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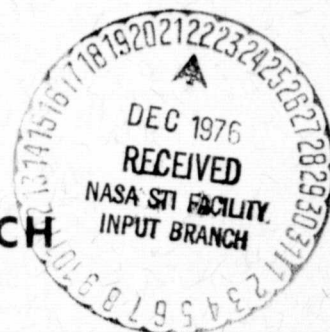
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GROUND DATA HANDLING FOR LANDSAT-D

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————— **GODDARD SPACE FLIGHT CENTER** —————
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GROUND DATA HANDLING FOR LANDSAT-D

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BIOGRAPHICAL SKETCH

Thomas J. Lynch is Assistant Chief of the Information Extraction Division at the NASA-Goddard Space Flight Center (GSFC) in Greenbelt, Maryland where he directs the development of new multi-discipline information extraction systems for Space Applications data utilization. He received a B. E. E. from C. C. N. Y., an M. S. from M. I. T., and a Ph. D. from the University of Maryland—all in Electrical Engineering. He came to GSFC in 1961 and since that time has worked in data processing, telemetry, tracking, channel coding, communication satellites and data compression.

Before coming to GSFC, he worked on television development at RCA Laboratories, and radar systems development at both M. I. T. and Westinghouse.

During 1971 and 1972, he was a visiting research scientist, under a NASA fellowship, at the Technical University of Braunschweig, Germany, specializing in data compression research.

Dr. Lynch is a senior member of the IEEE, a member of both Tau Beta Pi and Eta Kappa Nu, and a Registered Professional Engineer in the State of New York.

ABSTRACT

The present plans for the Landsat-D ground data handling are described in relationship to the mission objectives and the planned spacecraft system. The end-to-end data system is presented with particular emphasis on the data handling plans for the new instrument, the Thematic Mapper. This instrument generates ten times the amount of data per scene as the present Multispectral Scanner and this resulting data rate and volume are discussed as well as possible new data techniques to handle them—such as image compression.

INTRODUCTION

The Landsat-D Mission is intended to serve as a prototype demonstration of a future Landsat operational system. This program will be a transition between the R&D-oriented missions of Landsats I, II, and C and a fully operational Landsat. In this paper the ground handling plans for Landsat-D are described and the differences between these plans and the present Landsat ground data operations are underscored. In order to understand the prototype-operational requirements for Landsat-D data, one must look at the end-to-end data flow, from the spacecraft all the way to the eventual data user. In order to do this in a logical fashion, the mission objectives and the baseline spacecraft system must be briefly examined as follows:

MISSION OBJECTIVES

The Landsat-D data will be used for a number of different applications and the following is a list of the most likely application areas:

- Global Food Production Forecasting
- Hydrological Land Use
- Petroleum and Mineral Exploration
- Land Use Monitoring
- Forestry
- Coastal Zone Mapping and Bathymetry
- Soil Management

An examination of these application objectives has shown that, compared to the present Landsat capability, certain improvements are needed in order to meet these objectives fully. Briefly stated, these improvements are:

- Improved spatial, spectral and radiometric resolution
- Improved image rectification and registration
- More reliable world-wide coverage
- More rapid throughput in the data dissemination to the user community

BASELINE SPACECRAFT SYSTEM

The spacecraft system that is proposed for Landsat-D will meet the needs of the first three improvements listed above. The ground data system will meet the last improvement need and this will be described in the next section.

The Landsat-D spacecraft will be a new spacecraft, different from the ERTS-type spacecraft used for Landsats I, II, and C. It will be the Multiple-Mission Modular Spacecraft (MMS) and it will carry a Multispectral Scanner (MSS) and a Thematic Mapper (TM). The MSS will be essentially the same instrument as that to be flown on Landsat-C (5 bands, 80 m resolution, and 6-bit quantization), but the TM will be a new instrument with 6 spectral bands, 30 m resolution and 8-bit quantization. The TM will provide the required improvement in spatial, spectral and radiometric resolution, and the MSS will provide data continuity with Landsat-C.

The Landsat-D MMS spacecraft will have greater attitude stability than its predecessors, as can be seen below:

	<u>Landsat-D</u>	<u>Landsats I, II, C</u>
RMS Pointing Accuracy	0.01 degree	0.7 degree
RMS Pointing Rate	10^{-6} deg/sec	0.002 deg/sec

This greater attitude stability in addition to greater scan linearity in the TM compared to the MSS will make possible the geometric rectification and registration of TM images to sub-pixel precision (in the order of 10 meters)—which is the second improvement required of Landsat-D.

