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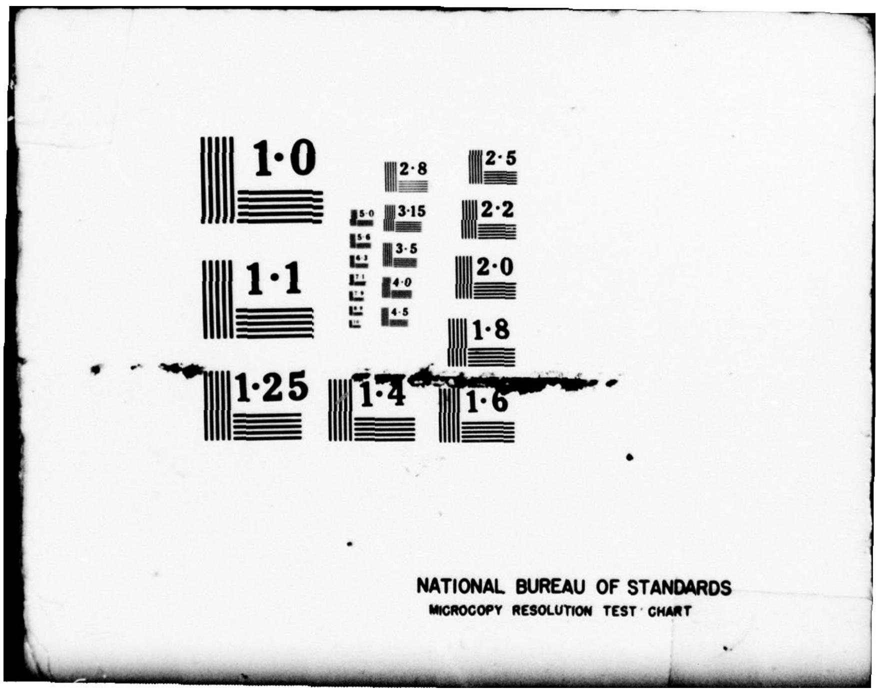
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LANDSAT D:

CORPS OF ENGINEERS INTERFACE WITH

ADVANCED NASA GROUND SYSTEMS STUDY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The object of the study was to determine and analyze alternative interface with the Landsat D ground data distribution system.
The approach taken was to identify and define the requirements for data needed to meet the demands of the Civil Works Operation. These were then word [used] as criteria for structuring alternative system options. The key issues eminating from the requirements portion of the study are: perishability of the data volumes required in each district. Landsat A data path was investigated with regard to these data needs leading to identification of access paths and data

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20. availability. Also, a characterization of the media of data transmission was provided.

This report discusses the parameters that must be considered to effectively evaluate the alternatives that are available to the COE for interfacing with the Landsat-D data system. Key issues of several alternatives are characterized.

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EXECUTIVE SUMMARY

In September 1977, the U.S. Army, Corps of Engineers, Engineer Topographic Laboratories, awarded a contract to General Electric to determine and analyze alternative interfaces with the Landsat-D ground data distribution system. The effort includes the definition of system options, associated hardware options and cost considerations for accessing Thematic Mapper digital data that would be used by COE-CW at a hypothetical Data Reception and Processing Facility (DRPF), typically located at Ft Belvoir, Virginia.

STUDY APPROACH

The first step within this study was to identify and define the requirements for data needed to meet the demands of the Civil Works operations. These requirements were then used as criteria in structuring alternative system options.

The Landsat-D data path was investigated with regard to these data requirements leading to identification of access points and data availability. An evaluation, at these points, of data throughputs and data quantity resulted in selecting the media of data transmission.

Finally, candidate configurations capable of satisfying the data requirements were defined. Quantitative and qualitative trade-off analyses, were performed on these alternative configurations to determine the cost-effective recommended approach. Cost estimates and design descriptions were generated for three approaches: the recommended approach, a more rapid data delivery variation of the recommended approach, and an alternate configuration based on relocation of part of the Landsat-D system from Goddard Space Flight Center near Washington to Sioux Falls, South Dakota.

ANALYSIS AND RESULTS

COE Data Requirements including average coverage estimates, applications techniques used in the projects and typical output data products per project were estimated for COE Civil Works activities. Only two areas were found to require 48 hour data delivery: flood prediction/damage assessment and the regulatory permit program. All others ranged from 7 to 30 days.

Thematic Mapper scene requirements were then estimated for the COE Civil Works programs. Total scene requirements sum to 3056 scenes per year. However the bulk of these scenes are required by the Flood Prediction Program (1035 scenes) and the Regulatory Permit Program (152 scenes). Applying a typical United States cloud cover probability factor of 0.65 results in 772 scenes to be processed in near realtime per year. The need for rapid data delivery is evident.

Scene Requirements per division were also estimated. Non perishable (not required in realtime) data averages less than one scene per day per division. Peak realtime load is 2 or less scenes per day for selected divisions. The load varies with time of year and is maximum in the March through June time period during snowpack melt.

Seven points in the Landsat-D system, shown in Figure 1 are available where data could be obtained for the COE. Each point has a different data delay and cost associated with it. A system configuration allowing data delivery to the COE Data Receiving and Processing Facility (assumed to be at Ft. Belvoir, Va) was defined for each access point. Configurations A and B almost exactly duplicate NASA facilities, are high cost and provide no significant advantages, and were eliminated early in the analysis.

The various alternates were evaluated based on mission suitability, reliability and cost (initial equipment, maintenance and operations personnel) as summarized in Table 1. Ease of expansion to include other satellites were also assessed but no significant differences were apparent between approaches. Alternate E is the preferred approach since it is lowest cost and provides both raw and preprocessed data in a timely fashion. Raw data is available in 1.5-16.5 hours after acquisition by the satellite; preprocessed data is available 25.5-64.5 hours after acquisition.

Relocation of the Data Management System from Goddard Space Flight Center in Greenbelt, Maryland to the EROS Data Center in Sioux Falls, South Dakota (currently under consideration by the Government) was also examined for its impact on the COE system. Alternate D then becomes the preferred approach, since the low data transfer cost advantage between the DMS and DRPF (because of their close proximity in the Washington area) for configuration E is lost.

Two options were considered for data distribution to the divisions: 1) all processing at the DRPF with distribution of the results and 2) realtime processing locally at the division with non real-time processing at the DRPF. Option 1 was much lower cost (a few hundred thousand versus 1.5 million dollars) due primarily to the cost of wideband telephone lines for Option 2.

The initial installation plus 3 year operations costs for the COE system are shown in Table 2. Configuration E2 is clearly lowest cost. Configuration E (1) has lower initial equipment (non recurring) cost than Configuration D (see Table 1) but requires more operations personnel. Hence over a three year period the costs are roughly equivalent with the $34,000 difference within the rough order of magnitude estimating accuracy.

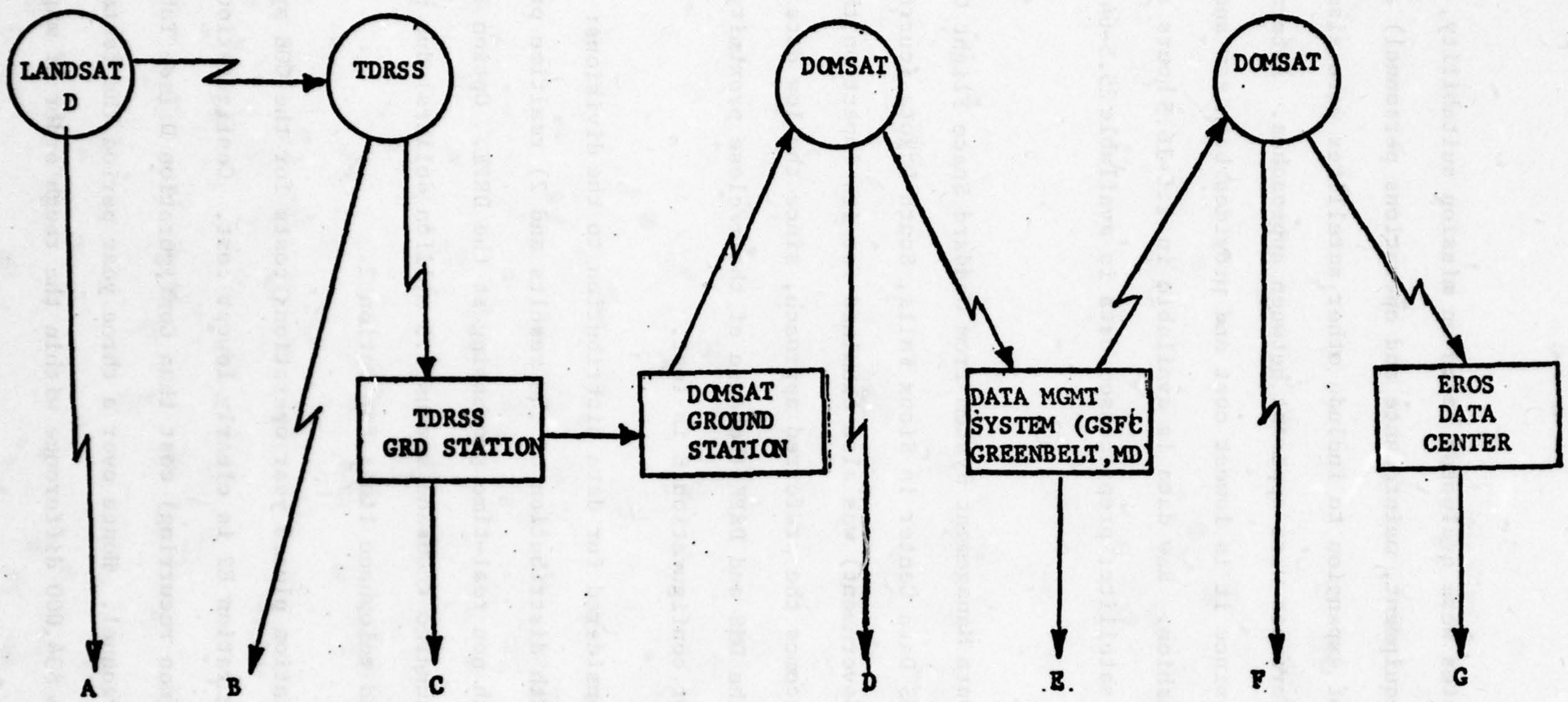

Figure 1. Access Points in the Landsat-D System

Table 1. Evaluation of the Various Configurations

CONFIGURATION	RAW DATA		PREPROCESSED DATA		COVERAGE	RELIABILITY	EQUIPMENT & MAINTENANCE COST PER YEAR (THOUSANDS OF $)	OPERATIONS PERSONNEL		COMMENTS
	AVAILABILITY	TIME DELAY (HOURS)	AVAILABILITY	TIME DELAY (HOURS)				2 SHIFTS	3 SHIFTS	
C	DIRECT FROM DOMSAT	1.3-15	PROCESSED BY DRPF	25.3-63	FULL	LOWEST	877	9	12	REQUIRES DOMSAT TRANSMIT AND RECEIVE TERMINALS
D	DIRECT FROM DOMSAT	1.3-15	PROCESSED BY DRPF	25.3-63	FULL	HIGH	334	5	7	REQUIRES DOMSAT RECEIVE TERMINAL
E(1) (MICROWAVE)	FROM DMS	1.5	FROM DMS	25.5	FULL	HIGH	196	8	11	RAW DATA NOT A STANDARD PRODUCT. AVAILABILITY REQUIRES SPECIAL AGREEMENT WITH NASA
E(2) COURIER	FROM DMS	16.5	FROM DMS	40.5-64.5	FULL	HIGHEST	69	4	NOT REQD	
F	FROM DMS	2.8-16.5	FROM DMS VIA DOMSAT	25.4-64	FULL	HIGH	334	5	7	DOMSAT TERMINAL USED FOR PREPROCESSED DATA COULD ALSO RECEIVE RAW DATA SIMILAR TO CONFIGURATIONS C OR D
G	FROM DMS	2.8-16.5	FROM EDC	75-112	FULL	LOWEST	877	9	12	ADDITIONAL PRODUCTS AND PROCESSING AVAILABLE FROM EDC MAY REDUCE PROCESSING REQUIREMENTS/COSTS FOR COE

Table 2. Three Year Costs for Preferred Configurations

Data Reception and Processing Facility

	Configuration		
	D	E(1)*	E(2)*
System Costs			
System Engineering	78	95	63
Hardware	803	627	323
Hardware Integration and Test	46	46	46
Site Installation and Checkout	93	93	93
Program Management	8	9	7
Total System	1,028	870	532
Maintenance and Operations Cost			
Manpower	405	609	304
Materials	374	356	179
Total M&O	779	965	483
System and M&O	1,807	1,835	1,015
Totals (10% fee plus 10% contingency)	2,186	2,220	1,228

All numbers are in 1977 dollars x 1000

*E(1) - data courier between GSFC and DRPF for twice daily transfer.

*E(2) - microwave link between GSFC and DRPF for continuous data transfer; reduces data delivery time by 15 hours.

PREFACE

This report was prepared under contract DAAK70-77-C-0237 for the U.S. Army Contracting Engineers, Engineer Topographic Laboratories, Fort Belvoir, Virginia. The contracting office's representative was Mr. Lawrence P. Murphy.

TABLE OF CONTENTS

LIST OF ILLUSTRATION

LIST OF TABLES

LANDSAT D CORPS OF ENGINEERS INTERFACE WITH ADVANCED NASA GROUND SYSTEMS STUDY

SECTION 1

INTRODUCTION

The pressing need to better survey and manage the earth's resources and environment has prompted man to explore the possibilities of remote sensing from space. Early efforts began with the analysis of hand held space photographs from Gemini and Apollo largely for geologic purposes, followed by a more formal multidisplinary earth resources experiment on Apollo 9 (S-065), and continued with multispectral data from the Landsat 1, 2 and 3 spacecraft. Landsat-D is currently approved as the next major step for the Earth Resources Program.

Landsat 1, launched in 1972, marked the start of NASA's Earth Resources satellite program. The successful spacecraft was followed two and a half years later with Landsat 2, a virtually identical spacecraft. The value of the first two Landsats has been demonstrated through hundreds of successful experimental programs. The third satellite, Landsat 3, was successfully launched in early 1978. This third satellite carries a modified (5 band) Multi-spectral Scanner, a substantially changed, higher resolution (40 meter) RBV and uses an improved digital ground system. NASA is now planning for the next step, Landsat-D, which will provide several major advances.

1.1 LANDSAT-D SYSTEM

The Landsat-D system will be based on NASA's new Multi-mission Modular Spacecraft (MMS) and will operate two remote sensing instruments: a Thematic Mapper (TM), with 30 meter ground resolution, and a Multi-spectral Scanner (MSS), with 80 meter resolution. The spacecraft will be in a sun-synchronous orbit with a descending node time of 9:30 AM (similar to current Landsats) but with a lower orbital altitude (705 km vs 920 km) then for Landsats 1/2/3. It provides near global coverage of the land and near coastal regions with a repeat cycle every 16 days.

Unlike previous Landsats, Landsat-D will transmit two frequency data directly from the satellite to domestic and foreign ground stations as the vehicle passes through their reception areas, TM and MSS data at X-band and MSS data (only) at S-band. A new third link will be provided by the Tracking and Data Relay Satellite System, (TDRSS), two spacecraft in geostationary orbits and a ground receiving system located in White Sands, New Mexico. The two operational TDRS plus an in-orbit spare will be in place in 1980.

The TDRS System will allow data acquisition and relay capability to NASA facilities in the United States. Present plans, illustrated in Figure 1-1, will have raw data forwarded from the TDRSS ground station in White Sands to Goddard Space Flight Center for processing. The processed data will be sent from Goddard to the EROS Data Center in Sioux Falls, South Dakota via a domestic satellite communications link for distribution to users. Several domestic service organizations including Western Union, RCA, and the American Satellite Corporation will be capable of supplying the required domestic communications services.

The Thematic Mapper (TM) is an evolutionary improvement of the MSS in several significant capabilities. The instantaneous field of view has been decreased to 30 meters (compared to 80 for the MSS), which will allow radiances to be detected for areas (pixels) less than one sixth the size of MSS. The TM will incorporate seven (7) spectral bands, which have been selected primarily to provide better discrimination of vegetation classes. In addition, the radiometric accuracy of the TM has been improved, over the MSS, by reducing the signal-to-noise characteristic in comparable channels and increasing the levels of digital quantization from six (6) to eight (8) bits. These instrument changes combined with a scan efficiency improvement of nearly two (2) to one (1) (by using the backscan of the mirror for data gathering), result in a data rate from the spacecraft of

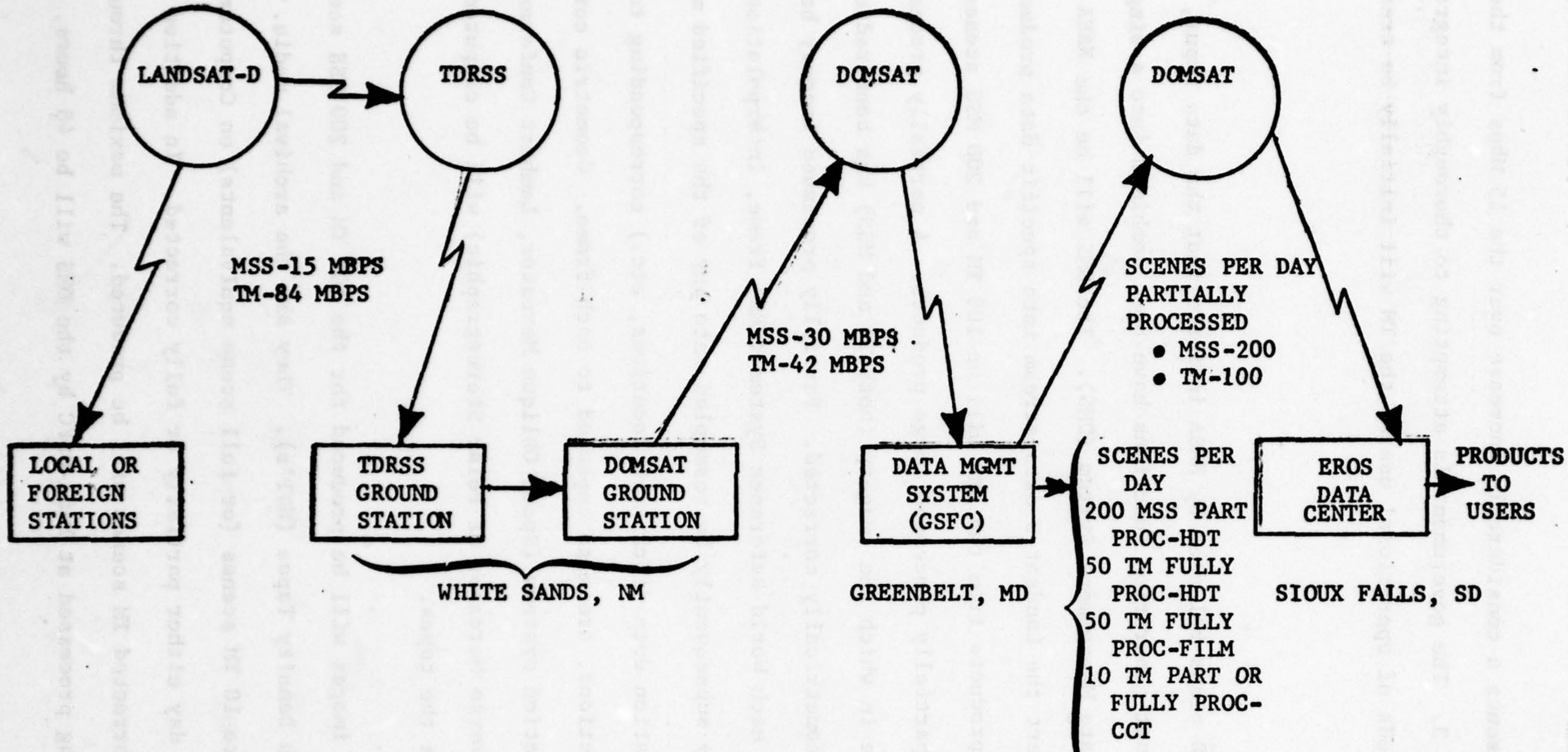

Figure 1-1. Landsat-D System

84 Mbps. This represents a considerable increase over the 15 Mbps from the MSS on Landsats 1, 2 and 3. The government is attempting to thoroughly integrate the MSS data with the needs of operational users; the TM will initially be treated as an experiment.

The latest Landsat-D plans released by NASA indicate that the data input, data processing and product generation functions have been combined into a single system called the Data Management System (DMS). The DMS will be the NASA ground system used to convert the Landsat-D data stream into specific data products. The primary output products from the DMS will be 100 TM and 200 MSS scenes per day in the form of partially processed image products. A partially processed image product is one in which the imagery (both TM and MSS) has been radiometrically corrected but not geometrically corrected. Partially processed imagery has appended to it, for each World Reference System (WRS) frame, interpolation grids, so that the imagery may subsequently be resampled into any of the specified map projections. Annotation data (tick mark locations, etc.) corresponding to specified map projections, are also appended to each frame. Geometric correction for three map projection systems (Space Oblique Mercator, Lambert Conformal Conic and Universal Transverse Mercator or Polar Stereographic) will be computed and appended to the image data on the tapes.

Partially processed images will be produced for the 100 TM and 200 MSS scenes in digital form on High Density Tapes (HDT's). They are the archival media. The DMS will also produce 10 TM scenes (or full scene equivalents) on Computer Compatible Tape per day either partially or fully corrected. In addition film products of fully corrected TM scenes will be produced. The maximum throughput time for images being processed at NASA-GSFC by the DMS will be 48 hours.

1.2 DATA UTILIZATION BY CORPS OF ENGINEERS

The U.S. Army Corps of Engineers is organized into three Divisions: Civil Works, Facilities, and Military Construction. The Civil Works Division is organized into 37 District offices as shown in Figure 1-2. Responsibility of the Civil Works extends over virtually all inland waters. The 1899 Act established Corps' responsibilities for all discharges and structures on navigable waters. Section 404 and related court decisions have extended that responsibility to headwaters (with flow rates of 5 cubic feet/sec) of all navigable waters including marshes and estuaries. The responsibility includes:

- Flood Control and flood protection
- Planning, construction, maintenance and operation of inland and coastal waterways
- Identification and surveillance of dams storing water of 50 acre/feet
- Coastal engineering associated with harbors, inlets and coastal erosion
- Environmental Quality Control of COE civil projects and military lands.

Since enforcement and, thus, field inspection may result from data analysis, rapid data delivery is desirable. The Corps of Engineers, through its Division and District field offices and R&D laboratories, has made limited operational use of Landsat Multispectral Scanner (MSS) data. Using MSS data and interactive machine data extraction techniques, processing time has been demonstrated to be in the order of 3 to 4 days, better than an order of magnitude improvement over manual techniques. Several COE offices are continuing techniques development, tests and analyses using the MSS digital data for the extraction of earth resources information. The results of these efforts have shown that it is potentially cost effective to extract earth resources

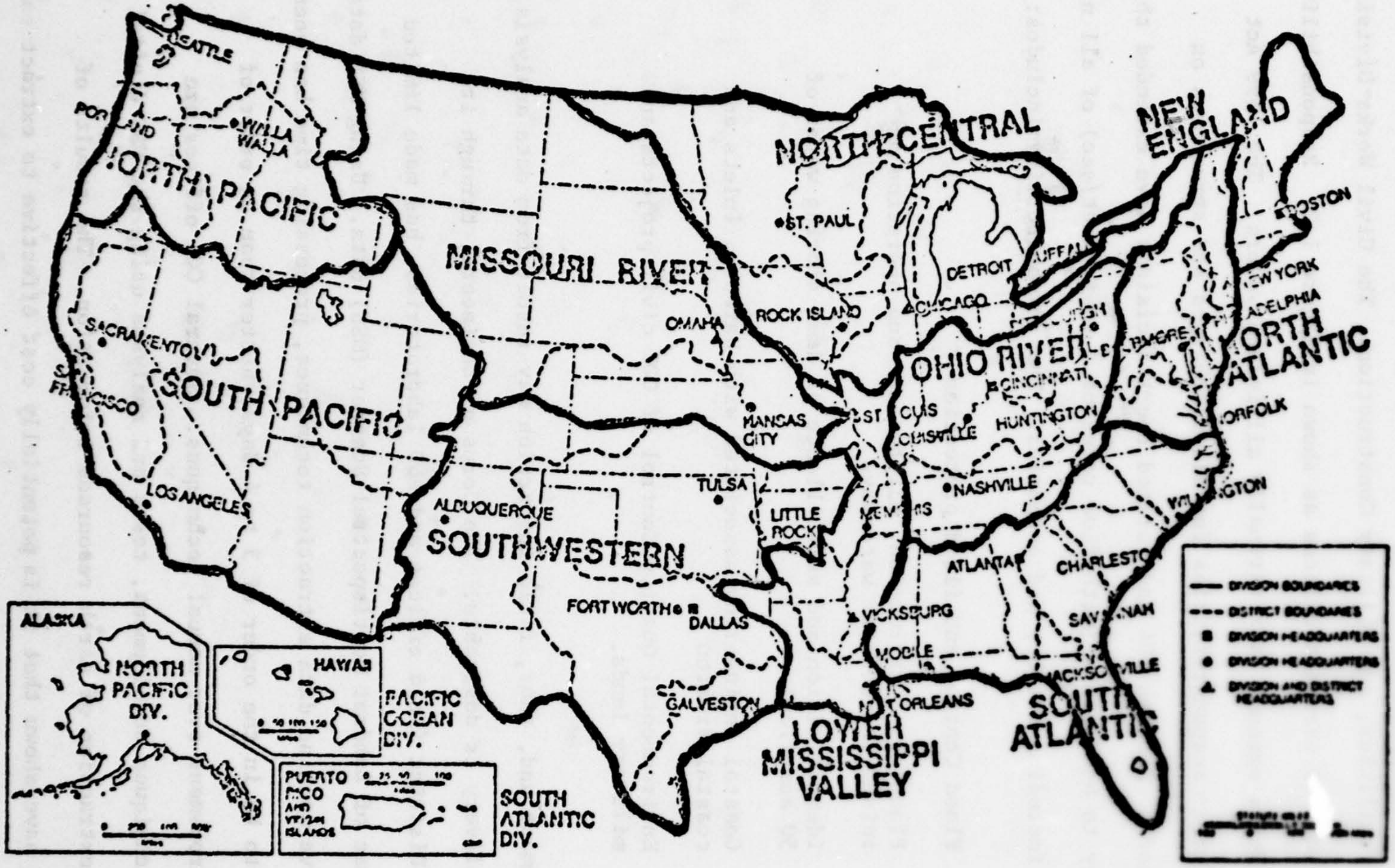

Figure 1-2. Divisions and Districts for Civil Works Activities

information for input into the COE storm run-off model, for the detection man-made lakes, and for the monitoring and measuring (areal extent) of changes to large rivers during conditions of flooding. The results obtained from these application tests utilized Landsat 1 and 2 MSS 80 meter data. In order to increase the accuracy of feature extraction outputs and to extend the COE use of Landsat data, it has been concluded that data from the higher resolution, Landsat-D Thematic Mapper will be needed.

SECTION 2

INVESTIGATION

In September 1977, the Engineer Topographic Laboratories awarded a contract to General Electric to determine and analyze alternative interfaces with the landsat-D ground data distribution system. The effort includes the definition of system options, associated hardware options and cost considerations for accessing Thematic Mapper digital data that would be used by COE-CW at a hypothetical Data Reception and Processing Facility (DRPF), typically located at Ft. Belvoir, Virginia.

The primary objective of this study was to identify design options and develop configurations that will allow the COE to interface with the Landsat-D ground system. The major tasks were:

1. Determine an appropriate interface related to accessing Landsat-D Thematic Mapper digital data for use by the COE Data Reception and Processing Facility

    - Access all bands of TM data.
    - Access raw (unresampled/uncorrected) data.
    - Access pre-processed (radiometerically corrected but not resampled) data in both computer compatible tape and High Density Tape formats. The data is radiometrically corrected and has appended geometric correction data so that the imagery may subsequently be resampled into any of the specified map projections.
    - Identify available system options.
    - Define hardware and software related to accessing the TM data, and transferring the data to DRPF.
    - Define quick look capability at the DRPF.

2. Define method(s) to extrapolate results to access data from other NASA and NOAA satellites. Table 2-1 is a list of anticipated satellites.

3. Define alternative(s) by which data from DRPF and DMS (GSFC/EDC) can be delivered to 37 Districts and 12 Divisions of the COE.

Figure 2-1 illustrates the study approach. The first step within this study was to identify and define the requirements for data needed to meet the demands of the Civil Works operations. These requirements, discussed in Section 3.1 were then used as criteria in structuring alternative system options.

The current Landsat-D data path was investigated with regard to these data requirements. This led to identification of access points and data availability. An evaluation, at these points, of data throughputs and data quantity resulted in selecting the media of data transmission.

Finally, candidate configurations capable of satisfying the data requirements were defined. Quantitative and qualitative trade-off analyses, discussed in Section 3.6 were performed on these alternative configurations to determine the cost-effective recommended approach. Cost estimates and design descriptions were generated for three approaches: the recommended approach, a rapid data delivery variation of the recommended approach, and an alternate configuration based on relocation of part of the Landsat-D system from Goddard Space Flight Center near Washington to Sioux Falls, South Dakota.

Table 2-1. Additional Remote Sensing Satellites

SATELLITE	KEY SENSORS	PRINCIPAL SATELLITE OUTPUTS	APPLICATIONS/OBJECTIVES
NIMBUS-G	COASTAL ZONE COLOR SENSOR TEMP. HUMIDITY IR RADIOMETER BACKSCATTER UV/TOTAL OZONE MAPPER OTHERS	OCEAN COLOR MAPS VERTICAL PROFILES GLOBAL OZONE MAPS IMAGERY	CHLOROPHYLL AMOUNTS ATMOSPHERIC TRACES AEROSOLS EARTH RADIATION BUDGET OZONE MONITOR POLLUTION MONITOR AIR/SEA INTERFACE
SMS/GOES	VISSR-VISIBLE IR SPINSCAN RADIOMETER	IMAGERY	CONTINUOUS CLOUD COVER MONITOR CLOUD TEMPERATURE MONITOR OCEAN SURFACE TEMPERATURE SPACE ENVIRONMENT MONITOR DATA RELAY
HCMM	HEAT CAPACITY MAPPING RADIOMETER	IMAGERY	THERMAL MAPPING ROCK/MINERAL IDENTIFICATION SOIL MOISTURE SNOW RUN-OFF PREDICTION
SEASAT	SYNTHETIC APERTURE RADAR PASSIVE MICROWAVE RADIOMETER SCATTEROMETER	IMAGERY PROFILES	GEOID/TIDAL MAPPING SEA STATE WEATHER FORECAST/WARNING
TIROS-N	AVHRR-HIGH RESOLUTION RADIOMETER HIRS/2-IR SOUNDER	IMAGERY PROFILES	VERTICAL TEMP/MOISTURE PROFILE CLOUD TOP TEMPERATURE GLOBAL CLOUD COVER MONITOR OCEAN SURFACE TEMPERATURE DATA RELAY

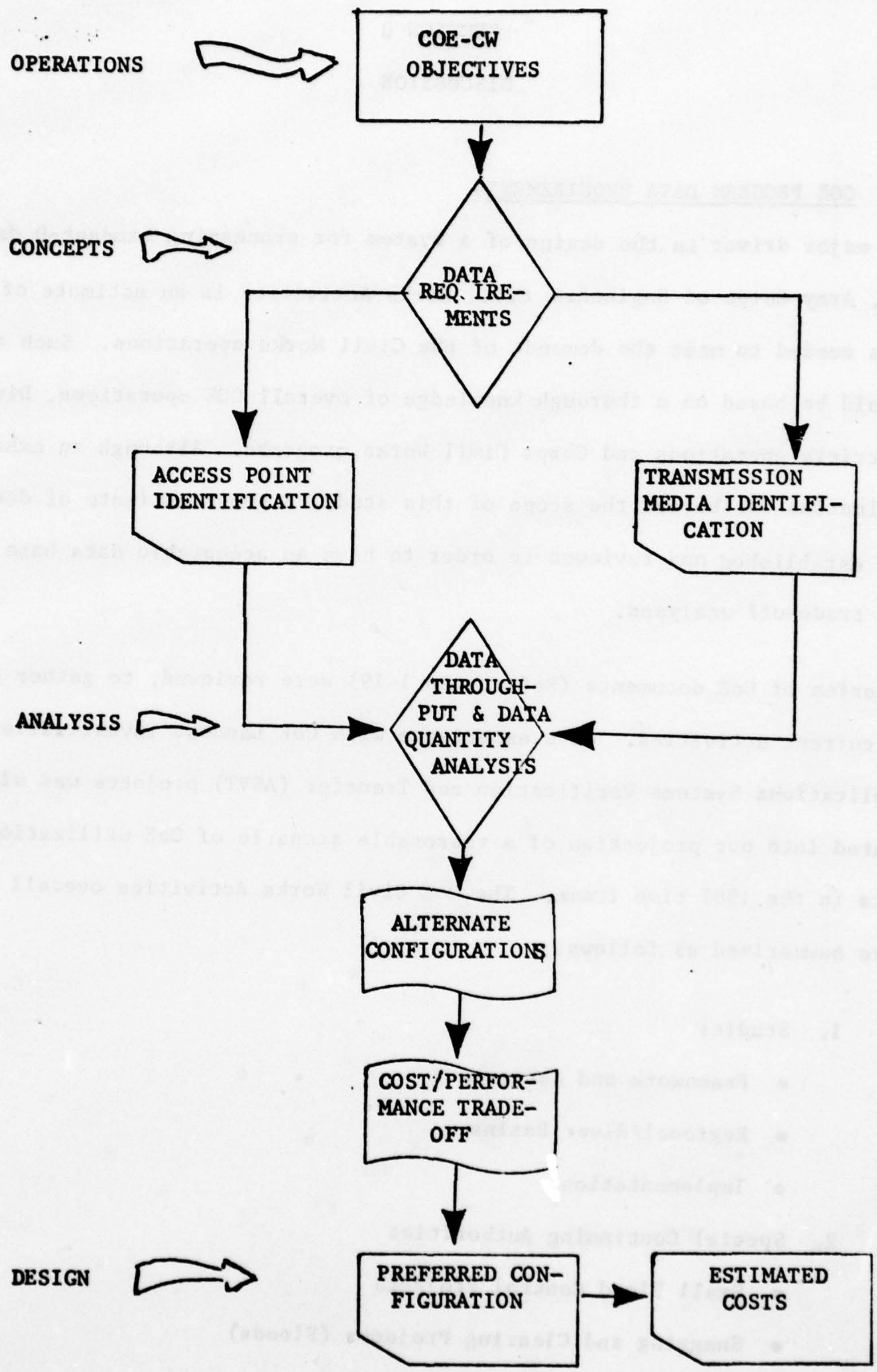

Figure 2-1. Study Approach

SECTION 3

DISCUSSION

3.1 COE PROGRAM DATA REQUIREMENTS

The major driver in the design of a system for processing Landsat-D data for the U.S. Army Corps of Engineers Civil Works Activities is an estimate of the data needed to meet the demands of the Civil Works operations. Such an estimate should be based on a thorough knowledge of overall COE operations, Division/ Districts operations and Corps Civil Works programs. Although an exhaustive evaluation was beyond the scope of this study, a gross estimate of data loading was established and reviewed in order to have an acceptable data base for use in the trade-off analyses.

