GSFC ID 1342B-PR03A-C -A000 PHONE 415-326-6200 (3019)

TITLE TIME-LAPSE DATA PROCESSING FOR DYNAMIC HYDROLOGIC CONDITIONS

NAME ROSS,DONALD S.
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510 LOGUE AVENUE
MOUNTAIN VIEW, CALIF. 94022

GSFC ID 1538A-PR03F-C -A000 PHONE 415-968-6137

TITLE PROPOSAL FOR OCEAN WATER COLOR ASSESSMENT FROM ERTS-A RBV & MSS IMAGERY

NAME LYON,RONALD J. P.
ADDRESS SCHOOL OF EARTH SCIENCES
STANFORD UNIVERSITY
STANFORD, CALIF. 94305

GSFC ID 1637A-UN03F-C -A000 PHONE 415-497-2747

TITLE MULTISPECTRAL SIGNATURES IN RELATION TO GROUND CONTROL SIGNATURES USING NESTED-SAMPLING APPROACH

NAME SWANLUND,GEORGE D.
ADDRESS HONEYWELL, INC.
2600 RIDGWAY ROAD
MINNEAPOLIS, MN. 55413

GSFC ID 1647A-PR03A-C -A000 PHONE 612-331-4093

TITLE DEVELOP AUTOMATIC METHODS TO INTERPRET SPACE & A/C IMAGERY FOR VEGETATION ANALYSIS

NAME ROGERS,ROBERT H., DR.
ADDRESS THE BENDIX CORPORATION
AEROSPACE SYSTEMS DIVISION
3300 PLYMOUTH ROAD
ANN ARBOR, MICHIGAN 48107

GSFC ID 1655A-PR03F-C -A000 PHONE 313-665-7766

TITLE INVESTIGATION OF TECHNIQUES FOR CORRECTING ERTS DATA FOR SOLAR AND ATMOSPHERIC EFFECTS

(PRIMARY DISCIPLINE)

PD: 8. INTERPRETATION TECHNIQUES DEVELOPMENT

NAME CARTMILL, ROBERT H., DR.
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MISSISSIPPI TEST FACILITY
BAY ST. LOUIS, MISS. 39520

GSFC ID 1665A-NA03G-C -A000

PHONE 601-688-4220

TITLE SATELLITE REMOTE SENSING & AUTOMATIC DATA TECHNIQUES FOR CHARACTERIZATION OF WETLANDS & COASTAL MARSHLANDS

PD: 9. SENSOR TECHNOLOGY

NAME DANKO, JOHN M. ADDRESS RCA ASTRO-ELECTRONICS DIV. P.O. BOX 800 PRINCETON, N. J. 08540	GSFC ID 1169A-PR09A-C -A000 TITLE METEOROLOGICAL UTILITY OF HIGH RESOLUTION MULTI-SPECTRAL DATA	PHONE 609-448-3400 2320
NAME KRIEGER,R. L. ADDRESS NASA, WALLOPS STATION WALLOPS ISLAND, VA. 23337	GSFC ID 1198A-NA098-C -D000 TITLE USE OF ERTS IN THE CHESAPEAKE BAY REGION	PHONE 703-824-3411
NAME PAULSON,RICHARD W. ADDRESS U.S. GEOLOGICAL SURVEY MAIL STOP 467 RESTON, VA 22092	GSFC ID 1210A-IN09B-C -R000 TITLE PERFORMANCE OF THE ERTS DATA COLLECTION SYSTEM IN A TOTAL SYSTEM CONTEXT	PHONE 703-860-6057
NAME SLATER,PHILIP N.,DR. ADDRESS OPTICAL SCIENCES CENTER UNIVERSITY OF ARIZONA TUCSON, ARIZONA 85721	GSFC ID 1618A-UN09A-C -A000 TITLE EVALUATION OF ERTS IMAGE SENSOR SPATIAL RESOLUTION IN PHOTOGRAPHIC FORM	PHONE 602-884-4242

(PRIMARY DISCIPLINE)

PD: 10. MULTIDISCIPLINARY RESOURCES SURVEY

NAME KATILI, JOHN A., DR.
ADDRESS INDONESIAN INST. OF SCIENCES
DJL. TEUKU TJIK DITIRO 43
DJAKARTA, INDONESIA

GSFC ID 1004B-F010C-C -0000
PHONE 475-87
TITLE REMOTE SENSING STUDY OF THE BARITO RIVER BASIN AND BALI

NAME WELBY, CHARLES W.
ADDRESS DEPT. OF GEOSCIENCES
NORTH CAROLINA STATE UNIV.
P.O. BOX 5966
RALEIGH, N.C. 27607

GSFC ID 1018A-UN10B-C -R000
PHONE 919-755-2212
TITLE USE OF ERTS-A IN GEOLOGICAL EVALUATION, REGIONAL PLANNING, FOREST MGT.& WATER MGT. IN N.CAROLINA

NAME MCMURTRY, GEORGE J., DR.
ADDRESS 220 ELECTRICAL ENG'R'ING WEST
PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK
PENNSYLVANIA 16802

GSFC ID 1082A-UN10C-C -A000
PHONE 814-865-9753
TITLE SUSQUEHANNA RIVER BASIN STUDY USING ERTS-A DATA

NAME ALTENSTADTER, JAMES D.
ADDRESS COCHISE CO. PLANNING DIRECTOR
P.O. DRAWER AC
BISBEE, ARIZONA 85603

GSFC ID 1100A-ST10C-C -0000
PHONE 602-432-5162
TITLE PROPOSAL FOR INVESTIGATION USING DATA FROM ERTS-A

NAME BELON, ALBERT E.
ADDRESS GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA 99701

GSFC ID 1110A-UN10B-C -A000
PHONE 907-479-7516
TITLE COORD & EST. OF CENTRAL FACIL. & SERVICES FOR UNIV. OF ALASKA ERTS SURVEY OF ALASKAN ENVIRON.

