(NASA-CR-141769) TERSSE: DEFINITION OF THE TOTAL EARTH RESOURCES SYSTEM FOR THE SHUTTLE ERA. VOLUME 3: MISSION AND SYSTEM REQUIREMENTS FOR THE TOTAL EARTH RESOURCES SYSTEM (General Electric Co.) 258 p HC

N75-31546

Unclas
G3/43 35385

NASA CR-141769

definition of the

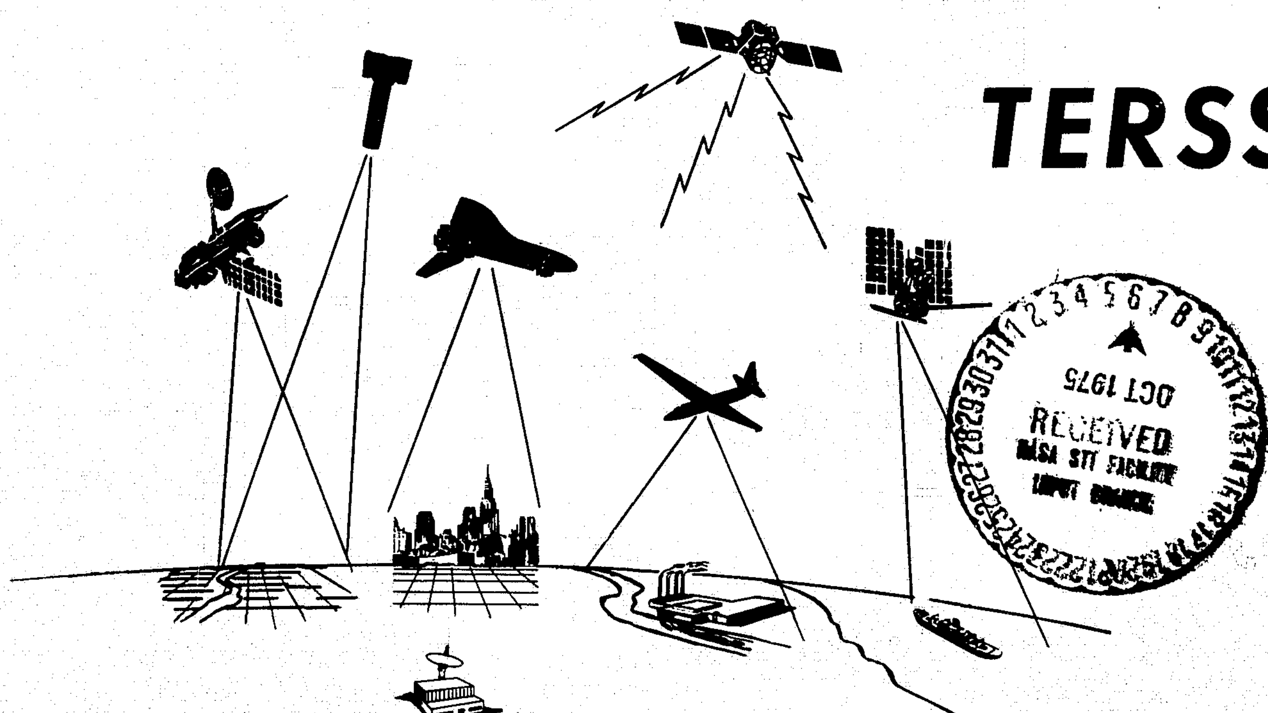
TOTAL EARTH RESOURCES SYSTEM

FOR THE

SHUTTLE ERA

VOLUME 3
MISSION AND SYSTEM REQUIREMENTS FOR THE TOTAL EARTH RESOURCES SYSTEM

TERSSE



GENERAL ELECTRIC
SPACE DIVISION

NOVEMBER 1974

CONTRACT NAS 9–13401
DRL NO. T–880 (MA–129TA)

TERSSE

DEFINITION OF THE

TOTAL EARTH RESOURCES SYSTEM

FOR THE

SHUTTLE ERA

VOLUME 3

MISSION AND SYSTEM REQUIREMENTS FOR THE TOTAL EARTH RESOURCES SYSTEM

PREPARED FOR

EARTH RESOURCES PROGRAM OFFICE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHNSON SPACE CENTER
HOUSTON, TEXAS

PREPARED BY

GENERAL ELECTRIC
SPACE DIVISION
Valley Forge Space Center
P. O. Box 8555 • Philadelphia, Penna. 19101

This document is submitted by the General Electric Company in partial satisfaction of DRL No. T-880 (Line Item MA-129-TA), Contract NAS 9-13401.

PRINCIPAL CONTRIBUTORS

W. KENT STOW, TASK LEADER
THEODORE AEPLI
R. W. ANDRYCZYK
DR. C. E. CHEESEMAN
FRED THOMSON, ERIM
LYNN FUJII
RAYMOND GINSBERG
DR. W. R. GUARD
RON KERN
RALPH PETERSON
ERIC STEIN
JOSEPH WELCH

APPROVALS:

DR. C. E. CHEESEMAN
TECHNICAL DIRECTOR

D. W. KELLER
PROGRAM MANAGER

Any questions or comments regarding this document should be addressed to:

Dr. C. E. Cheeseman,
Technical Director
General Electric Company
Valley Forge Space Center
P. O. Box 8555
Philadelphia, Pennsylvania 19101

John Mitchell,
Technical Monitor
Earth Resources Program Office
National Aeronautic and Space Administration
Johnson Space Center, Code HD
Houston, Texas 77058

PREFACE

The pressing need to survey and manage the earth's resources and environment, to better understand remotely sensible phenomena, to continue technological development, and to improve management systems are all elements of a future Earth Resources System. The Space Shuttle brings a new capability to Earth Resources Survey including direct observation by experienced earth scientists, quick reaction capability, spaceborne facilities for experimentation and sensor evaluation, and more effective means for launching and servicing long mission life space systems.

The Space Shuttle is, however, only one element in a complex system of data gathering, translation, distribution and utilization functions. While the Shuttle most decidedly has a role in the total Earth Resources Program, the central question is the form of the future Earth Resources system itself. It is only by analyzing this form and accounting for all elements of the system that the proper role of the Shuttle in it can be made visible.

This study, entitled TERSSE, Total Earth Resources System for the Shuttle Era, was established to investigate the form of this future Earth Resources System. Most of the constituent system elements of the future ER system and the key issues which concern the future ER program are both complex and interrelated in nature. The purpose of this study has been to investigate these items in the context of the total system utilizing a rigorous, comprehensive, systems oriented methodology.

The results of this study are reported in eight separate volumes plus an Executive Summary; their titles are:

Volume 1	Earth Resources Program Scope and Information Needs
Volume 2	An Assessment of the Current State-of-the-Art
Volume 3	Mission and System Requirements for the Total Earth Resources System
Volume 4	The Role of the Shuttle in the Earth Resources Program
Volume 5	Detailed System Requirements: Two Case Studies
Volume 6	An Early Shuttle Pallet Concept for the Earth Resources Program
Volume 7	User Models: A System Assessment
Volume 8	User's Mission and System Requirement Data
Executive Summary.	

TABLE OF CONTENTS

TABLE OF CONTENTS (cont)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (cont.)

LIST OF ILLUSTRATIONS (cont.)

LIST OF TABLES

SECTION 1

INTRODUCTION AND SUMMARY

1.1 INTRODUCTION AND REPORT ORGANIZATION

The Space Shuttle brings a new capability to Earth Resources Survey, but is only one element in a complex system of data gathering, translation, distribution and utilization functions. While the Shuttle most decidedly has a role in the total Earth Resources Program, the central question is the form of the future Earth Resources system itself. It is only by analyzing this form and accounting for all the elements of the system that the proper role of the Shuttle in it can be made visible. Thus, the major thrust of the TERSSE study is to define a top-level architecture for the total Earth resources system during the time frame of the early Space Shuttle era, the early 1980's.

The first major step in the process, that of establishing traceable user jobs which can be served by the TERSSE, has been documented in Volume 1. A second step, that of assessing the current state of the art of all system elements, has been reported - Volume 2. This volume completes the overall architecture defenition by defining a set of 1980's missions to be performed by the TERSSE and the performance requirement and configuration of the systems necessary to carry them out.

The specific study objectives covered in this report are:

1. Define specific mission requirements
2. Define system configuration and performance requirements for all elements of earth resources system
    a. Future system scenarios
    b. System performance specification
    c. Critical item development recomendations
3. Compare/evaluate system configurations

This volume is organized into several distinct sections (plus supporting appendices) which represent the major functional segments of the portion of the study effort. The sections and their contents are:

Section 1, INTRODUCTION AND SUMMARY: provides a brief overview of the effort and contains a brief summary of the key results, observations, and recommendations obtained.

Section 2, METHODOLOGY & STUDY APPROACH: describes the approach applied to the determination of the TERSSE and relates this effort to the other study tasks.

Section 3, TERSSE REQUIREMENTS: provides the 1980's scenario and the definition of the TERSSE users; it presents their mission and system requirements and the detailed information flows developed for each major resource management mission.

Section 4, REMOTE SENSING PLATFORMS: devlops the basic set of remote sensing platfoms and presents each mission's platform assignments.

Section 5, REMOTE SENSORS: develops the mission's remote sensor requirements and recomends necessary sensor developments.

Section 6, GROUND SYSTEM: develops the mission requirements, formulates alternative ground system concepts, and selects the recommended ground system architecture.

Section 7, SYSTEM CONFIGURATION: presents the overall TERSSE system on the combination of platforms, remote sensors, and a ground system; the Lead Missions concept for system evolution is described.

Section 8, RELATED ISSUES: contains the results of TERSSE related investigations into the subjects of: Orbit Mechanics, Cloud Cover, Resolution, Aircraft versus Satellites, and Coverage Cycle.

1.2 STUDY OVERVIEW & SUMMARY

One of the significant features of the TERSSE study is its consistent application of the fundamental systems methodology to the broad ERS program. As applied to TERSSE this approach consists of four basic steps (refer to Figure 1.2-1); these steps are:

1. Determination of user needs
2. Derivation of mission requirements
3. Formulation of system requirements
4. Synthesis of the system design

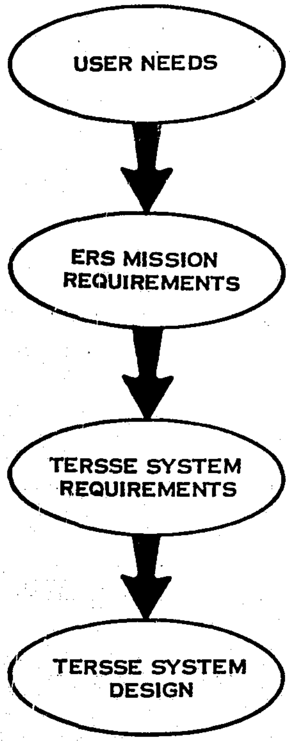


Figure 1.2-1. Task 3/4 Approach

This TERSSE task begins with the basic determination of "Who the users are" (reported in Volume 1) and proceeds to derive the TERSSE design. The essence of this task lies heavily in the methodology used in proceeding from the "needs" to the final system.

The approach taken, here as well as for all of the TERSSE study, is to evolve a system design that will "optimally" serve the identified users. This is in contrast to the more common approach of seeking out users or tasks that can be served by a given system. In the TERSSE approach the users will drive the system, not vice-versa. This approach applies the systems methodology to the definition of the ERS program.

The essential thread maintained throughout this TERSSE study is that the TERSSE concept will be founded upon the information needs of the resource managers. This top-down, user oriented approach is one of the essential differences between the TERSSE study solution and that produced by other system studies. The TERSSE requirements are determined by first determining "What do we want to do in the Shuttle era?" and then answering "What does it take to accomplish that?"

The overall approach to defining the system requirements begins with the establishment of a future scenario which will define the realm of reasonableness within which the TERSSE must lie. This scenario consists of a series of statements about the 1980's world in general and the 1980's Earth Resources Program in particular. Once this realm of reasonableness is established, a set of resource management mission statement for TERSSE, refer to Figure 1.2-2, can be developed with a reasonable confidence that they will be achievable. These basic mission statements (consisting of 30 missions spread across 6 resource management areas) are then defined in terms of specific representative users with specific resource management jobs to do. It is the requirements of these representative users (a total of 285 user tasks are used to represent the 30 mission statements) which are used to determine the Total Earth Resources System for the Shuttle Era, TERSSE. The hierarchy of the terminology just discussed in formulating the mission/system requirements is summarized in Figure 1.2-3.

It is worth emphasising that the resource management missions used to determine the TERSSE are those which could be reasonably expected to (1) benefit from remote sensing and (2) be operational in the Space Shuttle era. This does not in any way exclude those missions which may be operational much sooner than the Space Shuttle. In fact, many of the TERSSE missions are expected to be operational, at least in part, before the 1980's.

Automated spacecraft, Shuttle sortie flights and aircraft are the basic means of gathering remotely-sensed information for the earth resources management functions. No single observation platform can provide all the required information while operating within the following constraints:

1. Cost
2. Sensor power, weight, volume, thermal stability, data handling
3. Resolution, spatial and spectral
4. Frequency of observation
5. Sun illumination
6. Cloud cover

Therefore a set of seven remote sensing platforms were defined, as shown in Figure 1.2-4, from the user requirement data base.

For each of the TERSSE missions an assesment was made, utilizing the computerized requirements data base, of the observation requirements and the appropriate platforms assigned. This assignment of remote sensing platforms is shown in Figure 1.2-5. When reviewing these assignments it should be borne in mind that they represent the ultimate operational use of the TERSSE and do not imply that other platforms could not be used to serve a mission in the meantime.

The examination of the TERSSE sensors begins with an analysis of the resource managers requirements as represented in the mission and system requirements data base. The data base contains the spectral and spatial

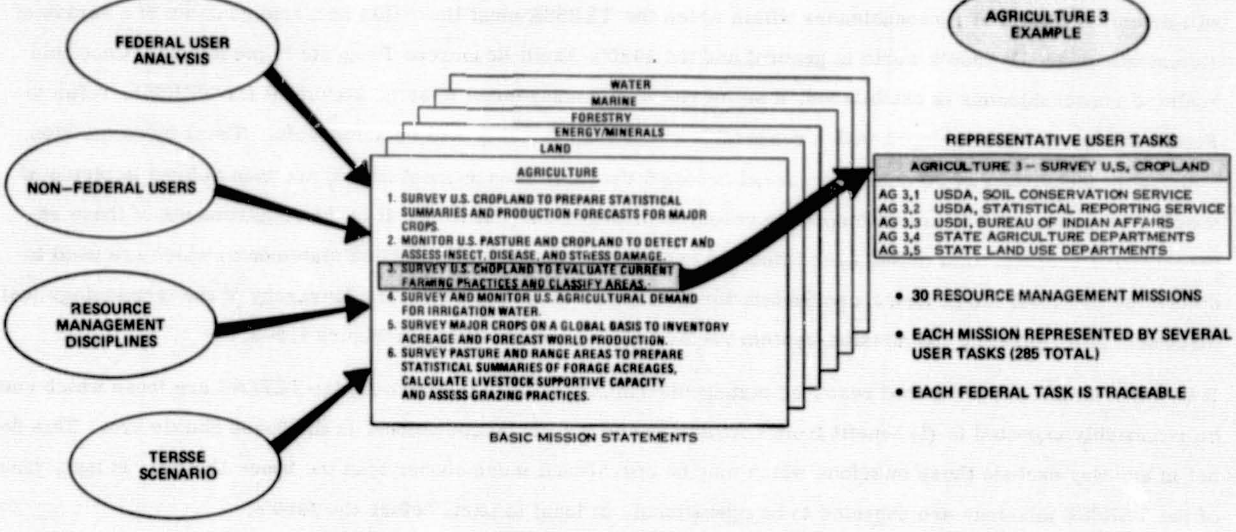


Figure 1.2-2. TERSSE Resource Management Missions

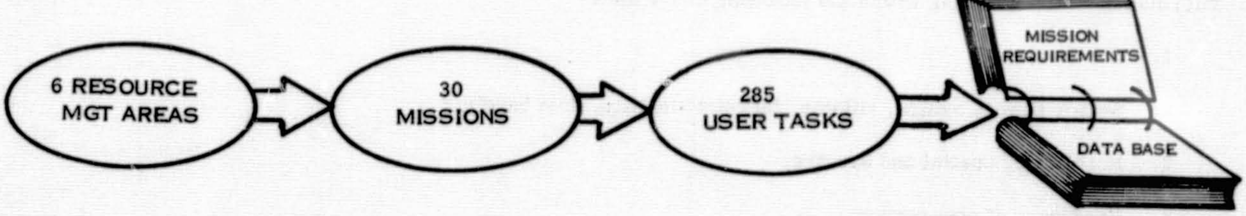


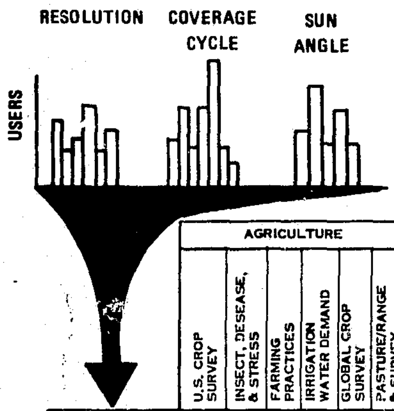
Figure 1.2-3. Definition of TERSSE Requirements

requirements for each of 285 representative user tasks. These disparate requirements were then processed through a sensor strategy in order to reduce the number of discrete sensors required. The result of this process is a set of twenty spectral band families which will satisfy all of the resource management missions.

Each of 30 basic TERSSE missions were then considered with respect to their spectral and spatial requirements so that a definite sensor assignment could be made for each mission. This process is represented in Figure 1.2-6. The spectral requirements in the IR-thermal region are not as variable as in the lower wavelength region and can probably be satisfied by a standardized sensor for that region. The visible-near IR region has more variable requirements which should be met with a multiband and modular design. The current state-of-the-art is such that development of these sensors can start now with a reasonable expectation of being achieved by the 1980's.