A series of CoE documents (References 1-19) were reviewed, to gather an overview of current activities. GE's experience with CoE Landsat investigations and NASA Applications Systems Verification and Transfer (ASVT) projects was also integrated into our projection of a reasonable scenario of CoE utilization of Landsat data in the 1981 time frame. The CoE Civil Works Activities overall programs were summarized as follows:

1. Studies
   - Framework and Assessment
   - Regional/River Basins
   - Implementation
2. Special Continuing Authorities
   - Small Flood Control Projects
   - Snagging and Clearing Projects (Floods)
   - Small Navigation Projects
   - Small Beach Erosion Control Projects
   - Mitigation of Shore Damage
   - Review of Completed Projects

- Emergency Bank Protection
- Snagging and Clearing Projects (Navigation)
- Removal of Wrecks and Obstructions

3. Disaster Assistance, Flood Fighting and Operation Foresight
4. Flood Plain Management Services
5. Urban Studies
6. Environmental Studies
7. Diked Disposal Area Program
8. Recreation, Fish and Wildlife Program
9. National Dam Safety Program
10. Permit Programs Regulatory
11. Ice Survey
12. Corps Information System Program

Within each of these general headings there exist areas where remote sensing data could be used. In the following discussion, the areas are described and the possible remote sensing applications are identified:

- Studies: There are three major types of studies. They are referred to as 1. Framework/Assessment Studies, 2. Regional/River Basin Studies, 3. Implementation Studies. They all may include (1) inventory, needs, and desires of people for the development and utilization of water and land resources, (2) problem solution, and (3) identification of areas for which more detailed investigation and analysis are needed. These studies may be regional or national in scope. The Framework/Assessment and the Regional/River Basin studies are directed by the Water Resources Council (WRC), with the Corps generally a major participant. Regional or River Basin Studies are devoted to evaluation of water and land resources and are more detailed in scope andlimited in area than framework studies. They are intended to solve complex, long-range problems identified by framework studies.

The third type of studies, the implementation studies include most Corps investigations. These are detailed study programs for the purpose of recommending authorization or initiation of plans to solve resource problems.

In each of the appropriate study categories data from the Thematic Mapper has application to the areas of geological structure mapping, environmental geology, physiographic mapping and land cover mapping.

- Special Continuing Authorities: Under this item, nine categories are identified:

1. Small Flood Control Projects: The category allows the Corps to build small flood control projects that have not been specifically authorized by Congress. It is assumed that remotely sensed data would be applied to the areas of environmental geology and cover mapping and change detection mapping (flood vs. non-flood conditions) for this category.

2. Snagging and Clearing (Floods). This category provides for clearing and straightening of stream channels and the removal of accummulated snags and other debris in the interest of flood control. It is assumed remotely sensed data is not applicable to this category.

3. Small Navigation Projects: The Corps is authorized to construct small river and harbor improvements projects not specifically authorized by Congress. It is anticipated that Thematic Mapper data would be applicable to this category, especially for bathymetric mapping, wetland mapping, surface water pattern mapping, ice mapping, etc.

4. Small Beach Erosion Control Projects: The Corps provides for construction of small shore and beach restoration and protection projects not specifically authorized by Congress. The areas of application of Thematic Mapper data for this category are land cover mapping, bathymetric mapping, wetland mapping, change detection of shorelines, and water pattern mapping (sediment transport).

5. Mitigation of Shore Damages: The Corps is authorized to investigate, study and initiate projects for the prevention or mitigation of shore damage attributable to Federal navigation works. This category would use remotely sensed data in a manner similar to the use by the Small Beach Erosion Control Projects.

6. Review of Completed Projects: The Corps is authorized to review the operation of completed projects which are constructed by the Corps, in the interest of navigation, flood control, water supply and related subjects. It is assumed that Thematic Mapper data is applicable although remote sensing data is not currently used in this application.

7. Emergency Bank Protection: The Corps is authorized to restore or modify streambank and shoreline protection to prevent damage to highways, bridge approaches and other public works. Remotely sensed data is not applicable to this category.

8. Snagging and Clearing: This category authorizes snagging and clearing of navigable harbor, rivers and other waterways. Use of remotely sensed data is not applicable to this category.

9. Removal of Wrecks and Obstructions: The Corps is authorized to investigate wrecked vessels and other obstructions to navigation. Use of Thematic Mapper data is not applicable to this category.

- <u>Disaster Assistance, Flood Fighting and Operation Foresight:</u> The Corps has, at its discretion, funds for flood emergency preparations, flood fighting and rescue operations, or for the repair or restoration of any flood control work threatened or destroyed by flood. The Corps is authorized to provide emergency protection for hurricane and shore protection projects, when threatened. The Corps also cooperates with the Federal Disaster Assistance Administration, in providing assistance to state and local governments, in dealing with natural disasters. Operation Foresight is a program designed to enable the Corps to react, when every indication forecasts the threat of severe flooding. Data collected, relative to large snowpacks or other conditions, may indicate a potential for severe flooding. In these cases, the Corps may decide to send Operation Foresight teams into action.

  Thematic Mapper data is expected to be useful in several applications in this category, including change detection monitoring, snow mapping and land cover mapping.

- <u>Flood Plain Management Services:</u> The objective of the program is planning for flood damage prevention, at all government levels, to encourage and guide the use of flood plains, for the benefit of the national economy and welfare. Flood plain information reports and technical assistance on flood plain hazards are furnished to federal, state, and local government agencies. Typical reports include maps or mosaics, profiles, charts, tables and a narrative describing the extent, depth, probability and duration of flooding by floods of the past and the future. The Corps also provides technical assistance to state and local governments, upon request, to aid in preparation of flood plain regulations, interpretation of data in flood plain information reports, evaluation of flood hazards, flood proofing of structures and other pertinent information. In addition, the Corps, upon request of HUD, conducts flood insurance studies in selected communities. Under the 1974 Water Resources Development Act, the Corps can assist any state in the preparation of plans for the development, use and conservation of water and related resources of drainage basins located within its boundaries.

For this category, Thematic Mapper data would be applied to several areas, including physiographic mapping, land cover mapping, change detection monitoring and ice mapping.

- Urban Studies: The Corps Urban Studies Program is an input into Urban Area Comprehensive Planning. Specific areas dealt with by the Corps are urban flood control and flood plain management, municipal and industrial water supply, waste water management, bank and channel stabilization, lake/ocean/estuarine restoration and protection, recreation and regional harbor/waterway development.

  It is anticipated that the use of Thematic Mapper data, relative to the Urban Study Program, would include items such as environmental geology, land cover mapping and change detection monitoring.

- Environmental Studies: The Corps, in its comprehensive studies and project investigations, considers environmental values and needs equally with economic, engineering and social factors. For all project proposals, environmental impact assessment is required. From the assessment, decisions are made determining the need for environmental impact statements. The statement considers the environmental impact of the proposed action: the adverse effects, which cannot be avoided if the project is carried out, the alternatives to the proposed actions, the relationship between the short-term use of the environment and the maintenance of long-term productivity.

For this category, Thematic Mapper data would be applied to environmental geology, land cover mapping, change detection monitoring, sediment pattern mapping and water quality analysis.

- <u>Diked Disposal Area Programs:</u> The Corps is authorized, under a ten (10) year program, to construct diked disposal facilities on the Great Lakes for the confinement of polluted dredging material. Under this program, there appears to be no applicable use of the Thematic Mapper data.

- <u>Recreation, Fish and Wildlife Program:</u> Pre-authorization and post-authorization planning and project development is coordinated with both Fish and Wildlife Service and the agency administering fish and wildlife resources of the state wherein a project is contemplated. Any use of remotely sensed data, in this category, has been assumed to be included in the Environmental Study Category.

- <u>National Dam Safety Program:</u> The Corps of Engineers is authorized to inspect and assure the safety of dams. Inventory of reservoirs and dams is included in this program. Under this program, it is anticipated that remotely sensed data would be applied to environmental geology, physiographic mapping, water body mapping, change detection monitoring, water quality and pattern mapping.

- Permit Programs - Regulatory: Corps of Engineers permits are required for work or structures in navigable waters. The purpose of the program is to insure that the chemical/biological integrity of the waters is protected from discharge of dredged or fill material. The Corps evaluates each permit application, relevant to such factors as conservation, economics, aesthetics, flood damage prevention, water supply, and water quality. It is anticipated that the program would use Thematic Mapper data for such applications as change detection monitoring and water quality analysis

- Ice Survey: Although the Corps is not responsible for doing ice surveys, they are concerned with maintaining navigable waterways. Therefore, it is assumed that the Corps would be concerned in performing ice surveys in selected navigable waterways, i.e. Great Lakes, Chesapeake Bay, etc., using remotely sensed data.

- Corps Information System Program: Information (hydrologic, economic, environmental, etc.) gathered by the Corps will eventually be centrally filed into a Corps geo-coded reference data base. Remotely sensed data will be one data source assisting in the compilation. In general, Thematic Mapper data will be filed into the system. The system will serve several of the Corps programs, therefore, this item is not considered separately, but as an integrated part of other programs.

Table 3-1 was composed by considering the identified programs which could utilize information derived from Landsat-D data. This table describes a hypothetical utilization of TM data, to support the full range of projects being performed for each district. A set of requirement parameters were assigned. These parameters

Table 3-1 Program Related Requirements

Typical Corps Projects per District \ Requirement Parameters	Average Coverage Estimates: Fraction of Scene Used	Basic No. of Scenes	Temporal - Dates	Projects/Year	Data Ch. Required	Repeatability of Proj. (Years)	Timeliness of Data Days	Total Equival. Scenes per Year	Applications Technique Used in Projects: Environ. Geology	Geolog. Struc. Mapping	Geomorphology & Feature Mapping	Physiographic Mapping	Snow Mapping	Inventory Land Cover	Chng. Detec. Monitoring	Sediment Transport	Water Quality	Ice Mapping	Typical Output Data Products per Project: Thematic Maps 1	Thematic Maps 2	Thematic Maps 3	Overlays 1	Overlays 2	Overlays 3	Enhancements	Area Measurements	Distance Measurements	Product Utilization 4	Product Utilization 5	Product Utilization 6	Images (Film)
1. Studies (Large River Basins)	1	3	2	1	all	10	≥ 30	6	X	X		X		X					X			X			X	X	X	X	X	X	X
2. Special Continuing Authorities																															
Small Flood Projects	1/4	1	2	20	all	3	≥ 30	10	X					X	X						X			X		X		X			X
Small Navigation Projects	1/4	1	4	5	7	5	30	5							X			X			X			X				X			
Small Shorelines & Others	1/4	1	4	3	all	3	15	3	X		X			X	X	X	X				X			X	X	X		X			
3. Disaster Assistance, Flood Fighting and Operation Foresight							★																								
Damage Assessment	1/2	1	2	5	all	1	2	5						X	X						X			X		X		X	X		X
Flood Predictions	1	2	9	5	3,4 5,6	1	2	90					X		X								X			X					
4. Flood Plain Mgmt Services	1/2	1	2	5	all	5	7.3	2.5				X		X	X			X			X			X	X	X	X	X			X
5. Urban Studies	1/4	1	2	1	all	5	≥ 30	.5	X					X	X						X			X	X	X		X	X		X
6. Environmental Studies (Habitats) (Water Quality) (EIS)	1/2	1	4	5	all	1-3	30 15	10	X					X	X	X					X	X	X	X	X	X		X	X		X X
7. Nat'l Dam Safety Program (Updating)	1/2	4	4	2	4 6	5	15-30	8	X			X		X	X	X	X				X	X	X	X	X	X	X	X	X	X	X
8. Permit Program -Regulatory-	1/2	2	4	2	4 6	3	2 ★	4	X						X		X				X			X		X	X	X	X	X	X
9. R/D: Const. Eng. Res. Lab. - Springfield, VA; Hydrologic Eng. Ctr. - Davis, CA; Coastal Eng. Res. Ctr - Ft. Belvoir, VA; Cold Region R.L. - Hanover, NH; Waterway Exp Station - Vicksburg, MS	1/2	4	4	2	all	0	≥ 30	8	X	X	X	X	X	X	X	X	X	X			X				X	X	X	X			X

★ 48 HRS. TURNAROUND TIME

NOTE: All of these identified projects do not necessarily currently use Landsat data as input but the potential exists during the Landsat D Thematic Mapper period that a district could require the data.

LEGEND
1 = 1:250,000 SCALE
2 = 1:62,500 "
3 = 1:24,000 "

4= DISTRICT
5= DIVISION
6= EXTERNAL

are labeled as:

- Average Coverage Estimates
- Applications Technique used in Projects
- Typical Output Data Products per Project

The parameter, "Average Coverage Estimate", is divided into eight (8) categories. These categories are defined as follows:

- <u>Fraction of Scene Used:</u> An approximation of the portion of a 185 km by 185 km Thematic Mapper (TM) image required for analysis for the typical project identified.
- <u>Basic Number of Scenes per Project:</u> An approximation of the number of TM images required for a typical test site.
- Temporal Data: An approximation of the number of temporal data sets required for each project update cycle.
- <u>Projects/Year:</u> An estimate of the number of projects conducted by a CoE district annually per program.
- <u>Repeatability of Project:</u> An estimation of the number of years before updating a project.
- <u>Estimation of Data Channel(s) Required:</u> An estimation of TM data channels required for analysis.
- <u>Timeliness of Data:</u> The time required by CoE user to receive TM data in specified format. Critical turnaround time of two (2) days is associated with two (2) program areas, i.e. Disaster Assistance - Flood Fighting - Operation Foresight and Permit/Regulatory Programs. The first program requires the monitoring of floods and snowpacks. The second program relates to the environmental and regulatory monitoring requirements.

- Total Equivalent Scenes per Year per District: Derived by fraction of scene used, times basic number of scenes, times temporal data, times projects per year. This value yields an estimate of the amount of TM data required per CoE district. For these values to be applied to individual CoE districts, adjustments are made, relative to district size and geographic location.

The parameter "Application Techniques used in Projects" is divided into ten (10) categories. These categories are identified and defined as follows:

- Environmental Geology: Addresses the evaluation of sites for engineering structures in terms of geologic hazards, earth materials for engineering usage and environmental impact.
- Geological Structure Mapping: The mapping includes delineation and analysis of folds (anticlines, synclines, monoclines, structure terraces, etc.) and fractures.
- Geomorphic Feature Mapping: The mapping relates to glacial, fluvial, desert, permafrost features and features related to bedrock structures.
- Physiographic Mapping: The mapping of watershed basin area and shape, stream network organization, drainage density and pattern.
- Snow Mapping: Mapping snowpack areas of watershed for forecasting run-off. Activity is confined to the western, northwestern, north central and northeastern U.S.
- Inventory Land Cover: Classification of mapping of land cover, relative to political, watershed, etc. boundaries.
- Change Detection Monitoring: Temporal analysis, i.e. flood damage assessment, surface water inventory, periodic watershed land cover updates, etc.
- Sediment Transport: Mapping of patterns of suspended solids in lakes, reservoirs, navigable rivers, etc.

- Water Quality: Studies relating to water quality of reservoirs and lakes and corresponding surrounding land cover.
- Ice Mapping: Ice surveys and monitoring of ice conditions in navigable water bodies.

The final parameter in Table 3-1 is "Typical Output Data Products per Project". This parameter consists of seven categories. These categories pertain to output products and their distribution. The categories are listed as:

- Thematic Maps: Extracted theme data, coded at a specific map scale.
- Overlays: Extracted theme data, on registered transparent material, at specific map scales.
- Enhancements: Digitally enhanced images, processed using linear and non-linear stretches, ratios, filtering techniques, etc.
- Area Measurements: Computer printouts containing thematic area measurements, relative to geopolitical boundaries.
- Distance Measurements: Computer printouts of stream lengths, shoreline lengths, lineament lengths, etc.
- Project Utilization: Level of product distribution (district, division, external to Corps).
- Images (film): Thematic Mapper derived imagery.

3.2 TM SCENE REQUIREMENTS

In Table 3-2, the Thematic Mapper requirements are estimated for the Corps of Engineers Civil Works programs. The programs are defined as typical programs, performed by the specified districts with adjustments for district unique activities applied. For instance, certain districts are not involved in snow mapping; some districts have small coastal waterways. Adjustments are made in total equivalent scenes per year, relative to the districts. Likewise, only districts where the CoE laboratories are located are allocated TM data for R&D programs. TM scene requirements are shown in Table 3-2, relative to Corps districts (and divisions) and programs. Corps TM scene requirements sum to 3056 scenes/year.

An assessment was made of the actual number of TM scenes produced in each region per year to determine if the average Corps requirements exceed these limits. The limits were obtained by counting the number of Landsat-D World Reference System frame centers falling within the region multiplied by the number of orbit passes per year (23.8). No correction had to be applied since, in general, Corps requirements were lower than the limits.

Cloud cover statistics are functions of latitude and season, but averages over season and over the U.S. may be used to get gross estimates of the amount of data that must be processed to meet the Corps requirements. The probability of scenes having less than 55% cloud cover is about 0.65 for the U.S. For real-time data (continuously acquired and used), this means that only 65% of the scenes will be processed. On the other hand, the expected usable fraction of a scene is less than 0.5. This means that two (2) or more scenes (taken at different times) may be processed, to obtain full coverage of a given scene area for non-real time requirements. However, full coverage is not often needed for statistical assessments, and so no adjustments were made in the routine coverage numbers.

Table 3-2 TM Scene Requirements (No Cloud Adjustment)

DISTRICTS	DIVISIONS	1 STUDIES	2 SPECIAL CONTINUING AUTHORITIES: SMALL FLOOD PROJECTS	2 SPECIAL CONTINUING AUTHORITIES: NAVIGATION	2 SPECIAL CONTINUING AUTHORITIES: SHORELINE ETC.	3 DISASTER ASSIST: DAMAGE ASSESS.	3 DISASTER ASSIST: FLOOD PREDICTIONS (SNOW)	4 FLOOD PLAIN MGMT. SERVICES	5 URBAN STUDIES	6 *ENVIRONMENTAL STUDIES: HABITATS / WATER QUALITY / EIS	7 *NATIONAL DAM SAFETY	8 REGULATORY PERMIT PROGRAM	9 R&D LAB
NEW ENGLAND	NEW ENGLAND	6	10	5	3	5	45	2.5	.5	10	8	4	8
NEW YORK, NY	NORTH ATLANTIC				2								-
PHILADELPHIA, PA					2								-
BALTIMORE, MD					3								8
NORFOLK, VA					3								-
WILMINGTON, NC	SOUTH ATLANTIC				4								
CHARLESTON, SC					4								
SAVANNAH, GA					4								
JACKSONVILLE, FLA					4								
MOBILE, ALA					4								
NEW ORLEANS, LA	LOWER MISSISSIPPI VALLEY				4								-
VICKSBURG, MISS					—								
MEMPHIS, TENN					—								8
ST. LOUIS, MO.					—								-
GALVESTON, TEX	SOUTHWESTERN				4								
FORT WORTH, TEX				5	—	5							
ALBUQUERQUE, NM				—	—	2							
LITTLE ROCK, ARK				3	—	5							
TULSA, OKLA				3	—	5							
KANSAS CITY, MO.	MISSOURI RIVER			5			90						
OMAHA, NEBR				5			90						
NASHVILLE, TN	OHIO RIVER												
LOUISVILLE, KY													
HUNTINGTON, W VA													
PITTSBURGH, PA													
ST. PAUL, MINN	NORTH CENTRAL				—		90						
ROCK ISLAND, ILL					—		90						
CHICAGO, ILL					2		45						8
DETROIT, MICH					2		45						
BUFFALO, NY					2		45						
LOS ANGELES, CALIF	SOUTH PACIFIC				3		45						-
SAN FRANCISCO, CALIF					3		—						-
SACRAMENTO, CALIF					3		90						8
PORTLAND, OR.	NORTH PACIFIC				3		90						
SEATTLE, WASH					3		90						
WALLA WALLA, WASH					—		90						
ALASKA		6			3		90				8		
PACIFIC OCEAN		3	10	5	1	5		2.5	.5	10		-	
		225	180	181	68	187	1015	95	19	180	296	152	40

* Potential large growth areas

3056 Total Scenes
Adjusted 2241 Scenes

The near-real-time requirements in Table 3-2 are those for the Flood Prediction Programs (1035 scenes) and for the Regulatory Permit Program (152 scenes). The total number (1187 scenes) is the number of relevant scenes taken per year; no other scenes taken at other times of the year, can be substituted since this number accounts for all useful scenes and they are required in essentially realtime. Hence the number worth processing i.e. at least 45% free of cloud cover, is obtained by applying the probability factor 0.65 to the number available, yielding 772 scenes to be processed each year in near-real-time. Snow mapping and flood prediction exercises are performed primarily in the four (4) months from March through June, in the northern portion of the U.S.. Hence, the rate at which these data must be processed must be based on the four (4) month time interval rather than a year.

3.3 DATA DISTRIBUTION TO DIVISIONS/DISTRICTS

This section addresses the data distribution rates that would be required between DRPF and the Divisions.

High distribution rates will, in general, be associated with near-real-time requirements, and will be limited by the rate at which data can be acquired.

In Table 3-3, the mean number of Landsat-D passes per day and scenes per pass are given for each of the divisions.

In Table 3-4 the maximum number of scenes taken per day is displayed for each Division, i.e. the product of the number of scenes per pass, by the number of passes. The second column of this Table presents the numbers adjusted by the cloud cover "acceptance" factor of 0.65.

Finally, in Table 3-5, real-time requirements are divided into two (2) categories: monitoring of snowpacks (March through June) and selected real-time requirements. Processing rates are given for each category, both with and without adjustment for cloud cover rejection, in Table 3-5.

Table 3-5,also presents mean processing rates for routine requirements: Number of scenes needed per year, divided by 365 days per year. Implication of this table will be discussed later, but for now, it is sufficient to say that the non-perishable data related projects is less than one (1) TM scene (220 M Bytes) per day, per division. The real distribution system driver is the real-time projects which demand multiple TM scenes to be processed each day.

Table 3-3. Satellite Passes and TM Scenes, Per Pass, for the Divisions

DIVISIONS	PASSES DAY	MAX TM SCENES/PASS
New England	0.167	3
North Atlantic	0.167	5
South Atlantic	0.286	7
Lower Mississippi	0.325	8
Southwest	0.75	8
Missouri River	0.67	6
Ohio River	0.286	5
North Central	0.167	9
South Pacific	0.269	7
North Pacific (Alaska)	0.333	15
Pacific	0.25	2

Table 3-4. Estimates of Number of TM Scenes Available per Day, for the Division

DIVISION	AVERAGE NUMBER OF SCENES AVAILABLE PER DAY	SCENES PROCESSED PER DAY
New England	0.5	0.33
North Atlantic	0.83	0.54
South Atlantic	2.0	1.3
Lower Mississippi Valley	2.6	1.7
Southwestern	6.0	3.9
Missouri River	4.0	2.6
Ohio River	1.5	0.98
North Central	1.88	1.2
South Pacific	5.0	3.25
North Pacific (includes Alaska)	8.1	5.3
Pacific Ocean	0.125	0.16

Table 3-5. TM Scene Processing Load for Each Division

DIVISION	TM SCENES PER DAY				
	NON-PERISHABLE DATA PROJECTS	MARCH TO JUNE REAL TIME		SELECTED REAL TIME	
		REGULAR	ADJ.	REGULAR	ADJ.
New England	0.16	0.38	0.25	0.01	.0065
North Atlantic	.56	----	----	.04	.026
South Atlantic	.70	----	----	.04	.026
Lower Mississippi Valley	.55	----	----	.04	.026
Southwestern	.62	----	----	.05	.033
Missouri River	.26	1.6	1.0	.02	.013
Ohio River	.52	----	----	.04	.026
North Central	.68	2.6	1.7	.055	.04
South Pacific	.43	0.40	0.26	.032	.02
North Pacific	.54	3.0	2.0	.04	.026
Pacific	.11	----	----	.01	.0065

3.4 LANDSAT-D SYSTEM ACCESS POINTS

Current Landsat-D plans call for acquisition and production of 100 TM scenes (70 day/30 night) per day. Day scenes will be acquired on descending node passes, as on previous Landsat missions. Night scenes will be acquired on ascending node passes and will have only the thermal band (10.5-12.5 microns) processed. The spacecraft will be in a 705.3 km sun-synchronous orbit, with a repeat cycle every 16 days.

As with previous Landsats, Landsat-D will transmit data directly from the satellite to domestic and foreign ground stations, who have established memorandums of understanding with the government, as the vehicle passes through their reception areas. A new second image data link, however will be provided by the TDRS System, comprised of two (2) spacecraft in geostationary orbits and a ground station located in White Sands, New Mexico. The two (2) operational satellites, plus an in-orbit spare will be in place in 1980. The TDRS System will allow for near global data acquisition and relay capabilities with a blockage zone only over a portion of India.

Present plans, illustrated in Figure 3-1, indicate that Landsat-D data will be transmitted to TDRS and then data will be forwarded from the TDRSS ground station in White Sands to the Data Management System (DMS) at Goddard Space Flight Center (GSFC). From GSFC, partially processed data will be transferred to the EROS data Center in Sioux Falls, South Dakota. The two (2) paths utilize a domestic satellite communications link.

The currently planned Landsat-D data handling system provides seven (7) possible points where data could be obtained for use by the COE Data Reception and Processing Facility. Figure 3-2 illustrates the NASA system and the letters A through

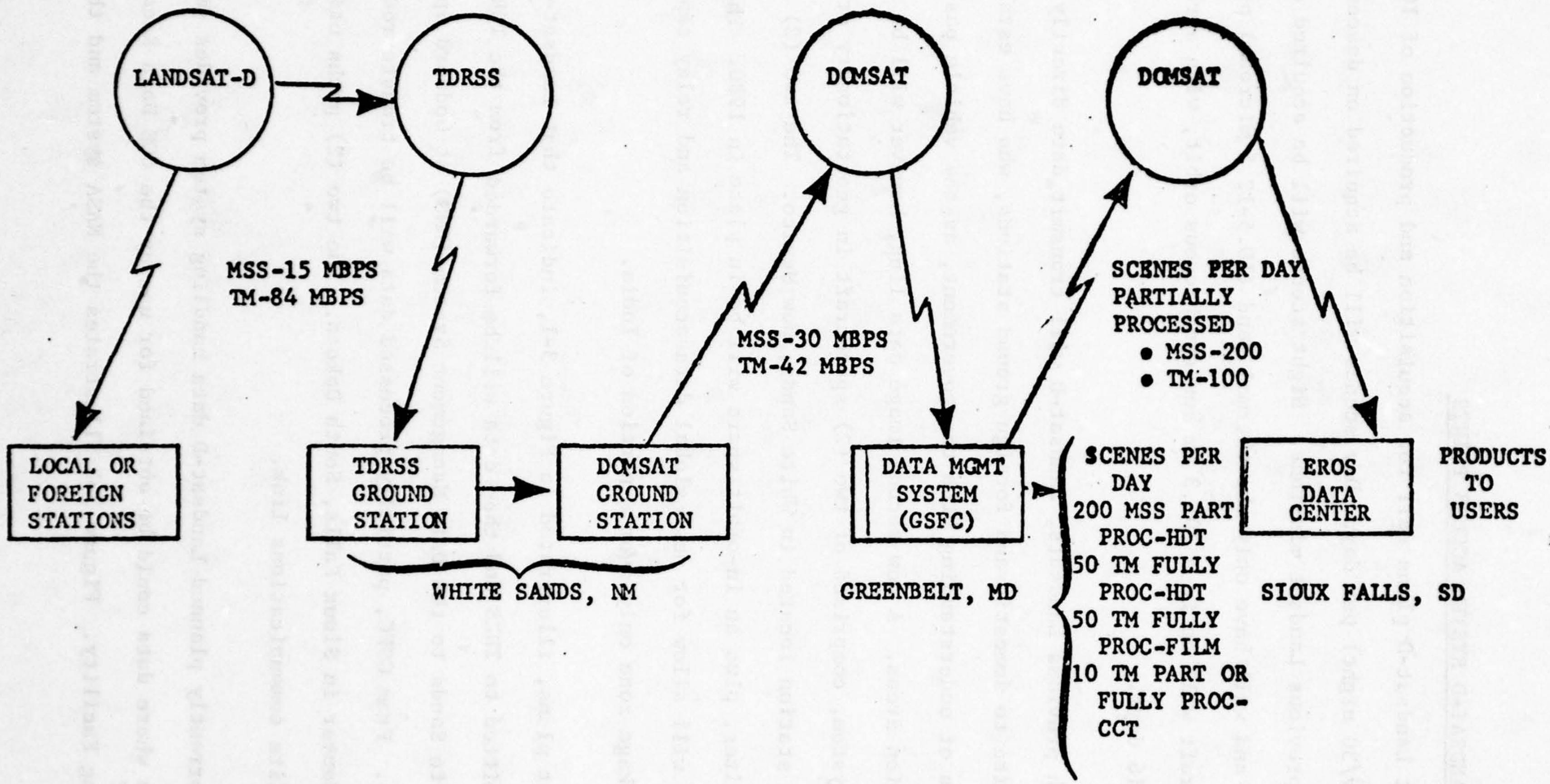

Figure 3-1. Landsat-D System

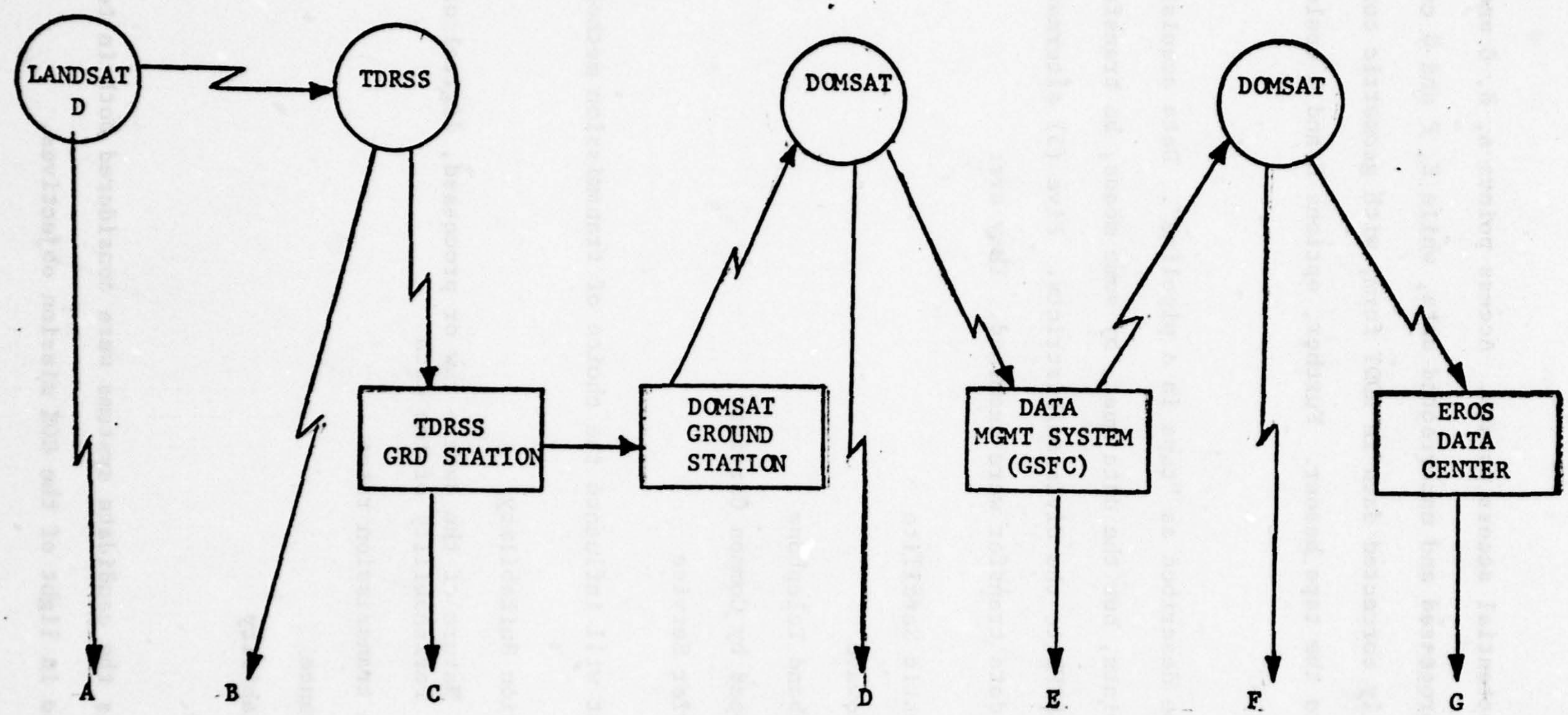

Figure 3-2. Access Points in the Landsat-D System

G identify these potential access points. Access points A, B, C and D can provide only raw, unprocessed and uncorrected data, while E, F and G could make available radiometrically corrected data in HDDT form, with geometric correction matrices applied to the tape header. Further, options E and G could provide CCT and image products.

These points can be described as "taps in a pipeline". Data acquisition is performed at these points, but the data must, by some means, be transferred to the DRPF and from the DRPF to the Division/Districts. Five (5) alternative methods of completing the data transfer were examined. They are:

- Domestic Satellite
- Microwave
- Wideband Telephone
- Shipped by Common Carrier
- Courier Service

The parameters that will influence the choice of transmission method are:

- Mission Suitability
  - Nature of the data - raw or processed, digital or hard copy
  - Perishability of the data
- Data transmission rates
- Distance
- Reliability
- Cost

During the analysis the candidate systems were considered both in terms of these parameters and also in light of the COE mission objectives.

3.5 CANDIDATE CONFIGURATIONS

At the beginning of this study, seven (7) locations, as illustrated in Figure 3-2, were under consideration as candidates from which Landsat-D data could be accessed. At each of these access points, a system configuration resulted in which the data could be acquired and transferred to the DRPF. Each of the seven (7) configurations is discussed herein, in terms of advantages, disadvantages, performance characteristics and estimated costs (where, for the preliminary evaluation, costs include the basic required component costs and do not include operating costs, maintenance costs, integration costs, etc.). Also, a Quick Look Display System (QLDS) is desired. The specifics of the QLDS have no impact in the evaluations of the various configurations, since each configuration will contain a QLDS. The specifics of the QLDS are described in Section 3.9.1.5. along with the selected configuration.

3.5.1 CONFIGURATION A - DIRECT TRANSMISSION FROM LANDSAT

The resulting system configuration, at access point A, provides the capability of receiving data whenever Landsat transmits data. To receive the data, a full Landsat ground station is required. That includes antenna, feed assembly, down converter assembly, pedestal assembly, receivers, demodulators, RF signal generators, time code generator, High Density Tape Recorders and control equipment capable of generating orbit parameters. This in reality means two stations to cover the 48 conterminous United States and excludes Alaska and Hawaii. Thus assuming an east coast DRPF, the resulting configuration, illustrated in Figure 3-3 closely resembles the existing NASA Landsat-C ground system (GSFC/NTTF and Goldstone, Cal.); the difference being that the COE configurations will use the DOMSAT to transfer data from the west coast ground station to a single DRPF, whereas NASA ships data to GSFC, using High Density Tapes.