NAME HENRY, HAROLD R., DR.
ADDRESS UNIVERSITY OF ALABAMA
P. O. BOX 1468
UNIVERSITY, ALA. 35486

GSFC ID 1271A-UN10B-C -A000
PHONE 205-348-6550
TITLE INVESTIGATION USING DATA IN ALA. FROM ERTS-A

NAME FISHER, N.H., DR.
ADDRESS BUREAU MINERAL RESOURCES
CANBERRA, A.C.T.
AUSTRALIA

GSFC ID 1303A-F010A-C -0000
PHONE 062-499111
TITLE MULTIDISCIPLINE STUDY OF EARTH RESOURCES OF AUSTRALIA, ANARCTICA, PAPUA & NEW GUINEA

NAME SVENSSON, HARALD, DR.
ADDRESS DEPT. OF PHYSICAL GEOGRAPHY
UNIVERSITY OF LUND
SOLVEGATAN 13
S-22362 LUND, SWEDEN

GSFC ID 1306A-F010C-C -0000
PHONE 046/124100/476
TITLE EVAL. OF DATA UTILITY FOR EARTH SCIENCES FROM METHODICAL POINT OF VIEW

PD: 10. MULTIDISCIPLINARY RESOURCES SURVEY

NAME BANNERT, DIETER, DR.
ADDRESS GEOLOGICAL SURVEY OF F.R.G.
ALFRED-BENTZ-HAUS
POSTFACH 4
3 HANNOVER-BUCHHOLZ, GERMANY
GSFC ID 1328A-F010C-C -0000
PHONE 0511-64-68-396
TITLE MULTIDISCIPLINARY GEOSCIENTIFIC EXPERIMENTS IN CENTRAL EUROPE

NAME GARCIA, LUIS, DR.
ADDRESS HQ. U.S. ARMY, IAGS
FOR. EROS GUATEMALA
APO NEW YORK, N.Y. 09827
GSFC ID 1369A-F010C-C -0000
PHONE 63281
TITLE RES.& LAND-USE IN SOIL EROS., DEFICIT., DEFOREST.& FLOODS; GEOLOGIC MAP.& TECTONIC STRUCTURE DELINEATION

NAME SKULBERG, OLAV M.
ADDRESS ROYAL NOR. COUNCIL-SCI.& IND.RS
NORWEGIAN INST.FOR WATER RES.
GAUSTADALLEEN 25, BLINDERN
OSLO 3, NORWAY
GSFC ID 1378A-F010C-C -0000
PHONE 46-49-60
TITLE MULTIDISCIPLINARY STUDY

NAME THOMAS, JEAN-CLAUDE, DR.
ADDRESS GEOGRAPHY DEPT.
CATHOLIC UNIVERSITY
WASHINGTON, D.C. 20017
GSFC ID 1524A-F010C-C -0000
PHONE 202-529-6000 (259)
TITLE ERTS DATA ANALYSIS OF RHONE DELTA

NAME DOMINGUEZ, OSCAR, DR.
ADDRESS INTA-INSTITUTO NACIONAL DE
TECHNOLOGIA AGROPECUARIA
CHILE 460
BUENOS AIRES, ARGENTINA
GSFC ID 1528A-F010C-C -0000
PHONE 34-7498(2656)
TITLE AGRICULTURAL-LIVESTOCK STUDIES

NAME MORLEY, L. W., DR.
ADDRESS DEPT.OF ENERGY, MINES & RES.
CENTRE FOR REMOTE SENSING
2464 SHEFFIELD RD.
OTTAWA, CANADA
GSFC ID 1532H-F010A-C -X000
PHONE 613-993-3350
TITLE PILOT STUDY TO PROVIDE ECONOMIC & EFFECTIVE INFO SYS TO RESPOND RAPIDLY TO NEEDS OF RES. & ENVIRON.

NAME DAVIS, A. EARL
ADDRESS THE RESOURCES AGENCY
1416 9TH ST., RM.1311
SACRAMENTO, CALIF. 95814
GSFC ID 1535A-ST10B-C -D000
PHONE 916-445-4422
TITLE STUDY COMBINING RES.& USE OF ERTS-A, SKYLAB & SUPPORT. A/C DATA FOR MORE EFF. RESOURCE MGMT.

NAME HOSSAIN, ANWAR, DR.
ADDRESS PLANNING COMMISSION
DACCA, BANGLADESH
GSFC ID 1564A-F010A-C -0000
PHONE
TITLE AGRICULTURE & WATER RESOURCE DEVELOPMENT

(PRIMARY DISCIPLINE)

PD: 10. MULTIDISCIPLINARY RESOURCES SURVEY

NAME OTTERMAN, JOSEPH ADDRESS C/O GODDARD SPACE FLIGHT CNTR. CODE 910 GREENBELT, MD 20771	GSFC ID 1568A-F010A-C -P000 TITLE MULTIDISCIPLINARY USES IN ISRAEL	PHONE
NAME FISCHNICH, O. E., DR. ADDRESS UNITED NATIONS FAO VIA DELLE TERMI DI CARACALLA 00100 ROME, ITALY	GSFC ID 1603A-F010D-C -0000 TITLE USE OF ERTS-A DATA FOR FAO INTEGRATED RESOURCE SURVEYS	PHONE 5797/3461
NAME EBTEHADJ, KHOSRO, DR. ADDRESS THE PLAN ORGANIZATION GOVERNMENT OF IRAN KOOSHK TEHRAN, IRAN	GSFC ID 1609A-F010A-C -0000 TITLE IRANIAN PARTICIPATION IN ERTS-A EXPERIMENTS	PHONE 883-429
NAME MALAN, O. G., DR. ADDRESS CHIEF RESEARCH OFFICER PHYSICAL RESEARCH LAB P. O. BOX 395 PRETORIA, SOUTH AFRICA	GSFC ID 1616A-F010A-C -0000 TITLE MULTIDISCIPLINARY PROPOSAL FOR PARTICIPATION IN ERTS-A	PHONE 74-6011 3448
NAME SABHASRI, SANGA, DR. ADDRESS NATIONAL RESEARCH COUNCIL 196 PHAHOLYOTHIN ROAD BANGKOK 9, THAILAND	GSFC ID 1620A-F010A-C -0000 TITLE ASSESSMENT OF UTILITY & ECONOMY OF ERTS DATA IN PLANNING & DEVELOPMENT & MANAGEMENT OF RESOURCES	PHONE 791121-30
NAME KONATE, MAMADU ADDRESS DEPT. OF MINES & GEOLOGY MIN.OF IND.DEV. & PUBLIC WORKS KOULOUBA, BAMKO REPUBLIC OF MALI	GSFC ID 1626A-F010A-C -0000 TITLE DELINEATE NATURAL RESOURCES CHARACTERISTICS & THEIR TEMPORAL & SPATIAL CHANGES	PHONE 238-21
NAME VACA, JORGE F. HINOJOSA ADDRESS COM.DE ESTUDIOS DEL TERR.NAC. DEPART.DE FOTOINTERPRETACION SAN ANTONIO ABAD 124 MEXICO D.F., MEXICO	GSFC ID 1631G-F010C-C -0000 TITLE COMPREHENSIVE STUDY OF LEON-QUERETARO AREA	PHONE 5-78-10-61
NAME HEPWORTH, J. V., DR. ADDRESS GEO. SURVEY & MINES DEPT. PRIVATE BAG 14 LOBATSE, BOTSWANA	GSFC ID 1643A-F010C-C -A000 TITLE AN ASSESSMENT OF THE VALUE OF SATELLITE PHOTOS IN RESOURCE EVALUATION ON A NATIONAL SCALE	PHONE 327

(PRIMARY DISCIPLINE)