EARTH SYNCHRONOUS	WESTERN HEMISPHERE	RAPID RESPONSE
SUN SYNCHRONOUS	GLOBAL, NOON ORBIT	SYSTEMATIC SURVEYORS – HIGH ILLUMINATION
	GLOBAL, MIDMORNING ORBIT	– SHADOWS, LOW TEMP
	GLOBAL, PREDAWN ORBIT	– THERMAL CONTRASTS
SHUTTLE SORTIE	GLOBAL, TAILORED ORBITS	FREQUENT FLIGHTS
NON-SUN SYNCHRONOUS POLAR	GLOBAL, TAILORED ORBIT	TUNED TO EARTH PHENOMENON
AIRCRAFT	REGIONAL COVERAGE	FLEXIBILITY

Figure 1.2-4. Seven Basic TERSSE Platforms



- SEVEN BASIC PLATFORMS REQUIRED
- MOST MISSIONS REQUIRE MULTIPLE PLATFORMS
- ASSIGNMENT CHOICES DEPENDENT ON SYSTEM EVOLUTION RATE, FORM

	AGRICULTURE						ENERGY MINERALS							FORESTRY			LAND USE				MARINE				WATER					
	U.S. CROP SURVEY	INSECT, DESEASE, & STRESS	FARMING PRACTICES	IRRIGATION WATER DEMAND	GLOBAL CROP SURVEY	PASTURE/RANGE & SURVEY	MINERALS SURVEY	GEOTHERMAL SOURCE SURVEY	SUBMARINE OIL SURVEY	EXTRACTION POLLUTION MONITOR	PIPELINE MONITOR	OIL POLLUTION MONITOR	THERMAL POLLUTION MONITOR	TIMBER INVENTORY	INSECT, DISEASE STRESS	FIRE MONITOR & ASSESSMENT	U.S. LAND USE INVENTORY	LAND FORM & COVER MAPPING	COASTLINE SURVEY	GEOLOGICAL HAZARD MAPPING	OCEAN DYNAMICS MONITOR	FISH ENVIRONMENT & LOCATION	MARINE POLLUTION MONITOR	NAVIGATION HAZARD MONITOR	URBAN/AG SUPPLY INVENTORY	HYDROELECTRIC SUPPLY INVENTORY	GREAT LAKES ICE	WATER QUALITY MONITOR	FLOOD MONITOR	COASTAL WETLANDS MONITOR
EARTH SYNC	B					B	B	A	A	B								B				A	A		A		A	B	B	B
PREDAWN SUN SYNC							A								A															
MORNING SUN SYNC		A		A						A	A											A			A					
NOON SUN SYNC	A	A	A	A	A	A	A			A	A		A	B	A	B	B	A		A		A	B		A	A		A	A	A
SHUTTLE SORTIE	B		B		B		B			B			B	A		B	A	A	B					B						B
NON SYNC S/C																					A			A						
AIRCRAFT		B		B			B			A		A			B	A	A		A	A	B			B	B		B			

A – PROVIDES ALL OR MAJOR PART OF DATA NEEDS
B – PARTIAL SATISFACTION OF DATA NEEDS

Figure 1.2-5. Platform Assignments for TERSSE Missions

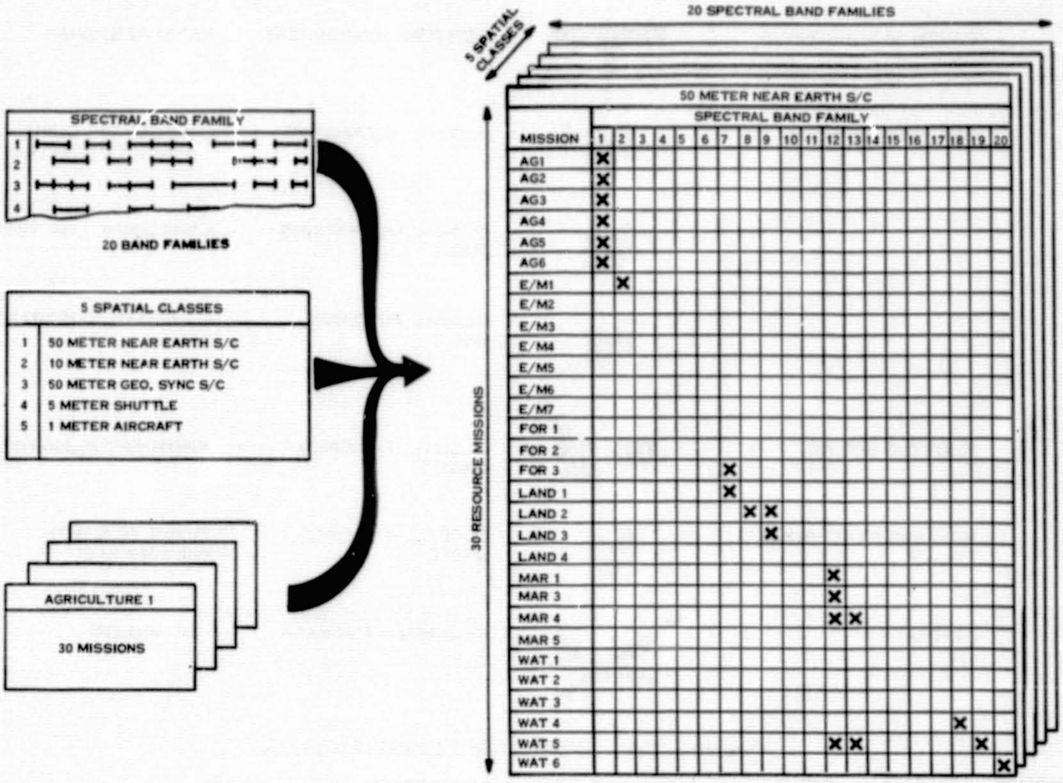


Figure 1.2-6. Resource Missions Assigned to Sensors

With respect to spatial resolution, a key sensor recomendation is for the development of a 10 meter IFOV scanner from near earth polar orbit altitudes. The need for a relatively large number of spectral bands and large optics with respect to the field of view will require the utilization of advanced technology. Therefore, the availability of this sensor should not be expected before the mid 1980's. However, with slightly reduced constraints, the design could begin soon for a Space Shuttle borne version which would be available by the late 1970's or early 1980's.

The analysis of the user's sensor requirements in conjunction with the state-of-the-art determination and the driving sensor design parameters leads to the following conclusions:

1. Development of the following sensors is indicated:

    a. 1-2 m (Aircraft)

    b. 5 m (Shuttle)

    c. 10 m (Polar and Shuttle)

    d. 30-50 m (Polar)

    e. 50-100 m (Synchronous)

2. These sensor configurations must be designed to accommodate a larger number of spectral bands and to achieve higher spectral resolution and narrower band widths than are manifested in current sensor designs.

3. Final specification of the ultimate operational sensor/mission assignment for TERSEE will require advancement in the state of knowledge regarding:

   a. Systems level sensor feasibility/cost as a function of the number of spectral bands

   b. Refined user requirements and weighting factors as to relative importance to mission success

   c. Relative importance of the particular user/mission/tasks

   d. Specific decisions on the assignment of one or more missions to a sensor design

In R&D operations, remote sensed data is disseminated through discrete and controlled channels to experimenters and selected Federal agencies. As operational systems come on line, and as user requirements broaden to include multi-disciplinary needs covering both remote sensed and other ancillary data, the data flow will increase and the single thread R&D approach will be unable to respond. A total systems approach to the TERSSE ground system is required to assure that the outputs of all earth resources data acquisition systems are readily accessible to all potential users whether they be technical or non-technical, or whether they be part of Government, public, or private agencies.

The ground system is the interface between the collection system (remote sensing platforms and sensors) and the user community. Existing ERS systems are adequate for the present needs because these needs are experimental, or R&D, in nature. The present needs can be characterized as being a thorough broadly oriented analysis of relatively limited quantities of data. This is in contrast to the needs of the TERSSE time frame where the users will be operational, requiring the routine and timely handling of large quantities of data (each for more narrowly oriented analysis). The expanded definition of the TERSSE ground system used during the study is portrayed in Figure 1.2-7 and can be seen to include the elements of Ground Station, Preprocessing, Extractive Processing, User Models, and Users, as well as the overall System Operational considerations.

Considering each of the missions singularly, there is a remote sensing portion and a ground portion which together represent the "system" for each mission. In Section 4 of this report the remote sensing platforms are discussed and each mission assigned to one or more specific remote sensing platforms. Similarly, the sensors are discussed and each mission assigned specific sensors (specified as to spatial resolution and spectral band requirements) in Section 5 of this report. The remote sensing portion of a mission's "solution" is determined by these platforms and sensor assignments and is depicted in Figure 1.2-8 using the Water 1 mission as an example.

The ground system element is discussed at length in Section 6 of this report. In that section and Section 3, specific information flow/processing diagrams are developed for each of the TERSSE missions; Figure 1.2-9 is an example of these for the Water 1 mission.

The entire system for each mission is then the sum of the remote sensing portion (Figure 1.2-8) and the ground portion (Figure 1.2-9). This is depicted in Figure 1.2-10 with the Surface Water Inventory mission as an example.

The TERSSE we have defined thus far is the sum of 30 separate systems each with different requirements and serving different users who have various degrees of readiness for the operational usage of remote sensing. The

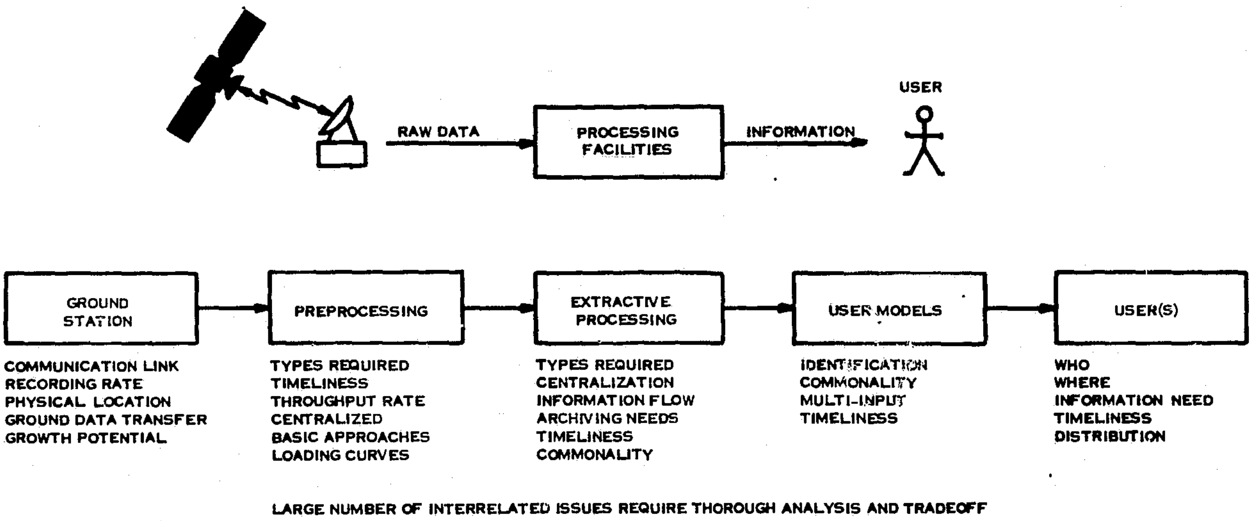


Figure 1.2-7. Elements of the TERSSE Ground System

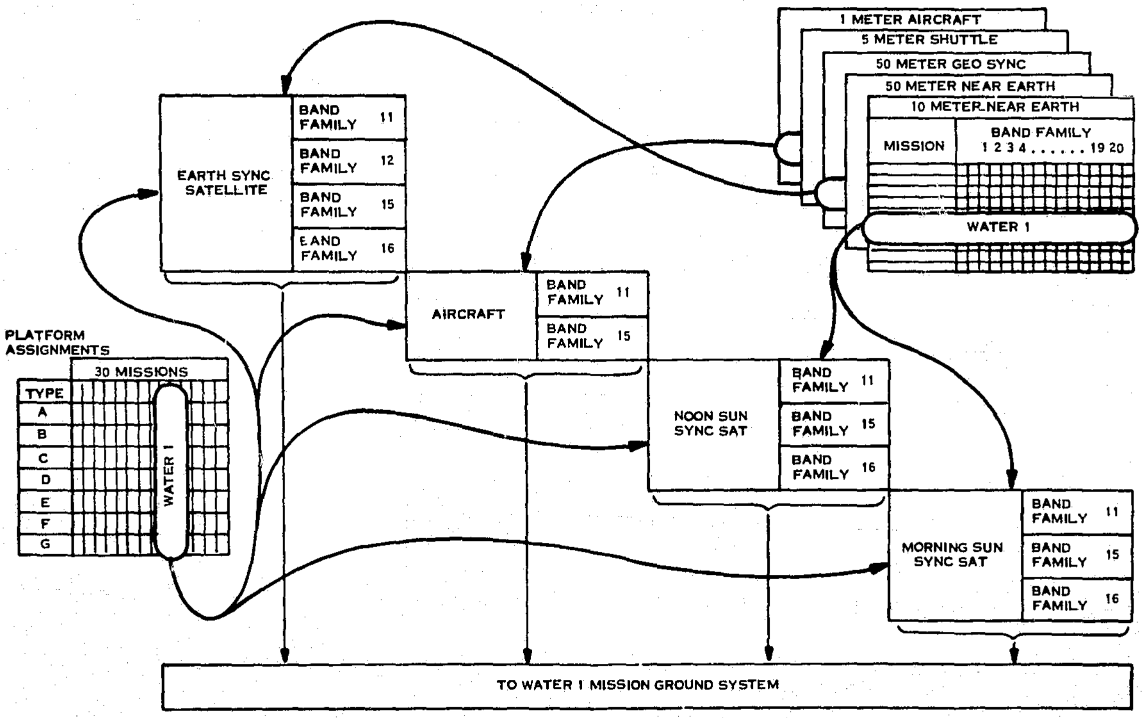


Figure 1.2-8. Remote Sensing Portions of TERSSE (Water 1 Mission Example)

SURVEY & INVENTORY THE VOLUME & DISTRIBUTION OF SURFACE GROUND WATER TO ASSESS AVAILABLE SUPPLIES FOR URBAN & AGRICULTURE CONSUMPTION (WATER 1)

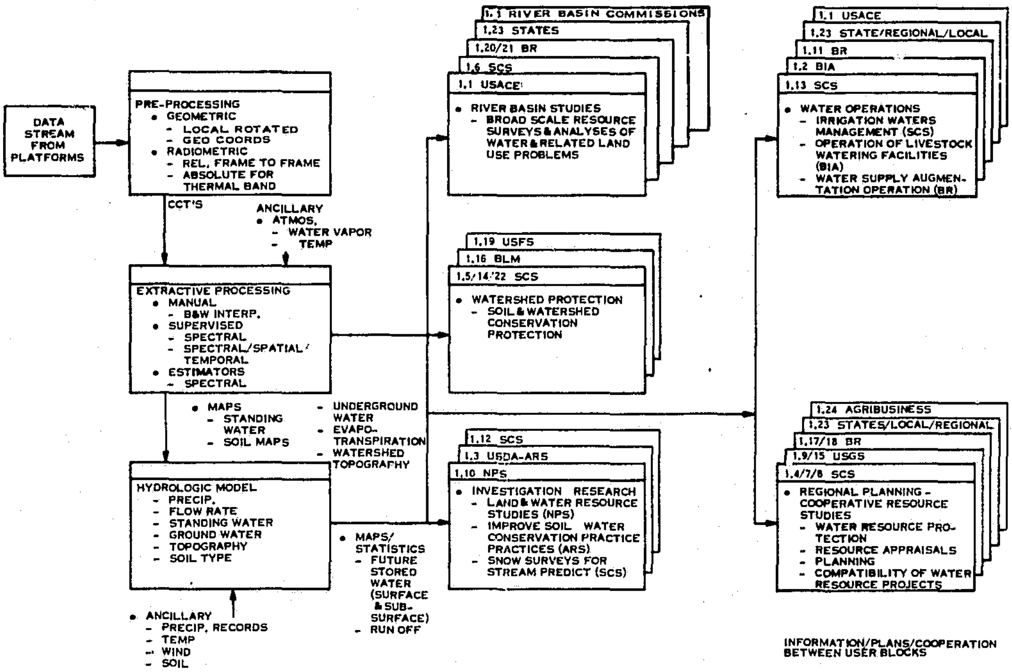


Figure 1.2-9. Information Flow - Water 1 Example

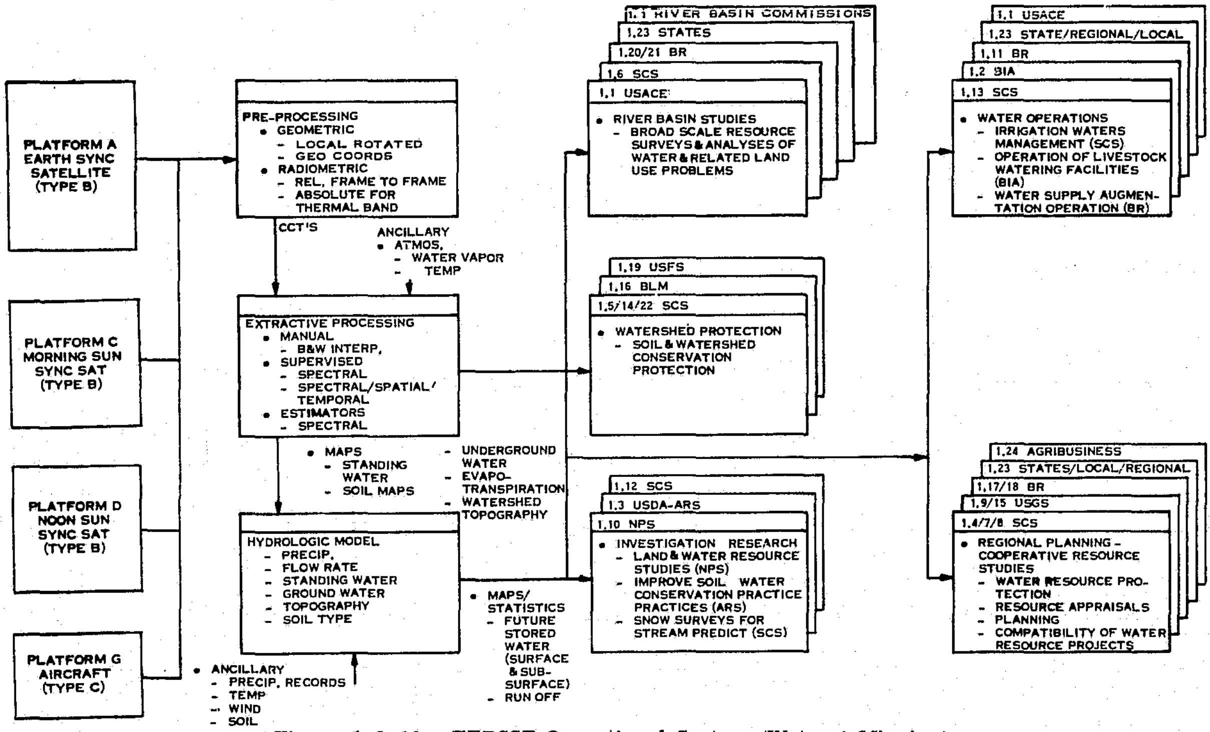


Figure 1.2-10. TERSSE Operational System (Water 1 Mission)

actual implementation of TERSSE must recognize and take advantage of those differences instead of attempting to be a one-time implementation of a singular "super system" that will serve all.

The TERSSE approach which takes these differences into account and which forms a primary mechanism for operational system implementation is referred to as the "Lead Missions Concept". Simply stated, the Lead Missions Concept indicates that specific Earth resources management missions will be selected and the "system" for implementing them will be developed as the need, technology, and user demand become available. A lead mission will, in general also satisfy the requirements for other (generally similar or related) resource management missions with little or no change to the specific system of the "lead mission". It is through this process of selecting lead missions and implementing their systems that the entire TERSSE will evolve. The first early candidate for a lead mission is the CROPSAT mission.

1.3 SYNOPSIS OF OBSERVATIONS AND RECOMENDATIONS

Throughout the conduct of the TERSSE study many observations and conclusions pertinent to the Earth Resources Survey program were obtained. This section summarizes and makes recommendations with respect to the more significant ones. In general, each of these is discussed in more detail and greater background is provided in the appropriate section of this TERSSE report volume. Each of these conclusions and recommendations is summarized on a single page for the sake of conciseness. Note that those conclusions pertinent to other TERSSE report volumes are contained in those volumes as appropriate; in particular, those relating to Space Shuttle are contained in Volume 4, The Role of the Shuttle in the Earth Resources Program.

DIFFERENT SYSTEMS FOR DIFFERENT MISSIONS

The broad scope and wide diversity of potential uses and missions of remote sensing in the 1980's cannot be effectively served by a single system. Rather, the Earth Resources Program of the shuttle time frame will be composed of several relatively independent systems each with more restricted disciplinary objectives and scope than ERTS-1 or Skylab. The future systems will be more like current NOAA and DOD programs (Figure 1.3-1) which, because of their precise scope, are able to be justified, designed, and implemented with a high degree of benefit and satisfaction on the part of the served community. The future ER systems will also differ from today's R&D systems by their necessary implementation as a total, end-to-end process.