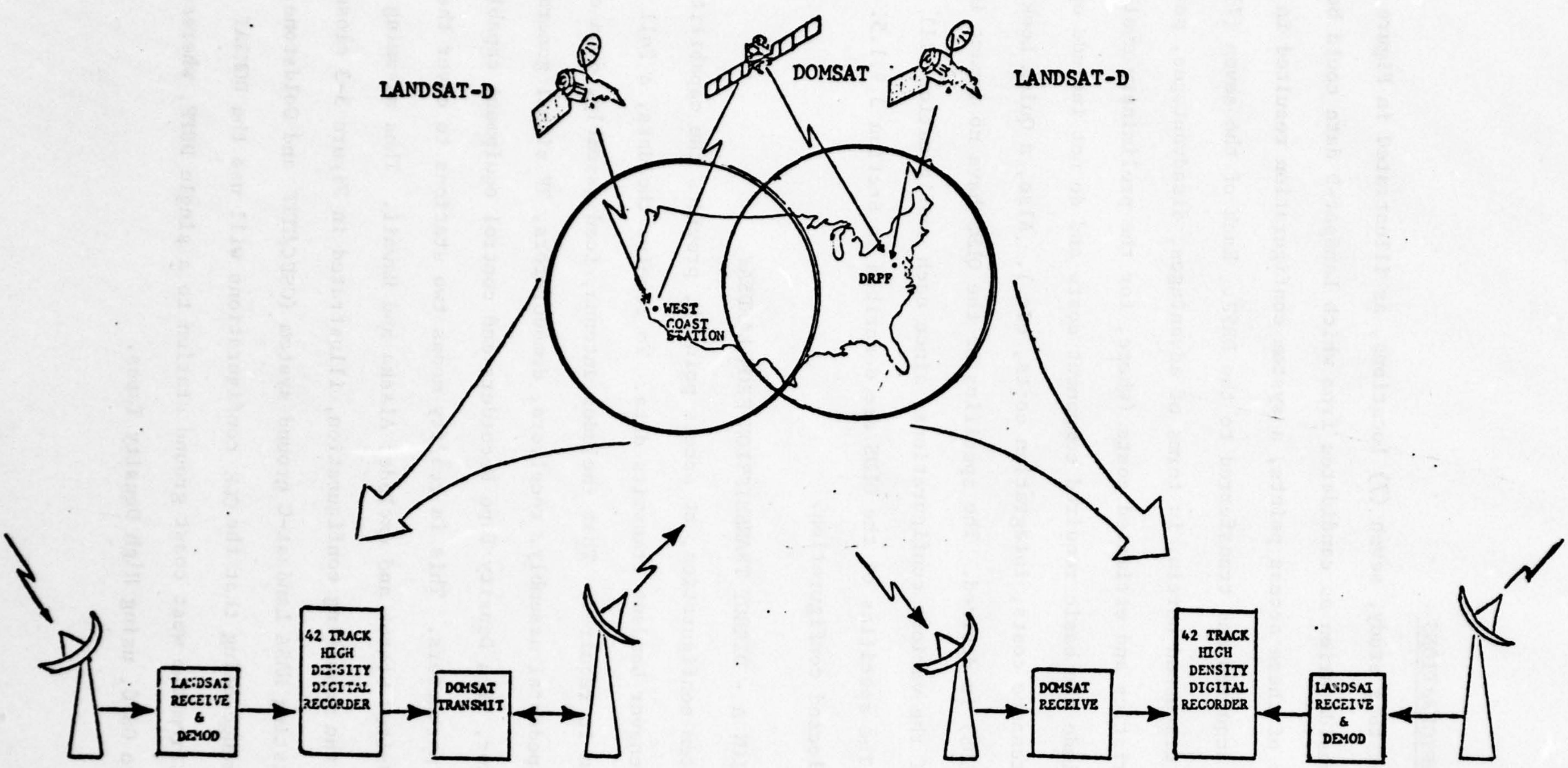

Figure 3-3 Configuration A-Direct Transmission from Landsat

This configuration has the capability of real time reception of eastern U.S. data and near-real time reception of western U.S. data. Western U.S. data is recorded by the west coast ground stations and then retransmitted via the DOMSAT to the DRPF. This configuration provides raw data to the DRPF.

3.5.2 CONFIGURATION B - DIRECT TRANSMISSION FROM TDRS

The system configuration resulting at point B, requires the installation of a TDRS "type" ground station and the necessary elements required to transfer (transmit/receive) data from the ground station to Fort Belvoir. The ground station, receiving and transmitting data from TDRS, requires two antennas (one for TDRS and one for DOMSAT), feed assemblies, down converters, receivers, transmitters, demodulator, RF signal generators, etc., and a 42 track High Density Digital Recorder (HDDR). At the DRPF receiving end, the equipment includes the DOMSAT antenna with support RF hardware and a 42 Track HDDR for recording of the TM data.

The ground station, receiving data from TDRS, would have to be located in the vicinity of White Sands. This constraint is due to the narrow transmitting beam of the TDRS. Thus the resulting configuration as illustrated in Figure 3-4, closely resembles the planned NASA TDRS to GSFC ground data handling link.

This configuration has the capability of near real-time data reception (data must be first recorded then retransmitted); it provides raw data to the DRPF.

3.5.3 CONFIGURATION C - DATA FROM TDRS GROUND STATION

The system configuration resulting at point C requires no RF receiving capability at White Sands. The Thematic Mapper (TM) data will be physically obtained from the TDRSS ground station, and retransmitted to DRPF. At White Sands a 42 track

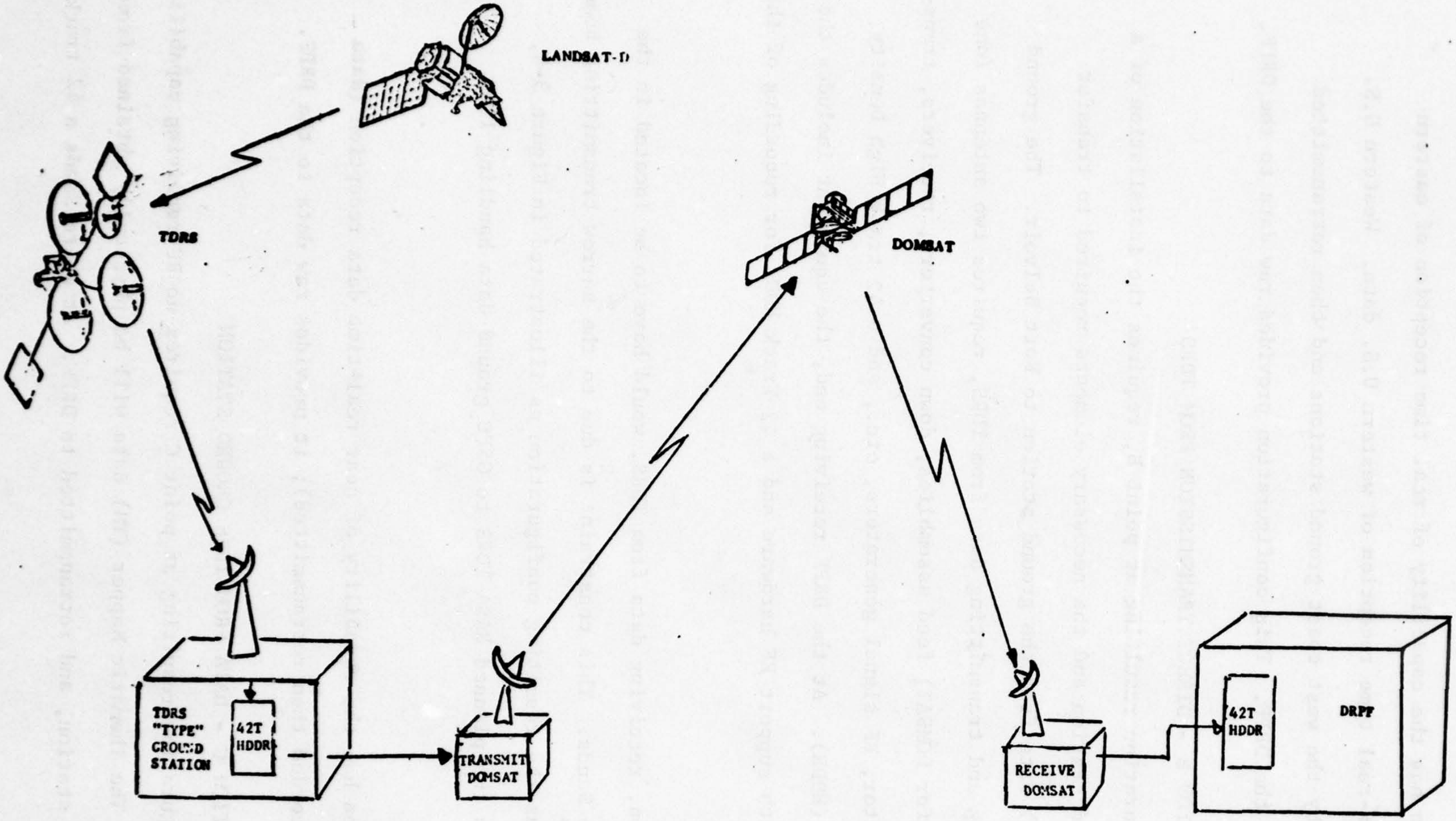

Figure 3-4 Configuration B-Direct Transmission From TDRS

HDDR (used for data playback) and the transmit elements for DOMSAT are required. On the DRPF receive end, the receive elements for DOMSAT and a 42 track HDDR are required. Note that the link portion required for the DRPF data transfer function, as shown in Figure 3-5, is a repeat of the NASA ground data handling configuration (Figure 3-1) in which data is transferred from TDRSS to GSFC via the DOMSAT. This configuration provides raw data.

3.5.4 CONFIGURATION D - DOMSAT TO DRPF

This configuration requires the receive elements of a DOMSAT ground station. The location of the ground station will be at DRPF, thus requiring no other links for data transfers. The approach of this configuration is to use the Landsat-D data that is transmitted via DOMSAT from White Sands to GSFC. That is, for COE to employ its own DOMSAT ground station to "tap" data from the NASA data transmission.

The equipment configuration, as illustrated in Figure 3-6, consists of the DOMSAT receiving elements and a 42 track HDDR. This configuration provides raw data.

3.5.5 CONFIGURATION E - DATA FROM THE DATA MANAGEMENT SYSTEM AT NASA/GSFC

The data can be transferred to DRPF in one of two ways. The method will depend on the philosophy that is employed in the transmitting the data from White Sands to DMS (at GSFC).

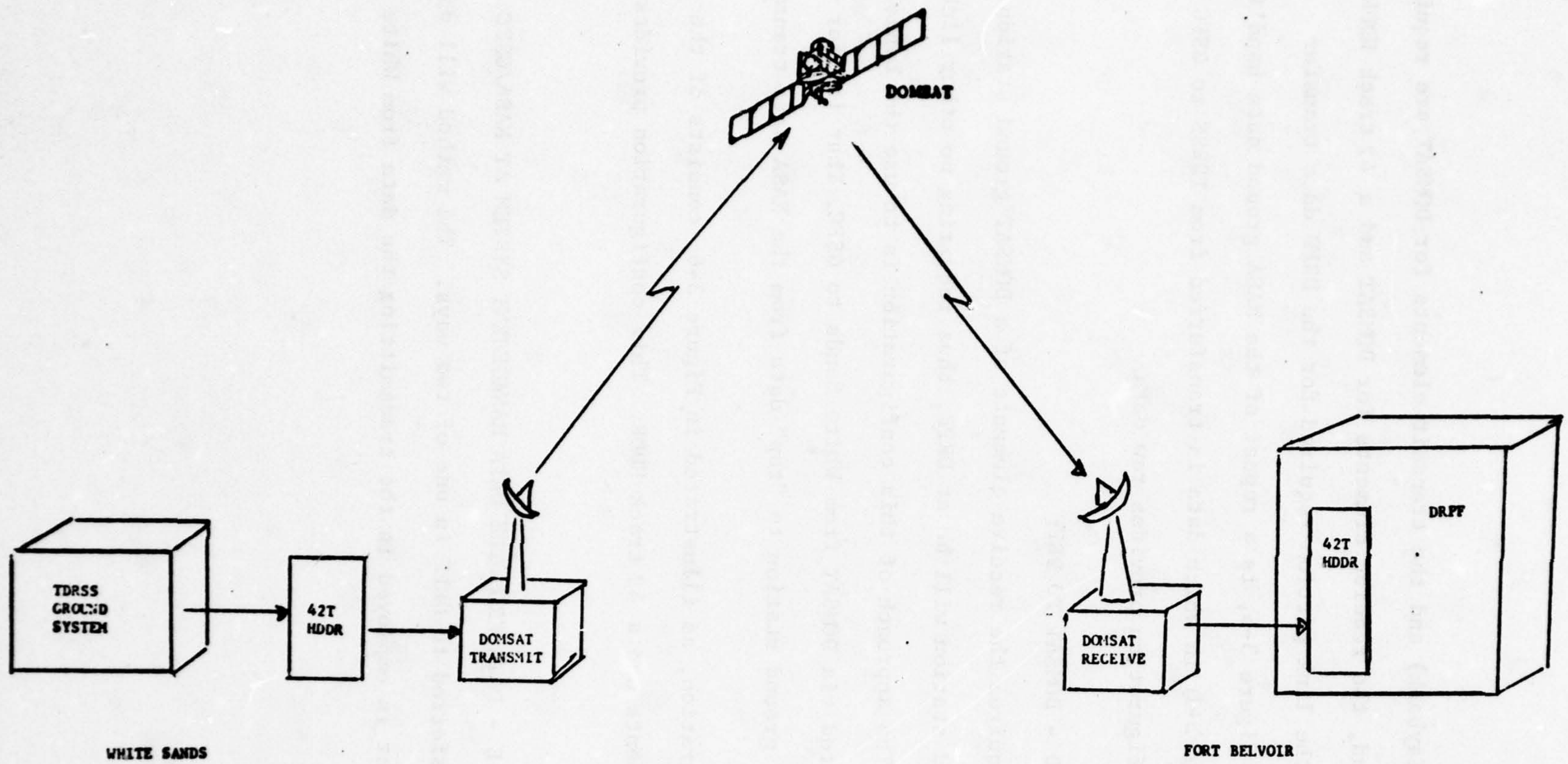

Figure 3-5 Configuration C-Data From TDRS Ground Station

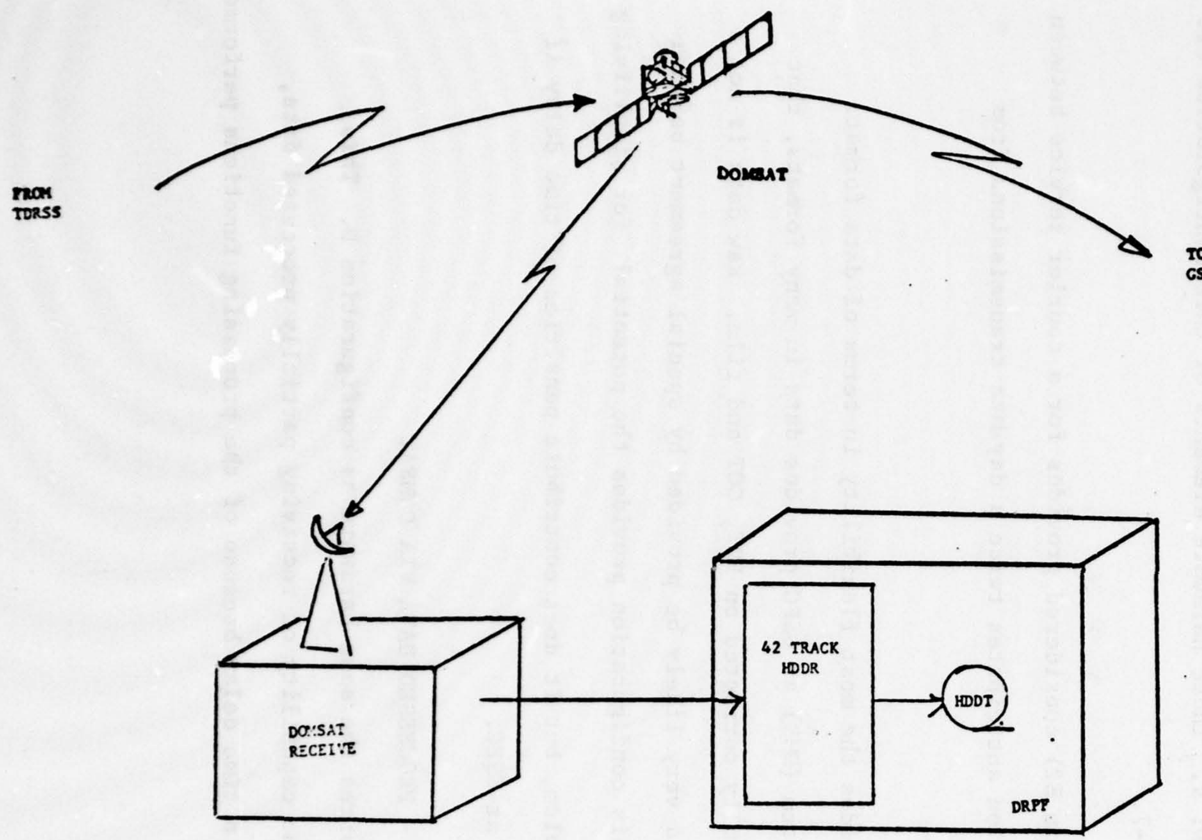

Figure 3-6 Configuration D-DOMSAT to DRPF

The first method (Option E1) considered provides for a direct link from DMS to DRPF. This method would be used if the data transmission from White Sands to DMS is on a continuous basis. The Landsat-D data will be recorded on HDDT's for the COE at GSFC. These tapes will then be played back on a dedicated HDDT and the data transferred to DRPF using microwave equipment. The received data, at DRPF, is recorded on HDDT's. These hardware elements of this configuration are illustrated in Figure 3-7.

The second method (Option E2) considered provides for a courier service between DMS and DRPF. This option anticipates twice a day data transmissions from White Sands to the DMS.

This configuration provides the most flexibility in terms of data format. The Data Management System (DMS) at GSFC provides data in many formats, that is, pre-processed, or fully corrected on HDT, CCT and film. Raw data is not a normal product but could very likely be provided by special agreement between NASA and COE. Thus, this configuration provides the potential for simplifying the DRPF data handling problem, but it does contribute penalties of time delay if all processing is done at GSFC.

3.5.6 CONFIGURATION F - PROCESSED DATA VIA DOMSAT

This configuration requires the same hardware as configuration D. This alternative provides the capability of receiving partially processed data, but it does contribute a time delay because of the processing functions performed at GSFC.

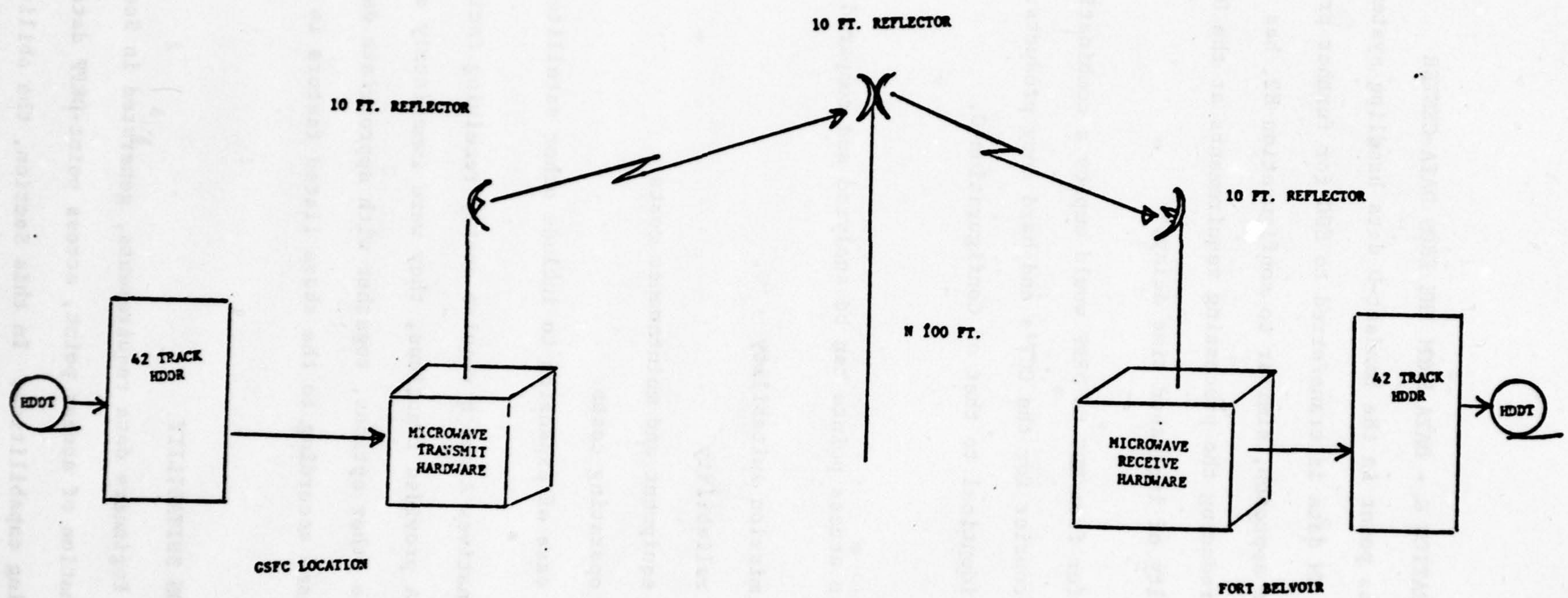

Figure 3-7 Configuration E-Data from DMS (GSFC)

3.5.7 CONFIGURATION G - DATA FROM THE EROS DATA CENTER

The final access point in the Landsat-D data handling system is the EROS Data Center (EDC). TM data is transferred to EDC for further processing and dissemination. These approach, similar to configuration E2, has the potential of substantially reducing the processing requirements at the DRPF but extracts a further penalty of increased time delay.

The data transfer from EDC to DRPF would employ a combination of the DOMSAT link and mail/courier for the CCT's and hard copy products. The hardware configuration is identical to that of Configuration C.

3.6 ANALYSIS

The alternative access points can be analyzed and compared according to:

- mission suitability
- reliability
- equipment and maintenance costs
- operating costs
- ease of expansion to include other satellites

Because alternatives A and B require costly receiving facilities, which simply duplicate NASA provided functions, they were immediately excluded from this analysis. The other options, together with appropriate data transfer methods will be assessed according to the above listed factors in Sections 3.6.1 through 3.6.6.

3.6.1 MISSION SUITABILITY

The Corps of Engineers data requirements, generated in Section 2.1, must be met by the combination of access point, access point-DRPF data transfer method and DRPF processing capabilities. In this Section, the ability of the various alternatives to meet these needs is discussed.

There are two (2) uncertainties in the NASA data path which seriously impact the question of timeliness (as well as operating mode) for these options.

1. The timing of data playback at the TDRS Ground Station and transmission to DMS via DOMSAT. The possible modes include: (a) immediate transmission, and (b) recording of up to N (probably 12) hours of data, followed by block transmission to DMS. The latter mode of operation could reduce transponder rental time, considerably, for NASA. Both modes have been included in the estimate of data delays.

2. The location of DMS. Currently, NASA's plans are to locate the DMS at GSFC. However, some consideration has been given to locating the DMS functions at EROS. We have assumed the DMS to be at GSFC.

Raw data has been utilized in many applications for several reasons:

- preprocessed data could not be made available on a regular basis from either NASA or EDC without incurring several weeks delay from the time of acquisition. This was far too long for applications with near real time data needs.
- the radiometric correction process for MSS data has been the subject of controversy among users. Many prefer to apply their own corrections.
- certain applications simply do not require corrected data.

The Landsat-D system will provide a major improvement in timeliness of data delivery, radiometric accuracy and geometric performance. Processing time within the DMS is less than 48 hours. (Allowing nominally 2 but no more than 12 hours delay for relay through the DOMSAT link from White Sands, preprocessed data will be available in 27 to 65 hours from the time of acquisition.

Radiometric accuracy will be within ±one quantum level; this accuracy will be achieved using both detector calibration data and scene content information.

Geometric accuracies using the correction information provided with each preprocessed scene are 0.3 pixel for registration and 0.5 pixel for geodetic location.

These high accuracies and 27 to 65 hour data delivery from the DMS will satisfy the large majority of all user applications. Only those applications which absolutely require data in less than 27-65 hours will utilize raw data.

The time delay varies depending on the configuration as shown in Figure 3-8.

- <u>Configuration C</u> - provides raw data directly from White Sands to the DRPF using COE leased DOMSAT link. Typical data delays are:
  - 0.5 to 12 hours accumulation time at TDRSS site depending on NASA accumulation philosophy and DOMSAT data link service (see Appendix A)
  - 0.5 hour rewind and handling time
  - 0.1 to 1.0 hour transmit time
  - 0.2 to 1.5 hour rewind and copy time in DRPF

  Hence raw data will be available for evaluation in the DRPF 1.3 to 15 hours after acquisition. Depending on equipment complexity and speed, preprocessed data will be available in an additional 24 to 48 hours*, either obtained from the NASA DMS or processed from the raw data at the DRPF.

- <u>Configuration D</u> - provides raw data to the DRPF by tapping the NASA DOMSAT link. Typical data delays are:
  - 0.5 to 12 hours accumulation time
  - 0.5 hour rewind and handling time
  - 0.1 to 1.0 hour transmit time
  - 0.2 to 1.5 hour rewind and copy time in DRPF

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*The assumption has been made that DRPF processing equipment complexity and speed will be consistent with data load and that NASA Landsat-D processing rates will be typical for COE equipment in the early 1980's time frame.

Hence raw data will be available for evaluation in the DRPF in essentially the same amount of time as for Configuration C but without the cost of a COE-unique DOMSAT transmit terminal at White Sands and COE leased DOMSAT link. Note that some sort of cost sharing between NASA and COE would most likely result for this configuration since both use the DOMSAT link; even with cost sharing the cost to COE is less than use of a COE-dedicated approach.

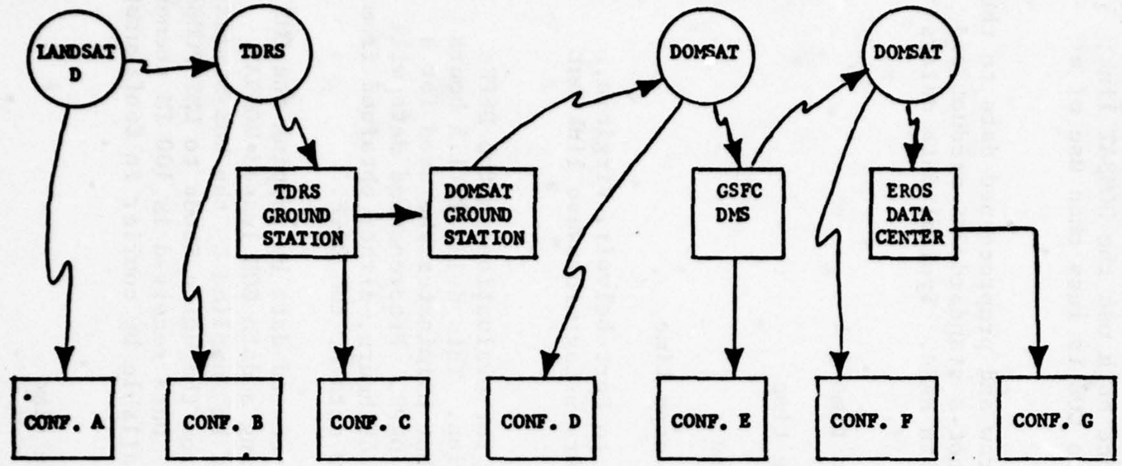
- Configuration E - provides both raw and preprocessed data to the DRPF from the DMS. Raw data is not a standard DMS product and will require special agreement with NASA. Typical data delays are:

  - 0.5 to 12 hours accumulation time
  - 0.5 hour rewind and handling time
  - 0.1 to 1.0 hour transmit time
  - 0.2 to 1.5 hours rewind and copy time
  - 1.5 hours courier from GSFC to Fort Belvoir, Virginia, (could be reduced to 0.2 hours using microwave link but at higher cost)

  Hence raw data will be available for evaluation in the DRPF 2.8 to 16.5 hours after acquisition. This delay is 1.5 hours longer than for configuration D but eliminates the need for a DOMSAT receiving terminal at the DRPF. Preprocessed data will be available in an additional 24-48 hours, either obtained from the DMS or processed from the raw data at the DRPF.

- Configuration F - provides preprocessed data by tapping the DMS to EDC DOMSAT link, hence requiring a data COE leased DOMSAT receive terminal. Raw data would be supplied by the DMS similar to Configuration E or received from the White Sands to DMS DOMSAT link similar to Configuration D. Data received is 100 TM scenes, the same preprocessed data as available by courier in Configuration E. Typical data delays are:

  - 0.5 to 12 hours accumulation time
  - 0.5 hour rewind and handling time
  - 0.1 to 1.0 hour transmit time
  - 24 to 48 hours DMS processing time
  - 0.1 to 1.0 hour transmit time
  - 0.2 to 1.5 hour rewind and tape copy time in DRPF



CONFIGURATION	RAW DATA		PREPROCESSED DATA		COVERAGE	COMMENTS
	AVAILABILITY	TIME DELAY (HOURS)	AVAILABILITY	TIME DELAY (HOURS)		
C	DIRECT FROM DOMSAT	1.3-15	PROCESSED BY DRPF	25.3-63	FULL	REQUIRES DOMSAT TRANSMIT AND RECEIVE TERMINALS
D	DIRECT FROM DOMSAT	1.3-15	PROCESSED BY DRPF	25.3-63	FULL	REQUIRES DOMSAT RECEIVE TERMINAL
E(1) MICROWAVE E(2) COURIER	FROM DMS FROM DMS	1.5 16.5	FROM DMS FROM DMS	25.5-49.5 40.5-64.5	FULL	RAW DATA NOT A STANDARD PRODUCT. AVAILABILITY REQUIRES SPECIAL AGREEMENT WITH NASA
F	FROM DMS	2.8-16.5	FROM DMS VIA DOMSAT	26.4-64	FULL	DOMSAT TERMINAL USED FOR PREPROCESSED DATA COULD ALSO RECEIVE RAW DATA SIMILAR TO CONFIGURATIONS C OR D
G	FROM DMS	2.8-16.5	FROM EDC	75-112	FULL	ADDITIONAL PRODUCTS AND PROCESSING AVAILABLE FROM EDC MAY REDUCE PROCESSING REQUIREMENTS/COSTS FOR COE

Figure 3-8. Mission Suitability of the Various Options

Hence the preprocessed data will be available for evaluation in the DRPF 25.4 to 64 hours after acquisition. Since

- data delays are essentially equivalent to Configuration E,
- this configuration requires a DOMSAT receive terminal,
- this configuration does not provide raw data,

it is a viable option only for a DRPF located remotely from the Washington, D.C. area where the cost of the DOMSAT link can be justified.

- Configuration G - provides data from EDC. Data may be either preprocessed or further processed to COE requirements. Raw data must be obtained from the DMS. Data delays are those of configuration F plus at least 48 hours to allow processing at EDC.

3.6.2 RELIABILITY

There are two (2) sources of uncertainty in any of the data paths under discussions:

1. Component failure, which can lead to loss of data;
2. Data degradation, at interfaces and in transmission.

Component failure can be protected against, by providing alternative paths or, in some cases, parallel paths, so that loss of one (1) path is not fatal. COE has the potential of using NASA and/or EDC as an archiving and data processing backup. Redundancy is built into the "fully redundant" earth station, the "fully protected" transponder, and the microwave transmitting and receiving hardware discussed in Appendix A. However, even with redundancy, there is a finite failure probability, which can be improved only by proper maintenance. The cost of redundancy, and of maintenance, is an increasing function of hardware complexity and quantity.

A measure of the success of single redundancy is the quantity P, the probability that a component and it's backup unit will be out of service simultaneously. P can be evaluated in terms of t, the mean time between failures of a component, and t_r, the time required to detect and repair (or replace) the failed unit. t_r is a function of good maintenance procedures, while t, depends on the quality of the unit. In terms of these times,

$$P \cong (t_r/t)^2$$

If regular maintenance is performed on a schedule such that T, the time between maintenance days is much less than t, and the "down time" for maintenance is equated with t_r, we can obtain an upper limit on P:

$$P \ll (t_r/T)^2$$

Some reasonable numbers are t_r = 8 hours and T = 30 days x 24 hrs/day = 720 hours. Then:

$$P \ll (8/720)^2 = 0.0001;$$

or

$$P * 100 \ll 0.01\%$$

Regular maintenance must of course be supplemented by trouble-alert procedures.

Each component, i of a multi-component system carries with it the potential for failure as given by P_i . For a complete data path, including the receiving equipment, recording equipment and data transfer equipment, the probability P that at least one component and its backup unit will be down simultaneously is the sum of the P_i's. For this reason, and because of the increased maintenance costs, multi-component systems, such as the microwave link for long distances, are not desirable.

Data degradation, as measured by bit error rate, occurs mainly at interfaces and is cumulative. The process of recording and playback of the TM data utilizes the HDDR. Lower playback rates decrease the signal to noise ratio and, for the 1:2 playback rate used here, the bit error rate is estimated at less than 10^{-6}. Most of this is recoverable by means of error checking and correction procedures. The RDS-60's, which are candidates for reception and transmission in the microwave link, have bit error rates, under normal operating conditions, of 10^{-11}. Thus data degradation, even for a complex link, is not considered a problem.

3.6.3 EQUIPMENT AND MAINTENANCE COSTS

Equipment and maintenance costs for data transfer are discussed in a general way in Appendix A. These costs, applied to the specific alternatives are presented in Table 3-6. The major addition to the cost of data transfer is that of the recording and playback equipment (42-track HDDR). For each of these units, a typical cost is $160,000. Since all initial costs are amortized over 3 years, the yearly cost per HDDR is $53,000.

Maintenance costs, figured at 0.1 man year per earth station or per HDDR, is $5,500. (1 manyear ≅ $55,000)

It is currently understood that the DMS will be located at GSFC. In that case, and if data transmission from White Sands is in the semi-continuous mode, Option E, which taps DMS for both raw and partially processed data, can be served by an HDDR at the source linked by microwave with another HDDR at the DRPF, assumed less than 60 miles away at Fort Belvoir. For twice-daily data transmission from White Sands (or at the option of the Corps), copies of the NASA HDDT's may be hand carried once or twice a day to the DRPF at Fort Belvoir. These two options are included in Table 3-6 under the identifications E_1 (DMS at GSFC microwave) and E_2 (DMS at GSFC courier) respectively. The third interpretation of Option E, E_3 (DMS at EDC), requires a full DOMSAT link, as in C, and is much less attractive as an option.

Table 3-6. Yearly Cost of Equipment and Maintenance for Options C through G. (Initial Costs are Spread over 3 Years)

OPTION	EQUIPMENT	COST/YEAR (Millions)	MAINTENANCE (Millions)	TOTAL (Millions)
C	2 HDDRs	0.107	0.02	
	2 Earth Stations	0.540		
	Transponder	0.21		0.877
D	1 HDDR	0.059	0.01	
	1 Earth Station	0.270		0.334
E_1 (DMS at GSFC)	2 HDDRs	0.107	0.01	
	Microwave Link (60 Miles)	0.079	Included in equipment cost	0.196
E_2 (DMS at GSFC)	1 HDDR	0.054	0.005	
	Transportation for Courier	0.010		0.069
E_3 (DMS at EDC)	Same as C			0.877
F	Same as D			0.334
G	Same as C			0.877

Table 3-7. Manpower Requirements for Options C-G

OPTION	PERSONNEL REQUIRED	
	TWO SHIFTS	THREE SHIFTS
C	9	12
D	5	7
E_1 (DMS at GSFC)	8	11
E_2 (DMS at GSFC)	4	-
E_3 (DMS at EDC)	5	7
F	5	7
G	9	12

It is clear, from Table 3-6, that E_2 (DMS at GSFC courier) is the least costly of the options to equip and maintain. If the plans for DMS are altered, D becomes the most cost effection option for raw data, but must be supplemented by adding processing at DRPF or, perhaps, direct dissemination of non time critical products from EDC to the districts.

3.6.4 OPERATING PERSONNEL REQUIREMENTS

Operating costs will be influenced by the transmission mode elected by NASA. If data are transmitted from White Sands, immediately following a satellite pass and HDDT rewind, then all of the near-real-time options under consideration (except E_2) require round-the-clock operation. On the other hand, if data are collected from TDRSS, over a 12 hour period, and then transmitted to DMS, the stations of the various options will require only (2) shifts of operation per day. Both of these modes of operation are addressed in Table 3-7. Each station must have a supervisor, who may well be one of the operators. Operators should be high level technicians, with some knowledge of electronics and thorough training in the specific equipment of the station. The entries in Table 3-7, columns 2 and 3, were obtained by taking the number of shifts per day, per station, multiplying by the number of stations for that option, and multiplying the result by a factor of 1.6, to allow for weekend operation, vacation and sick leave. This number was then rounded up to the next integer, and one (1) supervisor was added for each station. Option E_2 requires the least amount of manpower

3.6.5 DATA TRANSFER FROM DRPF TO THE DIVISIONS

This section addresses the task of data transfer from DRPF to the Divisions of the COE. The methods under consideration for accomplishing this task are discussed in Appendix A. The microwave link was eliminated on the grounds that the distances from DRPF to the Divisions are large, and it was shown that the cost of microwave equipment, operation and maintenance cost is many millions of dollars.