PD: 10. MULTIDISCIPLINARY RESOURCES SURVEY

NAME OMINO, J. H. O. ADDRESS MINISTRY OF NATURAL RESOURCES P. O. BOX 30126 NAIROBI, KENYA	GSFC ID 1658A-F010A-C -0000 TITLE PARTICIPATION IN ERTS-A PROGRAM	PHONE 23411 2555
NAME MINNEY, ORVAL H. ADDRESS DEPT. OF ENVIRON. RESOURCES BOX 1467 HARRISBURG, PA. 17120	GSFC ID 1699A-ST10B-A0'0-0X00 TITLE STATE OF PENNSYLVANIA INTERIM ERTS PROGRAM	PHONE 717-787-8137

J-49/50

LANDSAT FOLLOW-ON INVESTIGATORS

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(PRIMARY DISCIPLINE)

PD: 1. AGRICULTURE/FORESTRY/RANGE RESOURCES

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P.O. BOX 267
WESLACO,TEXAS 78596
GSFC ID 20040-AG01A-PC1-0YJ0
PHONE 512-968-5533 26
TITLE SOIL,WATER,AND VEGETATION CONDITIONS IN SOUTH TEXAS

NAME ROUSE,JOHN W.,DR.
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REMOTE SENSING CTR.
TEAGUE BLDG.
COLLEGE STATION,TX. 77843
GSFC ID 20540-UN01C-PC1-0YJ0
PHONE 713-845-5422
TITLE REGIONAL MONITORING OF THE VERNAL ADVANCEMENT & RETROGRADATION OF NAT. VEGETATION IN THE G PLAINS CORRIDOR

NAME NALEPKA,RICHARD F.
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P. O. BOX 618
ANN ARBOR, MI 48107
GSFC ID 2062L-OT01A-PB1-0YJ0
PHONE 313-994-1200 243
TITLE PROPOSAL TO MAKE WHEAT PRODUCTION FORECASTS USING ERTS AND A/C REMOTE SENSING DATA

NAME BAUER,MARVIN E.,DR.
ADDRESS PURDUE UNIV.,LARS
1220 POTTER DRIVE
WEST LAFAYETTE,INDIANA 47906
GSFC ID 21330-UN01A-PC1-0YJ0
PHONE 317-749-2052 250
TITLE CROP IDENTIFICATION AND ACREAGE ESTIMATION OVER A LARGE GEOGRAPHIC AREA USING ERTS MSS DATA

NAME WIGTON,WILLIAM H.
ADDRESS U.S.D.A.-SRS
R&D BRANCH--S. BLDG.
WASHINGTON,DC. 20250
GSFC ID 22780-AG01A-PA1-0NJF
PHONE 202-447-3131
TITLE AREA SAMPLING FRAME CONSTRUCTION FOR AN AGRICULTURAL INFORMATION SYSTEM WITH ERTS-B DATA

NAME ALDRICH,ROBERT C.
ADDRESS ROCKY MOUNTAIN FOREST AND
RANGE EXPERIMENT STATION
240 WEST PROSPECT STREET
FT. COLLINS, CO 80521
GSFC ID 2306A-AG01B-PA1-0YJ0
PHONE 8-323-5211
TITLE MONITORING FOREST (AND RANGE) RESOURCES WITH ERTS-B AND SUPPORTING AIRCRAFT IMAGERY

NAME COLWELL,ROBERT N.,DR.
ADDRESS SPACE SCIENCES LAB.
UNIV. OF CALIFORNIA
BERKELEY,CA. 94720
GSFC ID 2320B-UN01F-PA1-0NJ0
PHONE 415-642-5170
TITLE A STATEWIDE INVENTORY OF CALIFORNIA'S IRRIGATED LANDS BASED ON ERTS-B AND SUPPORTING AIRCRAFT DATA

NAME BENTLEY,R. GORDON
ADDRESS BUREAU OF LAND MANAGEMENT
BLDG.50,DENVER FEDERAL CTR.
DENVER, CO 80225
GSFC ID 23750-IN01C-PA1-0YJ0
PHONE 8-234-5677
TITLE FEASIBILITY OF MONITORING GROWTH OF EPHEMERAL AND PERENNIAL RANGE FORAGE PLANTS AND EFFECTS OF GRAZING MGMT.

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(PRIMARY DISCIPLINE)

PD: I. AGRICULTURE/FORESTRY/RANGE RESOURCES

NAME GARUTI, HUMBERTO C.
ADDRESS S.AGRICULTURA Y G-SENSORES RTS
PASEO COLON 974 - 3 OF.150
BUENOS AIRES, ARGENTINA

GSFC ID 27960-F001A-PO0-0Y00 PHONE 337511

TITLE AGRICULTURAL SURVEY: CROP IDENTIFICATION, QUANTIFICATION AND CENSUS

NAME OMINO, JOAB, H. O.
ADDRESS MINISTRY OF NATURAL RESEARCH
P.O. BOX 30126
NAIROBI, KENYA

GSFC ID 27990-F001C-PA1-0YJ0 PHONE NBI 28411 2555

TITLE THE DEVELOPMENT OF METHODS FOR QUANTIFYING MULTISPECTRAL SATELLITE IMAGES FOR USE IN RANGELAND HABITAT MONITOR

NAME JACKSON, A.A.
ADDRESS NATIONAL UNIVERSITY OF LESOTHO
ROMA, LESOTHO

GSFC ID 28090-F001A-PA1-0YJ0 PHONE 7662-201 495

TITLE NATURAL RESOURCES RESEARCH & DEVELOPMENT IN LESOTHO USING ERTS IMAGERY.

NAME DOW, TOM
ADDRESS HIGH FOREST DEVEL. PROJECT
FEDERAL DEPT. OF FORESTRY
P.M.B. 5011
IBADAN, NIGERIA

GSFC ID 2810C-F001B-UA1-0XJ0 PHONE

TITLE MONITORING OF HIGH FOREST COVER IN NIGERIA

NAME DUDAL, RAOUL
ADDRESS AGLS SERVICE STAF
UNITED NATIONS F.A.O.
00100 ROME, ITALY

GSFC ID 2810M-F001D-PA1-0XJF PHONE

TITLE APPLICATION OF ERTS IMAGERY TO THE FAO/UNESCO SOIL MAP OF THE WORLD

NAME MC GREEVY, MICHAEL G.
ADDRESS FOREST RESEARCH INST.
PRIVATE BAG
ROTORUA, NEW ZEALAND

GSFC ID 2823B-F001B-UA1-0NJ0 PHONE 82179-761

TITLE INDIGENOUS FOREST ASSESSMENT IN NEW ZEALAND

NAME TOURE, MOHAMED LAMW
ADDRESS DIRECTOR GENERAL
LIPTAKO-GOURMA AUTH.
B.P. 619, OUAGADOUGOU
UPPER VOLTA, AFRICA

GSFC ID 28590-F001H-PA1-0NJF PHONE 2030

TITLE EARTH RESOURCES INVENTORY AND ASSESSMENT OF UPPER VOLTA AND NIGER

NAME FINZI, SERGIO, DR.
ADDRESS EURATOM-
ISPRA (VA), 21020 ITALY

GSFC ID 28790-F001A-JC0-0NJF PHONE 780 131/5 218

TITLE AGRICULTURAL RESOURCES INVESTIGATIONS IN N. ITALY & S. FRANCE

PD: 1. AGRICULTURE/FORESTRY/RANGE RESOURCES

NAME ARNOLD,GRAHAM W.,DR.
ADDRESS CSIRO
RURAL SCIENCES LAB
WEMBLEY 6014, W. AUSTRALIA

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TITLE SURVEY OF CAPEWEED (ARCTOTHECA CALENDULA L.)DISTRIBUTION IN AUSTRALIA