The systems of the future TERSSE can be grouped into three categories:

1. Single Mission Systems - Appropriate for large, clear-cut, important, repetitive missions (e.g. world crop survey)

2. Multi-Mission Systems - Optimized for one or few lead missions but beneficial to many others; some compromise possible

3. Systems for AD HOC Missions - Smaller in scope; one-time or infrequent coverage, varied users (e.g. urban land use)

The number and implementation rate of such systems (Figure 1.3-2) is highly dependent upon their identification and vigorous development of all elements.

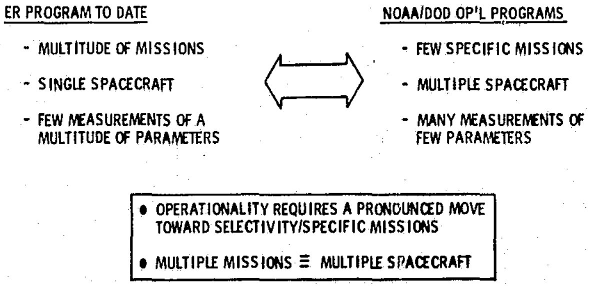


Figure 1.3-1. Comparisons

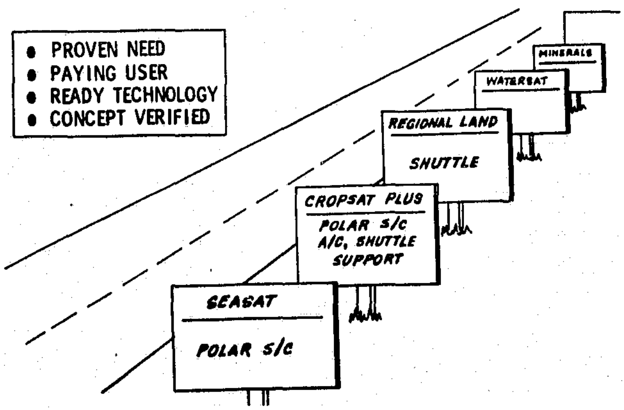


Figure 1.3-2. How Many Systems Are There ?

WIDE DIVERSITY OF ERS MISSIONS (USERS, SCOPE, IMPORTANCE, MATURITY) REQUIRE DIFFERENT SYSTEMS FOR OPERATIONAL SOLUTION

The major current limitation to the implementation of Earth resources management systems is the uneven readiness of the various system elements for an application. For every application there are several system elements ranging from the initial distinguishing characteristics to the final user model which together comprise the overall ER system (Figure 1.3-3). It is the lack of readiness in all elements together (especially the data processing and user model elements) which prevents an application (even the simpler ones) from being implemented.

To overcome this problem it is recommended that major program efforts be devoted to development of total application packages. These total packages must encompass all relevent system elements for an application and serve as a prototype system for solving the problems of the transition into an operational status. The transitional problems are numerous and have not yet been effectively addressed by today's R&D programs.

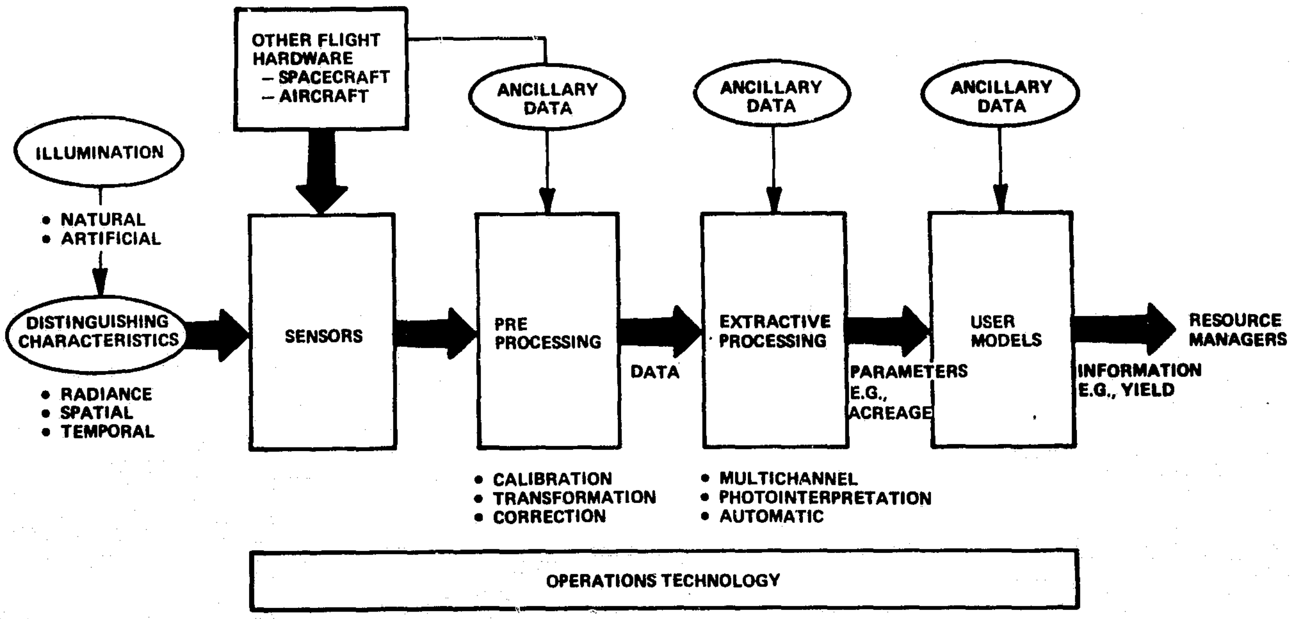


Figure 1.3-3. Overall Earth Resources System

THE MOST CRITICAL DEVELOPMENT REQUIREMENT IS FOR DEFINING AND PROVING COMPLETE APPLICATIONS PACKAGES

SIGNATURE EXTENSION: IMMEDIATE ATTENTION NEEDED

The application of remote sensing to resource management missions over a wide geographic area requires that sensed signatures be extendable over large distances. Today, several training sites are required for each image frame; this situation is at best expensive, and possibly inadequate, to operate on a large scale. The use of standard signature banks was once thought to be theoretically possible but the achievement of signature extension via the removal of measurable error sources appears to be the best solution (see Figure 1.3-4). Several ERS missions (Global Crop Survey, Water Quality, and Coastal Zone Management) are nearly ready to become operational yet are stymied by lack of appropriate signature extension techniques.

Inasmuch as atmospheric effects are the major culprit, effort should be placed on this area first. The sensitivity to atmospheric variables is beginning to be understood; the keys must still be selected from all the variables. Action is needed to coordinate ER Program efforts to:

1. Define atmospheric correction needs
2. Understand total atmosphere
3. Select key atmospheric parameters
4. Determine: How to measure
   How to implement

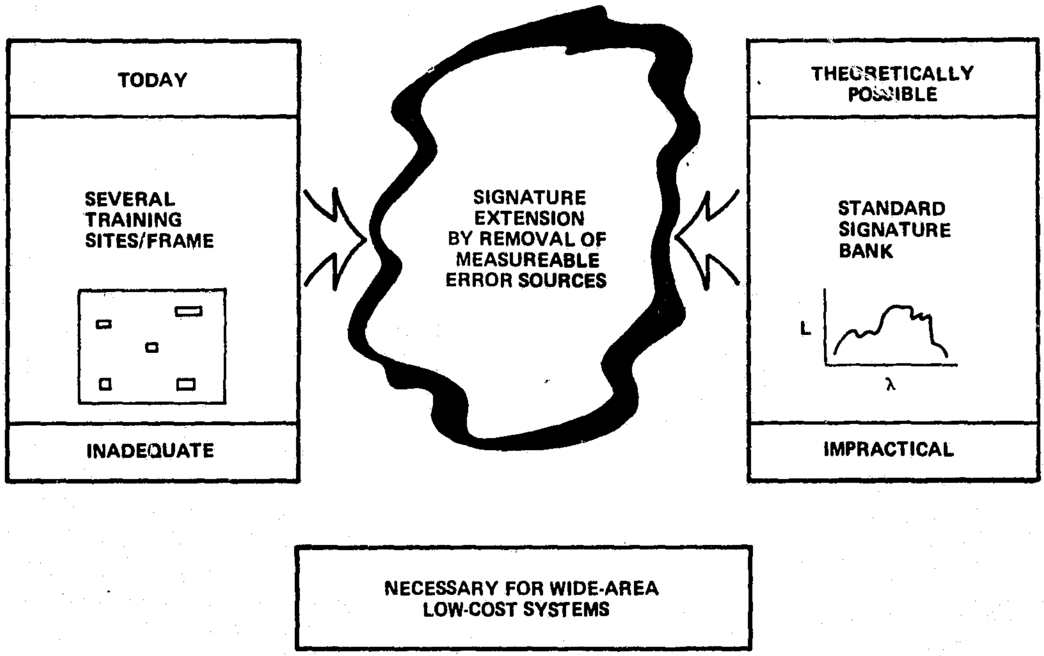


Figure 1.3-4. Signature Extension

WE MUST LEARN TO EFFICIENTLY CORRECT DATA FOR ATMOSPHERIC EFFECTS, DIURNAL AND SEASONAL VARIATIONS. SEVERAL NEAR TERM APPLICATIONS ARE STYMIED BY THIS LACK.

MULTIPLE PLATFORM SYSTEMS ARE REQUIRED

Not only are the several platform options open to the system designer complementary to each other. They must also in most cases be used jointly. The analysis of mission requirements and the assignment of missions to remote sensing platform, Figure 1.3-5, indicates that most missions individually require multiple remote platforms. The 1980's TERSSE will be comprised of seven basic types, Figure 1.3-6, of remote sensing platforms which complement each other in satisfying mission requirements. Of significance to note is the extensive use of aircraft as a "spot checker" to facilitate multistage statistical sampling along with the systematic surveyor platforms.

	AGRICULTURE						ENERGY MINERALS							FORESTRY			LAND USE				MARINE				WATER					
	U.S. CROP SURVEY	INSECT, DESEASE, & STRESS	FARMING PRACTICES	IRRIGATION WATER DEMAND	GLOBAL CROP SURVEY	PASTURE/RANGE & SURVEY	MINERALS SURVEY	GEOTHERMAL SOURCE SURVEY	SUBMARINE OIL SURVEY	EXTRACTION POLLUTION MONITOR	PIPELINE MONITOR	OIL POLLUTION MONITOR	THERMAL POLLUTION MONITOR	TIMBER INVENTORY	INSECT, DISEASE STRESS	FIRE MONITOR & ASSESSMENT	U.S. LAND USE INVENTORY	LAND FORM & COVER MAPPING	COASTLINE SURVEY	GEOLOGICAL HAZARD MAPPING	OCEAN DYNAMICS MONITOR	FISH ENVIRONMENT & LOCATION	MARINE POLLUTION MONITOR	NAVIGATION HAZARD MONITOR	URBAN/AG SUPPLY INVENTORY	HYDROELECTRIC SUPPLY INVENTORY	GREAT LAKES ICE	WATER QUALITY MONITOR	FLOOD MONITOR	COASTAL WETLANDS MONITOR
EARTH SYNC	B					B	B	A	A	B								B				A	A		A		A	B	B	B
PREDAWN SUN SYNC							A								A															
MORNING SUN SYNC		A		A						A	A											A			A					
NOON SUN SYNC	A	A	A	A	A	A	A			A	A		A	B	A	B	B	A		A		A	B		A	A		A	A	A
SHUTTLE SORTIE	B		B		B		B			B			B	A		B	A	A	B					B						B
NON SYNC S/C																					A			A						
AIRCRAFT		B		B			B			A		A			B	A	A		A	A	B			B	B		B			

A – PROVIDES ALL OR MAJOR PART OF DATA NEEDS
B – PARTIAL SATISFACTION OF DATA NEEDS

Figure 1.3-5. Platform Assignment

EARTH SYNCHRONOUS		WESTERN HEMISPHERE	RAPID RESPONSE
SUN SYNCHRONOUS		GLOBAL, NOON ORBIT	SYSTEMATIC SURVEYORS – HIGH ILLUMINATION
		GLOBAL, MIDMORNING ORBIT	– SHADOWS, LOW TEMP
		GLOBAL, PREDAWN ORBIT	– THERMAL CONTRASTS
SHUTTLE SORTIE		GLOBAL, TAILORED ORBITS	FREQUENT FLIGHTS
NON-SUN SYNCHRONOUS POLAR		GLOBAL, TAILORED ORBIT	TUNED TO EARTH PHENOMENON
AIRCRAFT		REGIONAL COVERAGE	FLEXIBILITY

Figure 1.3-6. The Seven Basic Platforms

THE ERS PROGRAM MUST BEGIN TO CONSIDER AND ACTIVELY DEVELOP INTEGRATED MULTIPLE PLATFORM SYSTEMS

SCANNER DEVELOPMENTS REQUIRE STEADY PROGRESS

In general, the progress of scanner technology development is moving ahead satisfactorily; little is required in the realm of dramatic breakthroughs. The scanner development recommendations from the TERSSE study are summarized in Figure 1.3-7 for each type of remote sensing platform.

Some of the key points with respect to the scanner recomendations include:

1. The users spectral and spatial requirements are highly varied (especially spectral) and still relatively poorly defined.
2. The 30-50 meter IFOV scanner for polar spacecraft is a major near-term need.
3. The 10 meter IFOV modular scanner is a key sensor requirement for the Shuttle - its development should begin soon.
4. A compatible aircraft borne scanner with a 1-2 meter IFOV is required as a comparison sensor for the shuttle and spacecraft scanners.
5. Ancillary sensors are required for signature extension; development should focus on providing accurate measurement of atmospheric effects and for radiometric calibration.

AIRCRAFT	MODULAR VISIBLE/ NEAR IR; COMMON MID, THERMAL IR 0.5 μM BANDWIDTHS (OR BETTER) 1 - 2 METER RESOLUTION
SHUTTLE	MODULAR VISIBLE/ NEAR IR; COMMON MID, THERMAL IR 0.05 μM BANDWIDTHS 50M, 10M NOW (5M EVENTUALLY?)
POLAR	ULTIMATE AGGREGATED CAPABILITY ~15-18 BANDS 50M, NOW-10M, LATER
SYNCHRONOUS	DESIRED AGGREGATED CAPABILITY ~15-19 BANDS APERTURE MAJOR LIMIT → OPTIMIZE FOR MAX POSSIBLE APERTURE
SPECIAL PURPOSE	PREDAWN THERMAL WATER QUALITY OCEAN COLOR

Figure 1.3-7. Scanner Development Recommendations

A STEADY IMPROVEMENT IN SPECTRAL/SPATIAL RESOLUTION AND SIGNAL-TO-NOISE RATIO IS REQUIRED FOR SMOOTH PROGRAM PROGRESS. ANCILLARY SENSOR DEVELOPMENTS ARE CRITICAL

MICROWAVE SENSORS: SOME READY, OTHERS NOT

The potential for applying microwave sensors to TERSSE spans most resource management missions. The two categories of microwave sensors considered are: (1) Grid measurers such as scatterometers and radiometers which have a relatively large non-contiguous footprint and (2) imagers such as synthetic aperture radar. The grid measurers and imagers generally fall into two categories with respect to the Water and Land Use resource disciplines:

1. Relatively well understood for use over water
    a. SAR "cloud-free B & W photography"
    b. Scatterometers/radiometers
2. Poorly understood for use over land
    a. Soil moisture a major parameter
    b. Terrain signatures for SAR

The TERSSE recommendations with respect to those sensors are shown in Figure 1.3-8.

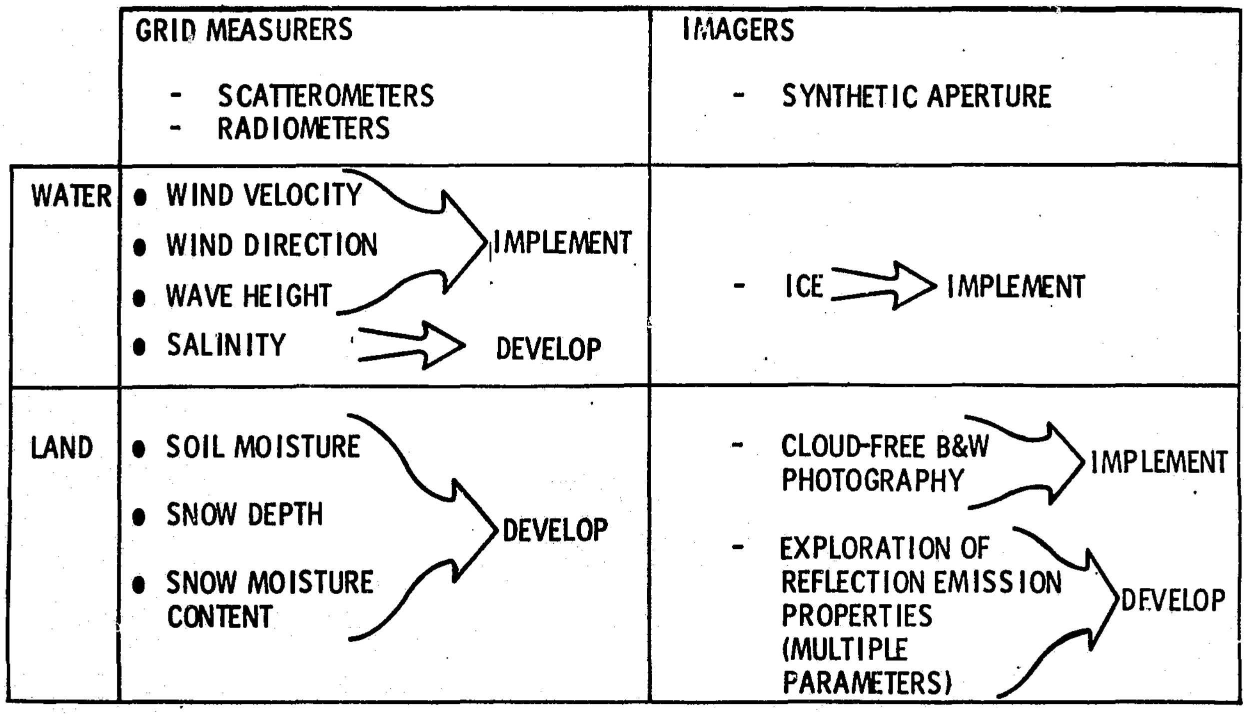


Figure 1.3-8. Microwave Sensors

DIFFERENT TECHNOLOGIES AND DEVELOPMENT STATUS EXIST FOR MICROWAVE SENSORS; PLANNING IS REQUIRED TO EXPLOIT THOSE WHICH ARE READY AND TO DEVELOP THOSE WHICH ARE NOT READY

AN INTEGRATED SYSTEMS APPROACH TO DATA GRIDS IS NECESSARY

Most Earth resources management missions have their own unique information grid scheme. This is represented in Figure 1.3-9 by the dashed lines. The collection of remotely sensed data (shown as the circles and squares) will usually be different from the user's grid not only in orientation (translation and rotation) but also in resolution or grid size.

The rapid digital manipulation of large volumes of pixels is now straight forward using special purpose hardware. The TERSSE should utilize this technology to convert multi-source data into the user's frame-of-reference. The actual source of the data is of no concern to the user and should be "invisible" to him; the ERS should adapt in order to "invisibleize" the data into the user's information grid.