The solution to the problem is driven by the nature of the data to be transferred.

Two scenarios have been postulated

1. All processing for real time requirements is performed at the DRPF, and results, in the form of statistical analyses, are sent to the appropriate Division(s) via teletype. Film and tape products (corrected to the degree required by the Division) are sent by air freight.
2. Real time Thematic Mapper requirements of the Divisions are served by delivering raw data over dedicated wideband telephone lines. All other products are sent to the division by air freight, as in (1).

Since both scenarios call for delivery of a large part of the data by air freight, this aspect of the scenario is first discussed. In Section A.4 of Appendix A this method of transfer was costed for all TM scenes (100 scenes per day) at just over \$100,000 per year, and a time delay of 1/2 to 2 days was projected. This cost must be adjusted by the amount of duplication or overlap of Division needs and by the number of products desired per scene. Delivery to the airport and pickup at the Division end must also be added to the cost.

In the first scenario, only the results of DRPF processing are delivered to the Divisions in near real time. Because the amount of data is small, the data rate of 12 Kbps associated with teletype transfer is sufficient. The cost of twelve such systems (e.g., two modems, one teletype unit, line service) is estimated at about \$100,000. An additional benefit, with processing at DRPF, is that some fraction of the TM data may be rejected for cloud cover and thus transfer of data and data products to the divisions will be inhibited.

The second scenario requires that the DRPF facility perform: (1) scanning for good data and (2) sorting of data with respect to Divisions and with respect to data type and product type desired. Those TM scenes needed in real time by the divisions would be formatted and transferred over the wideband telephone lines. The transfer format should be sized so that "lost" or "damaged" data can be sent again with small time penalty.

The specific band width of the telephone line can be chosen differently for each Division. The parameters influencing the choice are (1) anticipated maximum number of scenes to be sent in one day and (2) cost as a function of bandwidth.

Wideband telephone lines are now available from A.T.T. in a wide range of bandwidths. The system links the sender to a nearby city of the networks, provides transmission to a city near the receiver and then links with the receiver. Each of these three paths incurs a mileage charge, which is figured differently for different bandwidths. There are, in addition, customer service units for which bandwidth dependent installation and rental fees are charged. Fortunately, the yearly cost is almost linear in bandwidth, as shown in Figure 3-9. ROM costs are used for illustration and relative evaluation in selecting the optimum bandwidth for each Division.

In Figure 3-10, the transmission time per scene is plotted as a function of transmission rate. Some typical values are:

Time/Scene	Data Rate
6.0 Hours	96 kbps
2.4 Hours	230.5 kbps
0.37 Hours	1.544 Mbps

Referring back to Table 3-5 in which maximum processing rates are given for routine as well as real time needs, it is seen that the data rate that allows two scenes to be transmitted in an eight hour shift will suffice for any of the Divisions. A safe choice would be 230.4 kbps at a cost of about $220,000 per year per Division. Some of the Divisions would require only occasional use for one scene

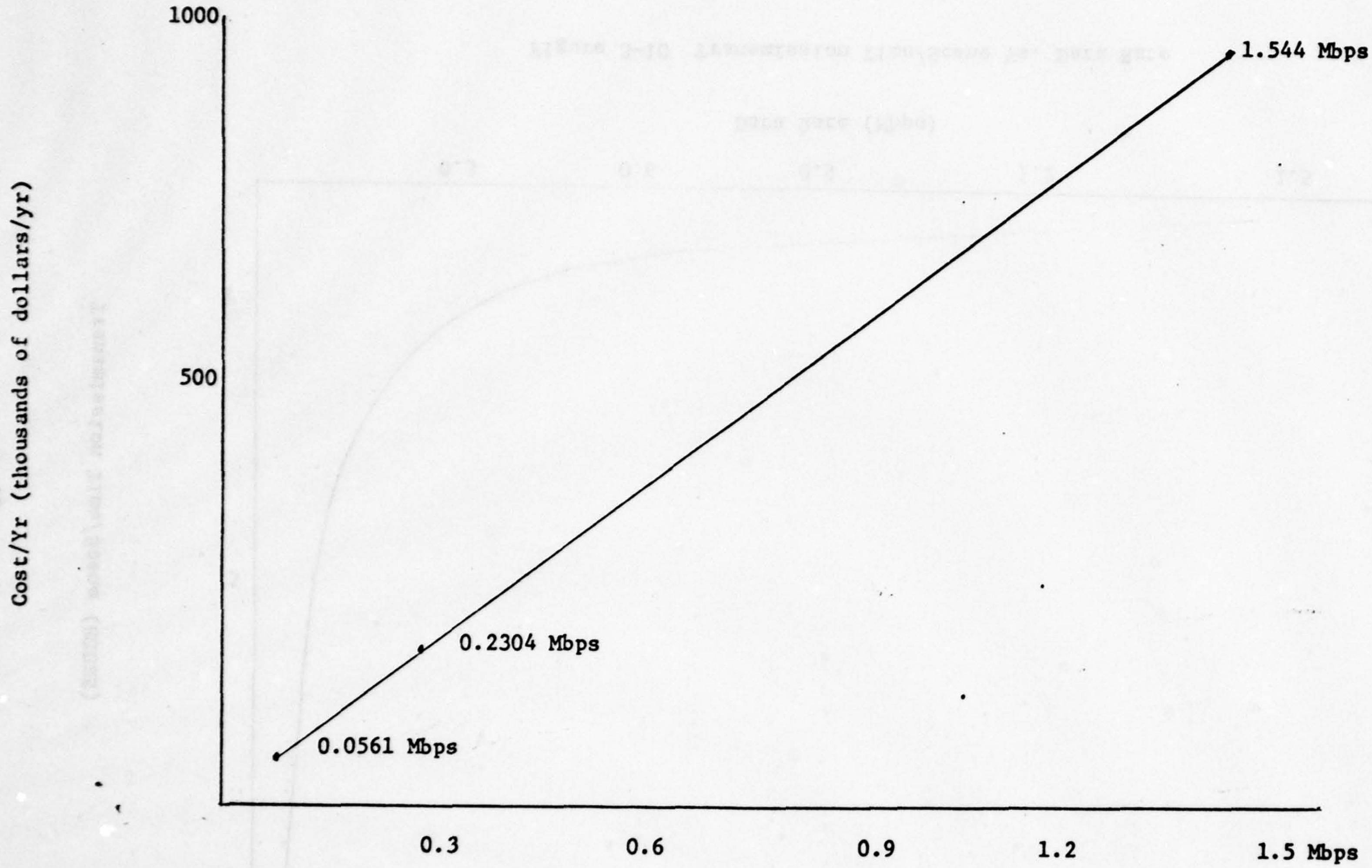


Figure 3-9 Yearly Cost of a 1500 Mile Line Vs. Data Rate

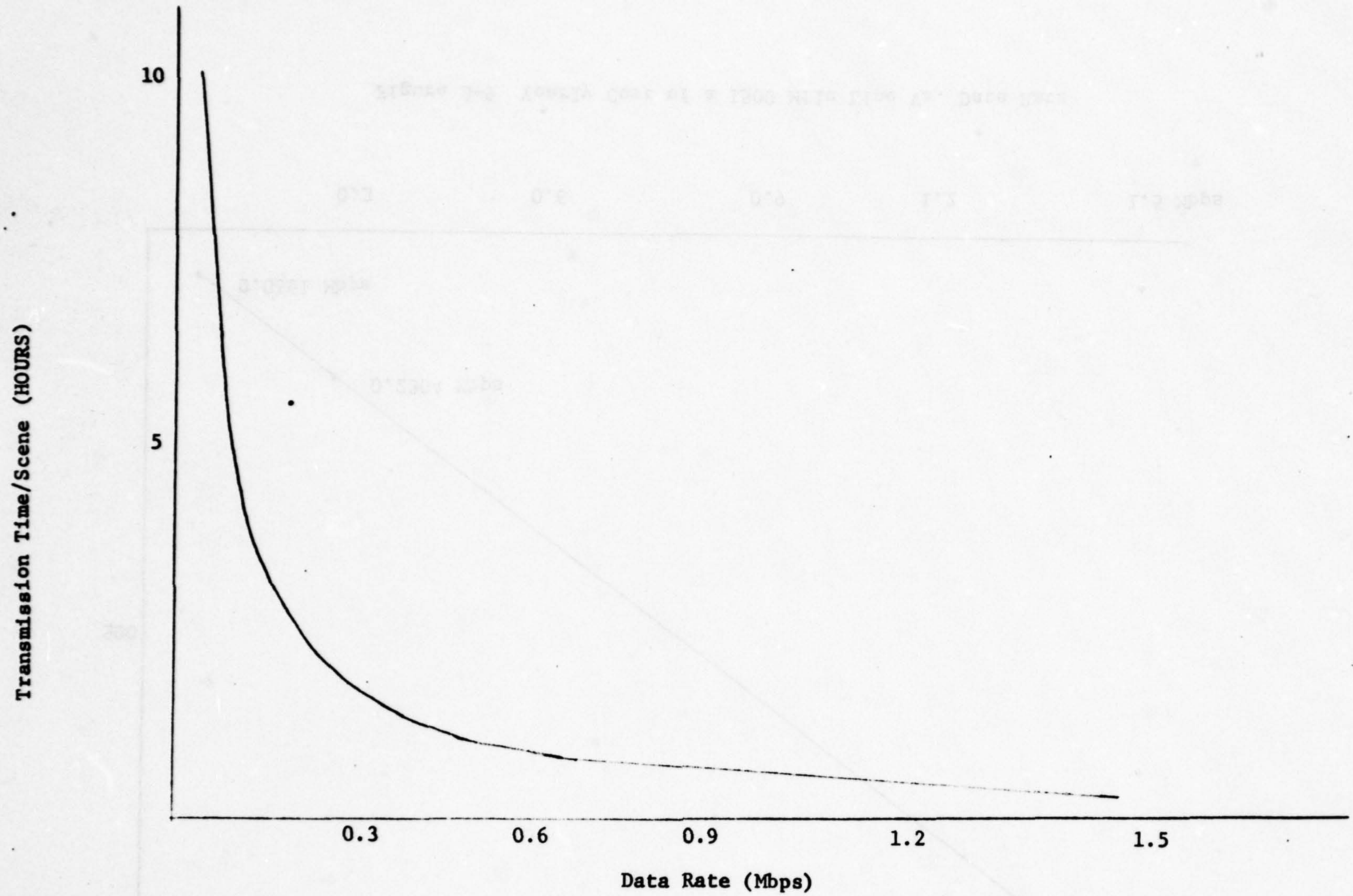


Figure 3-10 Transmission Time/Scene Vs. Data Rate

per day, and these needs could well be served by a data rate of 96 kbps at a cost of about $100,000 per year. If half of the divisions are placed in this category (96 kbps) and the other half at the 230.4 kbps rate, the yearly cost for transmission to all the Divisions is averaged at about $1,500,000. This arrangement would take care of all the raw data needs; only processed data and data products would be transmitted by air freight.

In summary, a plan which places the real time processing burden on the DRPF, with results sent by teletype and data products by air freight will incur yearly transmission costs of a few hundred thousand dollars. A plan which leaves processing in the hands of the Divisions, sending raw data by dedicated, high data rate telephone lines, and products by air freight, will cost considerably much more.

3.7 ASSESSING DATA FROM OTHER SATELLITES

There are many other satellites providing both imagery and point source data that should be of use to the Corps of Engineers - Civil Works. Among the most prominent current or near future satellites of interest in addition to Landsat-D are:

- Landsat-C
- HCMM (Heat Capacity Mapping Mission)
- SEASAT
- NIMBUS-G
- TIROS-N
- GOES (Geostationary Operational Environmental Satellite)
- DMSP (Defense Meteorological Satellite Program)

Each of these satellites has a unique data receiving, processing and user distribution system; and, until a centralized national archiving and distribution agency is established, a user must access each system independently. Figures 3-11 through 3-19 display the satellite, sensor complement, ground processing and user interfaces for each of the satellites listed above. Several key points are important to the Corps of Engineers:

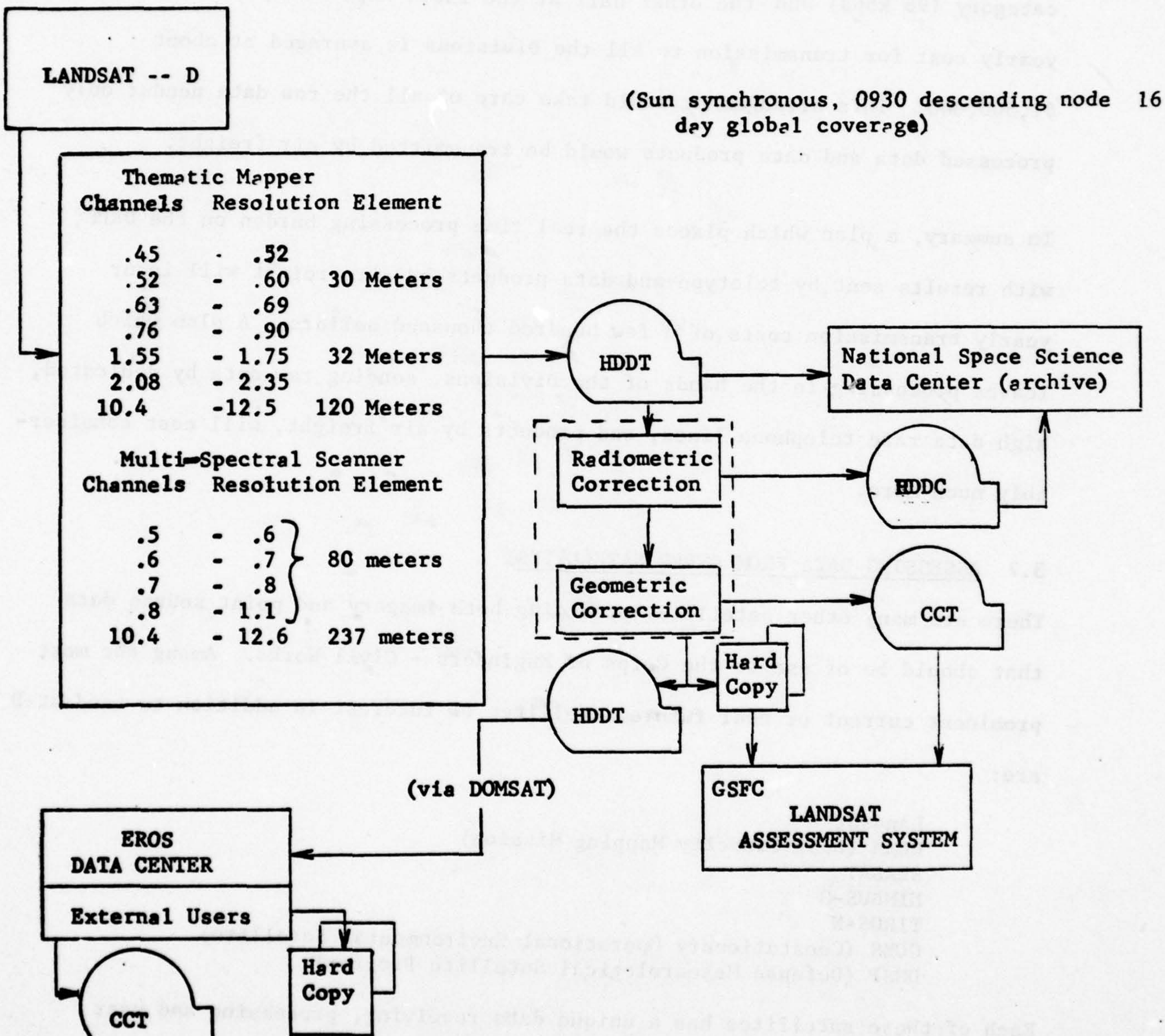


Figure 3-11. NASA Earth Resources Survey Program - Landsat-D

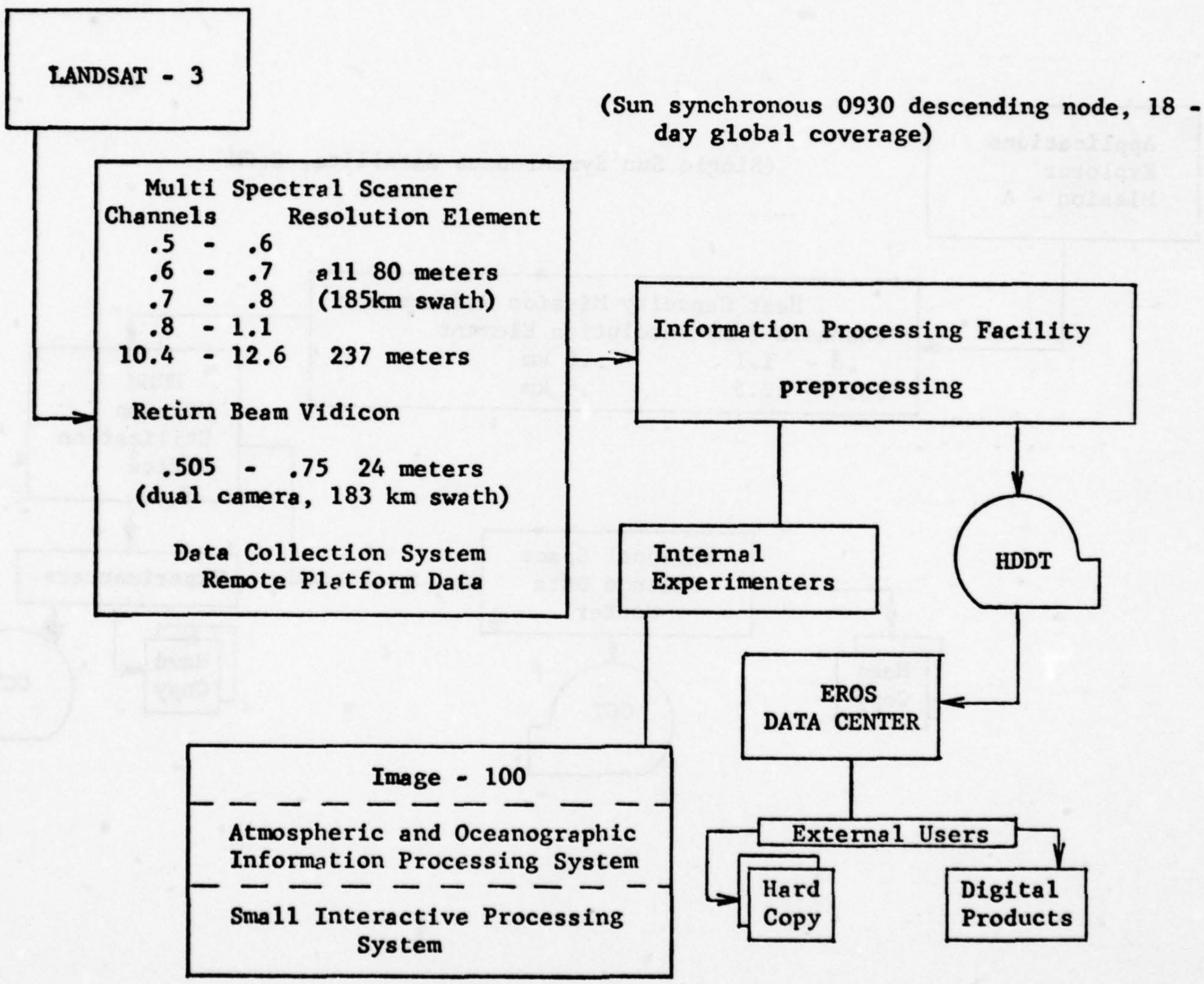


Figure 3-12. NASA Earth Resources Survey Program - Landsat 3

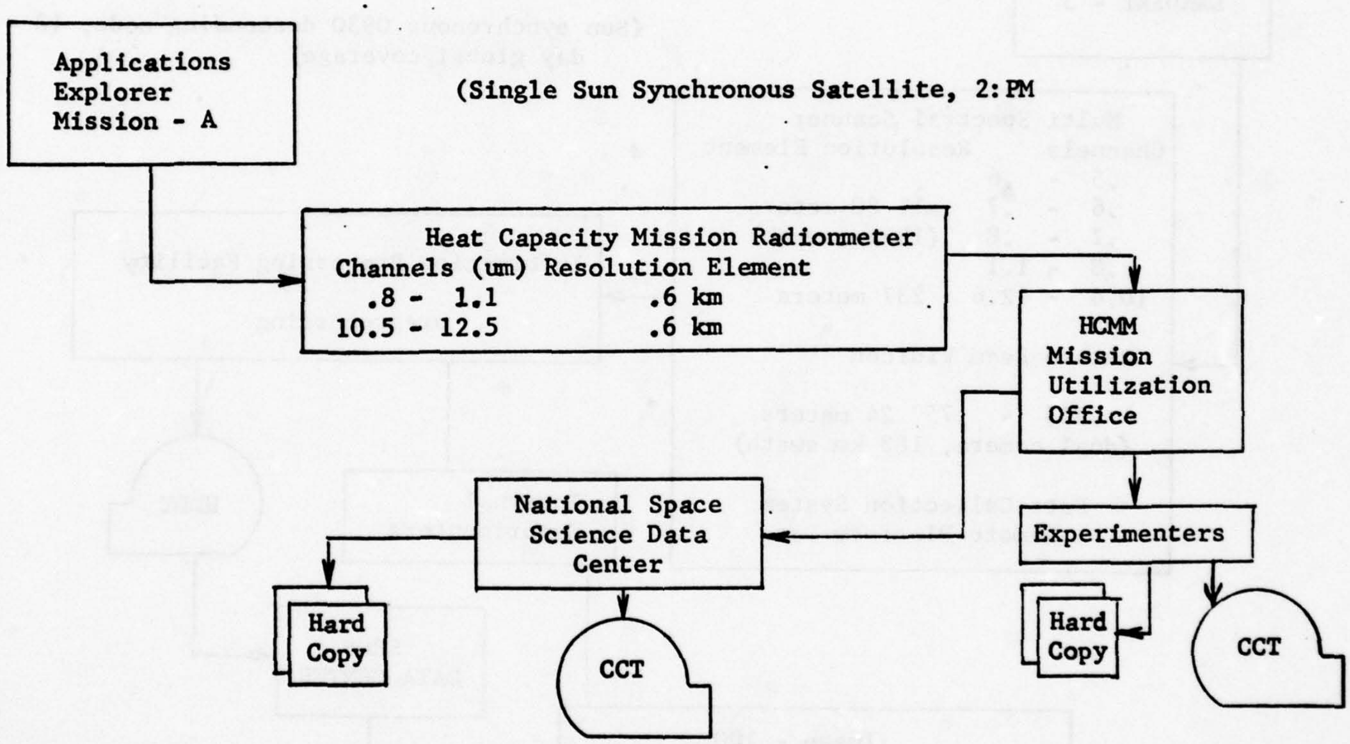


Figure 3-13. NASA Heat Capacity Mapping Mission (HCCM)

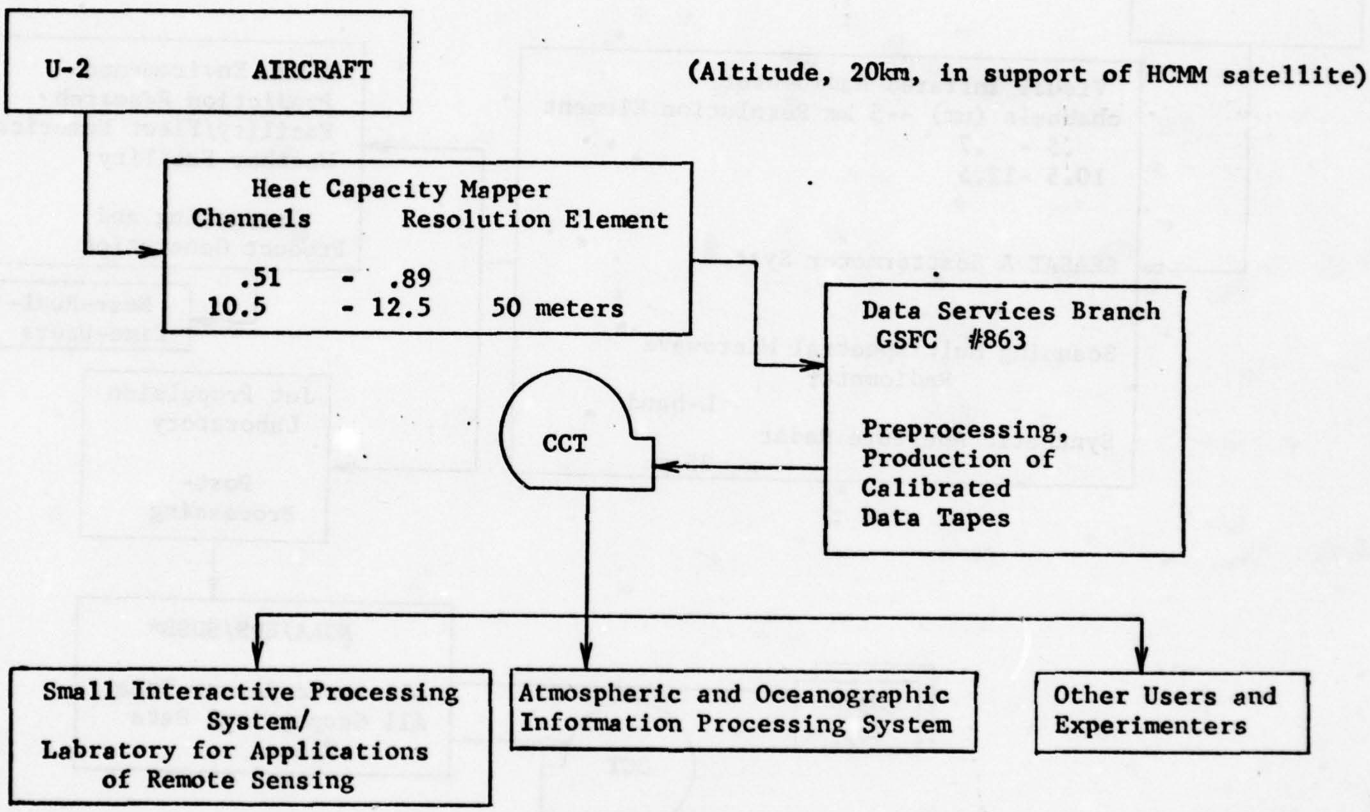
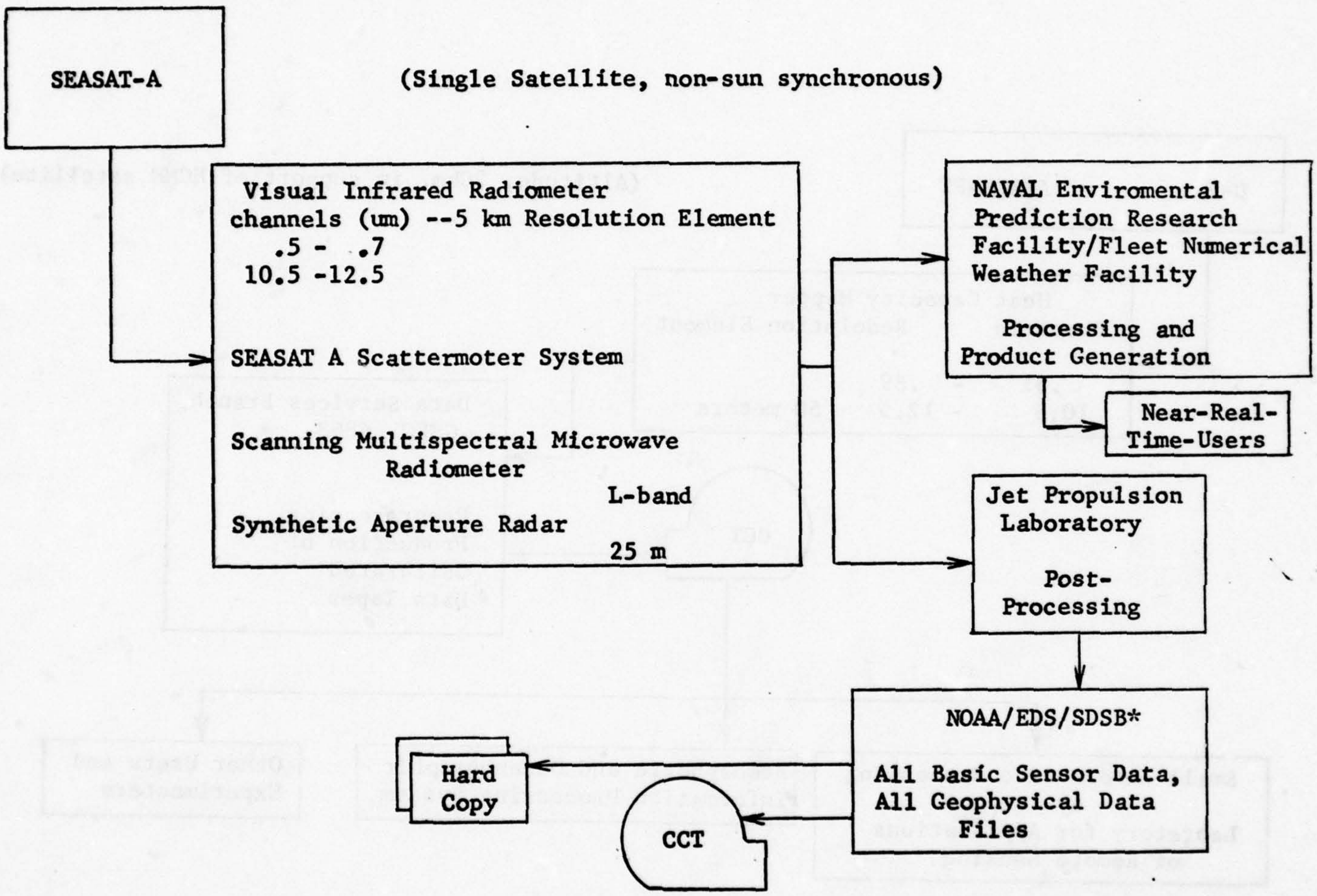
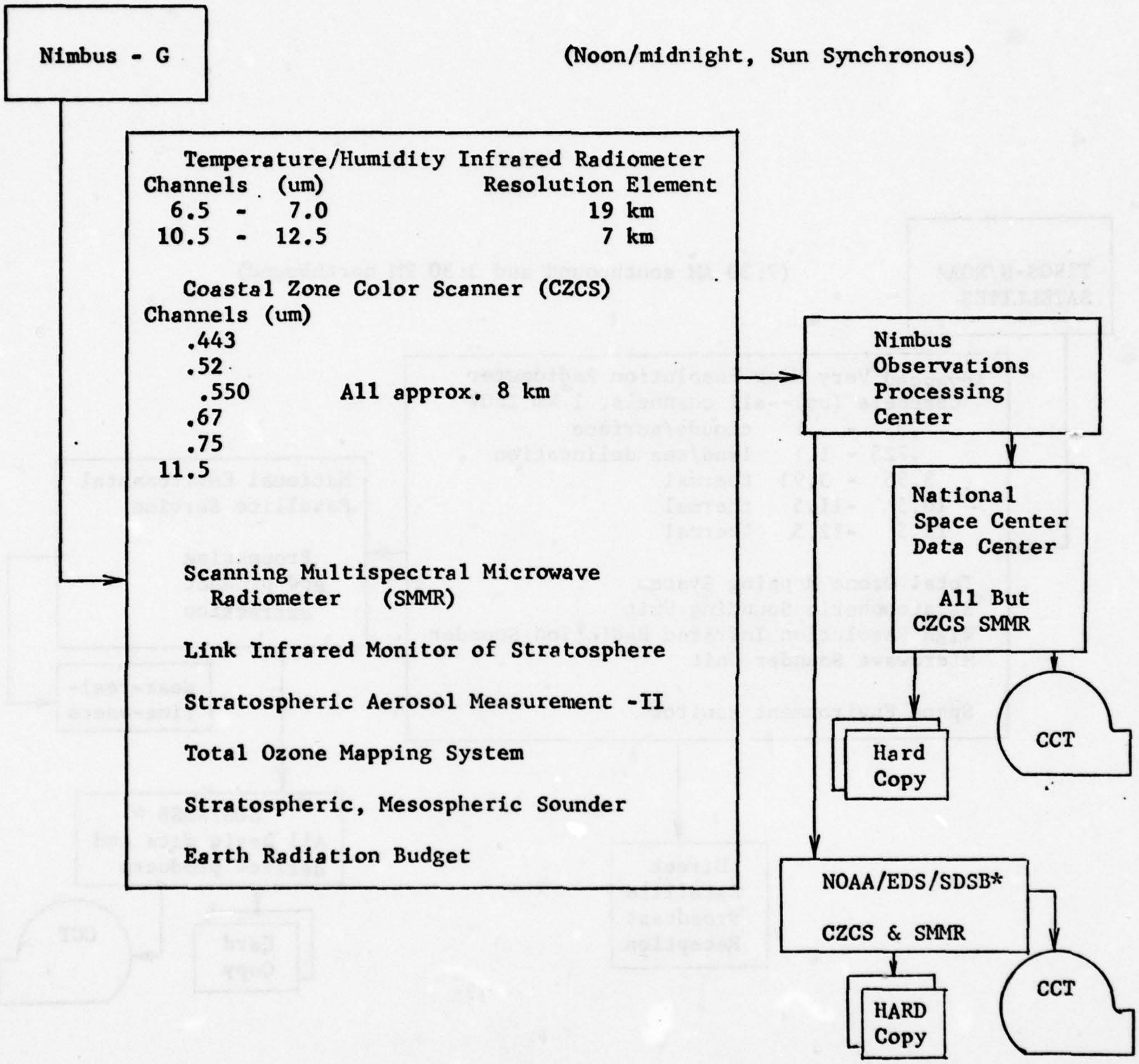


Figure 3-14. NASA Heat Capacity Mapping Experiment -- Airborne



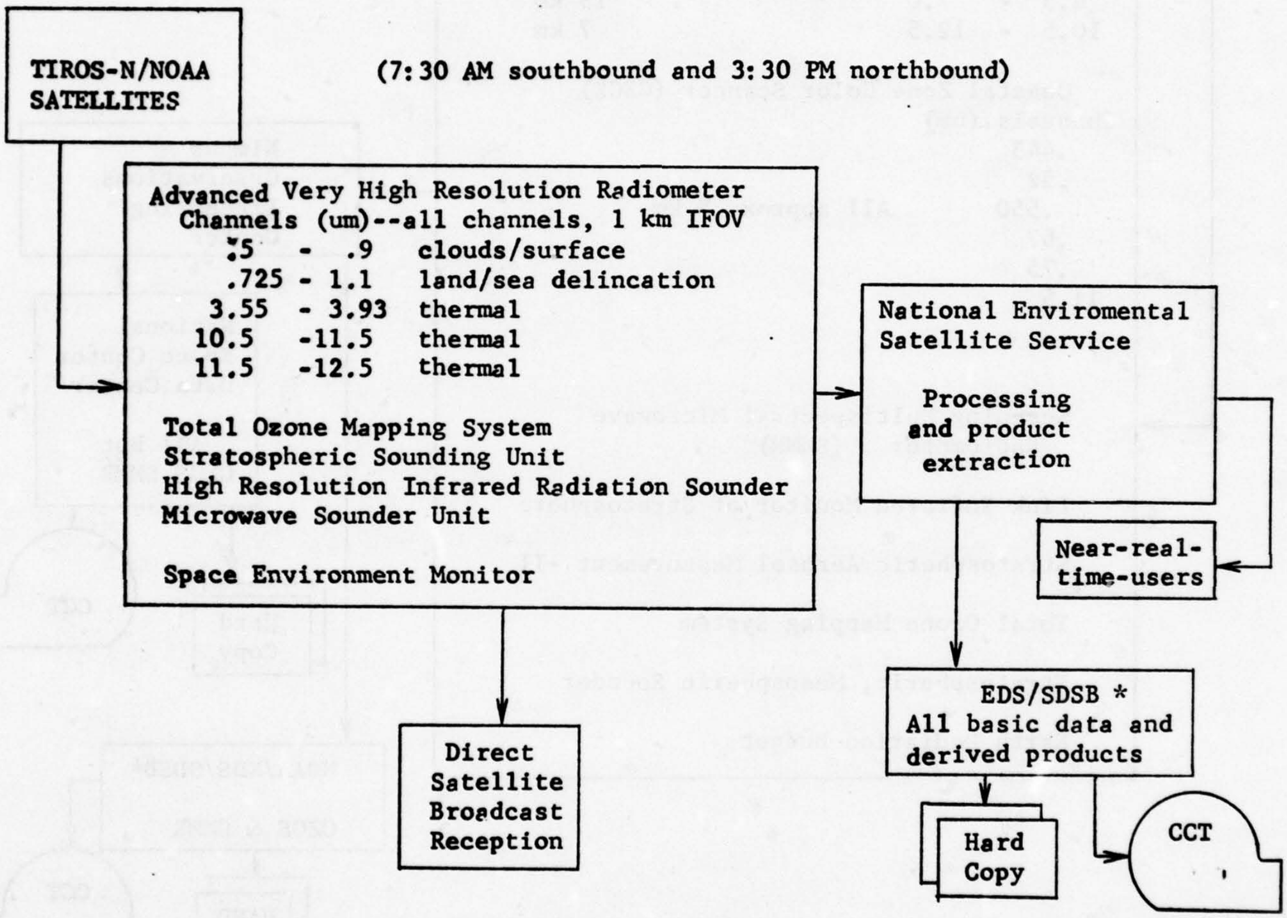
*National Oceanographic and Atmospheric Administration/ Environmental Data Service/Satellite Data Services Branch.