NAME HOOPER,A.D.
ADDRESS DEPT.OF THE N.TERRITORY
LAND CONSERVATION SECTION
ANIMAL INDUSTRY AGRI.BR.
DARWIN N.T.5790,AUSTRALIA

GSFC ID 2896F-F001I-UA1-0NJ0 PHONE 898840

TITLE DALY BASIN- DEVELOPMENT MONITORING

NAME SILVA,M.
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315 VAUXHALL ST.
P.O. BOX 569
COLOMBO 2, SRI LANKA

GSFC ID 29040-F001H-PA0-0NJ0 PHONE 26464

TITLE AGRICULTURAL RESOURCES INVESTIGATION IN SRI LANKA

NAME SUTCLIFFE,JAMES P.
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MBABANE,SWAZILAND

GSFC ID 29900-F001H-PA0-0NJ0 PHONE 2731

TITLE NATURAL RESOURCE IVESTIGATION FOR AGRI. DEVELOPMENT AND LAND USE PLANNING IN THE KINGDOM OF SWAZILAND.

PD: 2. LAND USE SURVEY AND MAPPING

NAME CARLSON,MARVIN P.,DR.
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UNIV. OF NEBRASKA
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GSFC ID 2015B-UN02A-PA2-0YJ0
PHONE 402-472-3471
TITLE APPLICATION OF ERTS-B IMAGERY IN LANDUSE INVENTORY AND CLASSIFICATION IN NEBRASKA

NAME SIZER,JOSEPH E.
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ST. PAUL, MINN. 55101
GSFC ID 20320-ST02A-PA2-0YJ0
PHONE 612-296-3985
TITLE ERTS(B)APPLICATIONS TO MINNESOTA RESOURCE MANAGEMENT

NAME BANKSTON,PRESTON T.,DR.
ADDRESS OFFICE OF SCIENCE & TECH.
OFF.OF THE GOVERNOR
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JACKSON,MS. 39201
GSFC ID 20820-ST02A-PA2-0NJ0
PHONE 601-354-6517
TITLE APPLICATION AND EVALUATION OF ERTS DATA AND ADP TECHNIQUES FOR LAND USE AND RESOURCE MANAGEMENT

NAME NEZ,GEORGE
ADDRESS FEDER. ROCKY MNTN. STATES,INC.
2480 W. 26TH AVE.
DENVER,CO. 80211
GSFC ID 22550-ST02A-PA0-0N00
PHONE 303-458-8000 36
TITLE CONTINUOUS REGIONAL LAND USE SURVEY SYSTEM WITH A MODIFIED USGS CLASS. BASED ON REMOTE SENSED AND OTHER DATA

NAME HANNAH,JOHN W.
ADDRESS BREVARD CO. BD. COMMISSIONERS
COUNTY DEVEL. DIV.
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MERRITT ISLAND, FL 32952
GSFC ID 22670-ST02A-PA2-0YJ0
PHONE 305-452-9480 EX
TITLE REGIONAL PLANNING IN EAST CENTRAL FLORIDA

NAME RAINEY,FROELICH,DR.
ADDRESS UNIV. OF PENNSYLVANIA
THE UNIV. MUSEUM
PHILADELPHIA,PA. 19174
GSFC ID 23220-UN02F-PD2-0NJF
PHONE 215-386-7400 241
TITLE DETECTION OF CROP MARK CONTRAST FOR ARCHAEOLOGICAL SURVEYS

NAME BOLTON,RONALD
ADDRESS NOAA - NAT'L.OCEAN SURVEY
ROCKVILLE, MD. 20852
GSFC ID 23260-CO02B-PA2-0YJ0
PHONE 301-443-8881
TITLE ERTS-B IMAGERY AS A DATA SOURCE FOR PRODUCING VEGETATION OVERLAY INFORMATION ON VISUAL AERONAUTICAL CHARTS

NAME LOVING,HUGH B.
ADDRESS DEPT. CHIEF
OFC. RES. & TECH. STDS.
USGS-MAIL STOP 519 NATL. CTR
RESTON, VA. 22092
GSFC ID 23650-IN02B-PC2-0N00
PHONE 703-928-6291
TITLE PROCESSING OF ERTS IMAGERY FOR DISSEMINATION PURPOSES

(PRIMARY DISCIPLINE)

PD: 2. LAND USE SURVEY AND MAPPING

NAME MAC DONALD, HAROLD C., DR.
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UNIVERSITY OF ARKANSAS
FAYETTEVILLE, ARK. 72701

GSFC ID 23710-UN02A-P22-0XJ0 PHONE 501-575-3355

TITLE LAND USE CHANGE DETECTION WITH ERTS-B DATA FOR MONITORING AND PREDICTING REGIONAL WATER QUALITY DEGRADATION

NAME COLVOCORESSES, ALDEN P., DR.
ADDRESS U.S. GEOLOGICAL SURVEY
NATIONAL CENTER
MAIL STOP 522
RESTON, VA 22092

GSFC ID 23960-IN02B-JA0-0YJ0 PHONE 703-928-6285

TITLE EVALUATION OF ERTS-B IMAGERY FOR OPERATIONAL CARTOGRAPHIC APPLICATION

NAME OPRESCU, NICOLAIE PRO.
ADDRESS LABORATORY FOR REMOTE SENSING
COLLEGE OF CIVIL ENGINEERING
B-DUL REPUBLICII 176
BUCHAREST, ROMANIA