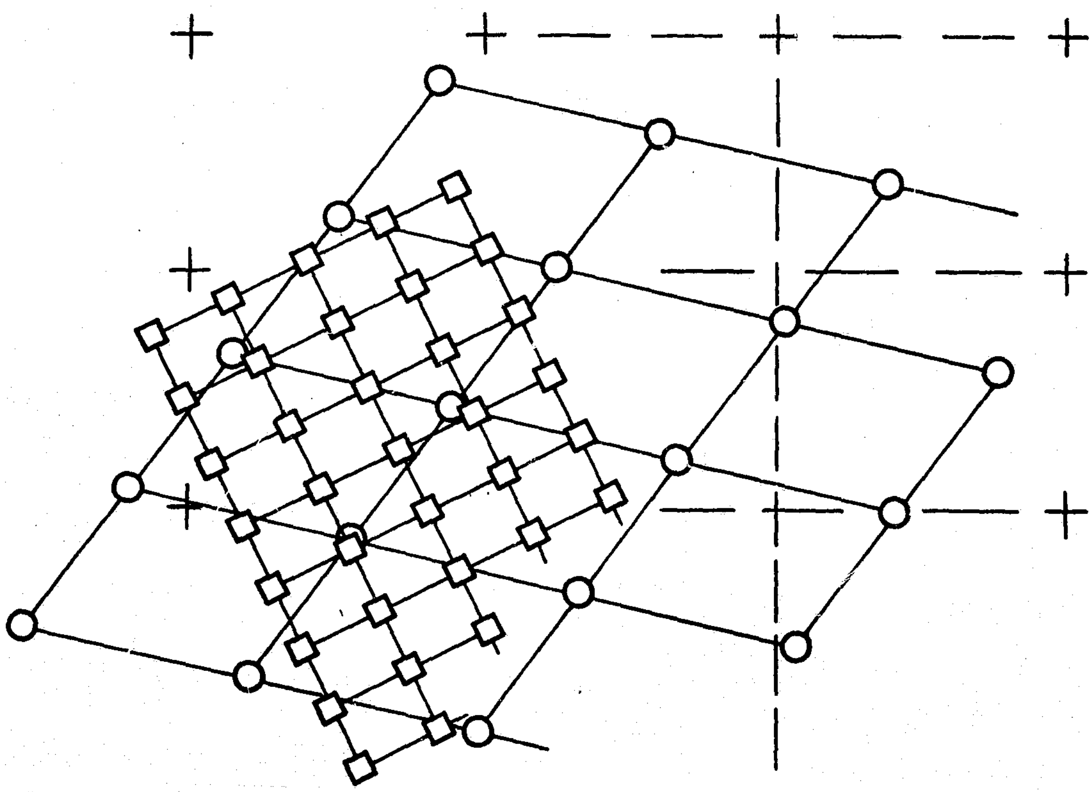


Figure 1.3-9. The Data Gridding Problem

MULTI-SOURCE DATA CORRELATION IS THE NEXT MAJOR REQUIRED ADVANCE IN GEOMETRIC PREPROCESSING: FILM AND DIGITAL DATA FROM DIFFERENT SENSORS AT DIFFERENT TIMES TRANSFORMED TO USER TAILORED GRIDS.

Photointerpretation uses the integrative and pattern recognition powers of the human. Automated machine analysis uses the rapid quantitative and analytical capability of digital computers. These two techniques for extractive processing are often incorrectly viewed as competitive alternatives. Instead, the unique features of each can be combined into an integrated approach which synergistically utilizes the natural features of each.

Contemporary special purpose hardware (e. g., General Electric Image 100 System) can classify an entire image in less than a second while it takes the human operator on the order of minutes to analyze the results and instruct the machine. This situation is thus well suited for a time shared interactive system which can iterate rapidly between the two modes, Figure 1.3-10. But for fuller use of the man/machine capabilities, (and in particular the human visual channel) better display capabilities are required in future systems.

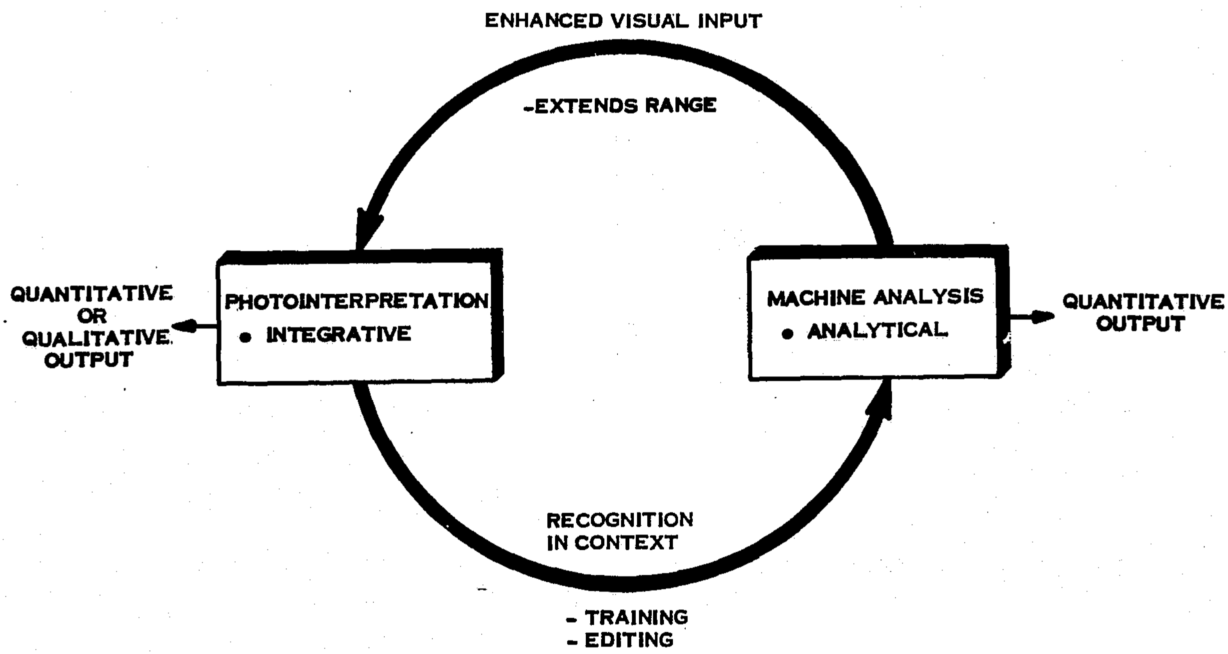


Figure 1.3-10. Interactive Systems

PHOTOINTERPRETATION AND MACHINE ANALYSIS ARE NOT COMPETITIVE BUT COMPLEMENTARY TECHNIQUES. FAST INTERACTIVE SYSTEMS ARE THE ROUTE TO THEIR JOINT USAGE.

DATA HARDWARE TECHNOLOGY IS MOSTLY FREE

The basic hardware technology for data processing and the handling of large data bases is progressing well; the large data processing industry can be expected to continue this technology advancement without the assistance of the Earth Resources Program. The large data base technology, with archiving and rapid access/retrieval implements, needed by the TERSSE as it grows in size and complexity will generally be available. Figure 1.3-11 contains a currently available example of a large, rapid access mass storage archival and retrieval system.

Even though the state-of-the-art for data storage is relatively well advanced, see Figure 1.3-12, there is a need for a new high density digital storage medium. This new medium must be developed to be computer compatible with the TERSSE data processing and extraction equipment. With respect to extractive processing, the advances beginning to become available from special purpose digital hardware (e.g., General Electric Image 100 System) should be continued and exploited for the TERSSE. Special purpose digital hardware is frequently better suited to the relatively routine handling of large quantities of similar data; the optimal determination of the general purpose/special purpose role is a key system design factor.

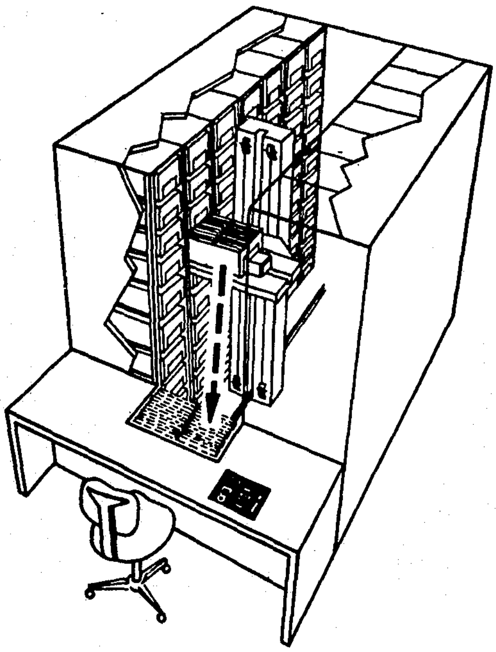


Figure 1.3-11. Rapid-Access-Mass Storage System

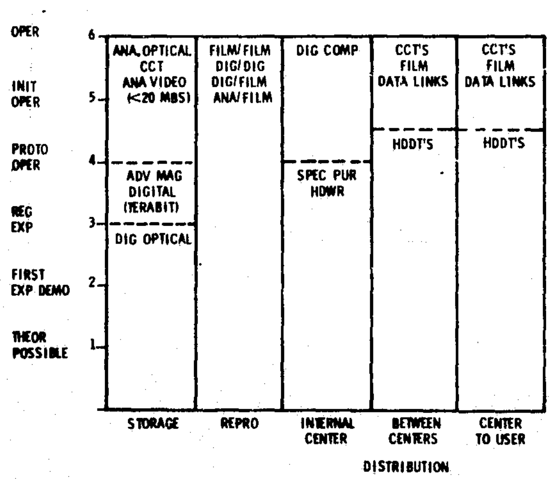


Figure 1.3-12. Data Systems Storage/Reproduction/Distribution

DATA SYSTEMS EQUIPMENT TECHNOLOGY IS ADVANCING RAPIDLY WITHOUT ERS ASSISTANCE. ERS SYSTEMS DESIGN MUST EXPLOIT BY DEVELOPING NEEDED SPECIAL PURPOSE HARDWARE AND SYSTEMS.

The cost of rapidly transfering large volumes of data from point to point via a domestic communication satellite link are decreasing, see Figure 1.3-13. The combination of plummeting channel costs and the advent of low-cost Earth stations make the feasibility of multi-point extractive processing an attractive possibility. Total coverage of the United States is possible with a single DOMSAT channel; this will allow the placement of subscribers and their extractive processors at convenient geographic locations. The recommended TERSSE ground system architecture utilizes this DOMSAT capability to redistribute remotely sensed data to the several Information Analysis Centers after it has been preprocessed and archived at a single national center.

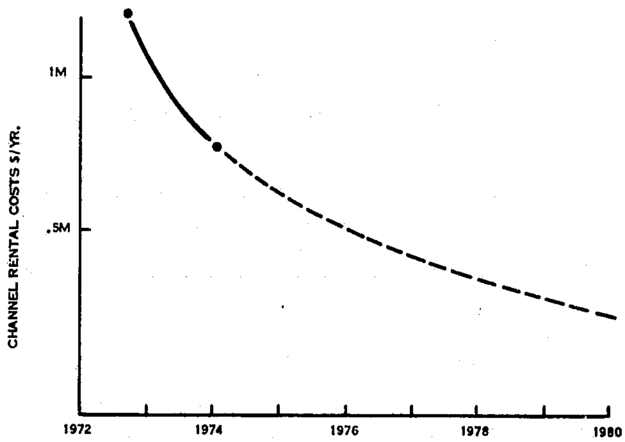


Figure 1.3-13. Domsat Channel Costs

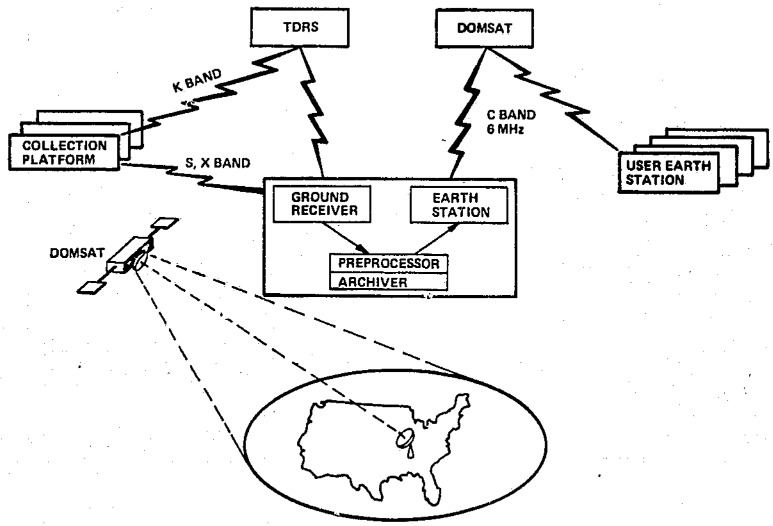


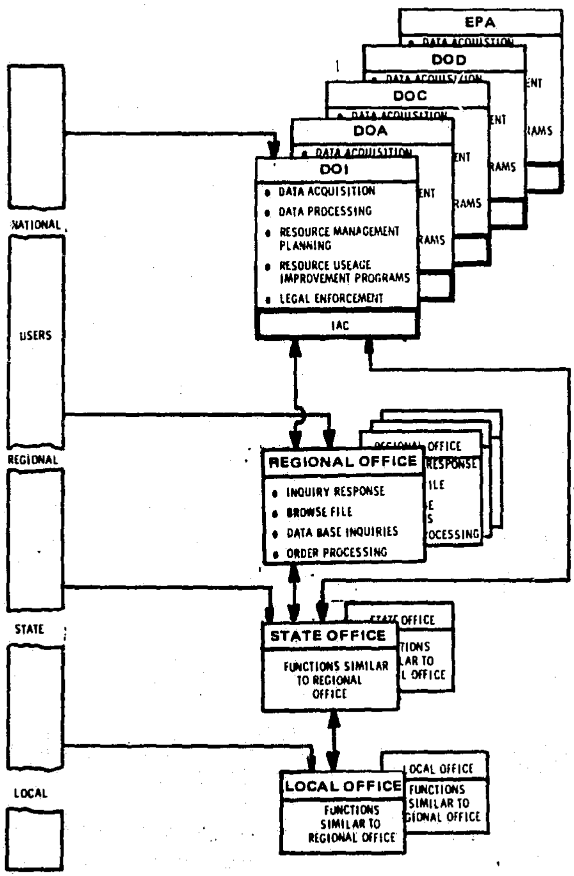
Figure 1.3-14. Domsat's Role

DOMSAT CAPABILITY NOW COMING INTO EXISTENCE WILL REVOLUTIONIZE INFORMATION TRANSFER - ERS MUST POSITION ITSELF TO EXPLOIT THIS TECHNOLOGY

GROUND SYSTEM: PARALLEL USER'S STRUCTURE

The architectural structure of the TERSSE ground system should be mission tailored and parallel the user's organizational structure. Some missions are naturally centralized (e.g. World Crop Survey); however, most have a decentralized and geographically distributed user network, even in those with heavy Federal involvement. This need, coupled with the recurrence of a tiered hierarchal user structure (local, district, state, regional) leads to the recommended TERSSE ground system concept (Figure 1.3-15) of Lead Federal Agencies with distributed system terminuses located in the facilities of the operational users.

The majority of missions will evolve to standard output products, routinely issued in user-oriented formats. On the other hand, some missions are by their very nature ad hoc; their output products are not routine and will require greater flexibility in the user interface. The users terminal equipment will range from simple read only devices to complete interactive extractive processing equipment.



- CONSISTS OF SEVERAL HIERARCHIES
  - ORGANIZED BY RESOURCE DISCIPLINE
  - ORGANIZED AT FEDERAL LEVEL
- TERMINUS OF SYSTEM CO-LOCATED WITH USER ORGANIZATIONS
- TERMINAL EQUIPMENT RANGES FROM
  - FACSIMILE EQUIPMENT
  - CRT DISPLAY (READ ONLY)

  TO

  - EXTRACTIVE PROCESSING SYSTEMS
  - RAPID CALL UP DISPLAYS (INTERACTIVE)

Figure 1.3-15. User Oriented Ground System

REGIONAL/LOCAL EFFORTS SHOULD CONCENTRATE ON DEVELOPING STRONG, RAPID-ACCESS TIES FOR REGIONAL/LOCAL MISSIONS. TERMINUS FACILITIES SHOULD BE MISSION ORIENTED AND CO-LOCATED WITH USER ORGANIZATIONS.

THE 1980'S ERS: AN OPERATIONS CHALLENGE

The operation of the 1980's TERSSE will represent a significantly more complex task (Figure 1.3-16) than the operation of todays more limited experimental systems. The problems associated with coordinating the operation of several autonomus systems (e.g. ERTS, EOS, SHUTTLE, CROPSAT, SEOS, etc.) in order to optimally serve the users and maintain flexibility will require new and expanded techniques. These should be investigated and developed in the intermediate future and plans made to review and modify them as the TERSSE evolves.

The major issues effecting the operation of TERSSE can be divided into the two categories of: (1) Internal Adaptivity and Reconfiguration, and (2) External Responsivity. Not only the operations concerned with multiple platforms but also those which operate and coordinate multiple ground facilities and flow processes are in need of analysis. Areas of concern include:

1. Internal adaptivity and reconfiguration
   - a. Multiple uses of key system elements
   - b. Fill from inventory vs new data
   - c. Merge data from multiple sources
   - d. Inter-platform support
   - e. Accept and use in-situ data
   - f. Real-time use of meterological system - planning, processing
2. External responsivity
   - a. Turn on when asked - collect what's needed
   - b. Resolution of priorities
   - c. Standing orders - special requests
   - d. Enable user to use multi-source multi-time data
   - e. Cope with multiple reaction times

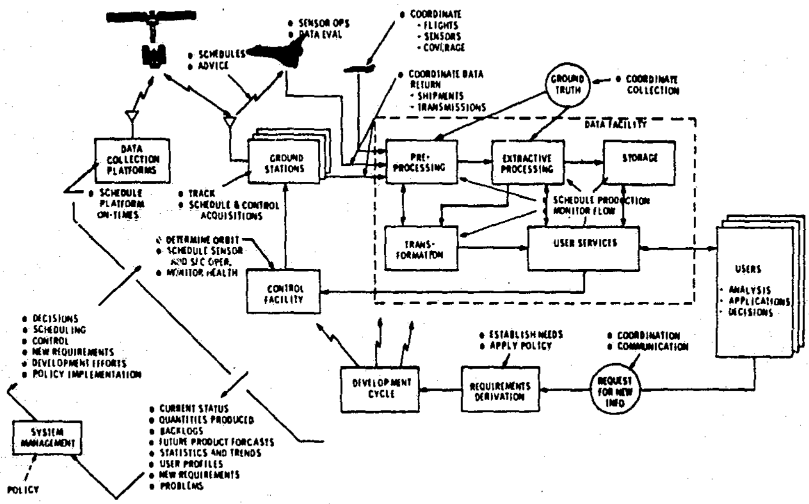


Figure 1.3-16. Shuttle Operations Technology

> **OPERATING COMPLEX MULTI-ELEMENT SYSTEMS REQUIRES A SIGNIFICANT ADVANCE IN OPERATIONS TECHNOLOGY - THE PROBLEM SHOULD BE STUDIED AS THE SYSTEMS TAKE SHAPE.**

SECTION 2

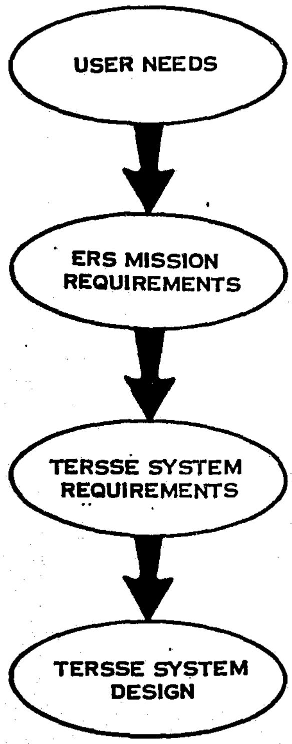
METHODOLOGY AND STUDY APPROACH

One of the significant features of the TERSSE study is its consistent application of the fundamental systems methodology to the broad ERS program. As applied to TERSSE this approach consists of four basic steps (Figure 2-1); these steps are:

1. Determination of user needs
2. Derivation of mission requirements
3. Formulation of system requirements
4. Synthesis of the system design

The task reported in this volume begins with the basic determination of "Who the users are" (reported in Volume 1) and proceeds to derive the TERSSE design. The essence of this task lies heavily in the methodology used in proceeding from the "needs" to the final system.