Figure 3-15. NASA Experimental Oceanographic Satellite System



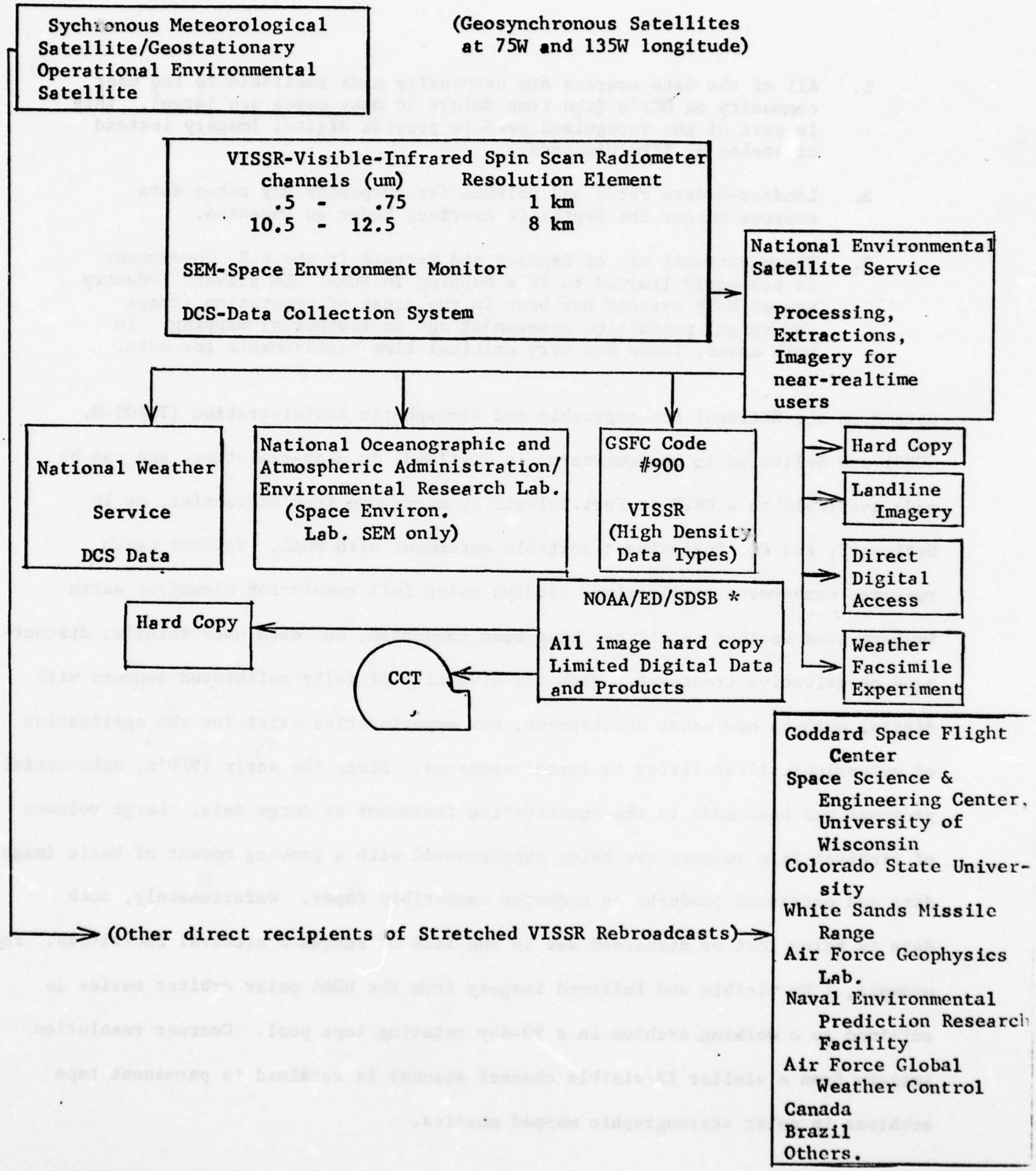
* National Oceanographic and Atmospheric Administration/ Environmental Data Service/Satellite Data Serivces Branch

Figure 3-16. NASA Experimental Meterorological Satellite System



*Environmental Data Service/Satellite Data Services Branch

Figure 3-17. NOAA Operational Dual Polar Orbiter Sun Synchronous System



*National Oceanographic and Atmospheric Administration/ Environmental Data Services Branch

Figure 3-18. NOAA Operational Dual Geostationary System

1. All of the data sources are eventually made available to the user community on CCT's (the time delays in many cases are large). This is part of the recognized need to provide digital imagery instead of analog or film products.

2. Landsat-D data rates and volumes far surpasses any other data sources except the Synthetic Aperture Radar on Seasat-A.

3. Theoperational use of Landsat and Metsats in the U.S. Government is presently limited to Snow Mapping in NOAA. In private industry use of both systems has been in the areas of vegetation (crops and range) production assessment and in geothermal mapping. In both cases, there are very critical time requirements for data.

Data from the National Oceanographic and Atmospheric Administration (TIROS-N, GOES) are delivered to headquarters, in Suitland, in near-real-time, and can be made available to a DRPF at Fort Belvoir by microwave link or courier, as in Options E_1 and E_2, following a suitable agreement with NOAA. Several earth resource management applications studies using full resolution cloudfree earth imagery from weather satellites have been conducted, but data uncertainties discouraged quantitative treatment. With the diversity of fully calibrated sensors with digital outputs now under development, new opportunities exist for the application of meteorlogical satellites to earth resources. Since the early 1970's, substantial progress has been made in the quantitative treatment of image data. Large volumes of archival film imagery are being supplemented with a growing amount of basic image data and extracted products on computer compatible tapes. Unfortunately, much data is being lost or discarded due to the lack of adequate archival facilities. For example, 1 Km visible and infrared imagery from the NOAA polar orbiter series is retained as a working archive in a 90-day rotating tape pool. Coarser resolution imagery from a similar IR/visible channel scanner is retained in permanent tape archives in polar stereographic mapped mosaics.

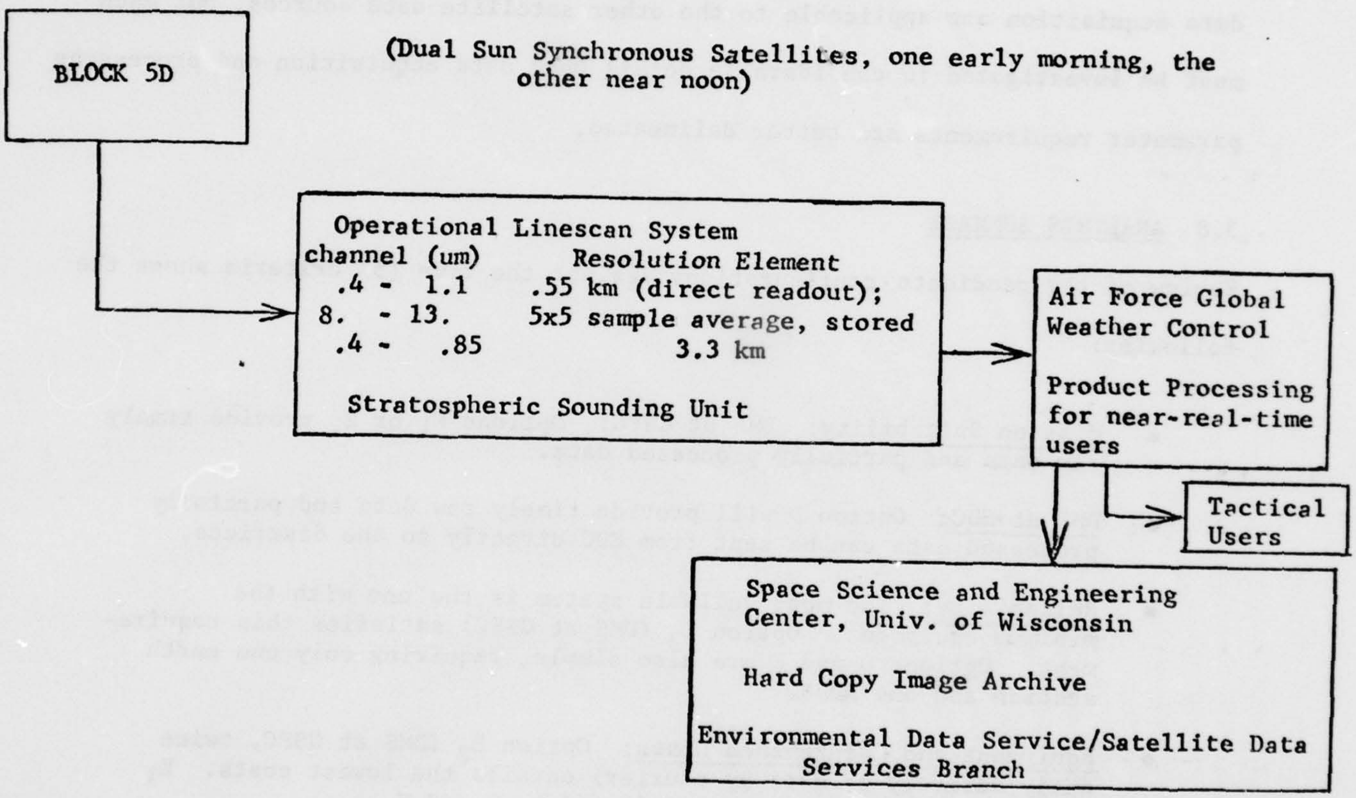


Figure 3-19. Defense Meteorological Satellite Program

The SMS/GOES program marked the beginning of on-board digitizing of operational weather satellite imagery. The new TIROS-N polar orbiter series will also provide digital 1 Km imagery from a multi-channel Advanced Very High Resolution Radiometer (AVHRR).

Many of the issues and approaches discussed throughout this report on Landsat-D data acquisition are applicable to the other satellite data sources, but each must be investigated in considerable detail once data acquisition and processing parameter requirements are better delineated.

3.8 ANALYSIS SUMMARY

Review of the candidate configurations against the five (5) criteria shows the following:

- Mission Suitability: DMS at GSFC: Options E_1 or E_2 provide timely raw data and partially processed data.
- DMS at EDC: Option D will provide timely raw data and partially processed data can be sent from EDC directly to the districts.
- Reliability: The most reliable system is the one with the minimum equipment. Option E_2 (DMS at GSFC) satisfies this requirement. Options D and F are also simple, requiring only one earth station and one HDDR.
- Equipment and Maintenance Costs: Option E_2 (DMS at GSFC, twice daily delivery of data by courier) entails the lowest costs. E_1 is the next lowest in cost, followed by D and F.
- Operating Costs: Operating costs increase in the following Order: E_2, E_1, and D (or F).
- Acquiring Data from Other Satellites: Data from the NOAA satellites are readily available in near-real-time by courier from Suitland, Maryland. The process need not influence the choice of acquisition for Landsat-D data.

In view of the above, Option E_2 is the clear choice, if the DMS is at GSFC, and if NASA transmits data typically only twice daily. Option E_1 would be the choice, if 1) NASA transmits data on a continuous basis, and 2) COE cannot afford the additional delay to accumulate the data for the two courier trips. If the DMS is located at EDC, then the recommended option is D.

Thus, the selection of a configuration which satisfies the study objectives is much dependent on NASA operational and facility decisions. Since these decisions are currently not fully resolved, it was felt that it would be in the COE's best interest to present and discuss all of the above options. Sections 3.9 through 3.12 address the configuration descriptions, along with estimated costs for these configurations.

3.9 SELECTED CONFIGURATION DESCRIPTIONS

3.9.1 CONFIGURATION D

The functions performed by Configuration D of providing TM data and providing a quick look at the DRPF, are depicted in Figure 3-20. The key element of this configuration is the receive-only components of the DOMSAT ground station. The approach taken by this configuration is to "tap" into the DOMSAT data transmissions that are occurring between the TDRSS receiving site at White Sands and the NASA/DMS

In this configuration, the unprocessed TM data is received, using a redundant receive-only ground station. The data is received, demodulated, bit synchronized and recorded on a 42-track High Density Digital Recorder (HDDR). Data recording is at a tape speed of 75 ips, with a DOMSAT transmitted data rate of 42 Mbps. The full 100 TM scenes transmitted daily will require about five (5) HDDT's. This recording is similar to the recording procedure that will be employed in the NASA/DMS.

Simultaneously, with the HDDT production, that data may be input to the quick-look component of this configuration. The data is decommutated and one band (preselected) is formatted and displayed on a 25 inch high-resolution TV monitor. This function can be performed during HDDT recording and/or subsequent playback.

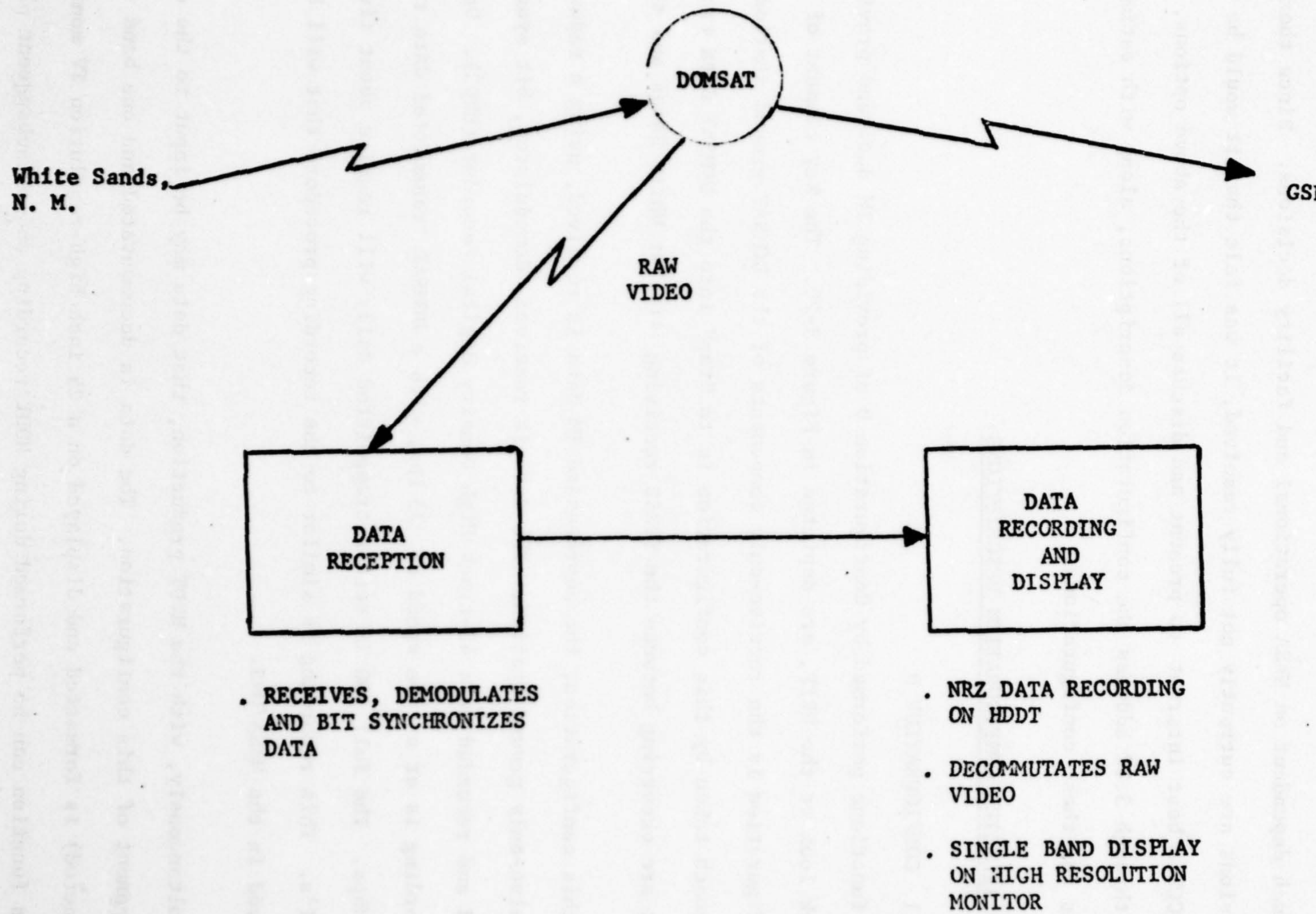


Figure 3-20. Configuration D System Functions

The image displayed may have a "moving window" (if selected) effect, i.e., the image will be updated with every detector input of the selected band, resulting in a motion of the display image, as if the viewer were inside the spacecraft. The monitor will display 512 pixels per line. The instantaneous image on the monitor will be comprised of 512 pixels by 512 lines.

The hardware, shown in Figure 3-21, includes:

- One (1) Domsat Receive-only Redundant Station
- One (1) Bit Synchronizer
- One (1) 42-track High Density Digital Recorder (HDDR)
- One (1) Decommutator Unit
- One (1) Display Unit

3.9.1.1 Domsat Receive-Only Station

The receive-only redundant station contains the basic antenna, low noise amplifier (LNA), and receiver components. In addition, a second LNA and receiver, plus a protection switch are included for increased reliability.

The protection switch continuously monitors the primary LNA and receiver for proper operation and automatically switches to the standby units, should problems develop.

The redundant system provides considerable operational flexibility. It may be operated in several modes, selected by a front panel switch:

a. Fully protected with automatic LNA and receiver switching for maximum protection against outage.

b. Simultaneous operation of one primary and one secondary channel. The secondary channel is automatically pre-empted and switched into primary service, if need arises for protection of the primary channel.

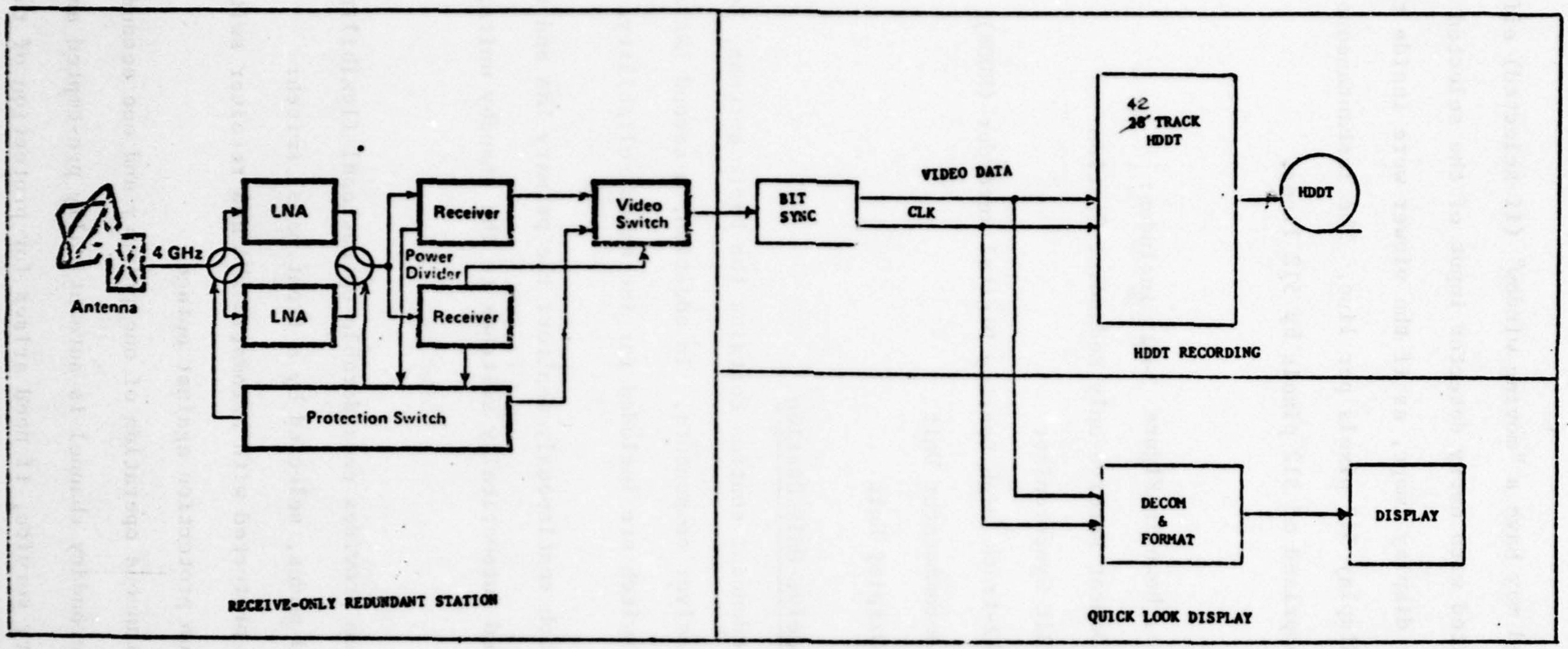


FIGURE 3-21 CONFIGURATION D SYSTEM HARDWARE

c. Simultaneous operation of two unprotected channels.

The size and performance of the station antenna affects the complexity, overall reliability and cost of the electronic equipment required for a quality station.

The antenna, which could be provided by several vendors such as Scientific-Atlanta Corporation, is a 10-meter diameter antenna, ideally suited for highly reliable stations. A 10-meter diameter permits the use of reliable and relatively inexpensive GaAs FET amplifiers for quality service. A 10 meter dish has a large cone of coverage, which means that fewer pointing updates are required to account for geosatellite drift.

Two general types of parabolic antennas are available. Either a dual reflector or a prime focused feed system may be selected. The dual reflector feed system is typically specified for stations which must transmit to, as well as receive from the satellite. The prime focused feed system, used in this configuration, consists of a radiating source, located precisely at the focal point of the parabolic reflector. The feed is supported from the main central hub of the antenna by a reinforced mounting mast. This type design has been optimized to provide improved illumination and spillover efficiencies and to minimize blockage and diffraction problems associated with dual reflector feed systems. As a result, the prime focused feed design produces minimal sidelobe radiation and has excellent cross polarization characteristics.

The prime focused feed is useful for receive-only station requirements where it is especially desirable to locate the antenna in areas that may be congested with potentially interfering terrestrial microwave traffic. This type of antenna, with its superior radiation patterns, provides maximum rejection of potentially interfering signals and increases the possibility of satisfying the FCC frequency coordination requirements at any given site.

The receiver is connected to the antenna mounted low noise amplifier (LNA) by coaxial cable, and may be located several hundred feet from the antenna. This receiver downconverts and demodulates the incoming 4 GHz video to the baseband frequency and clamps the baseband output.

Following the IF filter/equalizer, an IF amplifier provides a constant output level for the FM demodulator. The FM demodulator is a conventional discrimator, preceded by two stages of series shunting. Following the FM demodulator is a video amplifier which provides an input level control for the video data output.

3.9.1.2 Bit Synchronizer

The function of the bit synchronizer is to reconstruct serial PCM data streams from extremely noisy filtered or unfiltered serial data inputs.

The bit synchronizer accepts input data in NRZ at a bit rate of 42 Mbps. It produces a reconstructed NRZ data stream that is accompanied by an internally developed coherent clock.

The input signal is initially filtered, gain controlled, and adjusted for dc offset. Filter bandwidth, gain compensation, and DC offset compensations are all developed as functions of the data code and bit rate for optimum parameter selection and response.

An internal oscillator produces a clock, at the selected bit rate. The incoming data is examined for transition points, to detect the true bit rate. The phases of the true bit rate and the clock rate are compared, and a correction voltage is developed to lock the clock to the true bit rate. The resulting coherent clock is supplied with the data to synchronize ongoing recording and decommutation equipment.

It should be noted that the bit synchronizer can be used to monitor the incoming signal, should the quick-look equipment fail. Since the synchronizer performs bit sync on the signal, this can be a means of verifying that a signal of appropriate bit rate is being recorded.

3.9.1.3 High Density Digital Recorder

A 42-track High Density Digital Recorder (HDDR) is used to record/reproduce the TM data. NASA is currently procuring Martin Model 4277S units for the Landsat-D system.

The HDDR is capable of recording and reproducing, at fixed speeds, a serial data stream, along with a coherent data clock. The serial data stream will be in the format of NRZ-L serial data, at a rate of 42 Mbps. Recording of the serial data is typically distributed over 40 parallel digital tracks, with correspondingly lower data rate, at lower speeds or higher data rate, at higher speeds. Three (3) analog tracks are used for IRIG time code, narrowband telemetry and voice/servo reference.

Pertinent Model 4277S Tape Transport features are:

- Reel size: 10½ in. to 16 in. diameter
- Packing Density: 24 Kbpi
- Heads: 42-track
- 42 digital tracks (40 useful concurrently)
- 3 analog tracks
- Tape speeds (electronically switchable)
  a. 150 ips for 82 Mbps data
  b. 75 ips for 42 Mbps data
  c. 37.5 ips for 21 Mbps data
  d. 18.75 ips for 10.5 Mbps data
  e. 9.375 ips for 5.25 Mbps data
- Fast forward/reverse: 300 ips
- BER: 1 in. 10^6

3.9.1.4 Decommutator Unit

The Decommutator Unit is a GE design in use in all current and proposed Landsat related HDDT systems. This Unit consists of three (3) functional modules:

1. Synchronization and Data Stripping Module (SDSM)
2. Display Interface Module
3. Operator's Panel

The SDSM receives TM data at a rate of 42 Mbs, and performs the necessary synchronization task. To accomplish this, a pseudonoise synchronizer will search the data stream for the 816 bit Scan Line Start Code. The pseudonoise synchronizer is a feedback shift register which operated in two modes.

In the Load mode, ten (10) data bits are shifted into the register. In the Feedback mode, suitable taps, with associated "parity" gates, are connected to the input to allow the register to duplicate the pseudo number (PN) sequence generated by the spacecraft.

If the ten (10) bits loaded are, in fact, ten (10) consecutive error-free bits of the PN code, then the feedback circuit generates the succeeding bits. Should 16 error-free bits be so generated, "lock" is declared.

When lock is declared, the pseudo number synchronizer circuit continues scanning the incoming data. If three (3) bit errors are detected, over any eight (8) sequential bits, lock is cancelled and the circuit returns to Load. Otherwise, the circuit continues until the shift register contains all 1-bits.

At this time, Minor Frame Sync Search is initiated.

A 32-bit shift register is configured such that its contents are examined for the minor frame sync code. In particular, the number of bits which do not match the code are counted. The data stream is examined each bit time for the code until the mismatch count is less than, or equal to, a switch programmable limit.

When the code is found, a number of events take place.

First, a minor frame length counter begins counting. This counter inhibits the sync code search for 808 bit times, and then enables the search for the next 17 bit times. This provides a bit slip window of plus or minus 8 bits, relative to the nominal position. This process repeats throughout the scan line (6100 minor frames).

Second, a modulo 8 counter is activated. This counter is used to assemble 8 bit bytes from the incoming data.

Third, a PN generator is initiated and used to decode the data bytes, since on the spacecraft the data is PN encoded.

Lastly, the minor frame decommutator is started, so that the data may be properly sorted.

Data is then sorted and stripped for the duration of the minor frame.

The operator's panel has a thumb wheel switch which selects the band to be displayed. The data stripper circuit uses the setting of this switch to select the pixels.

For bands 1, 2, 3, 4, 5 and 7, there are approximately 37,000 pixels per line. Since the display has a resolution of 512 pixels per line, when any of these bands are selected, the 192 pixels contained in 12 minor frame are averaged in hardware, prior to being delivered to the display. For band 6, the 12 pixels contained in 12 minor frames are averaged.

The averaged pixels are buffered, line reversed, as required, and transmitted to the Display Unit via the Display Interface Module.

As an additional convenience for the operator, a TM simulator is provided. When selected from the operator's panel, the simulator generates all signals needed to display a test image on the Display Unit. This allows rapid verification of end-to-end system performance, as well as easy diagnosis and repair of system malfunctions.

3.9.1.5 Display Unit

The display unit of the Quick Look Display Equipment uses solid state refresh memory, along with a 25 inch high resolution monitor for data display. COMTAL Model 8100 units have been used in similar applications, or the Interactive Displays of the DRPF's Information Extraction System could be used.

The image data is retrieved from the refresh storage and presented on the monitor. The display is a black and white presentation of the image, with spatial resolution of 512 x 512 pixels. The decommutator performs the sub-sampling by selecting the 7th pixel and all subsequent modulo N pixels (N is switch selectable). Sampling every 12th pixel reduces the number of pixels per line to 512, which is the single line capacity of the refresh memory. When a line of data is transferred, the new line is written on the monitor, pushing previously written lines up one position on the screen.

The operator may select to hold or "freeze" a display for closer examination, causing the current scene to be held static as long as the operator wishes. When the hold is released, the display will continue with the moving window presentation.

In addition, the unit can perform enhancement on the data after it is retrieved from storage, without change to the original data.

General features of the display unit include:

- A display presentation of 512 x 512 resolution cells (262,144 pixels) presented in a one by one aspect ratio.
- An eight (8) bit refresh-stored data value is used to describe each and every image pixel.
- The refresh-stored data is continuously read out at a rate of over 240 million bits per second.
- The image display processing is performed entirely in a digital manner and controlled in real-time.
- All pseudo-color, contrast enhancement, linear and non-linear manipulations are performed and changed in real-time, without altering the refresh-stored image.
- Sixty-four linear brightness levels are available for display of each presented image and/or primary color.
- A simplified local control panel provides for optimum man/machine interfacing, and also provides 100% self-check of the display, on a stand-alone basis.

- All input data is fully buffered, providing data word input rates from zero to greater than 2×10^6 pixels/second.
- The capability to non-destructively read, on the local control panel or external digital device over the system interface, all refresh-stored information is standard.
- All refresh-stored images may be displayed, using one of four digital processing modes. One mode applies the high order six (6) bits of the eight (8) bit refresh-stored image data equally to three (3) high speed digital to analog converters. The output of each converter is applied to one of the display monitor's color primaries. This mode produces a linear black and white image. Another display mode uses the same high order refresh-stored six (6) bits and produces a pseudo colored presentation. Another display mode applies all eight (8) bits of the refresh-stored data to the address input of a function memory. The six (6) bit output of the function memory is applied to the output digital to analog converters, in the same manner as described for the first display mode. The final display mode provides a combination of the second and third display modes.
- The scan conversion provides buffering for one complete image or graphic line of input data. The line, so buffered, can be designated to be loaded, and appear at any of 512 vertical locations on the display screen. The scan conversion section also provides the alternate capability of producing a moving window (falling or rising raster) presentation of the input information.
- All of the modes and features described may be controlled, either from the local control panel or one common set of data and control lines from an external digital data source. This one interface is all that is required to operate any or all of the display system capabilities and options.

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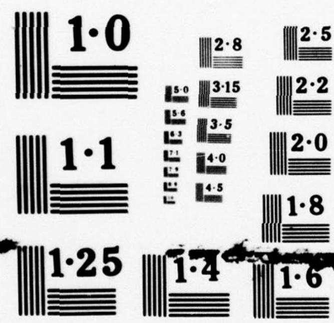
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1.4
1.6

3.9.2 CONFIGURATION E, OPTION 1

This configuration interfaces with the NASA Data Management System (DMS), to form a digital data link with one COE DRPF. The configuration consists of a digital data microwave transmission station, located at GSFC, and a digital data microwave receive station, located at DRPF. In addition, a digital receive/transmit unit needs to be positioned between the (2) locations. The receive station includes quick look display equipment, which provides display capability of the TM data, so that acceptability of the incoming digital imagery is determined.

The functions associated with this configuration are presented in Figure 3-22.

Within the NASA DMS, raw and pre-processed TM data is recorded on High Density Digital Tapes (HDDT's). These HDDT's are obtained by the COE station operator (at GSFC). Each HDDT is mounted on and played back on a High Density Digital Recorder (HDDT), at a tape speed of 75 ips into the microwave link. Prior to start of the data playback, the operator establishes telephone communication with his counterpart at the DRPF location.

The HDDR output is a serial NRZ bit stream with coherent clock. This bit stream is input to the Digital Microwave Transmission equipment, where the data is passed into randomizer circuits which process the data with a 15-bit pseudorandom sequence. This processing guarantees sufficiently random activity into the modulator to ensure that the transmitted spectrum will conform to FCC regulations. After randomization the data is modulated onto a 70 MHZ carrier. The 70 MHZ modulated signal is converted to 6 GHZ in a mixer, then filtered and amplified to a nominal 10 watts. The 6 GHZ RF signal is transmitted.

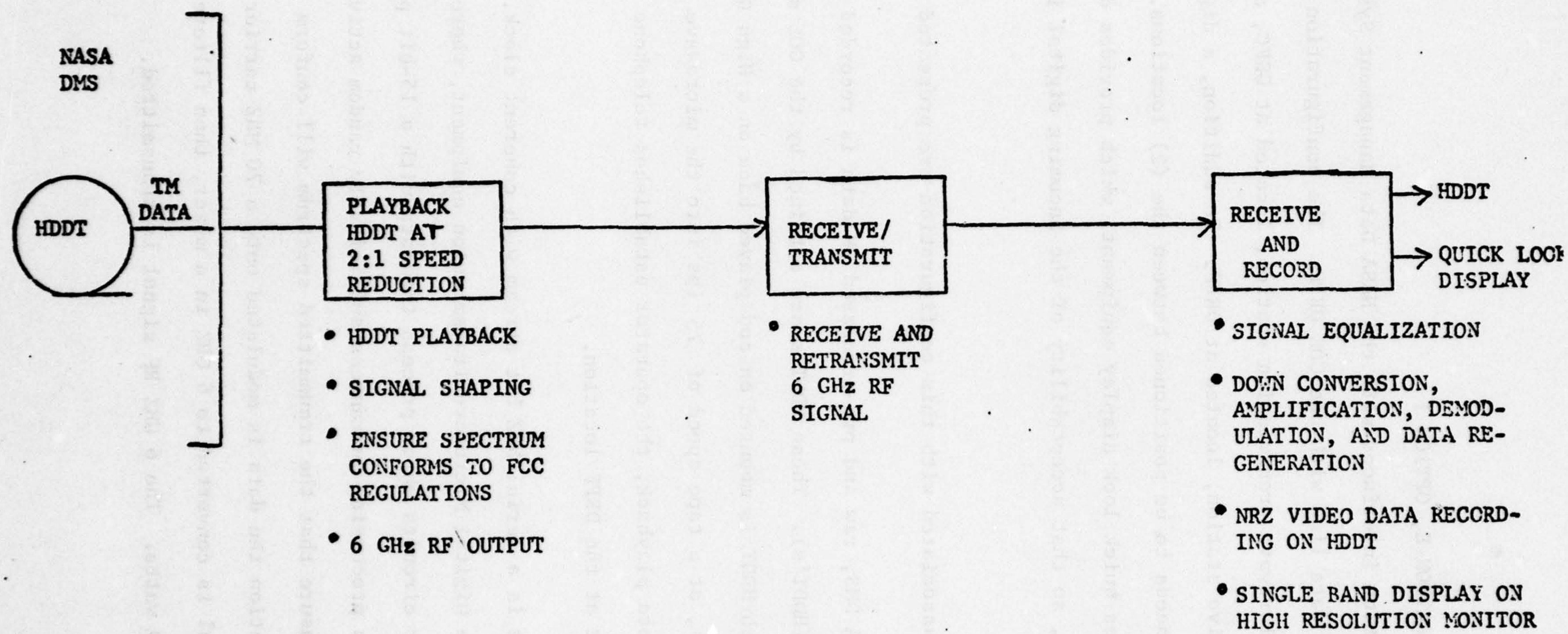

Figure 3-22. Configuration E (Option 1) System Functions

The receive/transmit repeater unit will be located about midway between GSFC and DRPF. This unit is employed so that maximum line of sight range (approximately 25 miles) is satisfied. An analysis needs to be conducted, to determine the optimum location of this unit, the necessary height and potential existing structures onto which the antennas can be mounted in order to eliminate the cost of constructing a tower.