GSFC ID 27940-F002A-P00-0X00 PHONE 354550

TITLE USE OF ERTS DATA FOR NATURAL RESOURCES INVESTIGATION IN THE DANUBE DELTA AND THE COASTAL SEDIMENTATIONS

NAME DICKSON, W.L.
ADDRESS DEPT. OF SURVEYS AND LANDS
PRIVATE BAG 37
GABORONE, BOTSWANA

GSFC ID 28070-F002A-PA2-0XJF PHONE 4234

TITLE EVALUATION OF ERTS-B IMAGERY AS AN AID TO THE DEVELOPMENT OF BOTSWANA'S RESOURCES

NAME POMALAZA, JOSE C., DR.
ADDRESS INSTITUTO GEOFISICO DEL PERU
APARTADO 3747
LIMA, PERU

GSFC ID 28180-F002A-PA2-0YJ0 PHONE 32-17-59

TITLE APPLICATION OF REMOTE SENSING TECHNIQUES FOR THE STUDY AND EVALUATION OF NATURAL RESOURCES

NAME STIRLING, IAN F.
ADDRESS DEPT. OF LANDS & SURVEY
P.O. BOX 8003
WELLINGTON, NEW ZEALAND

GSFC ID 2823C-F002A-UA2-0NJ0 PHONE 44435-776

TITLE MAPPING, LANDUSE, AND ENVIRONMENTAL STUDIES IN NEW ZEALAND

NAME DEL CAMPO, CARLOS
ADDRESS P.I. ON REMOTE SENSING
CETENAL
SAN ANTONIO ABAD #124
MEXICO 8 D.F.
MEXICO

GSFC ID 28710-F002A-P02-0YJ0 PHONE 5-78-62-00 116

TITLE COMPREHENSIVE STUDY OF LEON-QUERETARO AREA

NAME CUEVAS, RODOLFO, DR., ING.
ADDRESS INST. GEOGRAFICO Y CATASTRAL
GENERAL IBANEZ IBERO 3
MADRID 3 SPAIN

GSFC ID 28760-F002A-P00-0NJ0 PHONE 233.34.44

TITLE THEMATIC MAPPING ON LAND USE, GEOLOGICAL STRUCTURE AND WATER RESOURCES IN CENTRAL SPAIN.

(PRIMARY DISCIPLINE)

PD: 2. LAND USE SURVEY AND MAPPING

NAME CHOI,JAE HWA
ADDRESS NATIONAL GEOGRAPHY INSTITUTE
43-1 HWIKYEONG-DONG
DONGDAEMUN-KU
SEOUL,KOREA

GSFC ID 29910-F002A-P)2-0NJ0

PHONE 96-0954

TITLE LAND USE SURVEY & MAPPING AND WATER RESOURCES INVESTIGATIONS IN KOREA

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

NAME MARTIN, JAMES A. — GSFC ID 20070-ST03A-PA3-0NJ0 — PHONE 314-364-1752 — 39
ADDRESS CHIEF, MINERAL RESOURCES
DEPT. OF NATURAL RESOURCES
GEOLOGICAL SURVEY
P.O. BOX 250
ROLLA, MO 65401
TITLE STRUCTURAL AND GROUND PATTERN ANALYSIS OF MISSOURI AND THE OZARK DOME, USING ERTS-B SATELLITE IMAGERY

NAME GEDNEY, LARRY D. — GSFC ID 20490-UN03E-PB3-0YJ0 — PHONE 907-479-7425
ADDRESS GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA, 99701
TITLE TECTONIC STRUCTURE OF ALASKA AS EVIDENCED BY ERTS IMAGERY AND ONGOING

NAME DAVIDSON, DAVID F., DR. — GSFC ID 21990-IN03M-PA0-0NJF — PHONE 8-928-6552
ADDRESS U.S.G.S. NATL. CENTER
MAIL STOP 917
OFFICE OF INTL. GEOLOGY
RESTON, VA. 22092
TITLE PROPOSAL FOR THE PREPARATION OF A GEOLOGIC PHOTO MAP AND HYDROLOGIC STUDY OF THE YEMEN ARAB REPUBLIC

NAME LATTMAN, LAURENCE, DR. — GSFC ID 22840-UN03A-PC0-0NJ0 — PHONE 801-581-8767
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SALT LAKE CITY, UT. 84112
TITLE REMOTE SENSING IN MINERAL EXPLORATION FROM ERTS IMAGERY

NAME CARTER, WILLIAM D. — GSFC ID 23010-IN03A-PA0-0YJF — PHONE 8-928-7873
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TITLE EVALUATION OF ERTS-B IMAGES APPLIED TO GEOLOGIC STRUCTURES AND MINERAL RESOURCES OF SOUTH AMERICA

NAME KNEPPER, DANIEL H., DR. — GSFC ID 2313H-UN03D-PA3-0NJ0 — PHONE 303-492-6387
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TITLE THE APPLICATION OF ERTS DATA TO DELIMITATION OF AVALANCHE AND LANDSLIDE HAZARDS IN MONTANE COLORADO

NAME TABET, DAVID — GSFC ID 23370-ST03A-PA0-0N00 — PHONE 505-835-5640
ADDRESS N.M. STATE BUREAU OF MINES
AND MINERAL RESOURCES
SOCORRO, NM 87801
TITLE EARTH RESOURCES EVALUATION FOR NEW MEXICO BY ERTS-B

NAME DONOVAN, TERRENCE J., DR. — GSFC ID 23680-IN03B-PB3-0XJ0 — PHONE 602-774-5261 — 1453
ADDRESS US. GEOLOGICAL SURVEY
601 EAST CEDAR AVE.
FLAGSTAFF AZ 86001
TITLE STUDY OF ALTERATION AUREOLES IN SURFACE ROCKS OVERLYING

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

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NATL. CTR., MAIL STOP 906
RESTON, VA 22090
GSFC ID 23890-IN03A-PA3-0YJ0
PHONE 8-928-7461
TITLE DETECTION AND MAPPING OF MINERALIZED AREAS AND LITHOLOGIC VARIATIONS USING COMPUTER ENHANCED MSS IMAGES

NAME ABDEL-HADY, MOHAMED AHMED, DR.
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REMOTE SENSING RES. PROJECT
101, KASR EL-EINI STREET
CAIRO, ARE, EGYPT
GSFC ID 27930-XX03A-AD0-0X00
PHONE 405 372-2611 X530
TITLE GEOLOGICAL AND ENVIRONMENTAL RESOURCES INVESTIGATIONS IN EGYPT

NAME UNIS, MUFTAH M.
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MINISTRY OF PLANN. & SCI. AFF.
P. O. BOX 600
TRIPOLI, LIBYAN ARAB REPUBLIC
GSFC ID 28150-F003A-PA3-0NJ0
PHONE 3511-625
TITLE COMPARISON BETWEEN GEOPHYSICAL PROSPECTING AND SATELLITE REMOTE SENSING IN SOUTH LIBYA.

NAME SUGGATE, RICHARD P., DR.
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BOX 30368
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GSFC ID 2823A-F003A-PA3-0NJ0
PHONE 699059-867
TITLE SEISMOTECTONIC, STRUCTURAL, VOLCANOLOGIC AND GEOMORPHIC STUDY OF NEW ZEALAND

NAME IPLIKCI, TUNCER
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MADEN ARAMALAR SB.
KIZILAY, ANKARA, TURKEY
GSFC ID 2832B-F003A-PA3-0NJ0
PHONE 18-52-85
TITLE EVALUATION OF THE APPL. OF ERTS DATA TO MINERAL EXPLORATION, GEOLOGY AND HYDROLOGY IN ELAZIG REGION.