In the Landsat-D time frame (early 1980's—with launch planned in 1981) the NASA Tracking and Data Relay Satellite (TDRS) System will be operational. This TDRS system will consist of two satellites at geostationary altitude (33,000 km) that will relay data from lower orbiting spacecraft, such as Landsat-D, to a central TDRS ground station at White Sands, New Mexico. In this way, world-wide data coverage will be possible without the use of typically unreliable on-board tape recorders—the third improvement required of Landsat-D.

Landsat-D will be launched on a Delta launch vehicle, but will have the feature of being Space-Shuttle-retrievable. For this reason, as well as the TM design requirements, the Landsat-D altitude will be lower than that of its predecessors (705 km instead of 920 km). This orbit will provide a 16-day revisit time interval instead of the present 18-day interval, but the equator crossing time will be the same, 9:30 a. m.

END-TO-END DATA SYSTEM

As stated above, the fourth improvement required of Landsat-D is a more rapid throughput for data dissemination. This is achieved in two ways: by spacecraft transmission to Direct Readout Stations (DROS) in various foreign countries, and by high-speed processing, transmission and delivery of the data relayed via TDRS. A block diagram of the end-to-end data system is shown in Fig. 1.

The direct transmission to the DROS stations (shown schematically in Fig. 1) will make use of two carrier frequencies: one at S-band (~2GHz) for the MSS, and one a X-band (~8GHz) for the TM. It is anticipated that by the Landsat-D time frame, there will be more than ten DROS's able to receive both the TM and the MSS. These stations will supply data to their related data processing centers for eventual dissemination to the appropriate foreign users.

The data that are relayed through the TDRS will reach the ground at the White Sands station, as shown in Fig. 1. The MSS and TM data are time-division-multiplexed together at this point and this data stream will be sent to the Goddard Space Flight Center at Greenbelt, Maryland via a domestic communication satellite (DOMSAT) in order to avoid the possibility of a data backlog at White Sands.

At GSFC, a number of operations are performed on the data as shown schematically in Fig. 1. Upon reception at GSFC, the data are sent to the Data Input Sub-system (DIS) where the TM and MSS data streams are first separated for further processing. In the DIS, an automated cloud-cover assessment is made of the imagery using a subset of the TM bands. The results of this cloud cover

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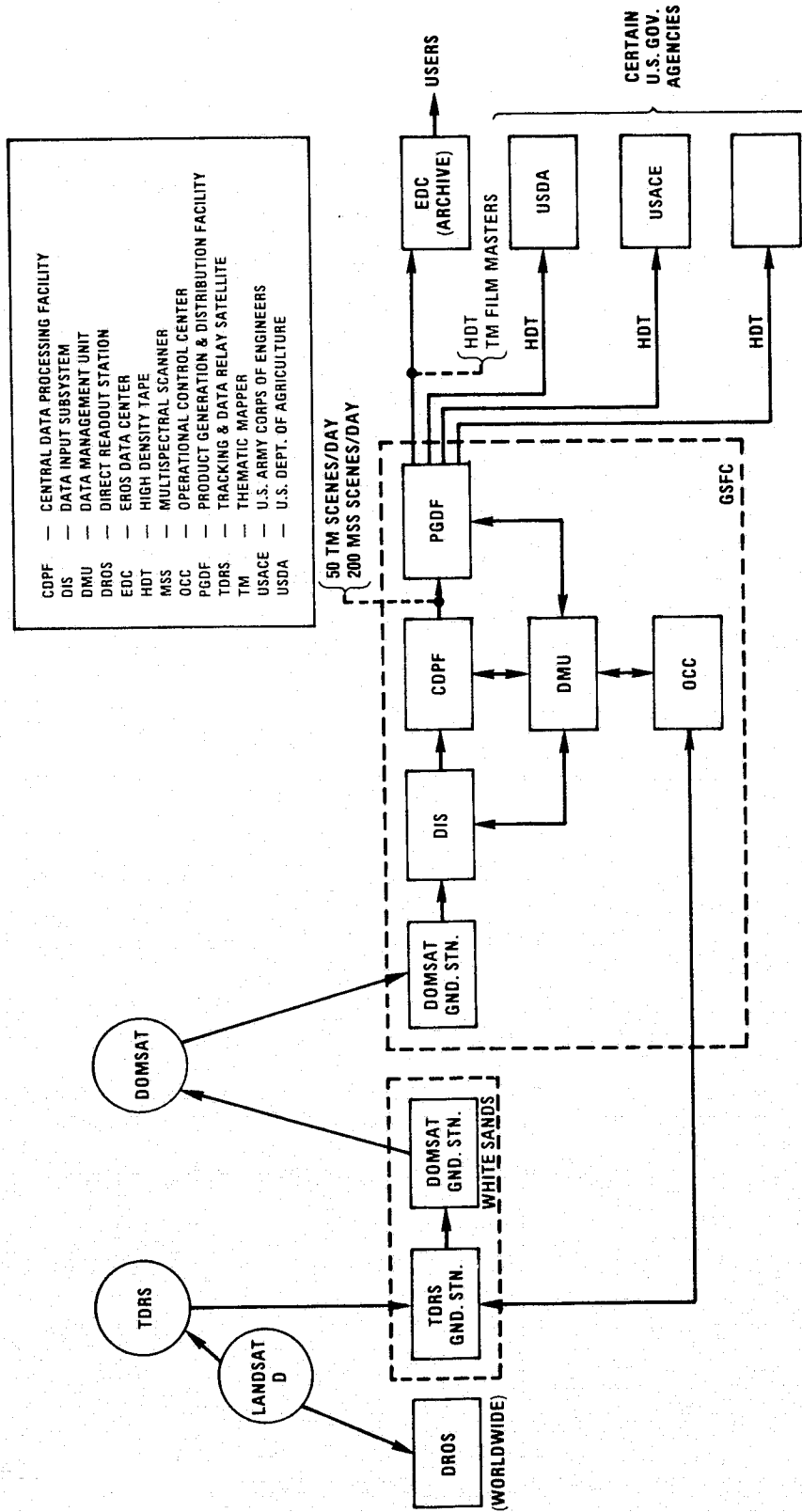