The approach taken, here as well as for all of the TERSSE study, is to evolve a system design that will "optimally" serve the identified users. This is in contrast to the more common approach of seeking out users or tasks that can be served by a given system. In the TERSSE approach the users will drive the system, not vice-versa. This approach applies the systems methodology to the definition of the ERS program.



- BEGIN WITH THE BASIC REQUIREMENTS
- OBSERVE THE STATE-OF-THE-ART CONSTRAINTS
- DEFINE THE OVERALL MISSION REQUIREMENTS
- TRANSLATE MISSION REQUIREMENTS INTO SYSTEM REQUIREMENTS
- DEVELOP SYSTEM DESIGN CONFIGURATIONS
- ITERATE AS NECESSARY TO OPTIMIZE

BASIC SYSTEMS APPROACH APPLIED TO ERS PROGRAM DEFINITION

Figure 2-1. Overall TERSSE Methodology

2.1 DEFINITION OF USER NEEDS

As a brief review of the previous work (Volumes 1 and 2) leading to the start of this task, consider the methodology presented in Figure 2.1-1. Volume 1 presented the necessary definitions of who (users) needs what (information) in the Earth resources domain. Once these user needs are firmly extablished, the TERSSE study proceeded to the establishment of the mission requirements reported in this Volume.

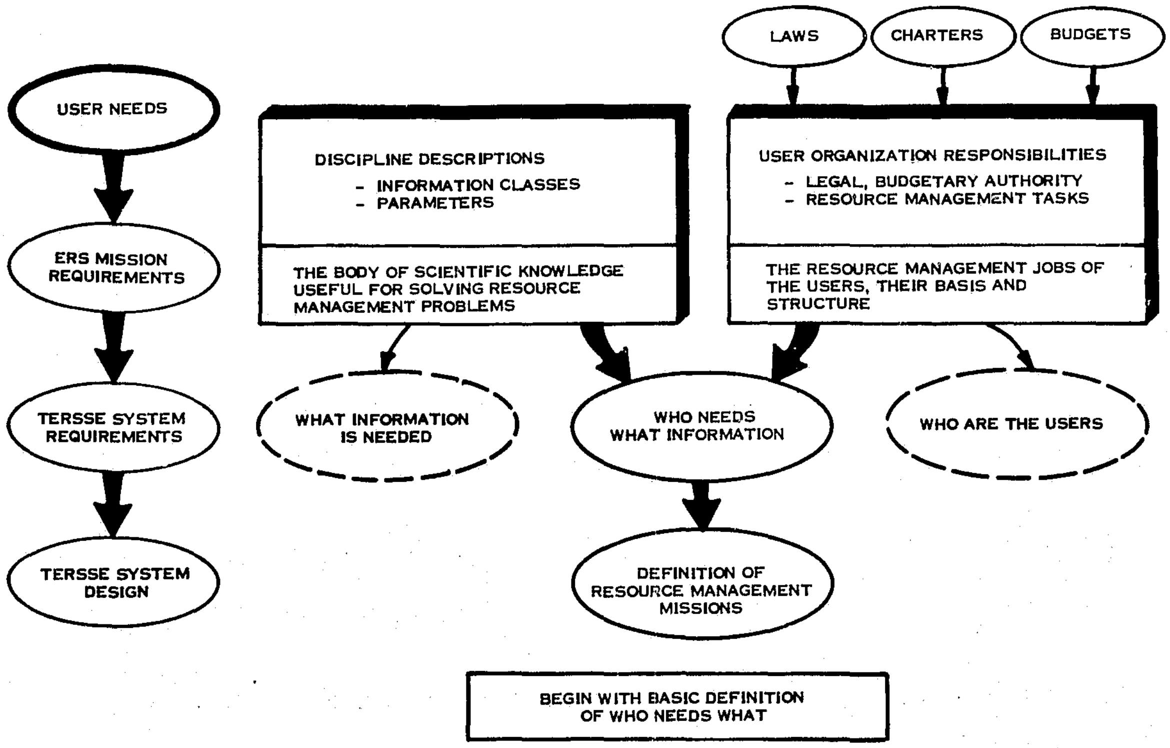


Figure 2.1-1. Definition of User Needs

2.2 DEFINITION OF MISSION REQUIREMENTS

Once the User's Needs were established, the overall mission requirements were developed (refer to Figure 2.2-1) such that when satisfied, the original user's needs will be satisfied.

The formulation of mission requirements requires an understanding of two distinct issues:

1. What the Resource Managers need to do their job.
2. What will be detectable and how.

The first issue relates to subjects such as the geographic area of concern, the timeliness and update cycle of the information required, and the granularity of the information needed. The second issue is more related to the various distinguishable characteristics of the subject or phenoma of concern. These can be grouped into general types such as:

1. Radiance or Spectral data
2. Spatial or positional data
3. Temporal or time domain data
4. Polarization of radiation

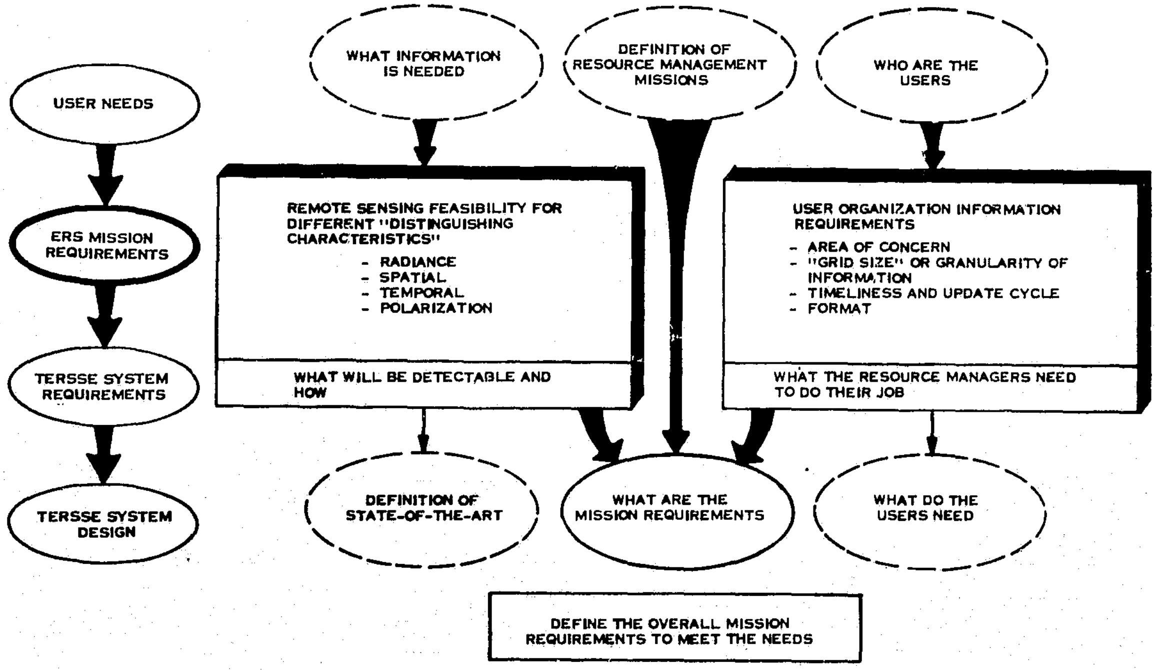


Figure 2.2-1. Definition of Mission Requirements

2.3 FORMULATION OF SYSTEM REQUIREMENTS

Continuing with the basic "systems approach" methodology it was now possible to translate the ERS Mission Requirements just developed into more specific System Requirements (Figure 2.3-1).

The System Requirements were developed by iterating possible conceptual systems and their specifications against the two basic fundamentals of:

1. What are the realistic solutions (State of the Art)?
2. Is this an acceptable solution (user needs)?

The result was a set of system requirements expressed in terms of the three major subsystems which when satisfied will meet the mission requirements. The three basic subsystems are:

1. Platforms
2. Sensors
3. Ground Systems

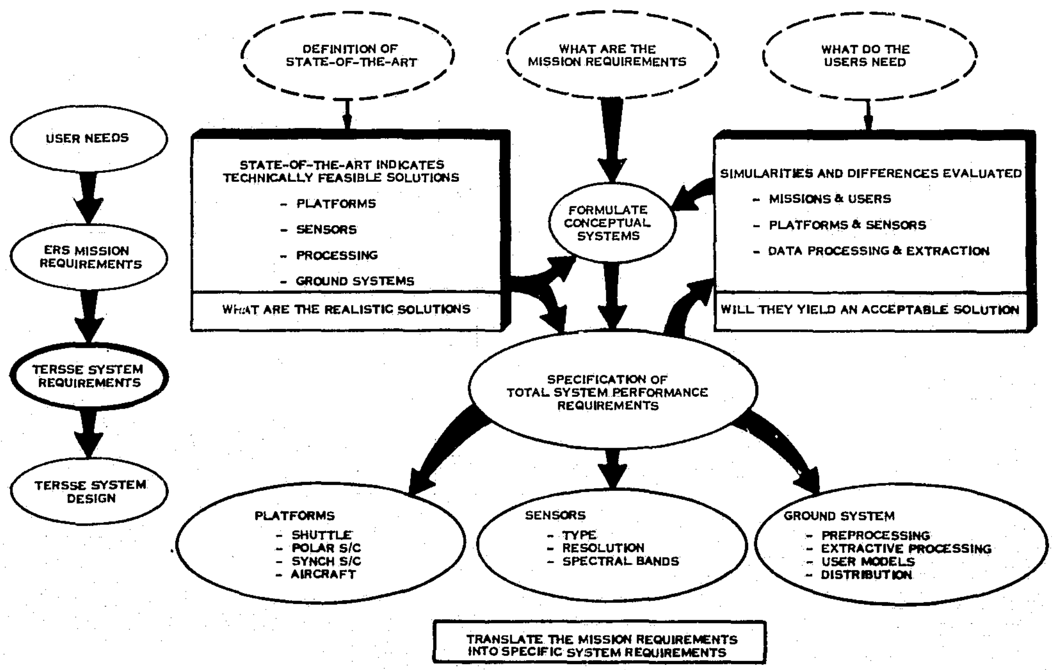


Figure 2.3-1. Definition of System Requirements

2.4 SYNTHESIS OF THE SYSTEM DESIGN

The last step in the fundamental systems approach to TERSSE was the development of the TERSSE system design (Figure 2.4-1) based on the previously established System Requirements.

The specification of the TERSSE system performance requirements, developed over the previous sections, now enabled specific system design concepts to be evolved and evaluated. This process was an iterative one and involved the introduction of both experience and pragmatism. The pragmatism and "real world" considerations introduced at this point included not only the technical state-of-the-art, but also such factors as:

1. Evolutionary growth
2. User readiness
3. Limited resources

The system was designed in terms of its major components; the platforms, the sensors, and the ground system.

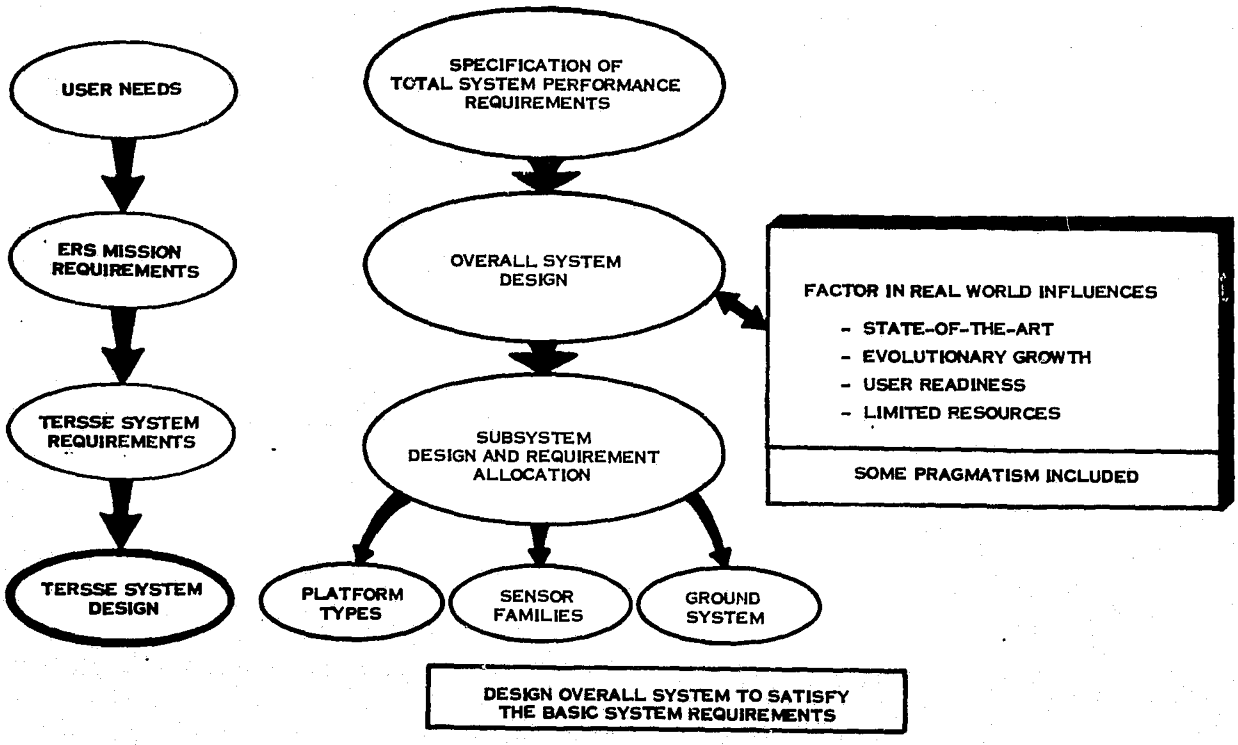


Figure 2.4-1. Synthesis of the System Design

2.5 THE SPACE SHUTTLE ROLE

Of particular interest throughout the TERSSE study was the role of the Space Shuttle. This issue was addressed (Figure 2.5-1) as part of the overall systems solution to the TERSSE study. In one sense the Space Shuttle is just another remote sensing platform which will be assigned its share of the total Earth Resources problem; however, the Shuttle is so different that its introduction will significantly effect the ERS program — beyond being just another platform.

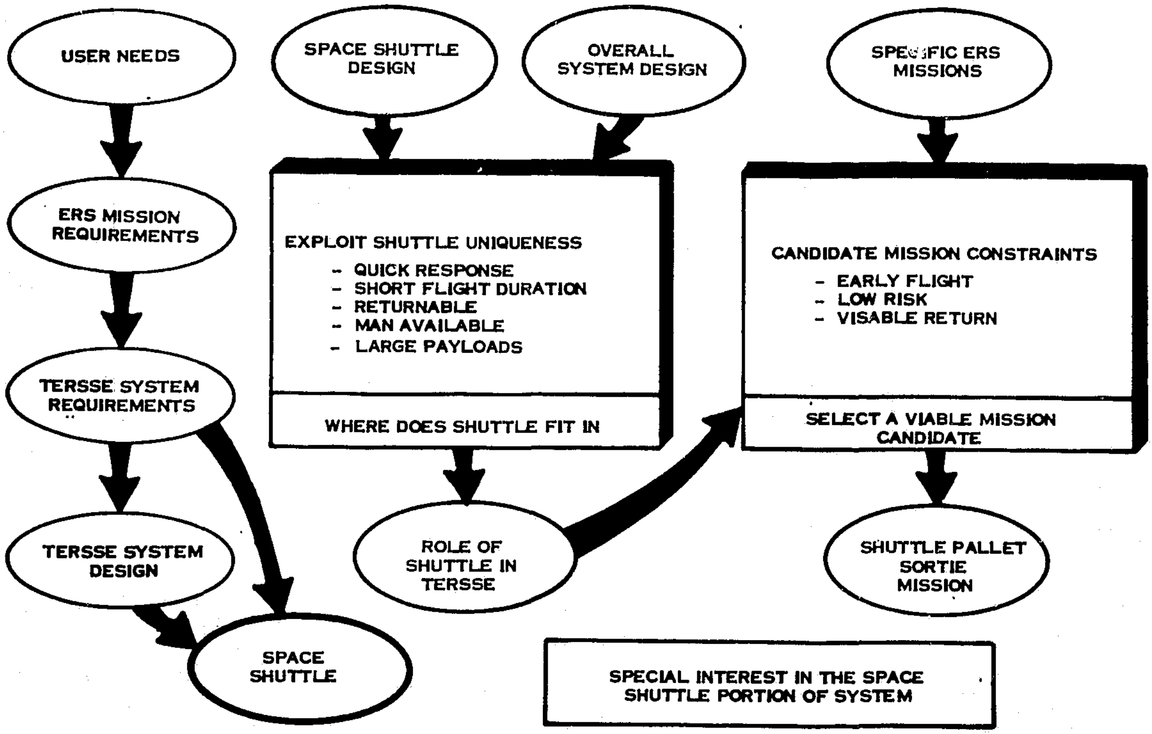


Figure 2.5-1. Definition of Space Shuttle Role

The role of the Space Shuttle was derived by analyzing the Shuttle design and capabilities in the context of the overall TERSSE design. Some of the unique Shuttle features which give it a special place in the set of operational platforms include:

1. Frequent flight opportunities
2. Quick response
3. Short flight duration
4. Returnable
5. Man is available
6. Large payload potential

Due to the significance of, and interest in, the Space Shuttle role, the relevant TERSSE study results are collected and reported in a separate report, Volume 4, The Role of the Shuttle in the Earth Resources Program.

SECTION 3
TERSSE REQUIREMENTS

The essential thread maintained throughout this TERSSE study is that the TERSSE concept will be founded upon traceable information needs of resource managers. This top-down, resource-management oriented approach is one of the essential differences between the TERSSE study solution and that produced by other system studies. TERSSE will fit a system solution to the user's needs; not select users to fit a system design. The TERSSE requirements are determined by first determining "What do we want to do in the Shuttle era?" and then answering "What does it take to accomplish that?"

The overall approach to defining the system requirements begins with the establishment of a future scenario which defines the realm of reasonableness within which the TERSSE must lie. This scenario consists of a series of statements about the 1980's world in general and the 1980's Earth Resources Program in particular. Once this realm of reasonableness is established, a set of resource management mission statement for TERSSE can be developed with a reasonable confidence that they will be achievable. These basic mission statements (consisting of 30 missions spread across 6 resource disciplines) are then defined in terms of specific representative users with specific resource management jobs to do. It is the requirements of these representative users (a total of 285 user tasks are used to represent the 30 mission statements) which are used to determine the Total Earth Resources System for the Shuttle Era, TERSSE.