NAME GUMUS, ALTAN, DOC., DR.
ADDRESS KARADENIZ TEKNIK UNIV.
YER BILIMLERI BOLUMU
TRABZON, TURKEY
GSFC ID 2832J-F003A-UA3-0NJ0
PHONE
TITLE EVALUATION OF THE APPL. OF ERTS DATA TO THE DETECTION OF COPPER ORE DEPOSITS IN TRABZON REGION

NAME ATUK, NIHAL, MRS.
ADDRESS DEVLET SU ISLERI
YERALTI SULARI D.
ANKARA, TURKEY
GSFC ID 2832L-F003J-UA3-0NJ0
PHONE 18-34-23
TITLE APPLICATIONS OF ERTS IMAGERY IN GROUND WATER, AGRICULTURE & PETROL

NAME CRAWFORD, MORRIS H.
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CENTRAL TREATY ORGANIZATION
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GSFC ID 28410-F003J-PA3-0NJF
PHONE 8-928-6418
TITLE REGIONAL INVESTIGATIONS OF TECTONIC AND IGNEOUS GEOLOGY IN IRAN, PAKISTAN, AND TURKEY

(PRIMARY DISCIPLINE)

PD: 3. MINERAL RESOURCES, GEOLOGICAL STRUCTURE AND LANDFORM SURVEYS

NAME NAPOLITANO,LUIGI G.,PROF. GSFC ID 28430-F003D-PD0-0NJ0 PHONE 619554-15 15
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UNIV. OF NAPLES
PLE. TECCHIO 80
NAPLES 80125,ITALY
TITLE LAND SLIDES INVESTIGATION IN SOUTHERN ITALY

NAME MARINO,CARLO M.,DR. GSFC ID 28450-F003D-PD3-0NJ0 PHONE 02-296-707
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CATTEDRA DI FISICA TERRESTRE
VIA VIOTTI 3-5
MILAN 20133,ITALY
TITLE GEOMORPHIC AND LANDFORM SURVEY OF NORTHERN APPENNINI

NAME TUOMINEN,HEIKKI V.,DR. GSFC ID 28600-F003A-PA3-0YJ0 PHONE 625969
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DEPT. OF GEOLOGY
SNELLMANINKATU 5
SF-00170 HELSINKI 17,FINLAND
TITLE INVESTIGATION OF ERTS-B IMAGERY ON CORRELATIONS BETWEEN ORE DEPOSITS AND MAJOR SHIELD STRUCTURES IN FINLAND

NAME HARRINGTON,HILARY J.,DR. GSFC ID 2896E-F003K-UA3-0NJ0 PHONE 067-724773 2556
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UNIVERSITY OF NEW ENGLAND
ARMIDALE, N.S.W.
AUSTRALIA 2351
TITLE STRUCTURES IN GRANITIC BATHYLITHS AND ASSOCIATED FOLDBELTS IN RELATION TO MINERAL RESOURCES

NAME COLE,MONICA M.,PROF. GSFC ID 2962B-F003A-UD3-0NJ0 PHONE 01-486-4400
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REGENT'S PARK
LONDON NW1 4NS
ENGLAND
UN. KINGDOM
TITLE ERTS IMAGERY IN RELATION TO AIRBORNE REMOTE SENSING OF TERRAIN ANALYSIS IN WESTERN QUEENSLAND AND AUSTRALIA

NAME CHUNG,S.K.,DIRECTOR GSFC ID 29830-F003A-PA3-0NJ0 PHONE 4274
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TITLE GEOLOGICAL AND HYDROGEOLOGICAL INVESTIGATIONS IN WEST MALAYSIA

NAME BROCKMANN,CARLOS E.,DR. GSFC ID 29950-F003M-PA3-0YJ0 PHONE
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LA PAZ,BOLIVIA
TITLE ERTS DATA INVESTIGATION TOWARS MINERAL RESOURCES DEVELOPMENT AND LAND USE

(PRIMARY DISCIPLINE)

PD: 4. WATER RESOURCES

NAME BLANCHARD, BRUCE J., ENG.
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COLLEGE STATION, TX 77843

GSFC ID 20780-AG04A-P34-0YJ0 — PHONE 713-845-5422

TITLE SPECTRAL MEASUREMENT OF WATERSHED RUNOFF COEFFICIENTS IN THE SOUTHERN GREAT PLAINS

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GSFC ID 21580-IN04A-P34-0YJ0 — PHONE 305-350-5382 — 22

TITLE SUBTROPICAL WATER-LEVEL DYNAMICS DISTRIBUTION

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GSFC ID 21610-IN04A-JA0-0YJ0 — PHONE 703-860-6071

TITLE NEAR REAL TIME WATER RESOURCES DATA FOR RIVER BASIN MANAGEMENT

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GSFC ID 22350-UN04A-PA0-0N00 — PHONE 605-688-4184

TITLE INVESTIGATION OF REMOTE SENSING TECH. AS INPUTS TO OPERATIONAL MODELS.

NAME COOPER, SAUL
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GSFC ID 22510-DE04F-PA4-0YJ0 — PHONE 8-839-7627

TITLE THE USE OF ERTS AND DCS IMAGERY IN RESERVOIR MANAGEMENT AND OPERATION

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GSFC ID 23170-CO04G-P34-0YJ0 — PHONE 301-763-1980

TITLE EVALUATION OF ERTS-B DATA FOR SELECTED HYDROLOGIC APPLICATIONS

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GSFC ID 23610-UN04A-PA0-0N00 — PHONE 602-884-1955

TITLE ERTS-B AND SUPPORTING DATA FOR TECHNOLOGY TRANSFER TO LOCAL AGENCIES.

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GSFC ID 23790-ST04C-PA4-0XJ0 — PHONE 512-475-5596

TITLE DEVELOP. & APPL. OF OPERATIONAL TECH. TO INVENTORY AND MONITOR RESOURCES AND USES IN TX COASTAL ZONE

PD: 4. WATER RESOURCES

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GSFC ID 28190-F00K-JA0-0YJ0
PHONE 819-997-1934
TITLE RETRANSMISSION OF HYDROMET DATA IN CANADA

NAME SHEPHERD, K. JOHN
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VICTORIA SQUARE
ADELAIDE 5000, AUSTRALIA
GSFC ID 2896D-F00B-UB4-0YJ0
PHONE 082284811 2575
TITLE WATER UTILIZATION-EVAPO-TRANSPIRATION AND SOIL MOISTURE MONITORING IN THE SOUTH EAST REGION OF S. AUSTRALIA

NAME ODEGAARD, HELGE A.
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GSFC ID 29020-F00G-PA4-0YJ0
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TITLE HYDROLOGICAL INESTIGATIONS IN NORWAY

NAME HAEFNER, HAROLD, DR.
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BLUEMLISALPSTRASSE 10
8006-ZURICH, SWITZERLAND
GSFC ID 29760-F00A-PC4-0YJ0
PHONE 01-28 96 32 14
TITLE NATIONAL RESOURCES INVENTORY AND LAND EVALUATION IN SWITZERLAND