Figure 1. Landsat-D End-to-End Data System

assessment are stored in a data file in the Data Management Unit (DMU) which provides overall control of the various data processing operations as well as communication with the Operational Control Center (OCC) at GSFC. Finally, in the DIS, ground control points are selected from the imagery on a multiple-scene swath basis. This is possible because of the greater attitude stability of the Landsat-D MMS spacecraft. The geometric correction information is computed using the ground control points and this information is added to each data file but not applied to the image pixels in each file.

In the Central Data Processing Facility (CDPF), the MSS and TM images that do not meet cloud-cover and other scene-selection criteria stored in the DMU are rejected and only those scenes selected are processed further. Radiometric correction is applied at this point in the CDPF.

In the next step, in the Product Generation and Distribution Facility, the MSS and TM digital scenes are prepared for transmission either by tape or communication link to the EROS Data Center (EDC), the U. S. Dept. of Agriculture (USDA), the U. S. Army Corps of Engineers (USACE), and other U. S. government agencies that will require a direct reception of data from the PGDF. The image data sent to EDC will be on radiometrically-corrected but not geometrically-corrected tapes for both MSS and TM. In the case of the TM, film masters may also be sent. EDC will provide a digital and photographic product service to users of Landsat-D data, and it will use the geometric correction information on the tapes in order to perform resampling and map projections as required by the users. In addition, EDC will maintain the digital and photographic archive for the Landsat-D data. The digital tape output of the PGDF in all cases will be in the form of high density tape (HDT); and these tapes may be geometrically as well as radiometrically corrected for certain user agencies other than EDC as required.

At the user end of the data system the data will be used typically as input to analytical, interpretive or predictive routines for the purpose of extracting information of a beneficial nature for a particular application. Such an operation is shown in simplified form in Fig. 2 for an agricultural application: crop

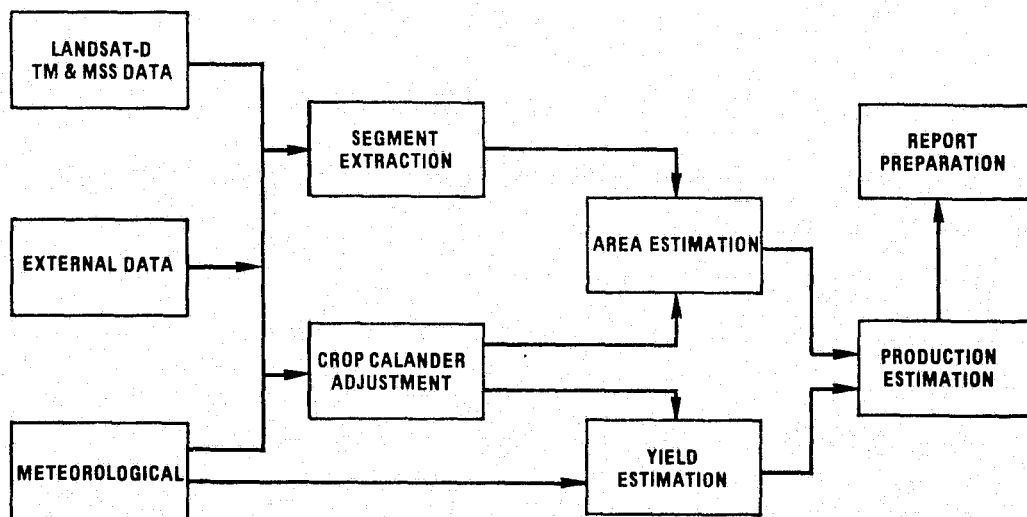


Figure 2. Landsat-D Agricultural Data Utilization Subsystem Functional Flow

production forecasting. In this computation of crop production, the area or acreage of a particular crop and the predicted yield per acre for that crop must be determined. As can be seen in Fig. 2, the image data are used for the area measurement and this is usually performed by an image classification technique for the given crop. One of the methods that is presently in use (e. g., in the Large Area Crop Inventory Experiment, LACIE) performs the classification on sample segments in each scene. As shown in Fig. 2 this can represent a saving in the geometric correction process, since only the pixels in the sample segment need be corrected.