From the repeater the 6 GHZ RF signal is transmitted to the DRPF receiving station. From the receive antenna, the RF signal passes through a bandpass filter and through a waveguide equalizer. After equalization, the 6 GHZ signal is down converted, amplified, filtered, demodulated and the data is regenerated. The regenerator restores the data to the form of the original signal applied at the GSFC transmitter modulator. The NRZ data and timing signals are then input to the HDDR.

Simultaneous with the HDDT production, the TM data is input to the Quick Look equipment. The Quick Look Unit decommutates the data, and one preselected band is formatted and displayed on a high resolution 25 inch monitor. The Quick Look Unit is identical to the one described in Section 3.9.1.

The transmit and receive system equipment, shown in Figure 3-23 consists of:

- Two 42-track High Density Digital Recorders (HDDR), one at each end of the link
- Two transmit microwave units
- Two receive microwave units
- Two 10 foot antennas
- One 100 foot tower or existing mounting structure with two 10 foot antennas
- One Decommutator Unit
- One Display Unit

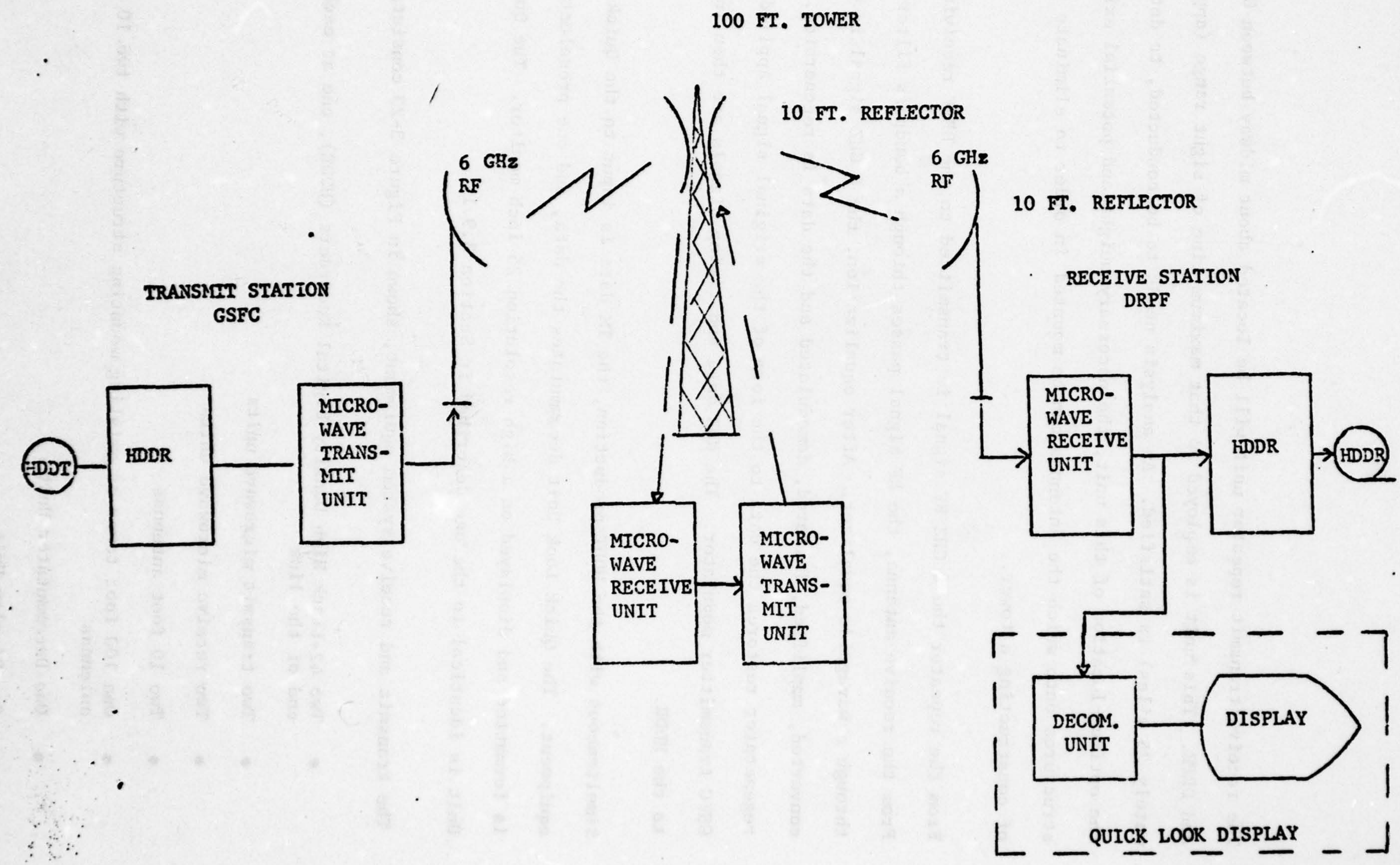

Figure 3-23. Configuration E (Option 1) System Hardware

3.9.2.1 High Density Digital Recorder

This unit is identical to the 42-track unit described in Section 3.9.1.

3.9.2.2 Digital Microwave Transmission Equipment

The Digital Microwave Transmission equipment consists of two (2) transmit and two (2) receive units. Several manufacturers have this equipment available. A typical supplier is the Raytheon Company. The Raytheon series RDS-60 transmitter, illustrated in Figure 3-24 accepts NRZ format data and passes the data to randomizer logic, where the data is processed with a 15-bit pseudorandom sequence. This processing guarantees sufficiently random activity into the modulator, under all circumstances, to ensure that the transmitted spectrum conforms to FCC regulations. Repetitive data sequences, that would otherwise be generated in some cases (such as lack of multiplexer inputs), would produce spectral lines in the transmitter output, that could exceed the limits defined by the FCC.

After randomization, the data is applied to an eight (8) level PSK modulator, where it is differentially encoded and modulated onto a 70 MHz carrier. The 70 MHZ modulated signal is up-converted to 6 GHz in a mixer, then filtered and amplified by a TWT, to a nominal 10 watts. Because the RDS-60 does not use baseband filtering to obtain optimum spectral shaping, the TWT may operate in a saturated mode thus delivering its full output. No special care is required when adjusting the TWT, since linear operation is not necessary.

The RDS-60 receiver is shown in Figure 3-24. After bandpass filtering, the 6 GHz RF signals pass through a waveguide equalizer. This unit provides approximately ±7 nanoseconds of group delay adjustment, and is used to cancel linear delay introduced by transmit and receive antenna system waveguide runs. Each hop is individually equalized at the factory, to remove equipment associated delay. Once installed in the field, the only delay equalization required is at the waveguide equalizer to remove feeder delay. Bay equalization is not disturbed or used to compensate for non-radio effects. After equalization, the 6 GHz signal is down-converted, amplified and filtered, before continuing on to the eight (8) phase demodulator and data regenerator. These two (2) modules recover the 70 MHz carrier and demodulate the PSK information. The data is de-randomized, to remove the extra activity supplied by the transmitter randomizer, and then applied to the separator, which reproduces the signal, originally supplied as input to the transmitter bay.

3.9.2.3 Transmission/Receive Antennas

Four (4) dual polarized, horizontal and vertical, ten (10) foot diameter micro-wave reflectors are employed. Two (2) reflectors are mounted on the repeater structure, one (1) is installed at GSFC, and the fourth is installed at DRPF. Typical electrical characteristics include:

• Reflector (diameter)	10 ft
• Gain	43:9 dBi
• Beam Width	1.0 degree
• First Side Lobe	-21 dB
• Wide Angle Lobe	-42 dB
• Front to Back Ratio	48 dB
• VSWR	
Standard	1.10
Low VSWR	1.06

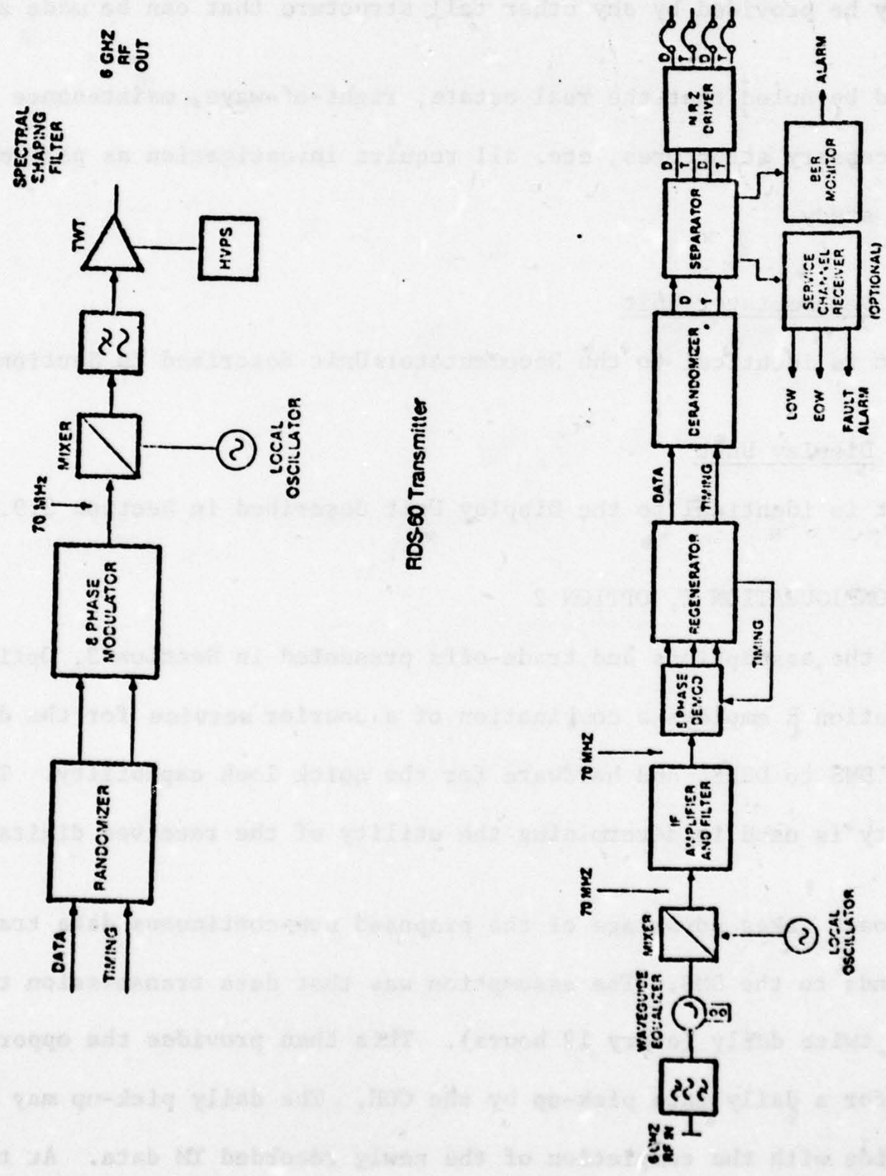

Figure 3-24. RDS-60 Transmitter and Receiver

3.9.2.4 Repeater Structure

A tower may be used to mount the two (2) microwave reflectors that provide for line-of -sight paths between the GSFC location and the DRPF location. The antenna must be mounted approximately 100 feet above the terrain. The functions of the tower may be provided by any other tall structure that can be made available.

It should be noted that the real estate, right-of-ways, maintenance roads, permits, necessary structures, etc. all require investigation as part of a more detailed study.

3.9.2.5 Decommutator Unit

This unit is identical to the Decommutator Unit described in Section 3.9.1

3.9.2.6 Display Unit

This unit is identical to the Display Unit described in Section 3.9.1.

3.9.3 CONFIGURATION E, OPTION 2

Based on the assumptions and trade-offs presented in Section 3, Option 2 of Configuration E employs a combination of a courier service for the data transfer from DMS to DRPF, and hardware for the quick look capability. The quick look capability is used in determining the utility of the received digital imagery.

The approach takes advantage of the proposed non-continuous data transmissions from White Sands to the DMS. The assumption was that data transmission to DMS is expected to occur twice daily (every 12 hours). This then provides the opportunity to arrange for a daily data pick-up by the COE. The daily pick-up may be arranged to coincide with the completion of the newly recorded TM data. At this time, pickup of the previous data transmission can be accomplished, along with pick-up of pre-processed data from the previous transmissions. In this approach, the courier would be waiting at DMS for the data and, after pickup, data delivery to DRPF could be accomplished within one and one half hours.

The HDDT's received by the DRPF are then sequentially mounted on and played back by the DRPF HDDR. HDDR playback tape speed will be at 75 ips, and the quick look procedure is as described in previous configurations.

The equipment shown in Figure 3-25 consists of:

- One 42-track High Density Digital Recorder
- One Decommutator Unit
- One Display Unit

3.9.3.1 High Density Digital Recorder

This unit is identical to the 42-track recorder described in Section 3.9.1.

3.9.3.2 Decommutator Unit

This unit is identical to the decommutator unit described in Section 3.9.1.

3.9.3.3 Display Unit

This unit is identical to the display unit described in Section 3.9.1.

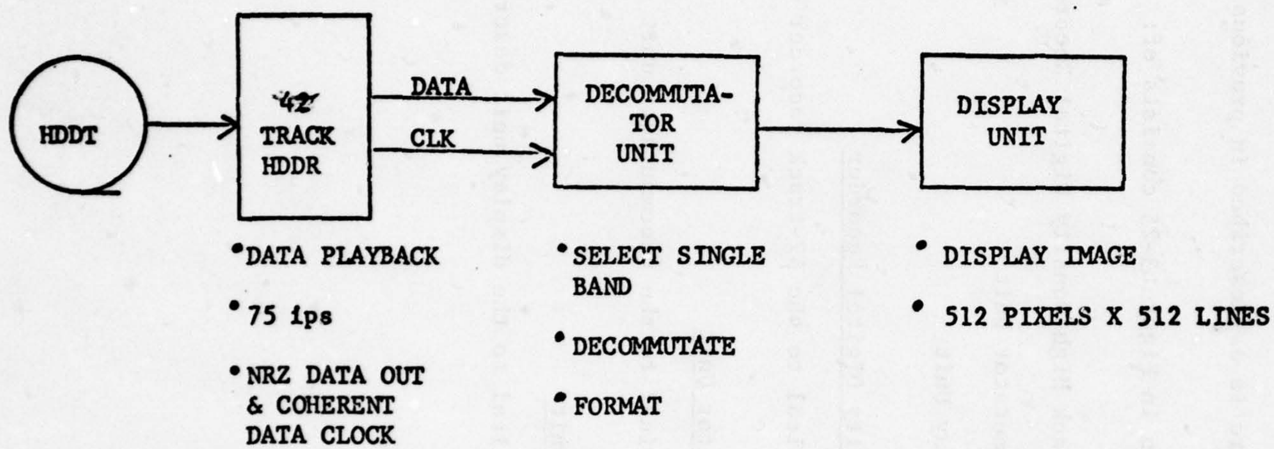

Figure 3-25. Configuration E (option 2) System Hardware

3.10 SCHEDULE

The overall development activities from initialization through the operational demonstration are the same regardless of the configuration. Only the specifics within each major task will be dependent on the configuration. The overall activities schedule is shown in Figure 3-26. The initial activity after the project is started will be a detailed design phase followed by a preliminary design review. This will establish the detailed requirements and approve the design concept so that long lead hardware items may safely be released for procurement. During the following 3 month period, in addition to finalizing the system design and monitoring the hardware procurements, the interface requirements will be initiated (i.e., NASA/COE, COE/FCC) and the facility should be prepared by the CoE.

Following the critical design review presentation and approval, all phases of the project will be finalized and additional hardware items procured. The implementation plan should use a modular design approach which provides an orderly build-up of the system configuration while obtaining continuous performance verification of the various elements.

During the twelfth month after contract award, all equipment will be validated and ready for installation. Within three months from the installation date, all equipment will be in place and ready for operation.

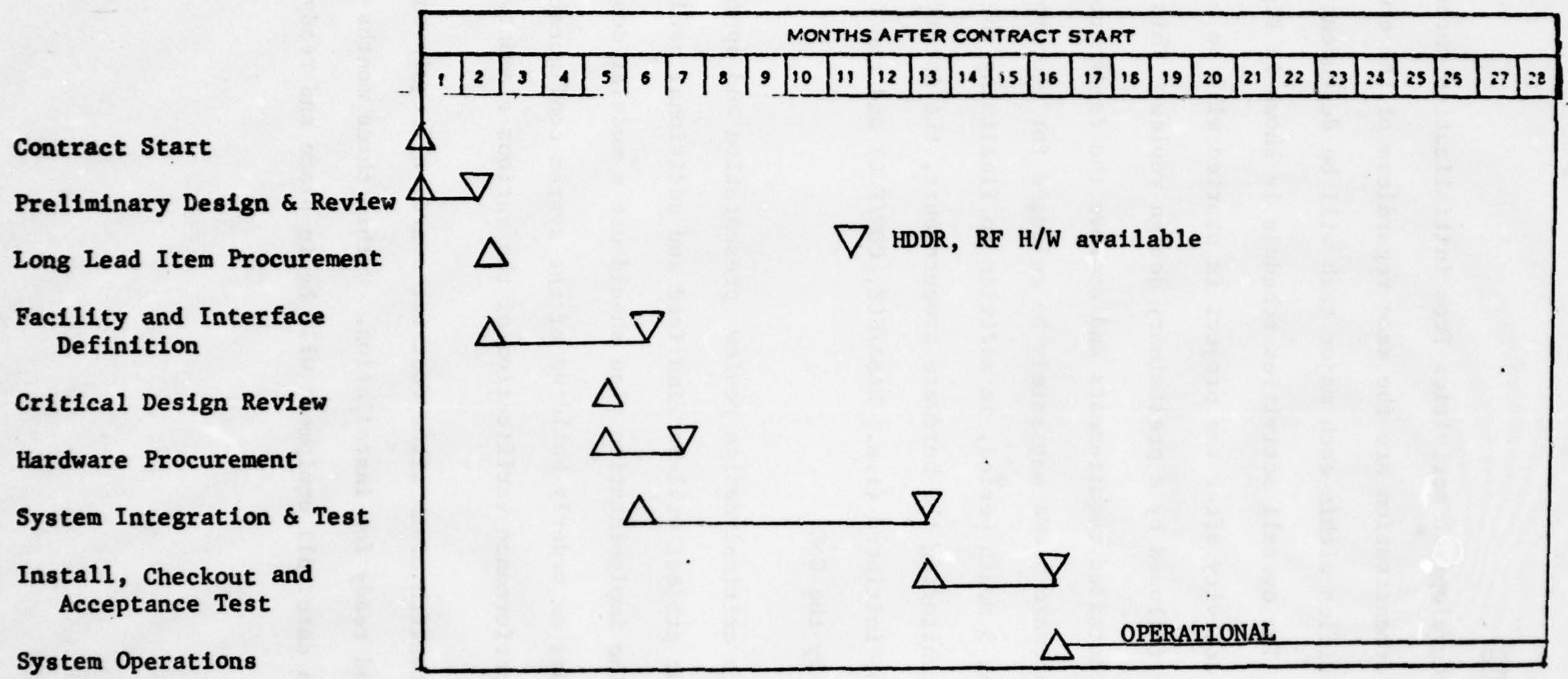

Figure 3-26. Master Program Schedule

3.11 OPERATIONAL STAFFING

Staffing estimates were made [illegible] tasks are performed by these personnel. The [illegible] schedule, seven day a week operation. [illegible] electronically and mechanically oriented personnel [illegible] adequately cover operational requirements. The operations supervisor would be required to cover for operations or maintenance personnel during periods of illness or vacation.

The major responsibilities of the type of personnel required are discussed and a summary list is given of the specific personnel needed in each of the categories for each of the alternatives.

3.11.1 OPERATIONS SUPERVISOR

There should be one technical/administrative type supervisor for the overall operation. He will be responsible for continuing operation of the system, maintaining throughput operations, providing operations procedures, on-the-job training, and detailed planning and scheduling of activities. He will also contribute as an active participant in the operations/maintenance of the facility. Additional responsibilities include recognizing the need for functional changes and taking corrective actions where required, planning shift schedules and personnel assignments for efficient facility operation, reviewing internal reports and preparing periodic reports.

3.11.2 HARDWARE TECHNICIAN

This individual should have a diversified technical background and experience. His major responsibility will be to provide routine day-to-day required system maintenance, troubleshooting and repair of equipment.

His responsibilities will include the coordination and scheduling all operational activities, performing functional and operational readiness verification prior to system operation. He will also perform all duties pertaining to procurement receipt, storage, inventory control and disbursement of data, maintain delivery control of output data by establishing a return receipt control system, maintain operational logs and prepare accurate, timely malfunction and repair reports.

3.11.3 CLERICAL

This individual will provide secretarial services for the supervisor and the other facility personnel. This individual will perform technical and administrative material typing as required, maintain the filing system, handle telephone communications and perform routine administrative functions for the operation.

3.11.4 LABOR REQUIREMENTS SUMMARY

The manpower requirements by labor category are presented in Table 3-8. These personnel requirements are based on yearly staffing. A factor of 1.6 was applied to cover illness, vacations and weekend operation.

Table 3-8. Manpower Summary

Personnel Category	Personnel per Configuration		
	Conf. D	Conf. E, OPT.1	Conf. E, OPT.2
Supervisor	1	1	1
Hardware Tech.	2	4	1
Clerical	1	1	1
Sub-total	4	6	3
Total *	7	10	5

*The total manpower includes the 1.6 factor.

3.12 COST ESTIMATES

One of the objectives of this study was to provide rough order-of-magnitude (ROM) estimates of the Recurring and Non-recurring costs for the design, development, installation and operation of the systems. Although every effort was made to make these cost estimates as accurate as possible, it must be remembered that these are only ROM estimates to be used for budgetary and planning purposes. The cost estimates are, of course, directly related to the system requirements and resulting design upon which they are based. As the selected approach becomes better understood, and the requirements more definitive, the accuracy and validity of the cost estimates will improve significantly.

3.12.1 COST ESTIMATING GROUNDRULES AND ASSUMPTIONS

The following ground rules and assumptions were adopted during this study for purposes of arriving at the cost estimates.

1. These costs do not reflect the additional costs of processing within the DRPF due to the disparity of input data content for each option. The burden of processing raw data as opposed to semi-processed data is the same order of magnitude as the entire data collection system described in this current study.

2. All costs provided are in basic 1977 dollars; no forward pricing or inflation factors were used in these estimates.

3. No provision in the cost estimates is made for the physical facilities, land, security, nor operational utilities (light, power, heat, etc.); all of these are assumed to be provided by the government at no explicit cost to the project.

4. An average labor rate of $55K per year through overhead and G & A (and before fee and contingency) was used for each applied man throughout the design, fabrication, and test phases of the program. This value represents a reasonable mean between the higher paid senior engineers/managers and the lesser paid technicians/shop personnel.

Table 3-9. Three Year Costs for Preferred Configurations

DRPF

	Configuration		
	D	E(1)	E(2)
System Costs			
System Engineering	78	95	63
Hardware	803	627	323
Hardware Integration and Test	46	46	46
Site Installation and Checkout	93	93	93
Program Management	8	9	7
Total System	1,028	870	532
Maintenance and Operations Cost			
Manpower	405	609	304
Materials	374	356	179
Total M&O	779	965	483
System and M&O	1,807	1,835	1,015
Totals (10% fee plus 10% contingency)	2,186	2,220	1,228

All numbers are in 1977 dollars x 1000

5. Published catalog prices were used for estimating purchased hardware whenever possible; in a few cases it was necessary to rely on engineering estimates and past experience for estimates of these purchased items. Costs were included for contract support and similar support activity, in addition to the basic catalog price for all purchased items.

6. Field rates were used for estimating the cost of recurring station operations without regard to affiliation (contractor or government personnel). These rates are through overhead and G & A per year.

   - Manager/Engineers/Supervisors - $43.5K
   - Lead Technicians/Operators - $33.9K
   - Clerical and Support - $23.9K

7. The cost estimates do not preclude the use of a private (for profit) contractor for design, development and operation of the facility and provision for fee or profit at the rate of 10% on total cost has been included. M & O training of government personnel in this eventuality have not been included but should be relatively small (less than $100K).

8. A contingency factor of 10% is included in the final total cost to account for some flexibility in requirements growth and unanticipated cost items. The 10% fee included may also act as a contingency for those portions of work performed by government personnel.

3.12.2 COST BREAKDOWN STRUCTURE

The cost estimates for the user data processing facilities were derived from a "bottom-up" analysis of each cost element. A cost breakdown structure was developed to four levels of depth as shown in Figure 3-27. Included on this figure are the major task elements which constitute the cost elements. The following descriptions summarize the third level of the cost breakdown structure.

1. System Engineering - this element provides for the overall design definition and integration of the various subsystem elements and all the tasks described as follows:

   a) Specification Requirements - This spec. would cover the total system requirements, analysis and pertinent FCC regulations. Included would be the appropriate requirements and necessary purchasing instructions for

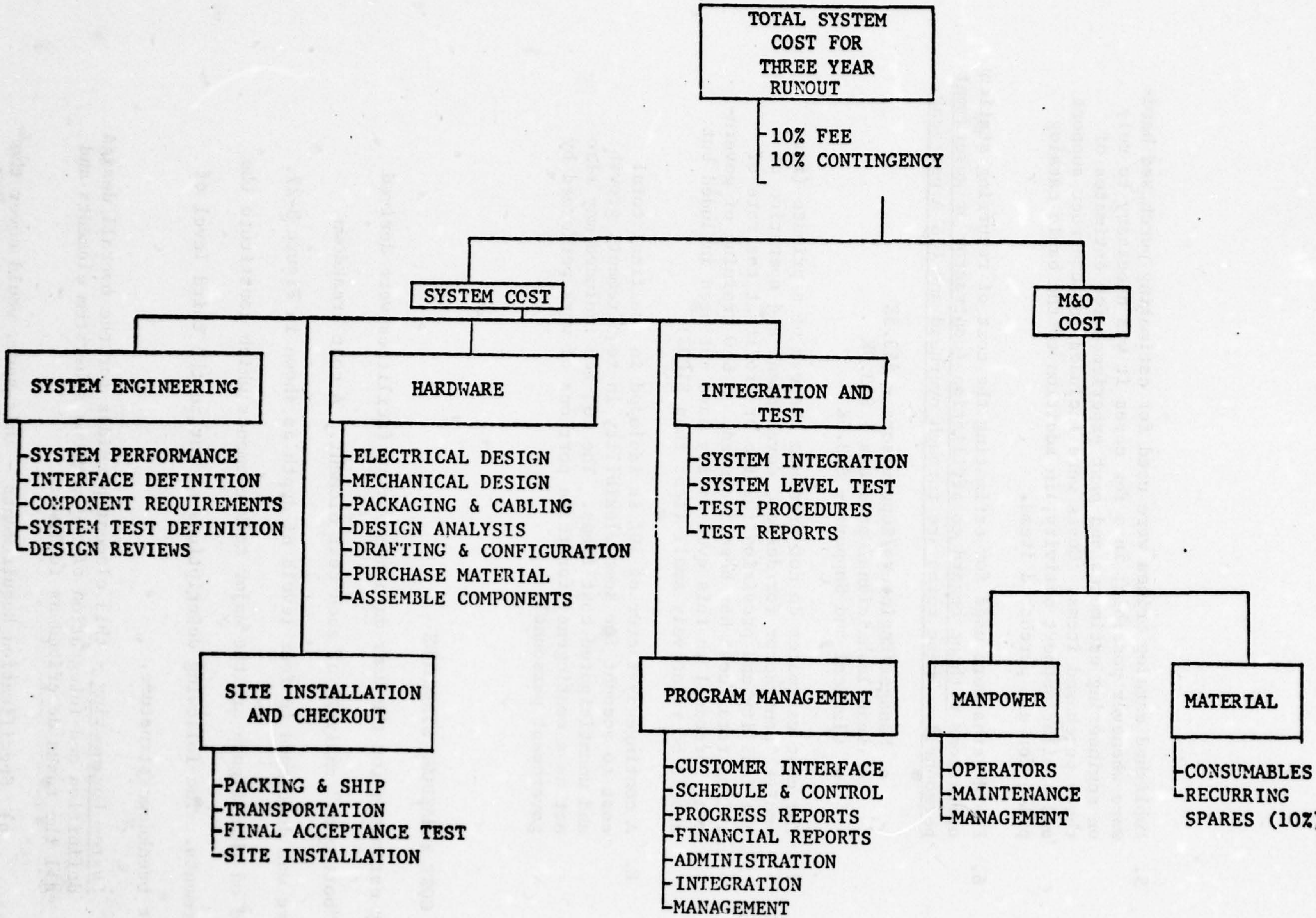

Figure 3-27. Cost Breakdown Structure

hardware.

Detail requirements for the decommutator. Prepare site preparation requirements for the hardware (e.g. microwave RF station)

b) Interface control document - Detail specification between the designed hardware and purchased hardware. Identify the specific formats for the input, output and interface points.

c) System documentation - Organize and maintain all system documentation, including drawings, system wire lists, system layout, etc.

d) Test & Integration procedure - Provide plan for system test & integration

e) Test & Integration support - Participate in system test & integration and provide all documentation

f) Inhouse & customer design reviews - Prepare one formal customer design review and provide, as required, in-house design reviews.

2. Equipment Design and Hardware Purchase - this element accumulates the cost of equipment design and manufacture. Purchase of material and bought components; the detailed electrical, mechanical, and packaging design; the necessary drafting and analysis support; and special test equipment design are all included in this cost element. Provisions for discounts or options are not included.

3. System Integration and Test - provides for the subsystem and system level tests of the integrated components. This is representative of the final test at the contractors facility prior to the shipping of equipment to the installation site.

4. Site Installation and Checkout - includes the actual shipment of equipment to the operational site as well as the performance of the final acceptance test on the system.

5. Program Management - provides for the overall management and control of the entire systems development acticity. Program management, adminsitrative, and clerical support are included as well as providing for reports and communication with the customer.

6. Maintenance and Operations - this cost element provides for the yearly recurring costs which begin following the final acceptance test. The principal cost here is that of the on-site field personnel responsible for operating and maintaining the system. Costs are also included for consummable material items as well as for replacement spare parts.

3.12.3 COST ESTIMATING PROCEDURE

The following paragraphs are intended to provide some understanding of the rules-of-thumb applied and the procedures followed. The initial engineering and manufacturing cost estimates were reviewed by three levels of management to ensure their consistency with recent experience.

For each of the systems, a parts list was developed with each part identified and costed. A percentage was added to the catalog price of purchased items for the contract support required to generate the documentation and provide the necessary controls to purchase all buy items. The cost of the materials required for the newly designed items was estimated based on experience with similar items developed for previous ground stations. The labor effort required to design and manufacturing effort to develop the source control drawings, procurement specifications, and to assemble the buy items, were also estimated based on experience gained with similar equipment.

Catalog prices were used for all purchased items. The labor effort required for the design, drafting, and manufacturing of new items was based on experience with similar equipment with appropriate complexity factors to adjust the total cost. Material costs were based on the number of electronic circuit boards, the number of parts per board, etc. The systems engineering task was costed based on a level of effort across the 15 month assumed program duration. No discounts were included in any of the hardware costing.

Ten (10) percent of the total material dollars were added to account for non-recurring spares. No specific analysis was conducted as to the detailed repair and replacement level nor were particular equipments identified for sparing. Rather, the 10% rule of thumb was applied across the board.

The System Integration and Test task was costed by estimating the number of people required to conduct and operate the particular subsystem equipment over the integration and test period.

The cost to pack and ship each subsystem was based on the number of equivalent single bay racks weighing approximately 800 pounds each. Each rack would be supported on a skid (100 pounds each) and the cost for shipping is approximately $20 per 100 pounds. The installation and acceptance test efforts were costed based on the estimated number of men required over the given installation and test periods.

Maintenance and operations were costed by estimating the number of man years/labor category required to perform the tasks. Typical corporate field rates were used.

3.12.4 COST ESTIMATES

Three year runout cost estimates are summarized in Table 3-9. They are shown in their breakdown structure format in Figures 3-29, 3-30 and 3-31.

3.12.5 HARDWARE MATRIX

Table 3-10 indicates the hardware complement used for each option. The prices do not include volume customer or GSA discounts. Also, no options above basic need have been included.