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GSFC ID 29810-F00A-PA4-0XJ0
PHONE 82510
TITLE WATER RESOURCES INVESTIGATION IN WEST PAKISTAN WITH THE HELP OF ERTS IMAGERY -- SNOW SURVEYS

NAME VAN DER OORD, WILLEM J.
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GSFC ID 29960-F00A-PA4-0YJF
PHONE 817422
TITLE AGRICULTURAL AND HYDROLOGICAL INVESTIGATIONS FOR WATER RES.DEV.PLANNING IN THE LOWER MEKONG BASIN

(PRIMARY DISCIPLINE)

PD: 5. MARINE RESOURCES AND OCEAN SURVEYS

NAME KLEMAS, VYTAUTAS, DR.
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GSFC ID 20570-UN05B-PA5-0YJ0
PHONE 302-738-1212
TITLE APPLICATION OF ERTS-B TO THE MANAGEMENT OF DELAWARE'S MARINE AND WETLAND RESOURCES

NAME KEMMÉRER, ANDREW, DR.
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NATL. SPACE TECH. LABS
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GSFC ID 20770-CO05A-PA5-0YJ0
PHONE 601-688-3650
TITLE ERTS-B/GULF OF MEXICO THREAD HERRING RESOURCE INVESTIGATION

NAME DOLAN, ROBERT, PROF.
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GSFC ID 21240-UN05H-PD5-0NJ0
PHONE 804-924-3809
TITLE APPLICATION OF REMOTE SENSING TO SHORELINE FORM ANALYSIS

NAME STRINGER, WILLIAM J., DR.
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GEOPHYSICAL INST.
FAIRBANKS, ALASKA 99701
GSFC ID 21300-UN05E-PA5-0NJ0
PHONE 907-479-7455
TITLE ERTS SURVEY OF NEAR-SHORE ICE CONDITIONS ALONG THE ARCTIC COAST OF ALASKA

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GSFC ID 22200-DE05H-PA5-0YJ0
PHONE 415-556-5371
TITLE CALIFORNIA COAST NEARSHORE PROCESSES STUDY-ERTS-B

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GSFC ID 28540-FO05B-PA5-0YJ0
PHONE 02-123650
TITLE SEA ICE STUDIES IN THE SPITSBERGEN-GREENLAND AREA.

NAME ORHEIM, OLAV, DR.
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NORWAY
GSFC ID 28550-FO05B-PA5-0NJF
PHONE 02-123650 52
TITLE GLACIOLOGICAL AND MARINE BIOLOGICAL STUDIES AT PERIMETER OF DRONNING MAUD LAND, ANTARCTICA

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PHONE 08-32-23-27
TITLE DYNAMICS AND ENERGY FLOWS IN THE BALTIC ECOSYSTEMS

(PRIMARY DISCIPLINE)

PD: 5. MARINE RESOURCES AND OCEAN SURVEYS

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PHONE 062-496011

TITLE MAPPING ISLANDS,REEFS AND SHOALS IN THE OCEANS SURROUNDING AUSTRALIA.

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PHONE 707-38-13

TITLE MULTIDISCIPLINARY STUDIES OF THE FRENCH ATLANTIC LITTORAL AND THE MASSIF ARMORICAIN

PD: 6. METEOROLOGY

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TITLE STUDY OF MESOSCALE EXCHANGE PROCESSES UTILIZING ERTS-B AIR MASS CLOUD IMAGERY

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TITLE INVESTIGATION TO USE ERTS-B DATA TO STUDY CUMULUS CLOUD BANDING AND OTHER MESOSCALE CLOUD FEATURES

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GSFC ID 23030-IN05A-PA7-0Y00 PHONE 303-234-2056

TITLE USE OF THE ERTS-B DATA COLLECTION SYSTEM IN THE UPPER COLORADO RIVER BASIN WEATHER MODIFICATION PROGRAM

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GSFC ID 2962A-F005A-P37-0NJ0 PHONE BRISTOL 24161 689

TITLE MESOSCALE ASSESSMENTS OF CLOUD AND RAINFALL OVER SOUTH-WEST ENGLAND.

(PRIMARY DISCIPLINE)

PD: 7. ENVIRONMENT

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TITLE CONTRIBUTION OF ERTS-B TO NATURAL RESOURCE PROTECTION AND RECREATIONAL DEVELOPMENT IN WEST VIRGINIA

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GSFC ID 21570-PR07B-PA7-0NJ0 PHONE 301-652-7130

TITLE IMPLEMENTATION OF THE PENNSYLVANIA SURFACE MINING CONSERVATION AND RECLAMATION ACT THROUGH ERTS-B SUPPORT

NAME GRIGGS,MICHAEL,DR.
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GSFC ID 22260-PR07A-PC7-0Y00 PHONE 714-459-0211

TITLE DETERMINATION OF THE ATMOSPHERIC AEROSOL CONTENT FROM ERTS-B DATA

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ALASKA COOP WILDL RES. UNIT
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GSFC ID 22280-UN07K-PA7-0YJ0 PHONE 907-479-7673

TITLE USE OF ERTS IMAGERY FOR WILDLIFE HABITAT MAPPING IN NORTHEAST AND EAST-CENTRAL ALASKA

NAME FISH, BIRNEY R.
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GSFC ID 22640-ST07B-PA7-0NJ0 PHONE 502-564-7320

TITLE A FEASIBILITY ANALYSIS OF THE EMPLOYMENT OF SATELLITE DATA TO MONITOR AND INSPECT SURFACE MINING OPERATIONS

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GSFC ID 23000-IN07K-PA0-0Y00 PHONE 701-252-5363

TITLE IMPROVING METHODOLOGY FOR INVENTORY AND CLASSIFICATION OF WETLANDS

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GSFC ID 23198-ST07C-PA0-0Y00 PHONE 916-445-7925

TITLE WATER RESOURCES CONTROL INVESTIGATIONS IN CALIFORNIA

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GSFC ID 23250-PR07C-PA7-0YJ0 PHONE 313-665-7766 512

TITLE APPL.OF ERTS TO SURVEILLANCE & CONTROL OF LAKE EUTROPHICATION IN GREAT LAKES BASIN

(PRIMARY DISCIPLINE)

PD: 7. ENVIRONMENT

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TITLE INVESTIGATION OF THE EFFECTS OF CONSTRUCTION AND STAGE FILLING OF RESERVOIRS ON THE ENVIRONMENT AND ECOLOGY

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8000 MUNICH 2, GERMANY

GSFC ID 28380-F007I-JD0-0YJF PHONE 5203-222

TITLE APPL. OF SEQUENTIAL SPACE BORN DATA FOR GEOL. INVESTIGATIONS IN GERMANY

NAME MARUYASU, TAKAKAZU, DR.
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GSFC ID 28990-F007A-PA7-0YJ0 PHONE 03-402-6231

TITLE INVESTIGATION OF ENVIRONMENTAL CHANGE PATTERN IN JAPAN

NAME EDWARDS, DENZIL, DR.
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PRETORIA, SOUTH AFRICA

GSFC ID 29580-F007F-PA7-0NJ0 PHONE 76-5580 8

TITLE MONITOR FIRE EXTENT AND OCCURENCE IN THE DIFFERENT VELD TYPES OF S.AFR. WITH REF. TO ECOLOGY AND RANGE MGMT.