DATA RATE AND VOLUME

The MSS and TM will cover the same swath on the ground but with different spatial, spectral and radiometric resolutions. The output bit rate of the TM is expected to be about 120 Mbps while that of the MSS will remain the same as present: 15 Mbps. Because of its higher spatial, spectral and radiometric resolution, the TM generates ten times as many bits per multi-band scene as does the MSS. The number of MSS scenes per day is expected to remain about the same as present, 200 scenes/day which corresponds to 4×10^{10} bits/day. However, the number of TM scenes a day has no precedent, and obviously will be an important factor in sizing the load capability of the data system. It has been determined that in a single day, between 70°N and 70°S latitudes, the TM could take about 500 different scenes over land masses. However, in order to prove out the capabilities of the Landsat-D, it has also been determined that a minimum of about 50 TM scenes/day is required. Table 1 shows the conversion of these upper and lower TM data acquisition bounds into bits and tapes. The significant result is that a minimum of 10^{11} bits/day of TM data must be processed and the maximum would be 10^{12} bits/day. This high data volume requires that many data processing functions be hardwired for faster thruput.

In addition, more sophisticated data handling techniques, such as image compression, may have to be applied to the TM as the data volume increases in order to maintain a cost effective system.

TABLE 1

Landsat-D Data Rate/Volume

	<u>THEMATIC MAPPER</u>	<u>MSS</u>
● Data rate out of the spacecraft:	120 mbps	15 mbps
● Scene size:	185 km x 185 km	185 km x 185 km
● Spatial resolution:	30 m	80 m
● Number of bands:	6	5
● Number of bits per multi-band scene:	$\sim 2 \times 10^9$ bits	$\sim 2 \times 10^8$
● Average number of scenes per day:	500 max 50 min	200
● Average number of bits/day into the central data processing facility:	10^{12} max 10^{11} min	4×10^{10}
● Number of high density tapes per day (capacity: 2×10^{10} bits/tape @ 20,000 bpi)	50 max 5 min	2

IMAGE COMPRESSION

Many techniques have been developed for the compression of images. By compression here is meant the removal of repetitive or redundant pixels and not information. The TM data, being multi-band is in effect a three-dimensional data set. This means that there can be three compression operations possible for the TM data. Actually, there can be a fourth compression operation performed after the other three, and this in block-to-variable length coding as shown in Fig. 3. It is anticipated that compression techniques will be applied first to the ground data system; and if proven to be cost-effective, these techniques may then be applied to the spacecraft data system of subsequent missions.

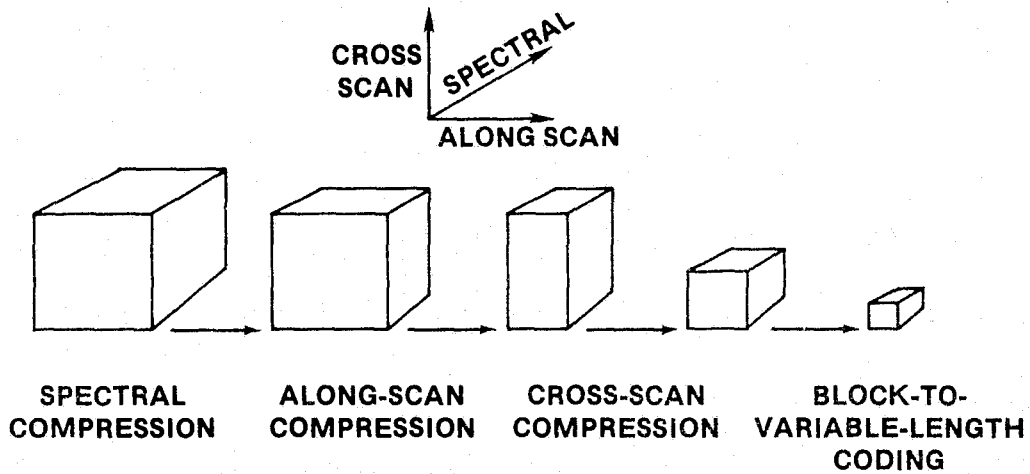


Figure 3. Compression in Three Dimensions