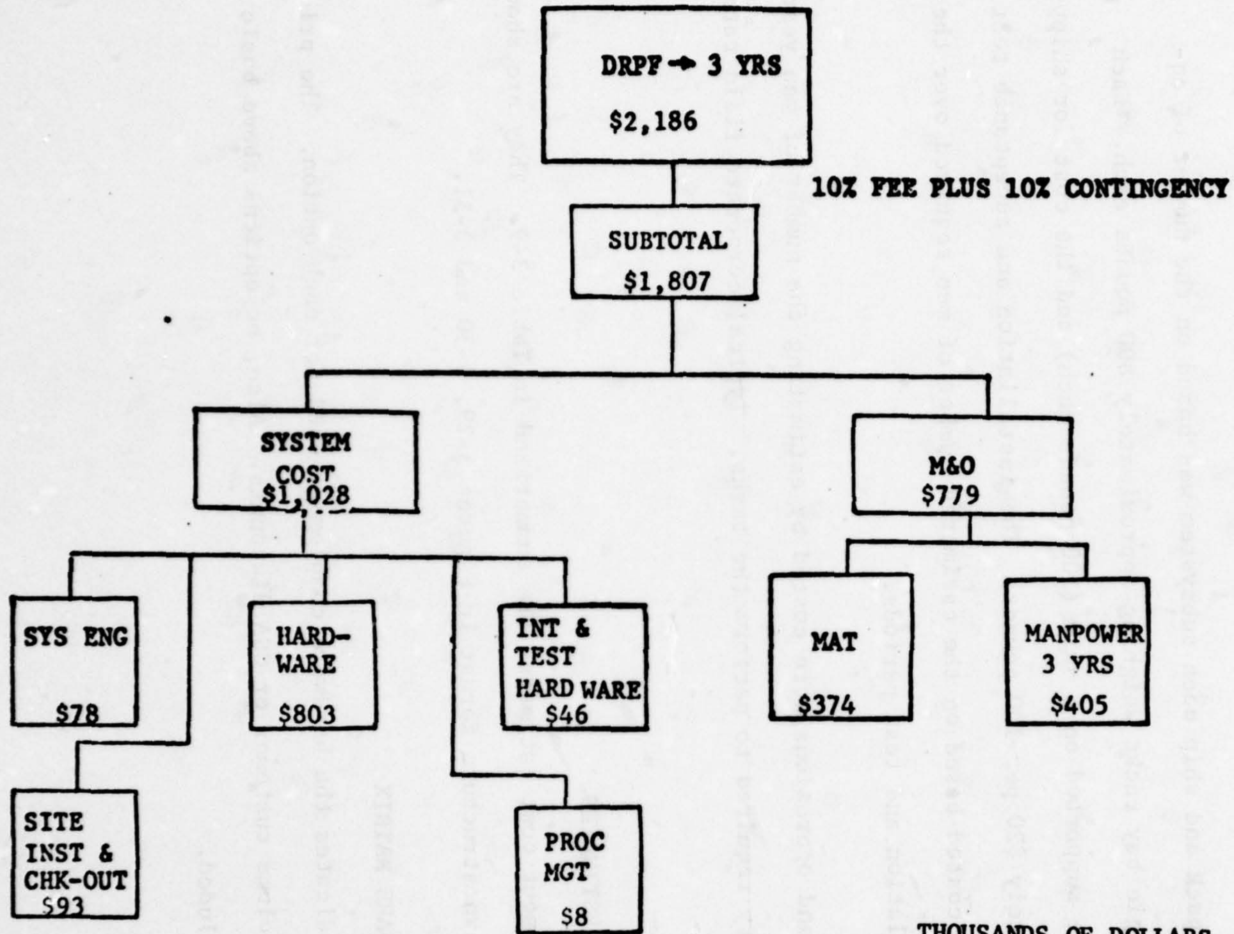

Figure 3-28. Cost Summary – Configuration D

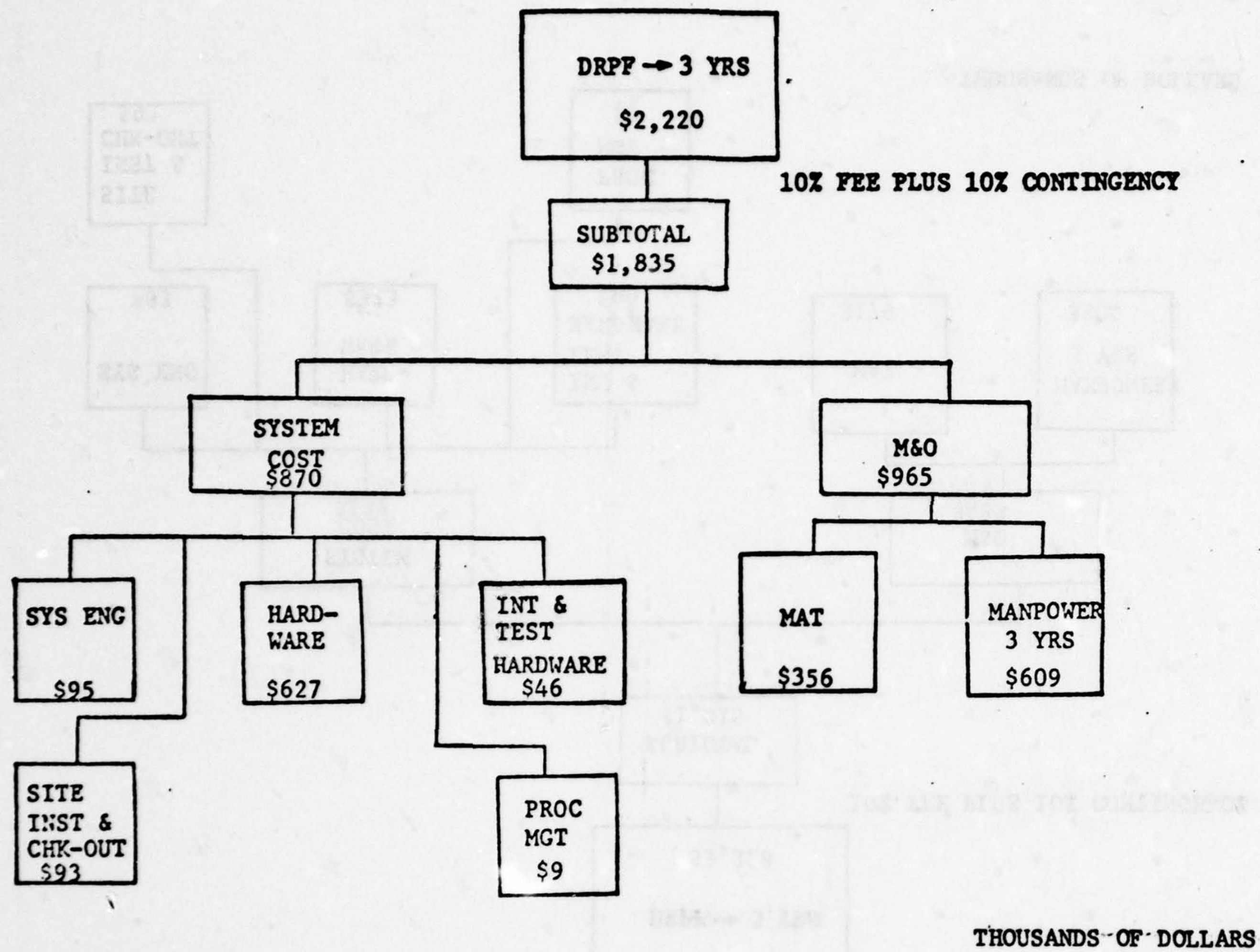

Figure 3-29. Cost Summary-Configuration E (1)

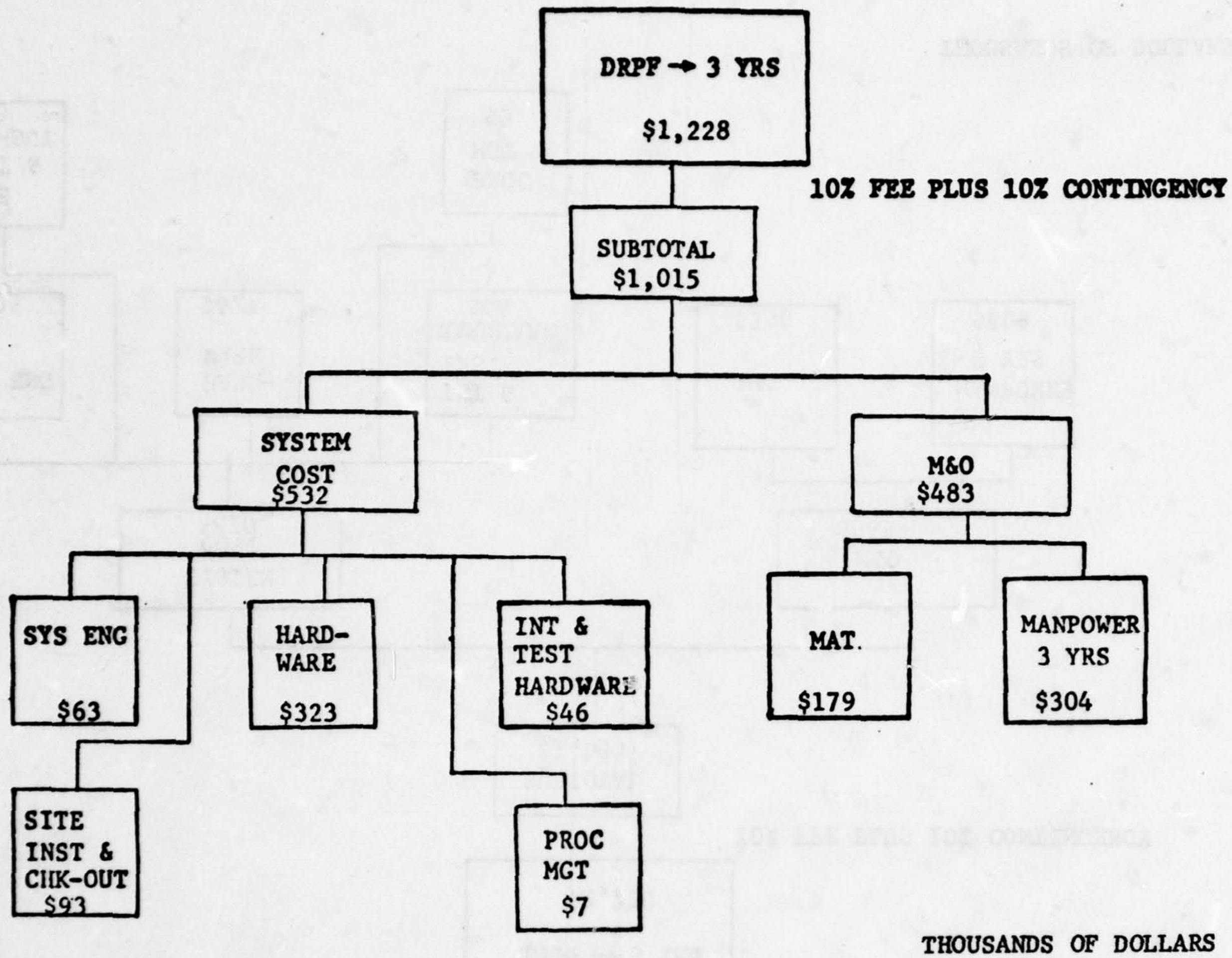

Figure 3-30. Cost Summary Configuration E (2)

Table 3-10 Hardware Matrix for each Option

	CONF./EQUIPMENT DESC.	QUANTITY	UNIT PRICE	COST INFO.
C	DOMSAT RECEIVE-ONLY REDUNDANT STATION	1	400K*	Letter from Western Union
O	BIT SYNCHRONIZER	1	80K	Vendor quote
N	HDDR	1	135K	Vendor quote
F.	DECOMMUTATOR	1	155K	GE est.
	DISPLAY UNIT	1	33K	Price list comtal
D.		TOTAL	$803K	
C	HDDR	2	135K	Vendor
O	DIGITAL MICROWAVE RECEIVE/TRANSMIT	4	38K	Raytheon Brochure
N	10 FT. REFLECTOR	4	1.7K	Price List
F.	100 FT. TOWER	1	10K	Eng-Estimate
	DECOMMUTATOR	1	155K	GE est.
E.	DISPLAY	1	33K	Price List Comtal
		TOTAL	$626.8K	
O				
P				
T.				
1				
C	HDDR	1	135K	Vendor quote
O	DECOMMUTATOR	1	155K	GE est.
N	DISPLAY	1	33K	Price List Comtal
F.		TOTAL	323K	
E.				
O				
P				
T.				
2				

SECTION 4

CONCLUSIONS

The significant conclusions derived during the study are summarized in the following paragraphs; references are included to the section of this document containing the detailed discussion.

- COE Data Requirements - average coverage estimates, applications techniques used in the projects and typical output data products per project were estimated for COE Civil Works activities (tabularized in Table 3-1). Only two areas require 48 hour data delivery: flood prediction/damage assessment and regulatory permit program. All others ranged from 7 to 30 days.

- Thematic Mapper Scene Requirements - were estimated for the COE Civil Works programs. Total scene requirements sum to 3056 scenes per year (tabularized in Table 3-2). However the bulk of these scenes are required by the Flood Prediction Program (1035 scenes) and the Regulatory Permit Program (152 scenes). Applying a cloud cover probability factor of 0.65 results in 772 scenes required in near realtime per year. The need for rapid data delivery is evident.

- Scene Requirements per Division - were also estimated (tabulated in Table 3-5). Non perishable (not required in realtime) data averages less than one scene per day per division. Peak realtime load is 2 or less scenes for selected divisions. Load varies with time of year and is maximum in the March through June time period during snowpack melt.

- Landsat-D System Access Points - Seven points in the Landsat-D System, described in Section 3.5, are available where data could be obtained for the COE. Each point has a different data delay and cost associated with it. Figures 3-1 and 3-2 show the Landsat-D system and the access points. A system configuration allowing data delivery to the COE Data Receiving and Processing Facility (assumed to be at Ft Belvoir, Va) was defined for each access point. Several (Configurations A, B and C described in Section 3.5) almost exactly duplicate NASA facilities, are high cost and provide no significant advantages, and were eliminated on that basis.

- Evaluation of Alternates - The various alternates were evaluated (Section 3.6) based on mission suitability (timeliness of data delivery and types of products), reliability and cost (initial equipment, maintenance and operations personnel). Ease of expansion to include other satellites was also assessed but no significant differences were apparent between approaches. Alternate E is the preferred approach since it is lowest cost and provides both raw and preprocessed data in a timely fashion. Raw data is available in 2.8-16.5 hours after acquisition by the satellite; preprocessed data is available 26.8-64.5 hours after acquisition.

- Relocation of the Data Management System - from Goddard Space Flight Center in Greenbelt Maryland to the EROS Data Center in Sioux Falls, S.D., (currently under consideration by the Government) was also examined (Section 3.8) for its impact on the COE system. Alternate D then becomes the preferred approach.

- Data Distribution to the Division - Two options were considered: 1) all processing at the DRPF with distribution of the results and 2) realtime processing locally at the division with non real-time processing at the DRPF. Option 1 was much lower cost (a few hundred thousand versus 1.5 million dollars) due primarily to the cost of wideband telephone lines for Option 2.

- System Costs - the initial installation plus 3 year operations costs for the COE system are $1,228,000 for Alternate E and $2,186,000 for Alternate D.

SECTION 5

RECOMMENDATIONS

5.1 RECOMMENDED BASELINE

Consistent with the results of this study it is recommended that Configuration E(2) be considered the baseline method of data access to the Landsat-D system given that the Data Management System remains at GSFC. It is the lowest cost, highest reliability system and meets the 48 hour data delivery requirement for COE-CW flood prediction and regulatory permit programs.

5.2 MONITOR DMS LOCATION DECISION

It is further recommended that the COE closely monitor the government decision process concerning the final location of the Landsat-D Data Management System. Should it be relocated to Sioux Falls, SD (or anywhere remote from the COE Data Reception and Processing Facility), then configuration D employing a DOMSAT link will be required at a substantial increase in cost.

5.3 FOLLOW ON STUDIES

Three key studies are recommended; both are aimed at defining the required capability of the COE Data Reception and Processing Facility. The studies are:

- District/Division Data Needs - This study is required to develop a detailed understanding of the actual Thematic Mapper data needs at the district and division levels in the early 1980's time frame. A very top level assessment was made as part of the current study to estimate the type of transmission media required between the DMS and the DRPF, and the DRPF and the districts/divisions. It was clear from this brief assessment that the data requirements for each district/division are different, varying as a function of:
  - Size of the district/division
  - Type of project
  - Time of year
  - Spectral band
  - Project repeatability
  - Timeliness of data
  - Applications techniques
  - Output data products/information

Since the type of processing required in the DRPF and the method of data transfer fromthe DRPF to the division/districts is highly dependent on these variables a detailed assessment is required to define and document the data requirements prior to a detailed design of the DRPF and the communications network.

- DRPF Processing Requirements and Hardware Definition - Once the district/division data requirements have been defined, a detailed design of the DRPF should be undertaken. This study will consolidate the district/division data requirements, develop DRPF processing options (including direct delivery of data to the districts/division from the EDC at Sioux Falls), assess current capabilities and their extension to Landsat-D, prepare alternate processing system designs, perform cost/timeliness trades, select a preferred approach, prepare detailed hardware/software designs and provide an accurate cost estimate. Some of the considerations in the design of a data processing/extraction system are summarized in Appendix B.

- Communication System Design - This study provides the detailed design of the communication network to distribute Landsat-D data from the DRPF to the districts/divisions. It will consider DOMSAT links, microwave, digital narrow and wideband phone links, shipment by common carrier, mail, voice and courier alternates for distribution of specific types and quantities of data. It will assess current methods of data transfer and their application or extension to Landsat-D. Specific methods will be defined for each district division and cost estimates prepared on both a division/district and system wide basis. This study compliments the DRPF Processing Requirements and Hardware Definition Study, should be done in parallel with or as part of it, and completes the detailed design of the COE Landsat-D data distribution system for the early 1980's.

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APPENDIX A

DATA TRANSFER METHODS AND COSTS

A.1 DOMESTIC SATELLITE DATA TRANSFER

Several DOMSAT service supplier organizations exist, which lease satellite-based transponders and lease or sell earth stations for receiving and/or transmitting the data. Current estimated costs were obtained by telephone conversations with Western Union, but are representative of all the carriers.

Typically, DOMSAT transponders have bandwidths of 34 or 36 MHz. Thus with QPSK data, one full transponder will be needed for the 42 Mbps data link. Lease of a transponder with full period protection* is currently $142,000/month or $1.7 million/year. A possible mode of data transfer is to accummulate a half day's TM scenes, and to transmit for one (1) hour every 12 hours. For this mode, a lease of transponder time for two (2) hours each day would suffice. Such time slots are not currently available, but probably will be available by launch time. We estimate this cost to be slightly more than 1/12 of a full day lease and assign it the number $200K per year.

The lease of a fully redundant earth station, including maintenance and installation fee, varies from $170 K/year to $270 K/year, depending on the type of equipment and length of contract. A fully redundant "transmit only" earth station can be purchased and installed for about $400 K.

A complete DOMSAT data link for a playback rate of 42 Mbps will require one "transmit only" and one "receive only" earth station and either one transponder or a part time transponder as discussed above. The cost is distance independent. Total cost per year, with initial costs amortized over a three year period are as follows:

	FULL TRANSPONDER LEASE	1/12 TIME LEASE
All equipment leased	$2.24 M/year	$0.75 M/year
Earth stations purchased	$1.93 M/year	$0.44 M/year

These costs do not include facility and operational costs; these are discussed in Section 3.6.3.

The advantages of the DOMSAT link, for long distances, are in the high data rate, low error rate, and absence of distance related cost penalties.

A.2 MICROWAVE DATA TRANSFER

The microwave data link can utilize 30 synchronous 1.5 Mbps channels, to achieve a data rate of up to 45 Mbps, and can thus accommodate the 42 Mbps rate of playback of thematic mapper data, mentioned in connection with satellite transmission.

Among others, Raytheon Data Systems offers a complete line of digital microwave transmission equipment. An RDS-60 Digital Microwave Radio, at $38K, and a 10-foot tower with dish antenna, at $3.5K, at each end of the link provides for protected reception and transmission at the data rate mentioned. Maintenance must be provided for each station at an estimated cost per year of $5K. For each 30 miles of separation, a repeater station must be configured with 2 RDS-60's ($76K) and a 100-foot tower with antenna ($10K). Maintenance for each repeater station is estimated at $10K per year.

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*Protected: A replacement transponder is designated and service will not be pre-empted.

An algorithm for this distance dependent cost is thus:

$$\text{Cost per year} = 1/3\left\{83K + 86K\left[\frac{M-1}{30}\right]\right\} + 10K + 10K\left[\frac{M-1}{30}\right]$$

$$\approx 38K\left\{1 + \left[\frac{M-1}{30}\right]\right\}$$

in which M is the distance in miles, and square brackets imply truncation.

A table is given below:

DISTANCE (MILES)	COST/YEAR (K DOLLARS)
30	38
60	76
90	114
210	266
510	646
2100	2660

The advantages of microwave data transfer are high data rate and relatively low cost for short distances. The disadvantages for long distances are increased costs and increased vulnerability to component failure.

A.3 WIDEBAND TELEPHONE DATA TRANSFERS

A wideband data channel, operating at 1.5 Mbps, is currently available from the Telephone Company for digital data transmission. Costs for this service are distance dependent and are:

1.	Line Service	\$768/year/miles - First 200 miles \$600/year/miles - Next 300 miles \$480/year/miles - > 500 miles
2.	Access Lines/Modems	\$700/location

Other variants exist, but are not described here, since the data rate is a more severe constraint than cost.

The total amount of data that must be transmitted per day from White Sands is 100 thematic mapper scenes.

$$84 \text{ Mbps} \times 25 \text{ sec./scene} \times 100 \text{ scenes} = 2.1 \times 10^5 \text{ Mb}$$

This implies a minimum data rate of

$$2.1 \times 10^5 \text{ Mb}/86400 \text{ sec./day} = 2.4 \text{ Mbps}$$

Thus, the wideband telephone line, with a continuous 24 hour use, does not meet the transfer of the daily data volume requirement from White Sands to the DRPF. The possibility exists to pre-edit only those passes or scenes of interest to the COE, but this will be difficult to accomplish and has not been included in this study as a viable option.

A.4 DATA SHIPMENT BY COMMON CARRIER

With time delays of up to two (2) days or more, shipment by common carriers offer a cost-competitive alternative to the foregoing. Costs are relatively independent of distance for domestic transfer, but are linear in weight. An HDDT, weighing 50 lbs., holds 20 scenes of raw or semi-processed data from NASA or Sioux Falls. Using a weight of 2.5 lb./scene, we can develop the following table for the years' 36,500 scenes:

Carrier	25 lb.	Cost per Year	Delay
Air Freight	$30	$0.1095 M	1/2 - 2 days
Surface Mail	$18	$0.0657 M	2 days +

There is, of course, an additional cost for delivery and pickup at the airport, which is shown in the next paragraph to be in the neighborhood of $100 per mile, per year. Also, all other transfer methods have operating costs associated with them, which will be treated elsewhere. For the common carrier, these costs are included in the above figures.

A.5 DATA TRANSFER BY COURIER

For very small distances, and data transfer once or twice a day, such as is applicable to Option E (DMS at GSFC), a dedicated courier service provides an inexpensive link with a DRPF in the Washington area. Raw data, accummulated on an HDDT(s) for the previous 12 or 24 hours, and CCT's containing partially processed data for some earlier period, can be transported to the DRPF by a courier service (government or commercial). Using the figure of $0.17 per mile and X miles per round trip, the cost, per year, for one (1) and two (2) round trips could cost:

One (1) trip = $62.05 X

Two (2) trips = $124.1 X

For example, one (1) round trip from GSFC, to a DRPF located at Fort Belvoir, is approximately 120 miles, leading to yearly costs of about $7500 for a single transfer, per day, and $15,000 for twice-daily transfer. Labor costs are not included, and a contracted service could be considerably more.

A.6 COST COMPARISON FOR DATA TRANSFER METHODS

The relative economy of the various data transfer methods can be assessed by plotting cost as a function of distance as in Figure A-1.

The DOMSAT link appropriate to alternatives A, B or C with real time transmission has been costed for fulltime lease of a transponder and the lease of two earth stations. Maintenance of the earth stations is not included, but represents a small perturbation of the total. This is the most costly method of data transfer for distances less than about 1700 miles.

Alternatives A, B, C and G, with transmission once or twice a day, would require only 2 hours per day of transponder time, and the yearly cost drops considerably. Alternatives D and F require a "receive only" earth station at the DRPF. Again, maintenance costs will perturb this figure by a few percent, but it is clearly less costly to utilize the existing NASA transmission system to get the data to the vicinity of the DRPF.

Air mail and surface mail only make sense in the context of large distances, large quantity of data, and are clearly the least expensive method of transferring HDDT's from the vicinity of White Sands or Sioux Falls to a DRPF at Fort Belvoir. However, with airport delivery and pick-up, fairly large time delays may be incurred.

The microwave link, with a distance dependent cost, is clearly cost-effective for small distances, less than several hundred miles This method can be used effectively with Option E (DMS at GSFC), provided that continuous near-real-time transmission of raw data is available at DMS and the same is required by the Corps. For transmission, once or twice daily, a dedicated courier service is far less expensive.

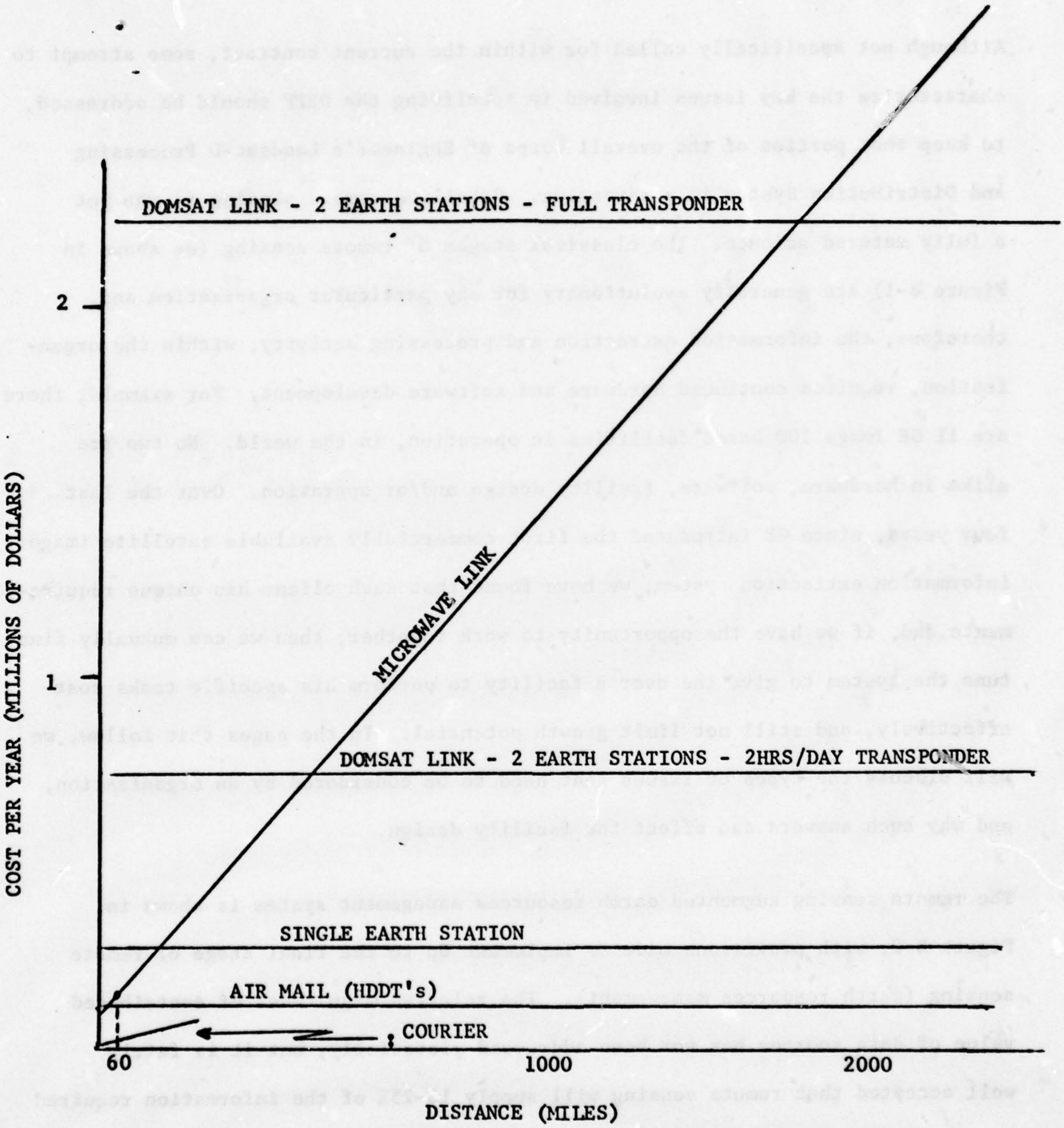


Figure A-1. Yearly Cost vs. Distance for Various Data Transfer Methods to the DRPF

APPENDIX B

INFORMATION EXTRACTION SYSTEM CONSIDERATIONS

Although not specifically called for within the current contract, some attempt to characterize the key issues involved in specifying the DRPF should be addressed, to keep that portion of the overall Corps of Engineer's Landsat-D Processing and Distribution System in perspective. Satellite remote sensing is not yet a fully matured science. The classical stages of remote sensing (as shown in Figure B-1) are generally evolutionary for any particular organization and, therefore, the information extraction and processing activity, within the organization, requires continued hardware and software development. For example, there are 11 GE Image 100 based facilities in operation, in the world. No two are alike in hardware, software, facility design and/or operation. Over the last four years, since GE introduced the first commercially available satellite image information extraction system, we have found that each client has unique requirements and, if we have the opportunity to work together, then we can mutually fine-tune the system to give the user a facility to perform his specific tasks cost-effectively, and still not limit growth potential. In the pages that follow, we will discuss the types of issues that need to be considered by an organization, and why such answers can affect the facility design.

The remote sensing augmented earth resources management system is shown in Figure B-2, with provisions made to implement up to the final stage of remote sensing (earth resources management). The relative magnitudes of contributed value of data sources has not been addressed pictorially, but it is fairly well accepted that remote sensing will supply 10-25% of the information required in any management situation. The remainder of the data required obtained by conventional techniques is illustrated in Figure B-2 as "ancillary data".

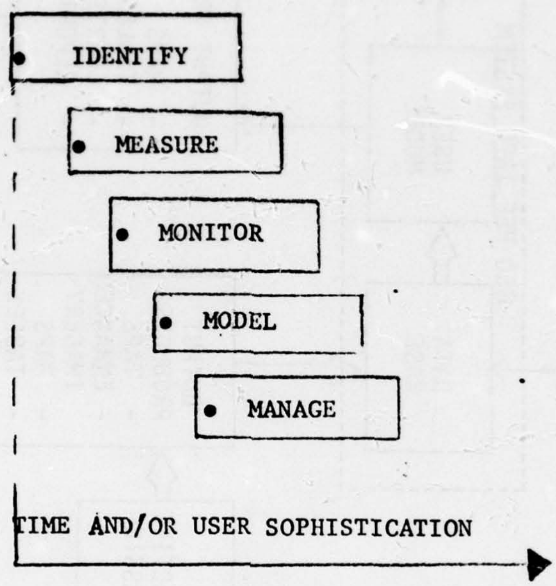


Figure B-1. STAGES OF REMOTE SENSING

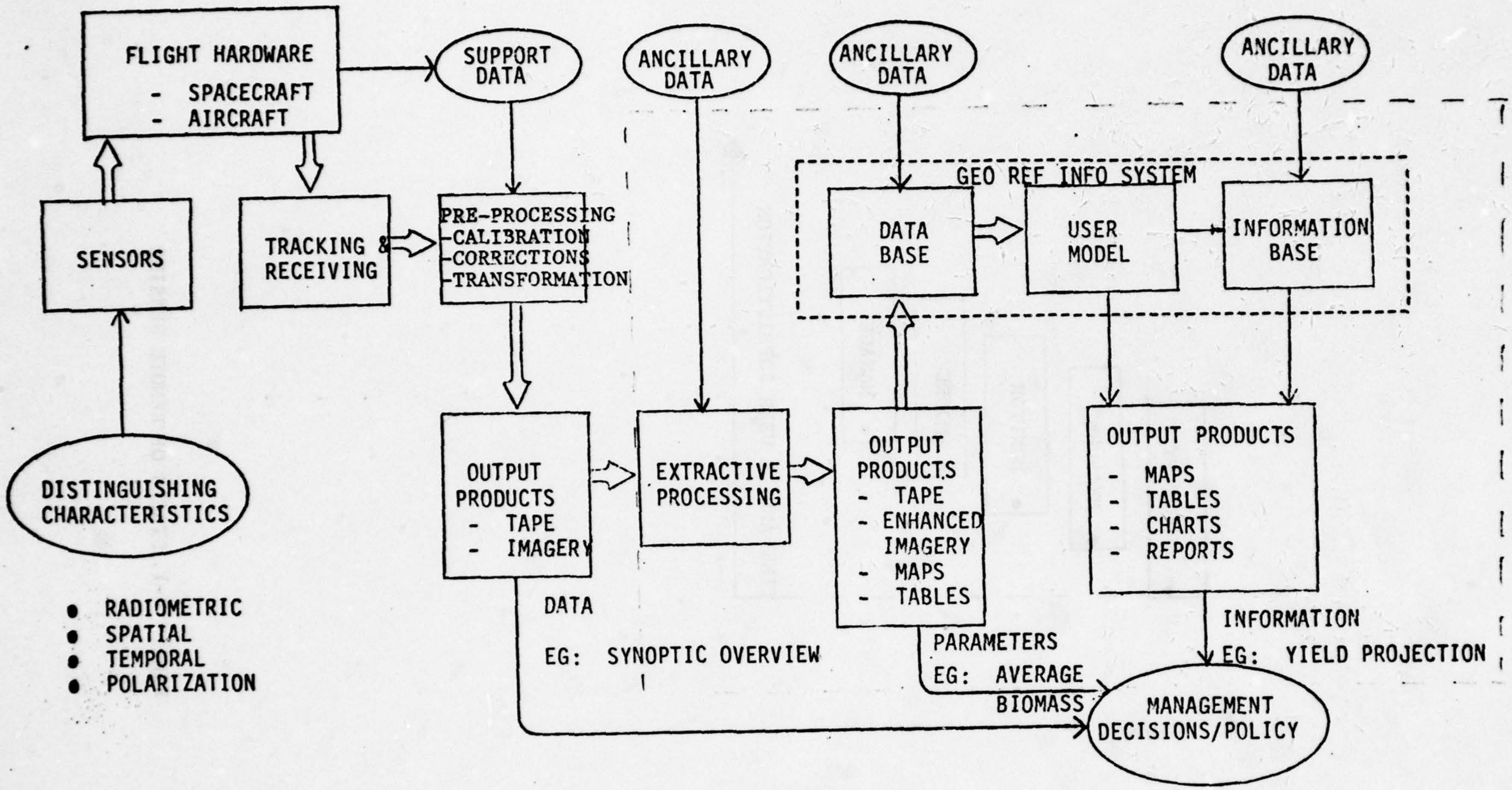


Fig B-2 REMOTE SENSING AUGMENTED
EARTH RESOURCES MANAGEMENT INFORMATION SYSTEM

Figure B-3 indicates the functions of a "Generic Information Extraction System" in more detail, and Figure B-4 expands the concept even farther, to indicate most of the software capabilities that the generic system should possess. Figure B-5 indicates one of many possible distributed information extraction system configurations. Information Extraction Systems are relatively complex, even in the abstract, and a number of facets need detailed attention, prior to generating system requirements. Ideally, the system designer(s) and the users meet in open discussion of expected near-term and long-range utilization of the facility, impacts of requirements imposed, and programmatic constraints on the system.

Many existing remote sensing image processing facilities were not planned but instead they evolved. As a result they are a mixture of hardware and software that are inefficient to use by current state-of-the-art standards. The present danger of such systems are that they have a predilection toward self-preservation: analysts learn to work around or live with the deficiencies, correction of system problems become extremely complex and generally never occur; retrofitted hardware (big disks, array processors) may be used to solve a major problem but are not integrated into the operation of the total system. General Electric has found that it is advisable when developing a new systems concept to base it on what may be required within 4 or 5 years in the future and then "skinny down" to what is currently needed. This permits the selection of the right CPU, operating system and design philosophy to carry the system into the most probable future. If budget constraints require a non optimized solution, at least the decision can be a conscious one.