(PRIMARY DISCIPLINE)

PD: 8. INTERPRETATION TECHNIQUES DEVELOPMENT

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TITLE LAND CLASSIFICATION OF SOUTH-CENTRAL IOWA FROM COMPUTER ENHANCED IMAGES

NAME HARALICK, ROBERT M., PROF.
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TITLE A COMPREHENSIVE DATA PROCESSING PLAN FOR CROP CALENDAR MSS SIGNATURE DEVELOPMENT FROM SATELLITE IMAGERY

NAME JAYROE, ROBERT R., DR.
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TITLE AUTOMATIC CHANGE DETECTION OF ERTS-B DATA

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TITLE TERRA EXPERIMENT--TECHNIQUES FOR COLLECTING AND PROCESSING EARTH RESOURCES DATA

(PRIMARY DISCIPLINE)

PD: 10. MULTIDISCIPLINARY RESOURCES SURVEY

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TITLE DEVELOPMENT OF A MULTIDISCIPLINARY ERTS USER PROGRAM IN THE STATE OF OHIO.

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GSFC ID 23760-UN10C-PA2-0YJ0
PHONE 303-492-6387 6387
TITLE MULTIPLE RESOURCE EVALUATION OF REGION 2 U.S.FOREST SERVICE LANDS UTILIZING ERTS MSS DATA

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TITLE BANGLADESH NATIONAL PROGRAM OF ERTS-B

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TEHRAN, IRAN
GSFC ID 28000-F010A-PA2-0XJ0
PHONE 883-429
TITLE UTILIZATION OF ERTS DATA FOR RESOURCE MANAGEMENT IN IRAN

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TITLE SUMMARY PROPOSAL FOR NIGERIAN ERTS PROGRAM

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PHONE 791-121-30
TITLE THAILAND NATIONAL PROGRAMME OF THE EARTH RESOURCES TECHNOLOGY SATELLITE

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APPENDIX K

LIST OF ACRONYMS

ACS Attitude Control Subsystem
A/D Analog to Digital
AGC Automatic Gain Control
AMS Attitude Measurement Sensor
APFO Aerial Photography Field Office (USDA)
ASCS Agriculture Stabilization and Conservation Service
ASVT Applications Systems Verification and Transfer Project

B&W Black and White
bps Bits per second

C&DH Communications and Data Handling
CCC Camera Controller Combiner
CCT Computer Compatible Tape
CLL Corrected Line Length
CMD Command
CRC Cyclic Redundancy Check
CRT Cathode-Ray Tube
CTLR Controller

D/A Digital to Analog
DCP Data Collection Platform
DCS Data Collection System
DCS/RSE DCS Receiving Site Equipment
DCST Data Collection System Tape
DID Digital Image Data
DPPS Digital Image Processing System
DS Digital Subsystem (formerly Special Processing Subsystem)
DSI Digital Subsystem Interface Unit
DSL Data Service Laboratory
DTG Digital Tape Generation
DTS Digital Transmission System

EBCDIC Extended Binary Coded Decimal Interchange Code
EBR Electron Beam Recorder
EBRIC Electron Beam Recorder Image Correction
EDC EROS Data Center (USGS)
ELC End of Line Code
EOF End of File
EOT End of Tape
EROS Earth Resources Observation Systems

FM Frequency Modulation
FOV Field of View
FSK Frequency Shift Keying

G Generation
GCP Ground Control Point
GDHS Ground Data Handling System
GMT Greenwich Mean Time
GPIP General Purpose Image Processor
GSFC Goddard Space Flight Center

HDT High Density Tape
HDTR High Density Tape Recorder

IAT Image Annotation Tape
ID Identification
IFOV Instantaneous Field of View
IG Initial Gap
IIGS Initial Image Generating System (formerly Bulk Processing Subsystem)
Intralab Information Transfer Laboratory (NASA/GSFC)
IPF Image Processing Facility (NASA)
IRG Inter-record Gap
ISM Interface Switching Module

kbps kilobits per second

LACIE Large Area Crop Inventory Experiment
LLA Adjusted Line Length
LLC Line Length Code
LPM Load Point Marker
LRC Longitudinal Redundancy Check
LTC Light Transfer Characteristics

MDP Master Data Processor
MERITS Marshall Earth Resources Information Transfer System
MNFS Minor Frame Synchronization
MODEM Modulator/Demodulator
MOI Moments of Inertia
MPP MSS Preprocessor
MSS Multispectral Scanner
MTF Modulation Transfer Function
MTP MSS Telemetry Processor
MTU Magnetic Tape Unit

NASCOM NASA Communications Network
NBTR Narrowband Tape Recorder
NESS National Environmental Satellite Service

NCIC	National Cartographic Information Center
NOAA	National Oceanic and Atmospheric Administration
NRZ	Non-Return to Zero
NTTF	Network Test and Training Facility
OAS	Orbit Adjust Subsystem
OCC	Operations Control Center
PAM	Pulse Amplitude Modulated
PCM	Pulse Code Modulation
PMT	Photomultiplier Tube
PPS	Photographic Processing Subsystem
PRN	Pseudo-Random Noise
PSK	Phase Shift Keying
QLPS	Quick-Look Processing System
QSL	Quarter Scan Line
RBV	Return Beam Vidicon
rms	Root mean square
RPP	RBV Preprocessor
RSE	Remote Site Equipment
RT	Real Time
S/C	Spacecraft
SCCI	Scene Corrected Images (no longer available)
SCS	Scene Correcting Subsystem (Precision Processing subsystem - no longer used)
SDSB	Satellite Data Services Branch (NOAA)
SIAT	Special Image Annotation Tape
SNR	Signal-to-Noise Ratio
SPS	Special Processing Subsystem (Digital Subsystem)
STDN	Space Tracking and Data Network
SYCI	System Corrected Images
TBD	To Be Determined
TBV	To Be Verified
TLM	Telemetry
TRKG	Tracking
TT&C	Telemetry Tracking and Command
TWT	Traveling Wave Tube
UHF	Ultra-High Frequency
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USB	Unified S-Band
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VCO	Voltage Controlled Oscillator
VHF	Very High Frequency
VPASS	Video Processor and Sync Separator
VTR	Video Tape Recorder
WBPA	Wideband Power Amplifier
WBVTR	Wideband Video Tape Recorder

APPENDIX L
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APPENDIX M
INDEX TO LANDSAT DATA USERS HANDBOOK