It is worth emphasizing that the resource management missions used to determine the TERSSE are those which could be reasonably expected to (1) benefit from remote sensing and (2) be operational in the Space Shuttle Era. This does not in any way exclude those missions which may be operational much sooner than the Space Shuttle. In fact, many of the TERSSE missions are expected to be operational, at least in part, before the 1980's.

3.1 FUTURE SCENARIO

A significant feature of the TERSSE approach is the emphasis placed on top-down requirement developments. However, requirements for a future system cannot be reasonably created in a total void. Rather they must be derived so as to be within a "realm of reasonableness. This realm of reasonableness is determined by establishing a scenario for the future, with respect to the Earth Resources Program, within which specific requirements can be derived.

Future system scenarios must take into account trends in ERS information needs and developments in applicable ERS technologies. Two other factors (Figure 3.1-1) are also of great impact. First, the world of the 1980's as seen by recognized futurologists was taken into account. It is important that Earth Resources systems of the future address problems of future times, and not merely address today's resources management problems with the technology of tomorrow. Second, Imagineering, that combination of imagination and engineering based on a thorough understanding of needs and capabilities was applied to this creative task. The output of this task, a future scenario, was used as a basis for generating performance requirements within a realm of reasonableness.

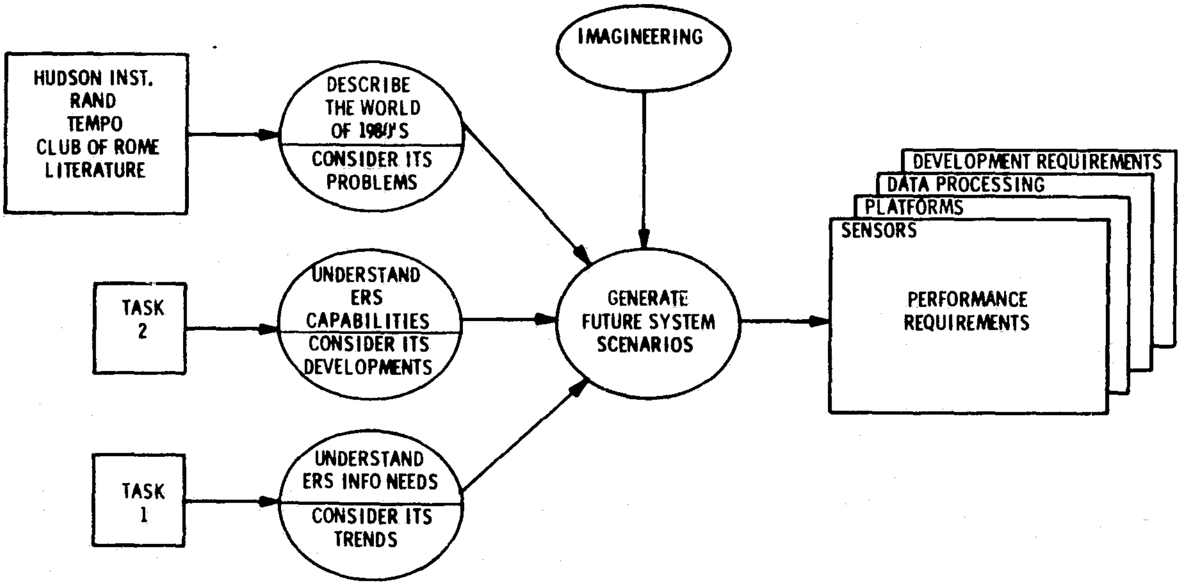


Figure 3.1-1. Approach - 1980's Scenario

A review of nearly 20 futures predictions indicates a nearly unanimous opinion that the effects of exponential growth will be felt by all mankind before the end of the 20th century (Figure 3.1-2). Increases in population and industrial growth will place increasing demands on the supply of resources and the ecological balance of spaceship Earth. International trade, particularly in food, energy and minerals, will increase dramatically with the Pacific Hemisphere Trading and Investment Area becoming increasingly important in all trading.

- POPULATION OF 3.8 BILLION VS 3.2 BILLION IN '73
- DRAMATIC INCREASES IN GWP, BUT U.S.A. SMALLER % OF TOTAL
- GROWING LIST OF CRITICALLY SHORT MINERAL RESOURCES
- EEC AND PAHTIA MAJOR FACTORS IN WORLD ECONOMY

- EXPANDING INTERNATIONAL - FOOD - MINERALS - ENERGY - TRADE
- INTENSIFIED LAND USE PRESSURES
- ENVIRONMENTAL SURVIVAL FACTORS INFLUENCE GROWTH
- PRESSURE MOUNTS FOR EQUILIBRIUM VS GROWTH

- INCREASING R&D IN ECOLOGICAL SURVIVAL - RESOURCES - ENV. - SURVEY
- INCREASING USE OF LARGE SCALE DATA BANKS
- NATIONALISTIC EMPHASIS ON RESOURCE MGT. AND WORLD TRADE

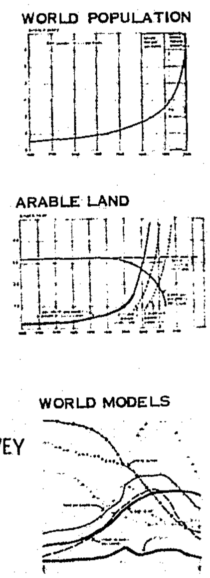


Figure 3.1-2. The 1980's World

Concurrent with increasing demands on resources, will be rapid technological advance and increasing Gross World Product. Many nations will have the ability to pay for the technological sophistication need to monitor and manage their own resources.

Increasing demand, dwindling reserves, improving technology, and better ability to pay for technological sophistication are all expected to impact upon earth resources systems of the future. The scenario for the World of the 1980's is summarized in Table 3.1-1 below.

Table 3.1-1. The 1980's World Scenario

Technology
An increasing use of large-scale data banks, computational capability and analytical techniques by all sectors of the population, brought on by the massive increases in computer power and data transmission capability of the 1970's, will be in full swing. A multiplicity of peripheral equipment and services will be available; the use of such technology will be thought of as commonplace and will no longer be an oddity.
Public acceptance of government-funded research and development will reach a new peak by the early 1980's as the pendulum swings back from the technological depression of the mid-sixties and early seventies caused by the Vietnam War. The new enthusiasm for technology will, however, be focused on questions social, such as health, and environmental/ecological, such as pollution-free power generation.
Economics
The U.S. will be the largest economic power in the world but, by 1980, be only the largest of several major powers rather than in a class by itself, as in the 1960's and 1970's. The European Economic Commission and the Pacific Hemisphere Trading and Investment Area will be major factors in world economy.
International trade of all types will reach a new high, with particular increases in foodstuffs. International cooperation in agricultural production and marketing will be widespread, as the world seeks to maximize its ability to feed itself.
Growth of the economic influence of the Middle East upon the energy-consuming world and the energy produced trade surplus of Middle East nations will peak in the late 1970's. As the U.S. begins to react tapping of new or presently unexploited sources of energy, such as the Colorado coal fields, will begin. A major shift in the international balance of economic power via control of energy resources will thus be imminent.

Table 3.1-1. The 1980's World Scenario (Continued)

Politics
While Federal spending will decline in relation to the GNP, an increase in the regulation and control of private activities will occur. The dynamics of the social issues of the seventies, such as pollution, will be becoming understood and measures will be put in place to alleviate trends thought to be disastrous. The treatment of such social issues will thus change from a subjective crisis reaction to a methodical analysis and control process led by the Federal Government.
A major realignment of power between the executive and legislative branches will have occurred in the 1970's, with the result that more issues will be actively participated in by the general population via the Congress. Congress will, in making such participation possible, reorganize itself and exploit new technology to permit better analysis of problems and more rapid and interactive communications with its constituencies. The ease with which a citizen may vote will increase, as well the number of issues on which he has a direct influence on the outcome.

Future earth resources systems will contain many elements which are in the planning stages today, refer to Table 3.1-2. In addition, elements which prove beneficial will be more widely applied, especially by nations and groups with resource management needs, ability to pay, and ability to exploit the information collected. The potential for an increasing number of ground systems, serving special needs, appears to be high.

Table 3.1-2. Elements of Future Earth Resource Systems

Programmed
Space Shuttle - EOS - IOS - SEOS - TIROS - SMS/GOES - SEASAT
Potential
Operational A/C integrated with space systems
Multiple polar orbiters - USA - Japan - USSR - Brazil - Germany - Integrated Orbits
Special purpose systems - HYDROS, CARTOS
On-board processors - Transmit information not just data
Regional - National - International Ground Systems - Intercommunicating
Commercial Systems in place - A/C - Space - Ground Receiving - Data Processing
Global Wheat Major Food Crop Surveys - Widespread, Timely, Dissemination
Environment Monitoring - Global Extent and Source Identification
All Weather Capability, Radar Satellite
Data Collection and Analysis on Request

These elements, both planned and projected, were factored into the future system scenario. The role of Space Shuttle in making the projections a reality received special emphasis.

The derivation of system performance requirements in Task 3 utilizes a 1980's scenario as a source of overall guidelines and requirements. This methodology, in contrast to a parametric synthesis, is substantially more efficient in the time it consumes and permits the use of creativity and broad experience in a more direct fashion.

The scenario development was oriented toward fashioning a set of short statements about the system and its configuration which when considered as a whole, describes the total system and all its functions. These statements are presented in Table 3.1-3.

Table 3.1-3. The Earth Resources Program of the 1980's

NASA

NASA-sponsored research will have passed through the intensive search of the 1970's for initial useful applications and study of multi-spectral analysis techniques. It will be entering a new phase where much higher level mathematics, coupled with new computational technology, sensor sophistication, and the increased use of external data will be under investigation to provide much greater detail about the state of the sensed resource. Integration of these techniques with predictive modelling of resource dynamics will be methodologically common and a substantial fraction of the effort will be integrated with resource control dynamics.

Hardware technology developments will be less tied to and constrained by infrequent flight opportunities than in the past and will thus be time-phased to provide a more uniform development (and weeding out) process. An increase in the economic efficiency of development funds and a decrease in development times will result.

Significant new sensor and applications advances will have been made through the flight of ERTS-2, Nimbus VII, and subsequent conventionally launched polar spacecraft flights. Microwave sensing, both active and passive, will be operational system elements. Synthetic aperture radar imagers will have flown on a developmental shuttle sortie mission. A second generation of land, water, and atmospheric pollution sensors will be flight-ready.

Spacecraft subsystem technology will have progressed sufficiently to permit simple onboard analysis of imager data to extract several significant parameters and transmit them to a large number of simple ground stations.

The first relatively simple shuttle sorties will have flown, demonstrating the utility of this flight mode for sensor development. The role of the scientist/astronaut in such flights will have been relatively primitive but the experience gained will have established the basis for extension of crew involvement into higher order tasks such as onboard data analysis. Preparation for the use of the sortie flight mode in a quick reaction surveillance mode will be underway and a standard "piggy-back" package for use on nearly all flights will have been developed and be in use.

The development of a synchronous satellite capability for moderately high resolution (approx. 50-100m) will have been completed and a major flight program will be underway to demonstrate the utility of this system element and to establish the operations technology necessary for its conversion to operational use. The spaceborne segment of this system element will have, from the start, been designed for hand-over to an operational agency.

The use of prototype projects to perform final development of a system segment will be in widespread use. New operational improvements will be added in complete sections, including platform, sensors, ground processing techniques and equipment, user models, and operations procedures. Substantial involvement by the receiving agency will be present but the prototype projects will be an essential element of the development process and will thus be NASA-initiated.

The Operational Segment

A Federal Government agency will have operated an initial ERTS-based operational system for several years, gaining the experience necessary to assimilate new technology and to effect a major expansion of this system. The areas of expansion will include both increases in the number of Federal bureau "subscribers" and also more formal and extensive services to the state, regional, and local government bureaus.

The expanded operational system will include several polar-orbiting spacecraft with different orbital repeat cycles and ascending node times which will be tailored to the system users' requirements. Several spacecraft will be flown with both operational sensors and those in an advanced developmental stage with NASA-organized users consuming the data from the latter.

Table 3.1-3. The Earth Resources Program of the 1980's (Continued)

A substantial fleet of long-range, high-performance aircraft will be owned and/or operated by a Federal Agency in much the same fashion as the agency operates the polar and geosynchronous satellite system segments. The aircraft will be optimally based throughout the U.S. and other territories of interest using existing airport facilities where feasible. These aircraft will be used not only for operational data collection where they are economically superior to satellites but also as elements in prototype projects. NASA and other agencies will continue to operate specialized aircraft for sensor and applications development and for use in prototype projects not requiring large fleet sizes. A hierarchy of ground facilities will have been set up for operational data handling. Major Federal facilities will be owned and operated by several heavy Federal users. Such Federal users will also be chartered to perform preprocessing, extractive processing and distribution to designated state, regional, and local government users. Other users will establish this capability independently in cases where special requirements dictate. A tracking and data relay satellite system will have been designed, launched conventionally, and operated in cooperation with multiple polar-orbiting spacecraft to relay high-rate data to a U.S. ground station. An increased capacity version of the spacecraft will have been designed for launch by the shuttle and tug. The advanced system will be capable of receiving aircraft data, handling additional spacecraft, and relaying to multiple ground stations in the U.S. Its use will be by both developmental and operational flights. Command and control of the data collection system elements will be centralized and tightly integrated; operations will be highly flexible and adaptive. Coordination of aircraft, polar spacecraft, and geosynchronous spacecraft will be performed by a control hierarchy which will capitalize on the relative strengths, both in performance and economics, of the various platforms. The system will be capable of accepting large transients in the type, quantity, and location of output product demanded and of rapidly reconfiguring itself to respond.

Projecting future requirements and systems is hazardous, but largely unavoidable because requirements and systems are dynamic, not static. Explicitness and completeness, without quantitative constraints, were the primary objectives; the parametric process of defining quantitative performance requirements and performing tradeoffs must use the scenario as a rigorous specification of top-level system content, form and function. The scenario presented here describes the 1980's system which should occur if limited only by reasonable technology growth and the general world situation.

3.2 DEFINITION OF THE TERSSE USER'S

3.2.1 ANALYSIS OF INFORMATION REQUIREMENTS

In order to establish the TERSSE users let us briefly review some of the earlier TERSSE Task 1 results and place them in the proper context for this task of defining the system. The complete results of the Task 1 effort are reported in TERSSE Volume 1, entitled: Earth Resources Program Scope and Information Needs.

The major thrust undertaken in the definition of information requirements for the TERSSE was that of analyzing the organizational needs relevant to the program. The users of the information potentially to be produced by the program were first separated into two classes (refer to Figure 3.2-1) to which different treatments could be applied: major Federal organizations and other dominant organizations.

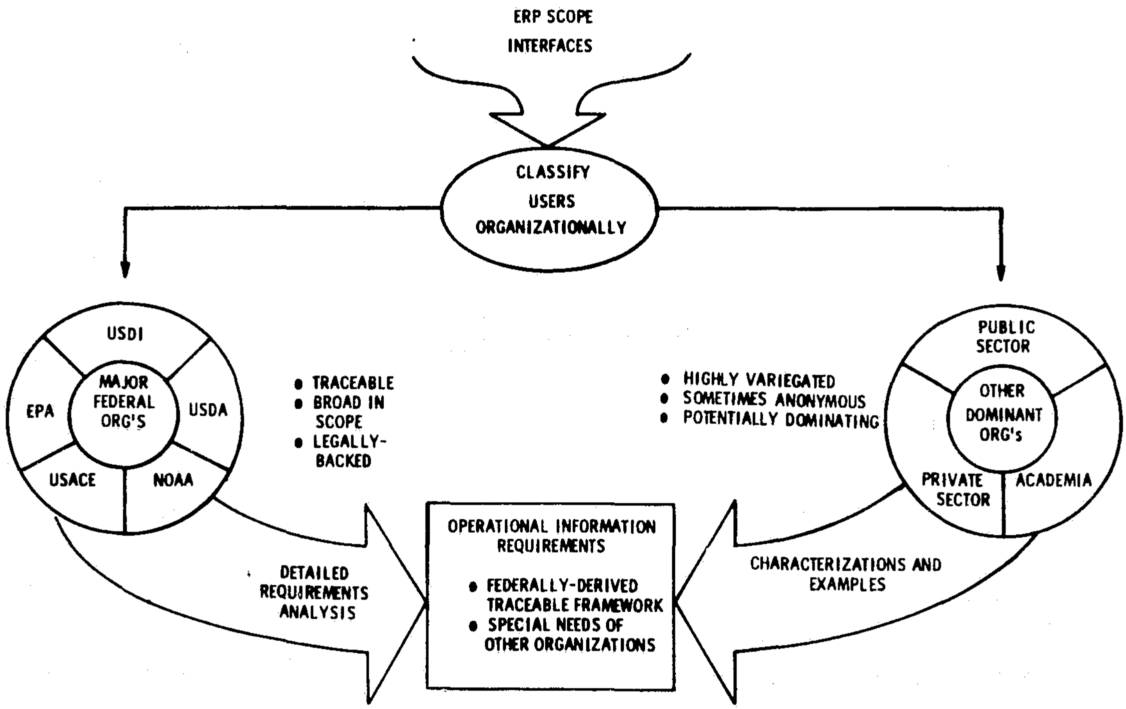


Figure 3.2-1. The Organizational Analysis

The Federal organizations provided a set of resource management-related missions which were traceable, comprehensive, and legally backed. This class of organization was able to be analyzed in great detail for job content and to be specifically correlated with or described in terms of discipline information classes. Included in the second class of organizations, other dominate organizations, were the several elements of the public, private, and academic sectors which could not be analyzed individually but which, when grouped and characterized by examples, reveal substantial impact upon the earth resources system performance requirements. A detailed framework for organizationally-based user requirements was thus derived from the Federal organizations and then modified to accommodate the deviations from the framework imposed by the second category, other dominant organizations.

From the Federal organizations reviewed, five were selected (Figure 3.2-2) which execute legally established resource management jobs. These five were analyzed to determine the missions of each and the functions necessary to carry out the missions. The analysis was structured to both provide an overall understanding of the resource management jobs carried out by the Federal government and also to provide the basis for the more detailed resource management task analysis which followed. This analysis began with the major cabinet level Departments and worked through to the specific resource management organization (e.g. Forest Service) and their particular resource management functions.

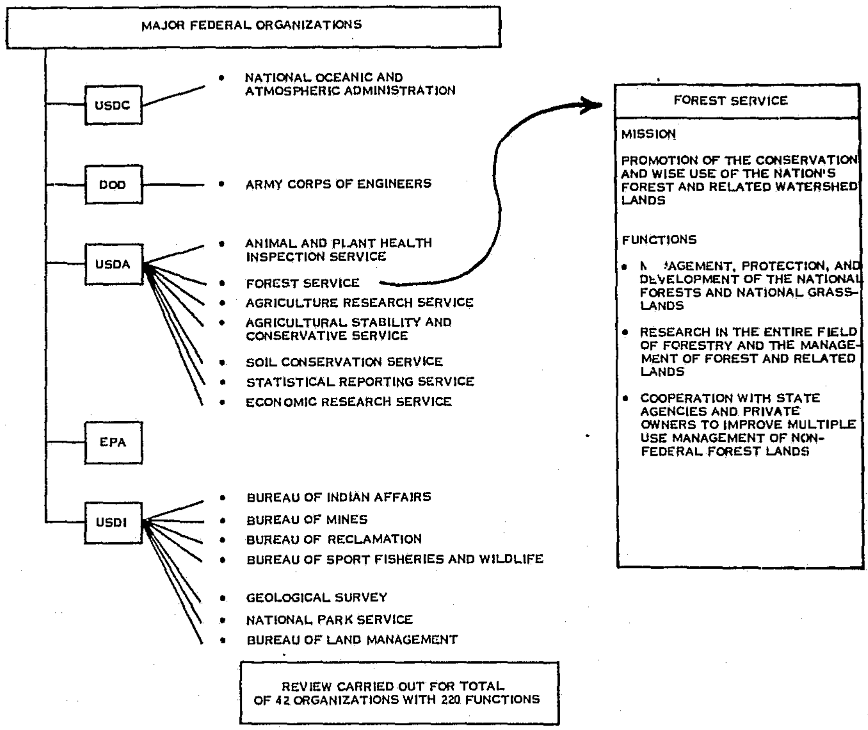


Figure 3. 2-2. Federal Organizations: Top Level Missions and Functions

Each of the selected Federal organizations underwent a detailed task analysis (Figure 3. 2-3) oriented toward establishing the specific content of the wide variety of resource management jobs performed by these organizations. Traceability to the Federal budget and existing statistics was maintained in the organization of the tasks. The primary value of the information generated lies in its comprehensiveness and depth in defining legally based, traceable work elements related to the interdisciplinary management of a resource.