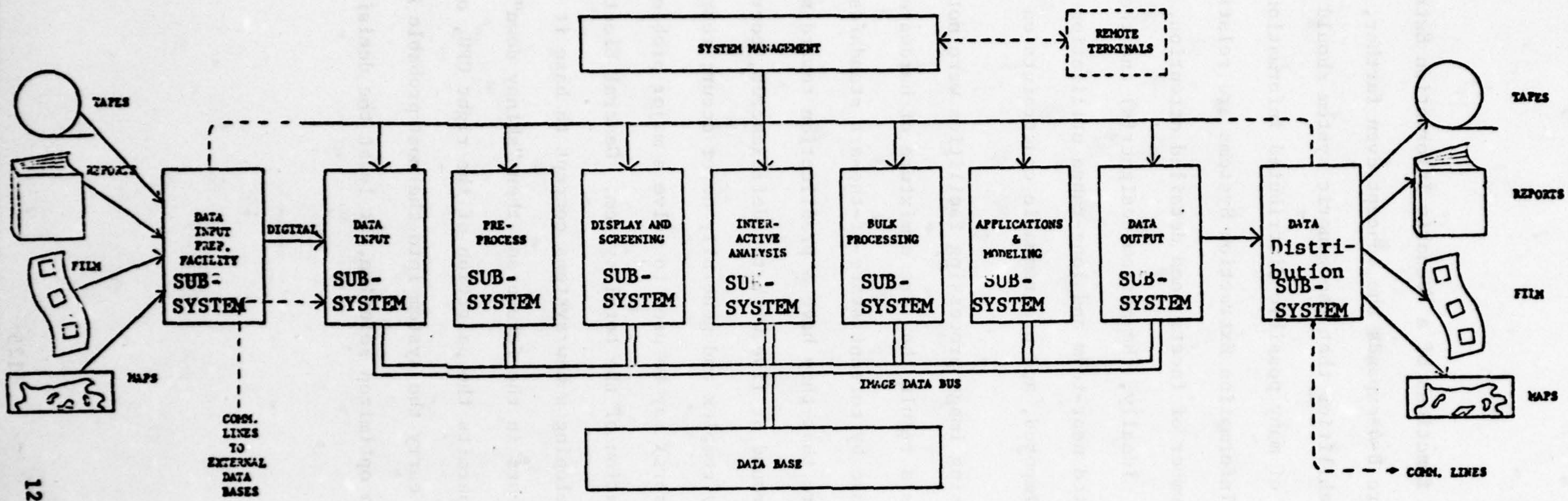
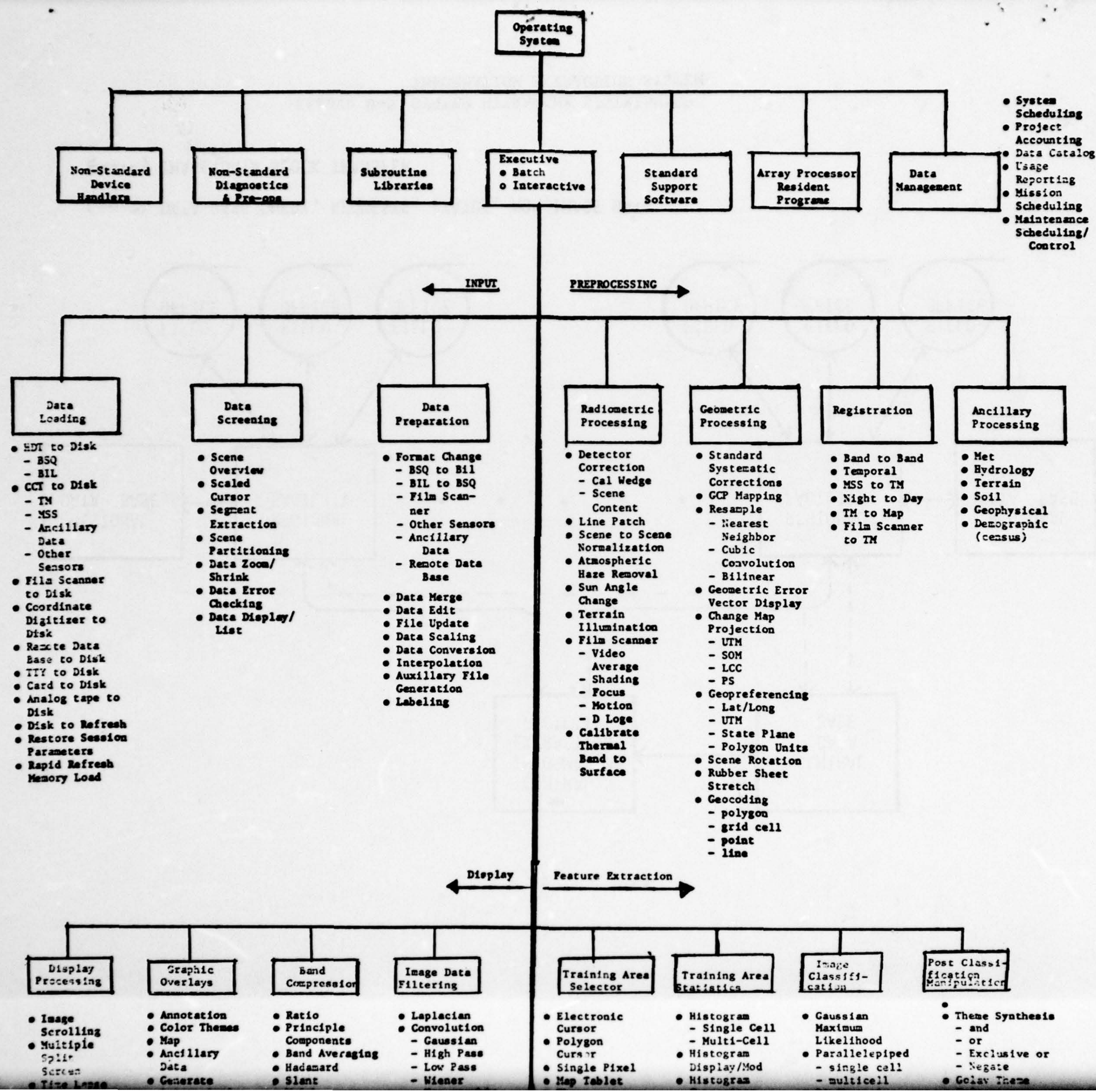


FIGURE B-3 Generic Information Extraction System



Operating System
Non-Standard Device Handlers
Non-Standard Diagnostics & Pre-ops
Subroutine Libraries
Executive
• Batch
o Interactive
Standard Support Software
Array Processor Resident Programs
Data Management
• System Scheduling
• Project Accounting
• Data Catalog
• Usage Reporting
• Mission Scheduling
• Maintenance Scheduling/ Control
INPUT
PREPROCESSING
Data Loading
• EDT to Disk
- BSQ
- BIL
• CCT to Disk
- TM
- MSS
- Ancillary Data
- Other Sensors
• Film Scanner to Disk
• Coordinate Digitizer to Disk
• Remote Data Base to Disk
• TTY to Disk
• Card to Disk
• Analog tape to Disk
• Disk to Refresh
• Restore Session Parameters
• Rapid Refresh Memory Load
Data Screening
• Scene Overview
• Scaled Cursor
• Segment Extraction
• Scene Partitioning
• Data Zoom/ Shrink
• Data Error Checking
• Data Display/ List
Data Preparation
• Format Change
- BSQ to Bil
- BIL to BSQ
- Film Scanner
- Other Sensors
- Ancillary Data
- Remote Data Base
• Data Merge
• Data Edit
• File Update
• Data Scaling
• Data Conversion
• Interpolation
• Auxillary File Generation
• Labeling
Radiometric Processing
• Detector Correction
- Cal Wedge
- Scene Content
• Line Patch
• Scene to Scene Normalization
• Atmospheric Haze Removal
• Sun Angle Change
• Terrain Illumination
• Film Scanner
- Video Average
- Shading
- Focus
- Motion
- D Loge
• Calibrate Thermal Band to Surface
Geometric Processing
• Standard Systematic Corrections
• GCP Mapping
• Resample
- Nearest Neighbor
- Cubic Convolution
- Bilinear
• Geometric Error Vector Display
• Change Map Projection
- UTM
- SOM
- LCC
- PS
• Geopreferencing
- Lat/Long
- UTM
- State Plane
- Polygon Units
• Scene Rotation
• Rubber Sheet Stretch
• Geocoding
- polygon
- grid cell
- point
- line
Registration
• Band to Band
• Temporal
• MSS to TM
• Night to Day
• TM to Map
• Film Scanner to TM
Ancillary Processing
• Met
• Hydrology
• Terrain
• Soil
• Geophysical
• Demographic (census)
Display
Feature Extraction
Display Processing
• Image Scrolling
• Multiple Split Screen
Graphic Overlays
• Annotation
• Color Themes
• Map
• Ancillary Data
• Generate
Band Compression
• Ratio
• Principle Components
• Band Averaging
• Hadamard
• Slant
Image Data Filtering
• Laplacian
• Convolution
- Gaussian
- High Pass
- Low Pass
- Wiener
Training Area Selector
• Electronic Cursor
• Polygon Cursor
• Single Pixel
• Map Tablet
Training Area Statistics
• Histogram
- Single Cell
- Multi-Cell
• Histogram Display/Mod
• Histogram
Image Classification
• Gaussian Maximum Likelihood
• Parallelepiped
- single cell
- multicell
Post Classification Manipulation
• Theme Synthesis
- and
- or
- Exclusive or
- Negate
• Golay Theme

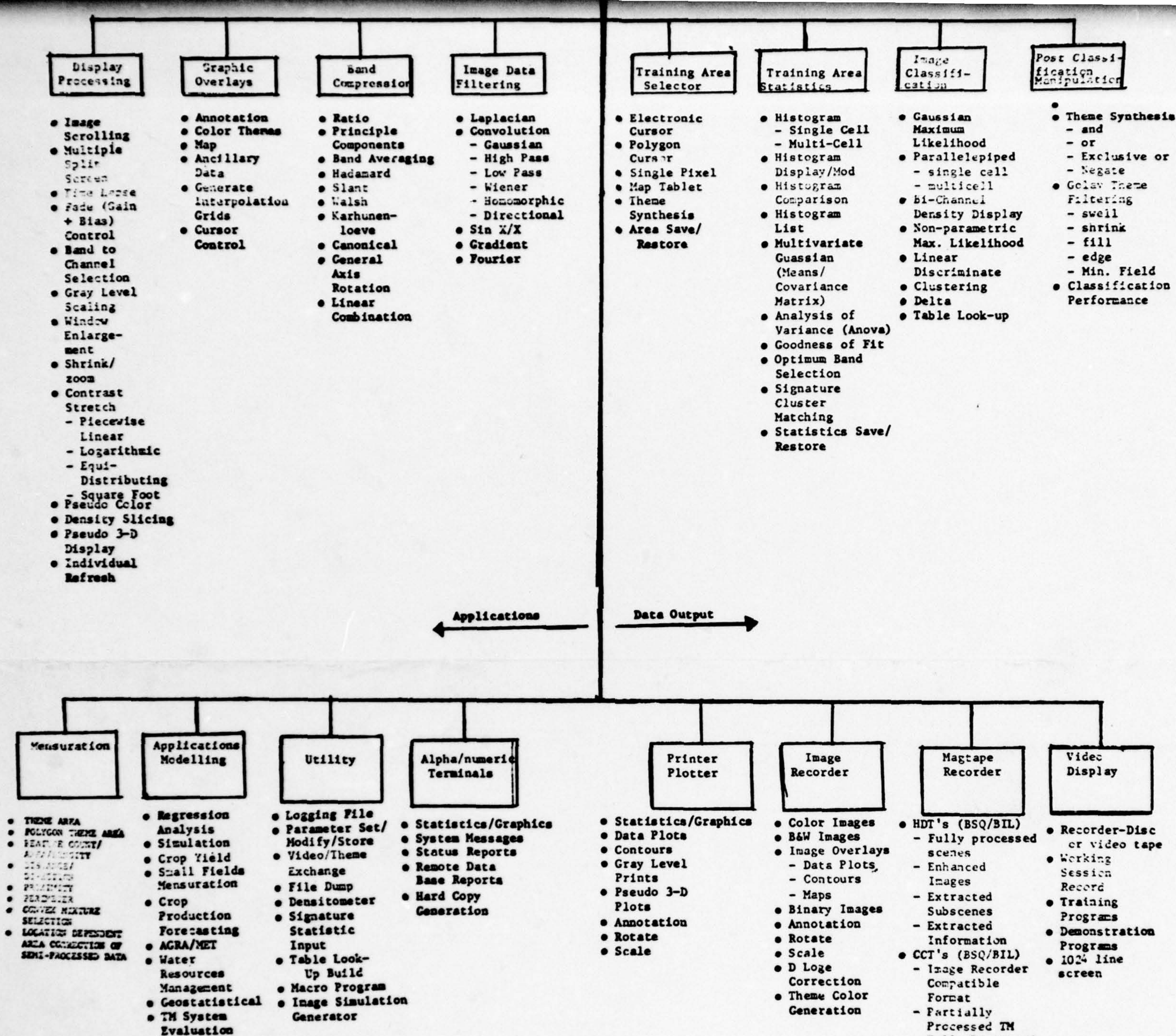


Figure B-4 COMPUTER CAPABILITIES OF THE EARTH OBSERVATION INFORMATION EXTRACTION SYSTEM (EOIES)

A functional organization of the software menu required to support a generic Integrated Earth Resources Data Correction/Extraction/Information Management System

2

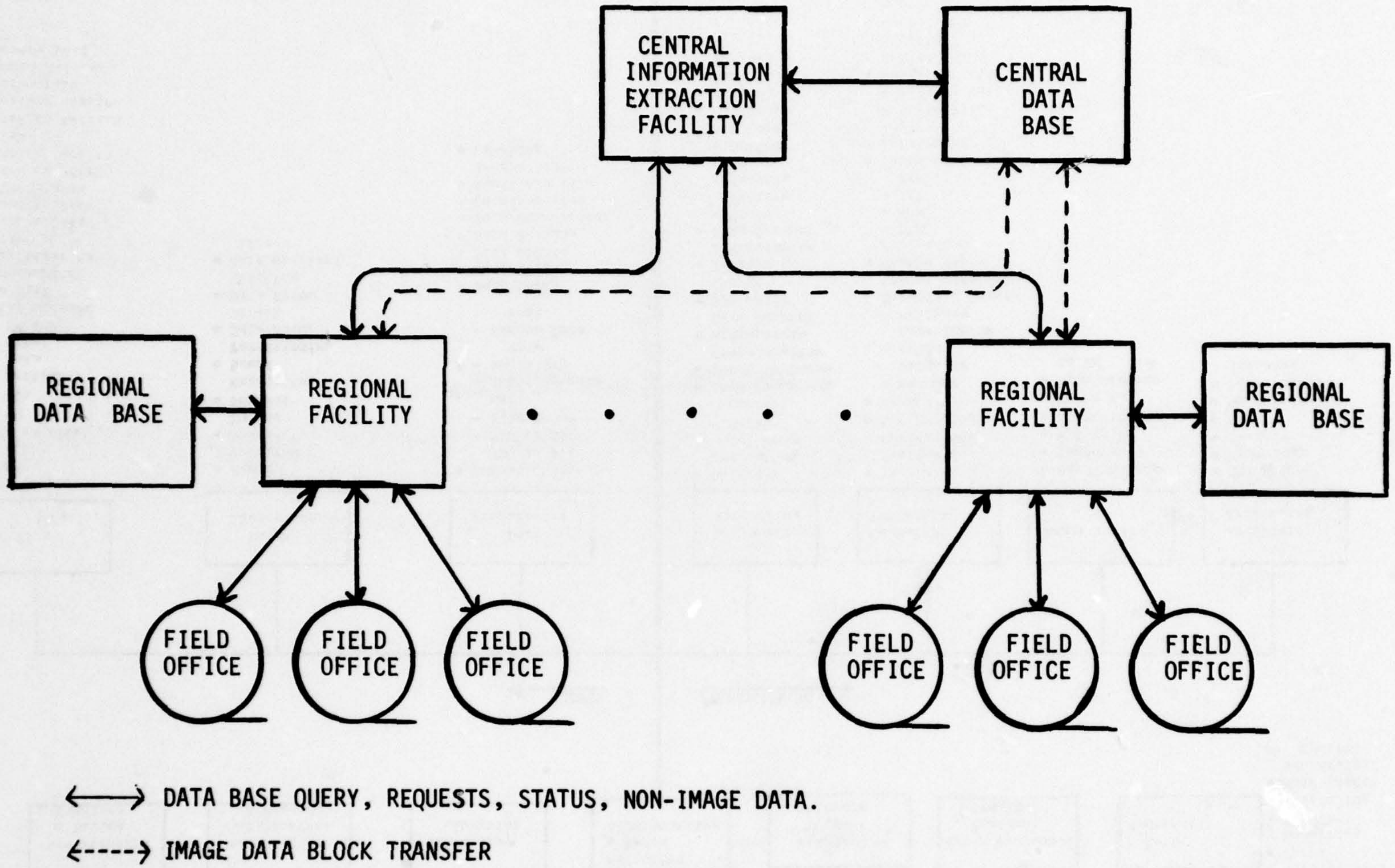


Figure B-5 SYSTEM HIERARCHY DISTRIBUTED INFORMATION EXTRACTION SYSTEM

Instead of the standard exhaustive list of questions that require answers for a total systems design, we've attempted to organize the parameters into logical groupings (Table B-1) that provide some insight into why such topics need to be addressed prior to the conceptual design being initiated. The abstract parameters that form the basis of the philosophy of the facility design are functions of the quantitative parameters listed. The functional relationships, however, can be quite esoteric, complex and interactive.

At a minimum, the parameters listed on the right of the equality signs in Table B-1 need to be addressed very early to aid in the conceptual design of the facility. Too many times, these topics are left to the hardware designer to make fairly irrevocable decisions without benefit or insight of long-range objectives and user desires.

To assure that the DRPF design will effectively meet the needs of the government for a system to conduct research and extract information from a wide variety of available data sources, an analysis should be made of representative applications development projects and their needs. The resulting requirements can then be used to refine the DRPF performance and hardware specification. Typically, several of the larger projects are defined in more detail to establish facility boundaries. Figure B-6 is a process flow developed for extracting remote sensing data and merging with ancillary data sources to provide useful output information for the resources manager. The number of functions through which the data is passed (including interactive iterations) is generally of the same magnitude for other disciplines. If the system is designed to process at interactive rates, most of the functions can be performed at one session. The alternative is to perform the functions in a batch mode; this invariably forces the analyst to take short-cuts or lower his acceptability standards.

Table B-1. Factors Affecting the Facility Design

1) Facility Utilization Philosophy = f^{-1} (number of interactive consoles, amount of program development, image data base management required, management information system required, facility redundancy/availability, distributed processing philosophy, quick look requirements, on-line storage, operating personnel required)

2) Distributed Processing Philosophy = f (organizational element autonomy, location of expertise, existing hardware, software capabilities, existing communications network, data media requirements)

3) Degree of interactiveness desired/required = f (facility/thruput, data perishability, sophistication of analyst(s), number and type of functions to be performed, multi-source data sets to be used, accuracy of extracted information required)

4) Facility Thruput = f (number of full scenes required, processing required prior to segment selection, areal extent of test sites, number of bands, ancillary data source processing requirements, temporal processing required, facility utilization philosophy, perishability of the data, typical processing flow scenarios per project)

5) Hardware Vendor Selection = f (facility utilization, distributed processing parameters, degree of interactiveness, facility thruputs, delivery schedule, vendor support, past experience, growth scenario, output product media, input media, etc.)

NOTE: f (...) indicates that a functional relationship exists
f^{-1}(...) indicates that the parameters enclosed are a function of the parameter on the left side of the equality sign.

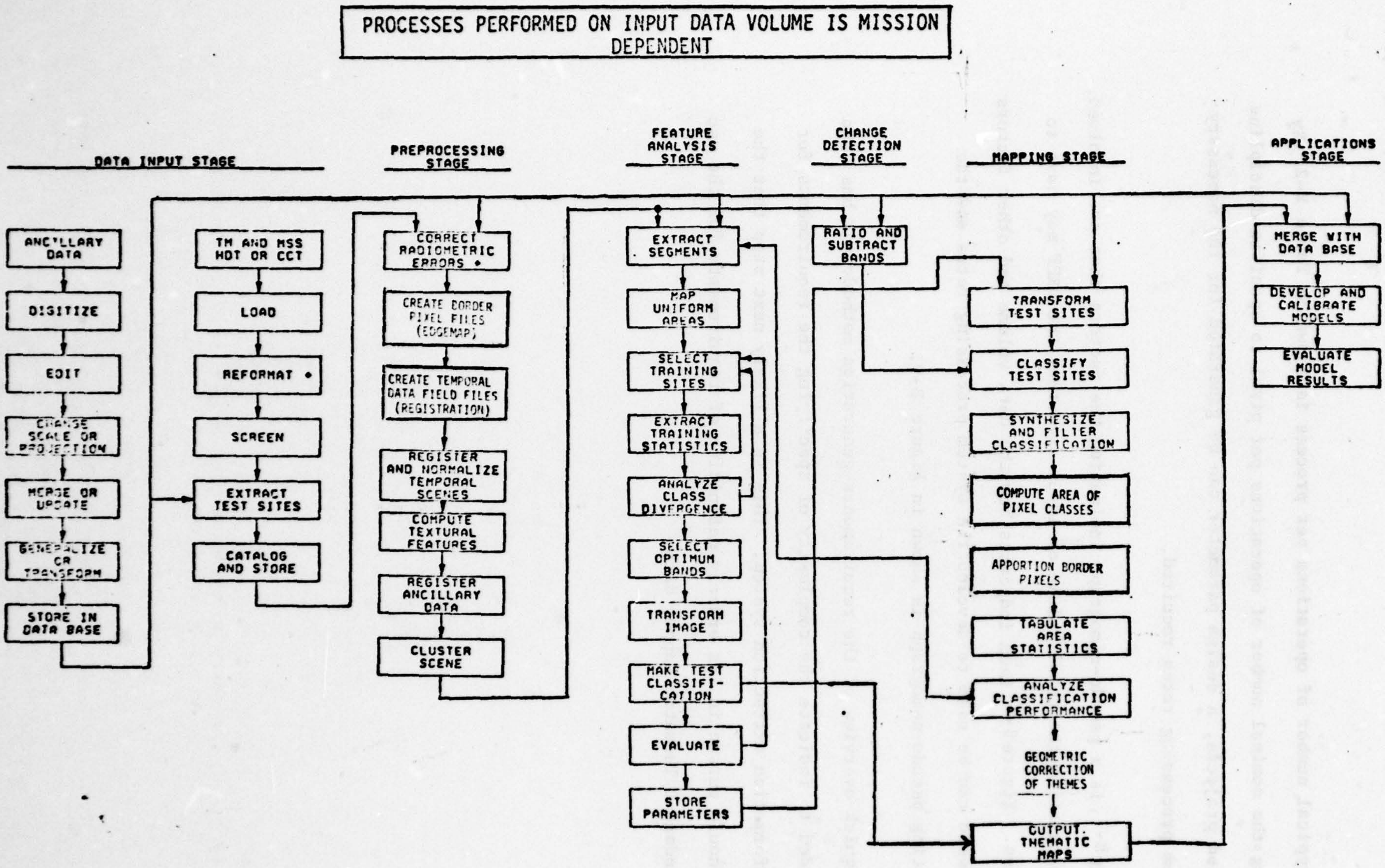


FIGURE B-6 LAND USE MAPPING/LAND USE CHANGE

*FUNCTIONS DEPENDENT ON INPUT FORMAT

The typical number of operations per process is shown in Table B-2. By adding the nominal number of operations per pixel to specific discipline related projects, a design parameter can be generated for the necessary system processing rates required.

Figure B-7 is a pseudo-nomograph indicating the factors that are involved in calculating the total volume of input data that the DRPF may have to process. Figure B-8 then indicates how the data volume and other factors discussed can be used to develop the system processing rates and the resulting pseudo-nomograph is shown in Figure B-9.

This quick overview of the requirements generation methodology has been included to indicate the complexity of specifying the requirements for an information extraction system. This is a likely next step that the COE should pursue in its orderly definition of requirements for the use of Landsat-D Thematic Mapper data.

Table B-2. Typical Number of Operations Per Process

PROCESS		TOTAL OPERATIONS per pixel per channel	
IMAGE CORRECTION			
RADIOMETRIC		1	
GEOMETRIC (CUBIC CONVOLUTION)		18	
IMAGE ANALYSIS			
CONTRAST STRETCH		1	
SPECTRAL TRANSFORMS (5x5)		9	
SPATIAL TRANSFORMS (4x4)		28	
RATIOING		22	A ≈ 20 NOM
NORMALIZATION		25	
DATA LOADING/SCREENING		2	
AFFINE TRANSFORM (NEAREST NEIGHBOR)		7	
NON-PARAMETRIC MAX LIKELIHOOD		1	
PARAMETRIC (GAUSSIAN) MAX LIKELIHOOD	5 CHANNELS 16 CLASSES	816	÷5= B ≈ 160 NOM
CLUSTERING (5 PASSES)		800	
MODELING			
MISSION DEPENDENT		50-500	C ≈ 200 NOM

*MULTIPLES, ADDS, TABLE LOOK UPS

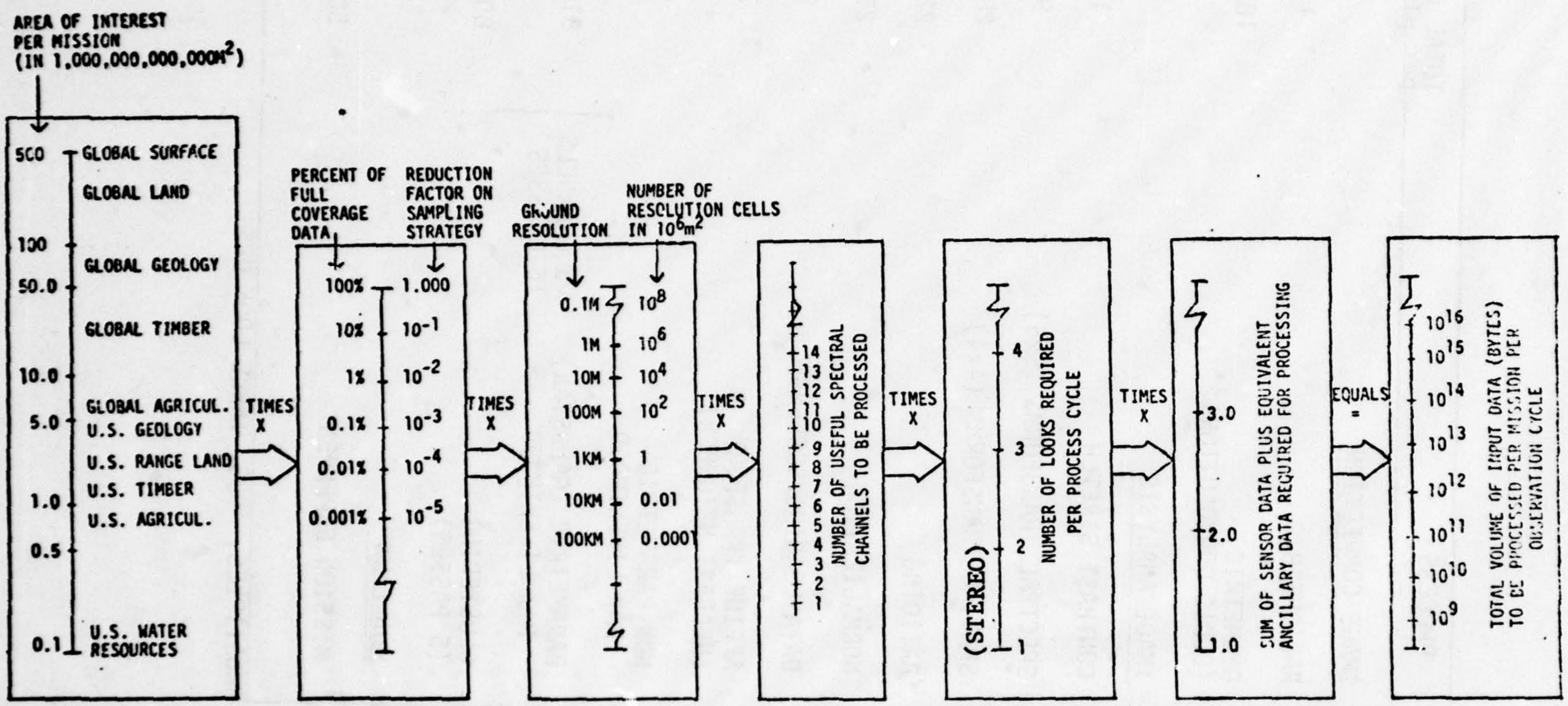


FIGURE B-7 FACTORS AND RANGE OF VALUES AFFECTING THE DATA VOLUME TO BE PROCESSED WITHIN THE INFORMATION PROCESSING SYSTEM

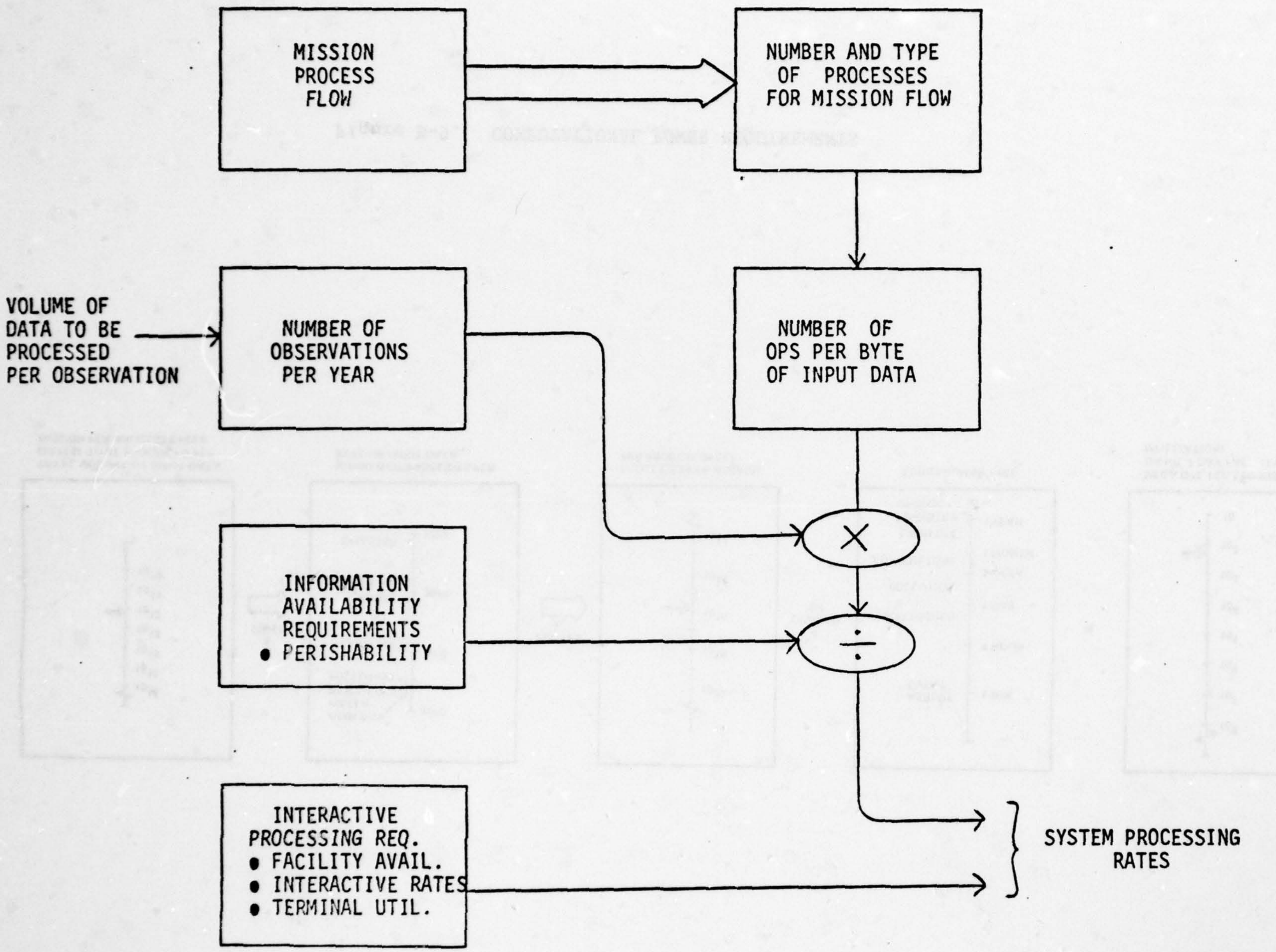


FIGURE B-8 SYSTEM PROCESSING VOLUME AND RATES

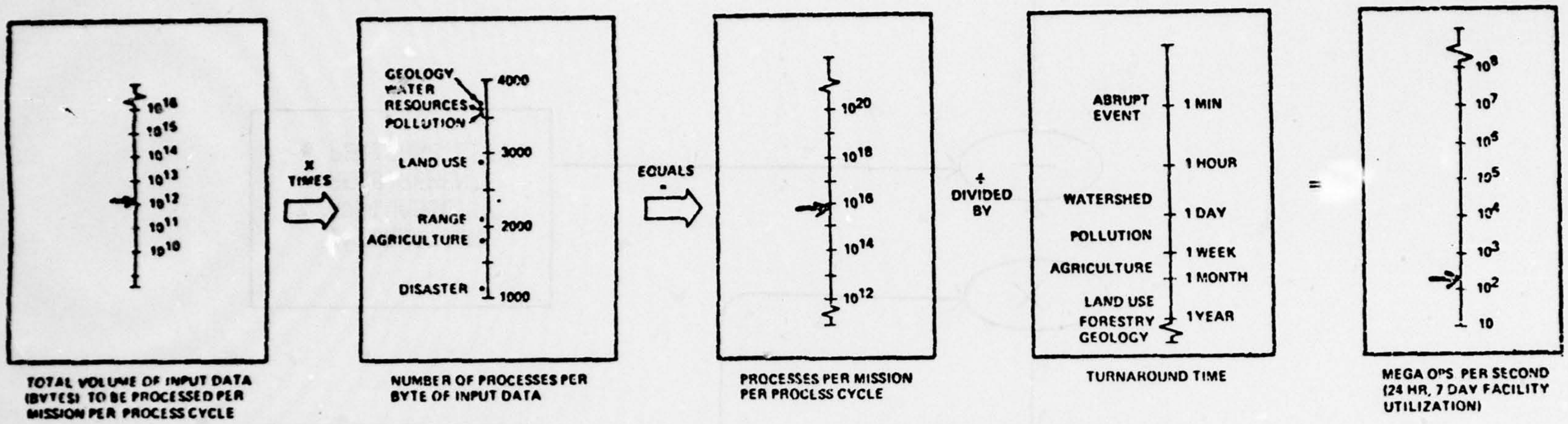


Figure B-9. COMPUTATIONAL POWER REQUIREMENTS

LIST OF ABBREVIATIONS

AGRA/MET	Agricultural/Meterological
ASVT	Applications System Verification and Transfer
BER	Bit Error Rate
BIL	Band Interleaved by Line
BSQ	Band Sequential
B&W	Black & White
CCT	Computer Compatible Tape
COE	Corps of Engineers
CPU	Central Processor Unit
CW	Civil Works
DMS	Data Management System
DMSP	Defense Meterological Satellite Program
DOMSAT	Domestic Communication Satellite
DRPF	Data Reception & Processing Facility
EDC	EROS Data Center
EROS	Earth Resources Observation System
ERTS	Earth Resources Technology Satellite
ETL	Engineer Topographic Laboratories
FCC	Federal Communications Commission
FET	Field Effect Transistor
FM	Frequency Modulation
G&A	General and Administrative
GOES	Geostationary Operational Environmental Satellite
GSA	General Services Administration
GSFC	Goddard Space Flight Center
HCMM	Heat Capacity Mapping Mission
HDDR	High Density Digital Recorder
HDT (or HDDT)	High Density Digital Tape
IF	Intermediate Frequency
IR	Infrared
IR&D	Independent Research and Development
IRIG	Inter-Range Instrumentation Group
Kbps	Kilobits per second
LCC	Lambert Conformal Conic
LNA	Low Noise Amplifier

Mbps	Megabits per Second
MMS	Multimission Modular Spacecraft
M&O	Maintenance and Operations
MSS	Multispectral Scanner
NASA	National Aeronautics and Space Administration
NOAA	National Oceanographic and Atmospheric Administration
NRZ	Non Return to Zero
NTTF	Network Test and Training Facility
PCM	Pulse Code Modulation
Pixel	Picture Element
PN	Pseudo Number
PS	Polar Stereographic
PSK	Phase Shift Keyed.
QLDS	Quick Look Display System
RBV	Return Beam Vidicon
R&D	Research and Development
RF	Radio Frequency
ROM	Rough Order of Magnitude
SDSM	Synchronization and Data Stripping Module
SOM	Standard Oblique Mercator
3D	Three Dimension
TDRSS	Tracking and Data Relay
TM	Thematic Mapper
TTY	Teletype
TWT	Traveling Wave Tube
UTM	Universal Transverse Mercator
VSWR	Voltage Standing Wave Ratio
WRS	World Reference System