Each organization was analyzed with respect to the Federal budget statutes in order to clearly identify their legal and budgetary authority. The output of this effort was a comprehensive identification of the resource management jobs being done by the Federal Government. All of these 125 activities and 816 tasks are traceable to the budget; where possible their statutory or governing authority was also established.

The significance of these results should not be understated. As a result of this effort there now exists for the Federal Government, a comprehensive set of users, each fully identifiable and traceable as to their functions and authority. This set, together with the major non-federal users will become both the starting point and the driving force for the TERSSE design.

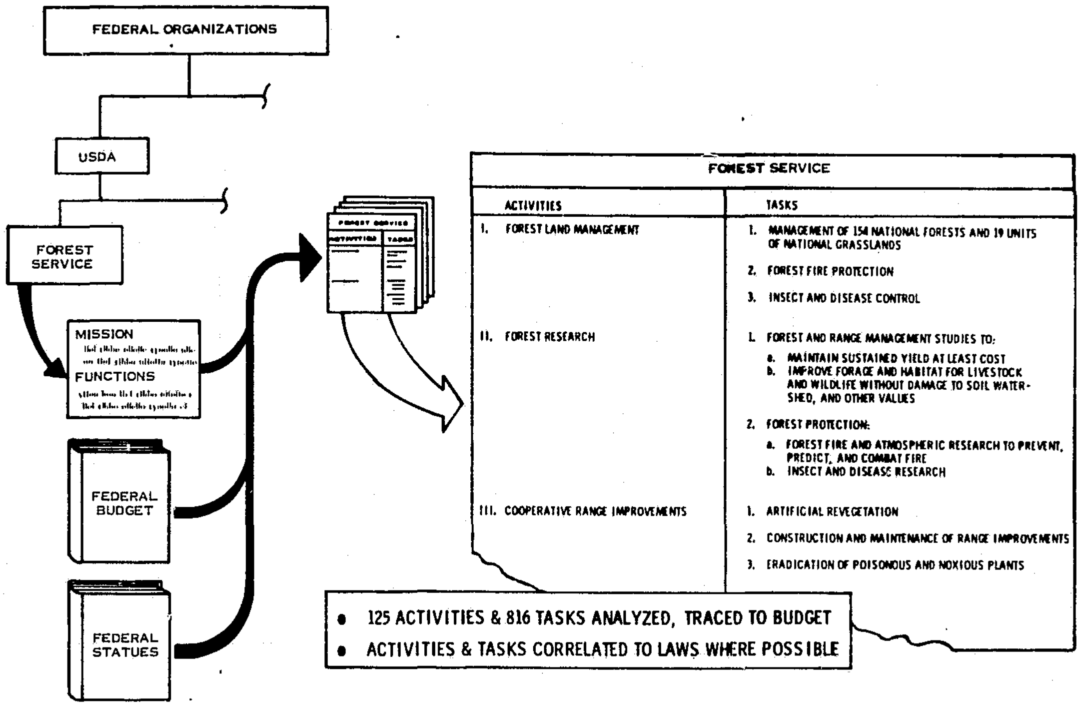


Figure 3.2-3. Major Federal Organizations Analysis of Activities and Tasks

The analysis of major Federal organizations established the general framework for the information requirements which need to be satisfied by the system. It is recognized, however, that there exists a host of other dominant organizations whose tasks are likely to perturb the general framework because of peculiarities with respect to geographic coverage, timeliness, accuracy, format, and particularly quantity of output products needed.

To keep the study tractable, other dominant organizations were analyzed collectively, instead of individually, as was the case with the major Federal organizations. As Figure 3.2-4 shows, this portion of the user community was treated in terms of three different sectors - public, academic, and private. The major subclasses under each sector were first characterized, then made specific through the use of examples, and finally analyzed for special requirements through the use of a checklist. The resulting data were used to modify the requirements framework established by the major Federal organization effort.

The resulting organizational analysis thus evaluated the needs of both the major Federal users and the various other sectors of the nation which are potentially dominating in their demands on the system. A traceable, task-oriented set of organizational information requirements has been produced as an input to the Task 3 requirements definition efforts.

PUBLIC SECTOR

- OTHER FEDERAL (E.G., USCG, TVA, USN, DMA, CSRS, FAS)
- STATE/COUNTY/MUNICIPAL (E.G., CALIFORNIA, L.A. COUNTY AND CITY)
- INTERGOVERNMENTAL (APPALACHIAN REGIONAL COMMISSION)

ACADEMIC SECTOR

- UNIVERSITIES, FOUNDATIONS, ACADEMIES, INSTITUTES

PRIVATE SECTOR

- CORPORATIONS, MARKETING ORGANIZATIONS, BROKERS, SPECIAL INTEREST GROUPS, INDIVIDUALS

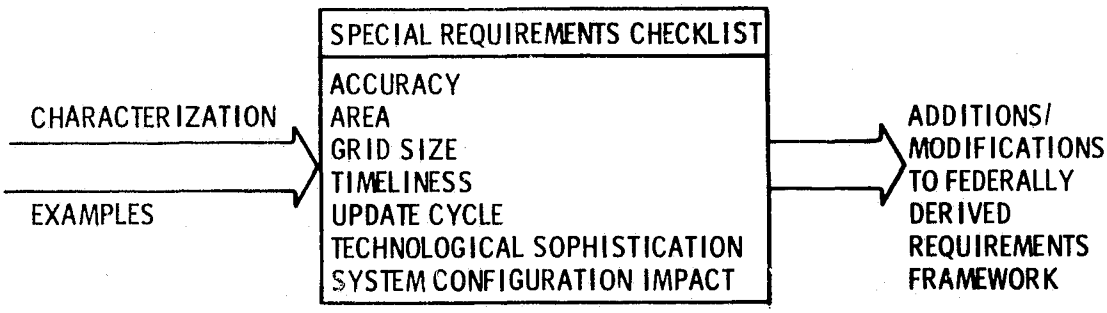


Figure 3.2-4. Other Dominant Organizations

3.2.2 DEVELOPMENT OF BASIC MISSION STATEMENT

In order to establish a concise set of resource management missions upon which to base TERSSE, the user needs (discussed in the previous section) were reviewed in the context of the Earth Resources scenario. This review process allowed a basic set of mission statements to be synthesized and established which are consistent with both the resource management needs and the projected realm of reasonableness as established by the scenario.

The synthesis of the TERSSE missions (Figure 3.2-5) was structured by dividing the field of resource management into six broad basic resource management discipline areas; these six are:

1. Agriculture
2. Energy/Minerals
3. Foresting
4. Land Use
5. Marine
6. Water

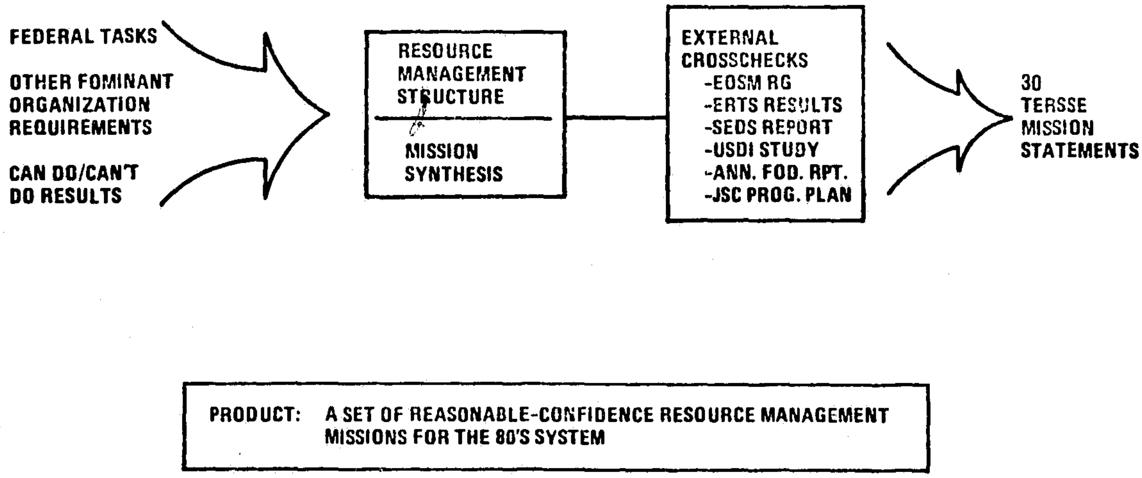


Figure 3. 2-5. Defining the TERSSE Missions

The basic criterion for the inclusion of a mission was that there be a reasonable chance of its being performed during the time frame under consideration. Definition of the missions was based on the following inputs from Task 1 of the study: (1) tasks of the Major Federal Organizations; (2) requirements of the Other Dominant Organizations; and (3) assessments of the relative amenability of the information classes to remote sensing. On the basis of a review and evaluation of these inputs in conjunction with the future scenario discussed previously, a list of 30 basic TERSSE missions was synthesized.

In order to ensure that no important mission would be overlooked, the tentative list of missions was checked against information contained in the JSC Program Plan, the ICCERSP Annual Report, the USDI Benefits Study, the SEOS Report, and the EOSMRG Report.

The result of this effort is a fundamental set of 30 reasonable resource management mission statements. These 30 mission statements, organized by the six resource management disciplines, are presented in Table 3. 2-1 below.

Table 3. 2-1. Basic TERSSE Missions

Agriculture

1. Survey U. S. Cropland to prepare statistical summaries and production forecasts for major crops.
2. Monitor U. S. pasture and cropland to detect and assess insect, disease, and stress damage.
3. Survey U. S. Cropland to evaluate current farming practices and classify areas on the basis of productivity.
4. Survey and monitor U. S. cropland to calculate short-and-long-run demand for irrigation water.
5. Survey major crops on a global basis to inventory acreage and forecast world production.
6. Survey pasture and range areas to prepare statistical summaries of forage acreages, calculate supportive capacity for livestock, and assess current grazing practices.

Table 3.2-1. Basic TERSSE Missions (Continued)

Energy/Minerals

1. Survey geological features to detect sites indicative of the location of mineral deposits.

2. Survey surficial thermal patterns to detect potential geothermal sources.

3. Survey waters of outer continental shelf areas to detect oil film possibly indicative of submarine oil deposits.

4. Monitor surface mining and oil drilling operations to detect resultant environmental pollution.

5. Monitor oil and gas pipelines to detect breaks or other environmental dynamics.

6. Monitor Deepwater ports to detect and assess oil pollution.

7. Monitor powerplant operations to detect and assess thermal pollution in adjacent waters.

Forest

1. Survey and monitor forestland to prepare forecasts of timber production, classify areas according to productive status, and assess the efficiency and ecological soundness of timber production and harvesting operations.

2. Monitor forests and grassland/brushland areas to detect and assess insect, disease, and stress damage.

3. Survey and monitor forests and grassland/brushland areas to assess fire potential, detect the outbreak of fire, assess the dynamics of fire, and assess damage.

Land

1. Survey and map current land use patterns within the U.S. in support of state land use planning and the management of federal lands.

2. Survey and map the natural vegetative cover, landforms, topography, underlying geology, and soil types of the U.S. land area.

3. Continuously survey lake and coastal shoreline morophology and the navigational channels within the coastal zone in support of shipping interests and the recreational use of coastal areas.

4. Survey, identify, and map the location of geological hazards over the U.S. land area.

Marine

1. Survey and map the physical and chemical properties of the global oceans relative to environmental prediction for optimum ship track routing, drilling operations, and other open ocean operations.

3. Survey and map the distribution and quantity of commercial and sport fish species in U.S. coastal and off-shore waters, their food supplies, and the appropriate environmental factors necessary to predict future catches.

4. Monitor the health of the global oceans by surveying the source, distribution and movement of the main pollutants in the marine environment, and marine organisms.

5. Survey and monitor hazards to navigation on the high seas, such as sea ice, icebergs, and severe wave conditions.

Table 3.2-1. Basic TERSSE Missions (Continued)

<u>Water</u>
1. Survey and inventory the volume and distribution of surface and ground water to assess available supplies for urban and agricultural consumption.
2. Monitor reservoir levels to manage the release of water through hydroelectric power generation facilities.
3. Survey and map great lakes ice cover and type to determine the passibility of navigational channels, the optimum routing of lake shipping, and the accessibility of ports.
4. Survey and monitor the quality of surface water throughout the U.S. and surrounding coastal zones with particular attention to lake eutrophication levels, agricultural and urban sources of water pollution, suitability for fish and wildlife and recreational use, and levels of pollutant discharge into the coastal zones from rivers and outfalls.
5. Survey and monitor surface water, snow cover, glaciers, and ground water levels and movement to identify potential flood conditions and to trace the movement of floodwaters.
6. Survey and monitor the surface water volume and indicator species of vegetation in wetlands and estuaries to evaluate the ecological productivity and development potential of wetland areas.

3.2.3 REPRESENTATIVE USER TASKS

To enable the detailed definition of mission and system requirements each of 30 basic TERSSE missions is represented by several specific resource managers and their resource management tasks. These mission representatives are referred to as user tasks. There are a total of 285 representative user tasks used to specifically define the basic 30 TERSSE missions.

As indicated by Figure 3.2-6 the representative users include examples from both the major federal organizations and the other dominant organizations. Referring to the Agriculture 3 mission statement shown as an example on the figure, it is seen that there are five representative users tasks for this mission. That is:

TERSSE Mission:

Agriculture 3 - Survey U.S. Cropland to Evaluate Current Farming Practices and Classify Areas.

User Task:

Agriculture 3.1 - USDA, Soil Conservation Service

Agriculture 3.2 - USDA, Statistical Reporting Service

Agriculture 3.3 - USDI, Bureau of Indian Affairs

Agriculture 3.4 - State Agriculture Department

Agriculture 3.5 - State Land Use Departments.

Note that although the mission statement lies within the Agriculture resource discipline group the user tasks include users from other organizations (USDI and State governments). In total, there are 285 user tasks used to represent the 30 TERSSE missions. These are presented in Table 3.2-2.

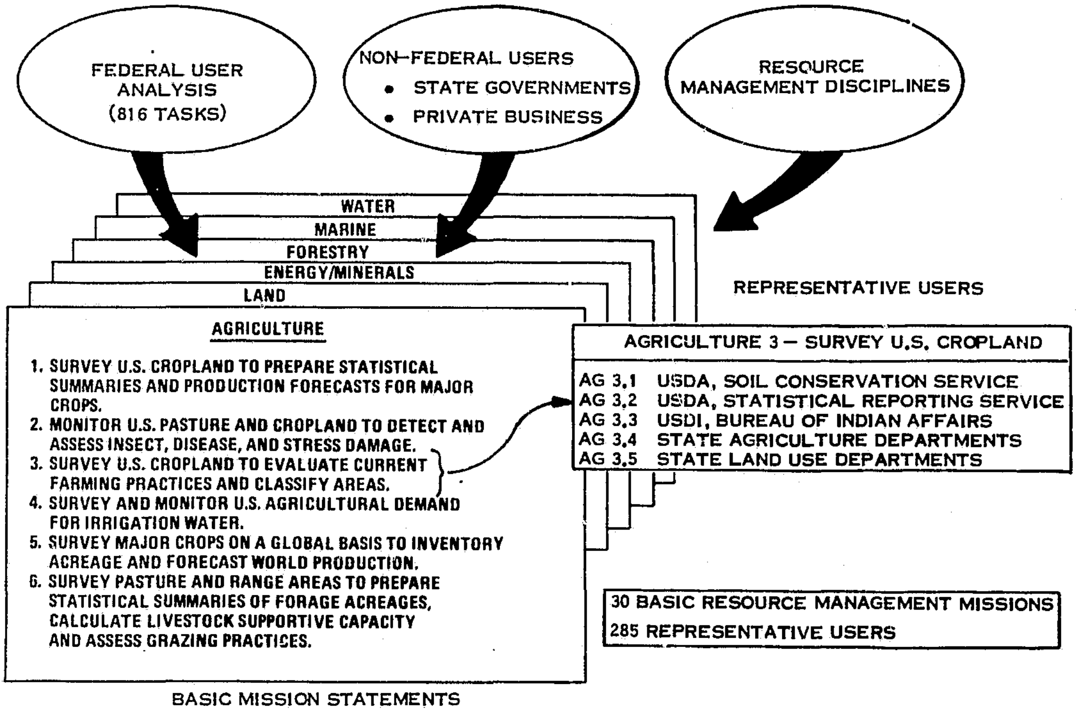


Figure 3. 2-6. Relationship Between TERSSE Missions and User/Tasks

It should be noted that the traceability of user requirements established in Task 1 is maintained in the 30 TERSSE missions and the user/task data base. The combination of letters, numbers, and Roman numerals following the Federal users in Table 3. 2-2 provide an index into the comprehensive Federal user analysis of Task 1. These designators are referenceable to Table 4. 3-1 of the TERSEE Task 1 report, Volume 1, "Earth Resources Program Scope and Information Needs".

3. 3 USER'S MISSION AND SYSTEM REQUIREMENTS

This section presents the specific requirement of the TERSSE users and the translation of these mission requirements into system requirements.

3. 3. 1 SPECIFIC USER REQUIREMENTS

The mission requirements were derived for each of the 30 TERSSE missions, as represented by the 285 representative user tasks. These requirements were determined by the TERSSE team together with the Environmental Research Institute of Michigan, ERIM, (under subcontract to General Electric).

The requirements were developed not by the specific users themselves, but rather by persons familar with the scientific disciplines, the 30 missions, and their objectives. The data included in the data base represents a broad-based definition of the amount, extent, and type of information needed for an earth resources management program in the era of the Space Shuttle. To provide the quantitative structure for defining the TERSSE architecture and requirements, an effort has been made to consider all aspects of resource management and to provide an overall and general view of earth observations requirements of the 1980's.

Table 3.2-2. Represeniative User/Mission/Tasks

AGRICULTURE 1•SURVEY U.S. CROPLANDS TO PREPARE STATISTICAL SUMMARIES AND PRODUCTION FORECASTS FOR MAJOR CROPS.

1.1 USDA-ASCS-B- OPERATION OF SUPPLY ADJUSTMENT, CONSERVATION AND PRICE SUPPORT PROGRAMS

1.2 USDA-SRS- CROP AND LIVESTOCK ESTIMATES

1.3 STATE AGRICULTURE DEPTS.

1.4 AGRIBUSINESS

AGRICULTURE 2•MONITOR U.S. PASTURE AND CROPLAND TO DETECT AND ASSESS INSECT, DISEASE, AND STRESS DAMAGE.

2.1 USDA-ARS - IMPROVEMENT OF CROP PRODUCTION PRACTICES.

2.2 USDA-SRS- CROP AND LIVESTOCK ESTIMATES.

2.3 USDA-PHIS- COOPERATIVE EFFORTS TO PREVENT SPREAD OF CROP PESTS.

2.4 USDA-USFS- FOREST AND RANGE MANAGEMENT

2.5 USDI-BLM- RANGE MANAGEMENT

2.6 USDI-BIA- FOREST AND RANGE SURVEYS; DEVELOPMENT OF MANAGEMENT PLANS

2.7 USDI-NPS IB1- FOREST MANAGEMENT

2.8 STATE AG DEPTS-

2.9 AGRIBUSINESS

2.10 RANCHERS

AGRICULTURE 3•SURVEY U.S. CROPLAND TO EVALUATE CURRENT FARMING PRACTICES AND CLASSIFY AREAS ON THE BASIS OF PRODUCTIVITY.

3.1 USDA-SCS-IA7

3.2 USDA-SRS- A2, A3 -ESTIMATES OF PRODUCTION ETC., CONDUCT OBJECTIVE MEASUREMENT SURVEYS

3.3 USDI-BIA-IE1- LAND-USE PRACTICES TO CONTROL EROSION AND PROMOTE MORE EFFECTIVE USE OF SOIL AND WATER RESOURCES.

3.4 STATE AG. DEPARTMENTS

3.5 STATE L.U. DEPARTMENTS

Table 3.2-2. Representative User/Mission/Tasks (Continued)

AGRICULTURE 4. SURVEY AND MONITOR U.S. CROPLAND TO CALCULATE SHORT AND LONG TERM DEMAND FOR IRRIGATED WATER.

4.1 USDI-BR IIIA- OPERATION OF PROJECTS FOR IRRIGATION, POWER, MUNICIPAL AND INDUSTRIAL WATER SUPPLIES.

4.2 USDI-BLM IA4d-DETERMINE NEED AND DEVELOPMENT OF PUBLIC LAND RESOURCES, IMPROVE WATER QUALITY, AND AVOID POLLUTION OF WATER.

4.3 USDA-SCS IV. WATER, WATERSHED, AND FLOOD PREVENTION OPERATION.

4.4 USDA-ARS IA1G- INVESTIGATIONS TO IMPROVE SOIL MANAGEMENT, STUDY HYDROLOGIC PROBLEMS.

4.5 STATE REG. WATER BOARDS.

4.6 AGRIBUSINESS

AGRICULTURE 5. SURVEY MAJOR CROPS ON A GLOBAL BASIS TO INVENTORY ACREAGE AND FORECAST WORLD PRODUCTION.

5.1 USDA ERS C2- FOREIGN ECONOMIC ANALYSIS ON SUPPLY AND DEMAND AND TRADE IN FARM PRODUCTS AND EFFECTS ON U.S. EXPORTS, ETC.

5.2 USDA-SRS A2,3- CONDUCT OBJECTIVE MEASUREMENTS SURVEYS; PREPARATIONS OF OFFICIAL ESTIMATES.

5.3 UN-FAO-

5.4 AGRIBUSINESS

AGRICULTURE 6. SURVEY PASTURE AND RANGE AREAS TO PREPARE STATISTICAL SUMMARIES OF FORAGE ACREAGE, CALCULATE SUPPORTIVE CAPACITY FOR LIVESTOCK, AND ASSESS CURRENT GRAZING PRACTICES.

6.1 USDA-FS IA1- MANAGEMENT OF 154 NATIONAL PARKS AND 19 NATIONAL GRASSLANDS.

6.2 USDI-BLM-IA2- RANGE MANAGEMENT

6.3 USDI-BIA IA1,4- FOREST AND RANGE SURVEYS

6.4 STATE AG. AND NAT. RES. DEPTS.

6.5 RANCHERS

ENERGY/MINERALS 1. SURVEY GEOLOGICAL FEATURES TO DETECT SITES INDICATIVE OF THE LOCATION OF MINERAL DEPOSITS.

1.1 USGS-IB - RESPONSIBILITIES UNDER MINING AND MINERALS POLICY ACT OF 1972

1.2 USGS-IB- RESPONSIBILITIES UNDER MINING AND MINERALS POLICY ACT OF 1972

1.3 USGS.IV.B.2 - MINERAL RESOURCES

1.4 USGS.VI.A.2 - MINERAL LEASE MANAGEMENT FOR FEDERAL AND INDIAN LANDS

1.5 BU MINES I.A.5.A - STUDY OF PHYSICAL NATURE OF ROCK STRUCTURE

1.6 BU MINES I.B.6.F - MINERAL SURVEYS OF LANDS INCLUDED OR CONSIDERED FOR INCLUSION IN THE NATIONAL WILDERNESS CONSERVATION SYSTEM

1.7 STATE GEOLOGICAL SURVEYS

1.8 OIL COMPANIES

1.9 MINING COMPANIES

ENERGY/MINERALS 2.SURVEY SURFICIAL THERMAL PATTERNS TO DETECT POTENTIAL GEOTHERMAL SOURCES.

2.1 USGS.I.C.3 - DEFINITION OF KNOWN GEOTHERMAL RESOURCE AREAS

2.2 USGS.I.C.6 - RECONNAISSANCE EXPLORATION OF U.S. FOR GEOTHERMAL RESOURCES

2.3 BUREC.I.B.1 - GEOTHERMAL INVESTIGATIONS

2.4 AEC

2.5 POWER COMPANIES

ENERGY/MINERALS 3.SURVEY WATERS OF OUTER CONTINENTAL SHELF AREAS TO DETECT OIL FILM POSSIBLY INDICATIVE OF SUBMARINE OIL DEPOSITS.

3.1 USGS.IV.C.1 - INVESTIGATIONS, GEOLOGIC MAPPING AND RESOURCE APPRAISALS OF CONTINENTAL SHELF AREAS

3.2 USCG/DOC

3.3 STATE GEOLOGICAL SURVEYS

3.4 OIL COMPANIES

ENERGY/MINERALS 4.MONITOR SURFACE MINING AND OIL DRILLING OPERATIONS TO DETECT RESULTANT ENVIRONMENTAL POLLUTION.

4.1 USGS.IV.A.1.C - DEVELOPMENT OF LAND USE INFORMATION SYSTEMS

4.2 USGS.IV.A.2.D - SURVEY AND INVESTIGATIONS

4.3 BLM.I.A.1.B - DEVELOPMENT OF ECONOMIC AND MORE EFFICIENT METHODS OF CONVERTING COAL TO CLEANER ENERGY FORMS

4.4 BLM-I.A.8.E - ANALYZE EXISTING OCS PIPELINE TO IDENTIFY POSSIBLE DAMAGES TO ENVIRONMENT TO DETERMINE HOW BLM RIGHT-OF-WAY REQUIREMENTS SHOULD BE STRENGTHENED

4.5 BLM-I.A.9 - TECHNICAL AND COMPLIANCE EXAMINATIONS FOR NEW ON-SHORE MINERAL LEASES

4.6 BUMINES - I.B.4 -

4.7 BUMINES-IIA - DRAINAGE OF ANTHRACITE MINES

4.8 EPA-C ENFORCEMENT

4.9 DOC/USCG

4.10 MINING COMPANIES

4.11 OIL COMPANIES

4.12 STATE NAT. RES. DEPTS.

ENERGY/MINERALS 5. MONITOR OIL AND GAS PIPELINES TO DETECT BREAKS OR OTHER ENVIRONMENTAL DYNAMICS.

5.1 USGS-VI.A.1.C - INVESTIGATIONS, GEOLOGIC MAPPING AND RESOURCE APPRAISALS OF CONTINENTAL SHELF AREAS

5.2 BLM-I.A.7.E - EVALUATION OF OVERALL ENVIRONMENTAL EFFECTS OF ALASKA PIPELINE AND ATTENDANT FACILITIES

5.3 BLM-I.A.1.B

5.4 BLM-I.A.8.D

5.5 BUMINES-I.A.2.C

5.6 STATE PUBLIC SERVICE COMMISSION

5.7 PIPELINE COMPANIES

ENERGY/MINERALS 6. MONITOR DEEP WATER PORTS TO DETECT AND ASSESS OIL POLLUTION.

6.1 DOC/USCG

6.2 EPA-C

6.3 PORT AUTHORITIES

6.4 STATE ENVIRONMENTAL QUAL. DEPARTMENT

6.5 SHIPPING COMPANIES

Table 3.2-2. Representative User/Mission/Tasks (Continued)

ENERGY/MINERALS 7.MONITOR POWER PLANT OPERATIONS TO DETECT AND ASSESS THERMAL POLLUTION IN ADJACENT WATERS.

7.1 BSFW-I.D.4.A - SURVEILLANCE AND INVESTIGATION OF ENVIRONMENTAL DEGRADATION INVOLVING WATER POLLUTIONS

7.2 BSFW-I.G.5 - MONITORING OF ENVIRONMENTAL WELL-BEING OF FISH RESOURCES AND THEIR HABITATS IN LARGE RIVERS

7.3 BSFW-I.I.1 - ENVIRONMENTAL IMPACT STUDIES FOR WATER RESOURCE PROJECTS, FACILITIES, CONSTRUCTION, DREDGING, ETC.

7.4 EPA-I.B.2.C - WATER POLLUTION ABATEMENT AND CONTROL

7.5 EPA-C

7.6 STATE DEPARTMENT NATURAL RESOURCES

7.7 POWER COMPANIES

FOREST 1.SURVEY AND MONITOR FOREST LAND TO PREPARE FORECASTS OF TIMBER PRODUCTION, CLASSIFY AREAS ACCORDING TO PRODUCTIVE STATUS, AND ASSESS THE EFFICIENCY AND ECOLOGICAL SOUNDNESS OF TIMBER PRODUCTION AND HARVESTING OPERATIONS.

1.1 BIA I A1-FOREST AND RANGE SURVEY

1.2 BIA I A2- DEVELOPMENT OF MANAGEMENT PLANS IN ACCORDANCE WITH PRINCIPLES OF SUSTAINED YIELD.

1.3 BLM IA3- FORESTRY

1.4 BLM IV B- FOREST DEVELOPMENT AND PROTECTION (OREGON AND CALIFORNIA)

1.5 USFS IB1A- MAINTAIN SUSTAINED YIELD AT LEAST COST

1.6 USFS IB4A- INVENTORY AND APPRAISE CONDITION OF FORESTRY

1.7 SRS IA3- PREPARATION AND ISSUANCE OF OFFICIAL NATIONAL ESTIMATES

1.8 STATE AG./FOR. DEPTS.

1.9 TVA

1.10 LUMBER CO'S

FOREST 2.MONITOR FOREST AND GRASSLAND/BRUSHLAND AREAS TO ASSESS INSECT, DISEASE, AND STRESS DAMAGE.

2.1 BIA IA7- FOREST AND RANGE FIRE DETECTION AND PRESUPPRESSION

2.2 NPS IB1A- CONTROL OF EXOTIC INSECTS AND DISEASES

2.3 BLM IVB- FOREST DEVELOPMENT AND PROTECTION (OREGON AND CALIFORNIA)

Table 3.2-2. Representative User/Mission/Tasks (Continued)

2.4 USFS IA4. INSECT AND DISEASE CONTROL IN TIMBER AREA

2.5 USFS I B2B. INSECT AND DISEASE RESEARCH

2.6 STATE FORESTRY DEPT., IVA, LUMBER CO.'S

2.7 TVA

2.8 LUMBER COMPANIES

FOREST 3. SURVEY AND MONITOR FOREST AND GRASSLANDS/BRUSHLANDS AREAS TO ASSESS FIRE POTENTIAL, DETECT THE OUTBREAK OF FIRE, ASSESS THE DYNAMICS OF FIRE AND ASSESS DAMAGE.

3.1 BIA IA7. FOREST AND RANGE FIRES DETECTION AND PRESUPPRESSION.

3.2 BIA IC1. SUPPRESSION OR EMERGENCY PREVENTION OF FIRE ON OR THREATENING INDIAN RESERVATION.

3.3 BIA IC2. EMERGENCY REHABILITATION OF BURNED-OVER AREAS

3.4 NPS IB2. FIRE PROTECTION SERVICES AND REHABILITATION OF BURNED AREAS

3.5 BLM IA5. FIRE PROTECTION

3.6 BLM IA 12. PUBLIC LAND FIRE PROTECTION

3.7 BLM IC1. PRESUPPRESSION AND SUPPRESSION OF FIRES ORIGINATING ON, OR JEOPARDIZING PUBLIC LANDS.

3.8 USFS IA3. FOREST FIRE PROTECTION

3.9 USFS IB 2. FOREST PROTECTION

3.10 STATE FORESTRY DEPT.

3.11 TVA

3.12 LUMBER CO.'S

LAND 1. SURVEY AND MAP CURRENT LAND USE PATTERNS WITHIN THE U.S. IN SUPPORT OF STATE LAND USE PLANNING AND THE MANAGEMENT OF FEDERAL LANDS.

1.1 USGS IA3. COORDINATION OF GEOLOGIC, HYDROLOGIC AND TOPOGRAPHIC DATA

1.2 USGS III B. RESEARCH ON COLLECTION, PROCESSING AND PRESENTATION OF ENVIRONMENTAL AND NATURAL RESOURCES DATA.

1.3 BSFW IH3. WILD LIFE ENHANCEMENT

1.4 NPS IC1. COOPERATIVE ACTIVITIES

1.5 BLM IA1. LAND AND MINERALS MANAGEMENT

1.6 BLM IA6. RECREATION AND WILDLIFE

1.7 BLM IA13. PUBLIC LAND INVENTORY AND ENVIRONMENTAL ANALYSIS

1.8 BR I A3. BASIN SURVEYS

1.9 SCS VI A1. AGRICULTURAL WATER MANAGEMENT

1.10 USAC E IA3. COMPREHENSIVE RIVER BASIN

1.11 USACE IB5. FLOOD PLAIN MANAGEMENT

1.12STATE LAND USE AGENCIES

LAND 2.SURVEY AND MAP THE NATURAL VEGETATIVE COVER, LAND FORMS TOPOGRAPHY, UNDERLYING GEOLOGY, AND SOIL TYPES OF THE U.S. LAND AREA.

2.1 USGS IIIB. RESPONSIBILITIES

2.2 USGS IV A1. DEVELOPMENT OF LAND USE INFO. SYSTEM

2.3 USGS IVC1. INVESTIGATION, GEOLOGIC MAPPING AND RESOURCE APPRAISAL OF CONTINENTAL SHELF AREAS.

2.4 NPS IC1. COOPERATIVE ACTIVITIES

2.5 BSFW D3. ANNUAL SURVEY TO DETERMINE ABUNDANCE, DISTRIBUTION AND TRENDS OF MIGRATORY GAME BIRD POPULATION.

2.6 BSFW.IF1. WATER FOWL MANAGEMENT RESEARCH

2.7 BLM IA6. RECREATION AND WILDLIFE.

2.8 BR IA1. RECONNAISSANCE OF WESTERN U.S. WATER PLAN

2.9 BR IA2. RECONNAISSANCE STUDIES OF SPECIFIC PROJECTS

2.10 BR IA3 . BASIN SURVEY

2.11 BR ID1 . WATER RESOURCES PLANNING AND ENGINEERING RESEARCH

2.12 SCS.IA2. PUBLICATION OF SOIL SURVEY WITH INTERPRETATION

2.13 SCS II A1. COMPREHENSIVE FRAMEWORK SURVEY

2.14 SCS V A1. SOIL AND WATER CONSERVATION

2.15 USACE.H AQUATIC PLANT CONTROL

2.16 STATE DEPT. NAT. RES..

LAND 3.CONTINUOUSLY SURVEY LAKE AND COASTAL SHORELINE MORPHOLOGY AND THE NAVIGATIONAL CHANNELS WITHIN THE COASTAL ZONE IN SUPPORT OF SHIPPING INTERESTS AND THE RECREATIONAL USE OF COASTAL AREAS.

Table 3.2-2. Representative User/Mission/Tasks (Continued)

3.1 NOAA IB2. NAUTICAL CHARTING

3.2 NOAA IB4. COASTAL ZONE MAPPING AND SERVICES.

3.3 USACE IA2. BEACH EROSION CONTROL

3.4 USACE IIC. BEACH EROSION CONTROL PROJECTS

3.5 STATE NAT. RES.

3.6 USACE IIB. NAVIGATION PROJECTS

LAND 4.SURVEY, IDENTIFY, AND MAP THE LOCATION OF GEOLOGICAL HAZARDS OVER THE U.S. LAND AREA.

4.1 USGS IA1,IIA1,IVA2,IVC2,IVC3

4.2 STATE NAT. RES. DEPT.

4.3 O.E.P.

4.4 INSURANCE CO.

4.5 RED CROSS

4.6 USDI BRID2. ATMOSPHERIC WATER RESOURCE MANAGEMENT PROGRAM

4.7 USDI. NPS IA1. MANAGEMENT OF PARK AND INTERPRETATION OF NATIONAL PARKS.

4.8 STATE DEPT. NAT. RES.

4.9 INS. CO'S RED CROSS

4.10 SKI RESORTS

4.11 USGS IVA2,3 EVALUATION AND PROJECTION OF WATER RESOURCES; COORDINATION OF GEOLOGIC, HYDROLOGIC, AND TOPOGRAPHIC DATA.

4.12 STATE DEPT. OF NAT. RES.

4.13 O.E.P.

4.14 USGS-IVA 2- SURVEY AND INVESTIGATIONS OF EARTH HAZARDS

4.15 OEP, INSURANCE COS, RED CROSS, STATE NAT. RES. DEPTS., STATE HIGHWAY DEPTS.

4.16 USACE-II D1- CONSTRUCTION OF RESERVOIRS FOR FLOOD CONTROL AND OTHER PURPOSES.

4.17 INSURANCE COS. ; MINING COS.

4.18 BM IA5-MINING

4.19 USGS- IA1-IDENTIFY EARTH HAZARDS IVA2- SURVEYS AND INVESTIGATIONS OF EARTH HAZARDS

Table 3.2-2. Representative User/Mission/Tasks (Continued)

4.20 INSURANCE CO'S; STATE NAT. RES. DEPT.

4.21 INSURANCE CO'S; MINING CO'S

4.22 USACE IID1. FLOOD CONTROL PROJECTS.

MARINE 1.SURVEY AND MAP THE PHYSICAL AND CHEMICAL PROPERTIES OF THE GLOBAL OCEANS RELATIVE TO ENVIRONMENTAL PREDICTION FOR OPTIMUM SHIP TRACK ROUTING, DRILLING OPERATIONS, AND OTHER OPEN OCEAN OPERATION.

1.1 USGS IV C2. STUDIES OF SEDIMENT MOVEMENT, SUBMARINE SLOPE, ETC.

1.2 NOAA IB2. NAUTICAL CHARTING

1.3 NOAA IB3. MARINE GEOGRAPHYSICAL MAPPING AND SERVICES

1.4 NOAA IB4.COASTAL ZONE MAPPING AND SERVICES

1.5 USACE ICF. COASTAL ENGINEERING R + D

1.6 STATE DEPT. NAT. RES.

MARINE 3.SURVEY AND MAP THE DISTRIBUTION AND QUANTITY OF COMMERCIAL AND SPORT FISH SPECIES IN THE U.S. COASTAL AREA AND OFFSHORE WATERS, THEIR FOOD SUPPLIES, AND THE APPROPRIATE ENVIRONMENTAL FACTORS NECESSARY TO PREDICT FUTURE CATCHES.

3.1 NOAA ID1. RESOURCE ASSESSMENT

3.2 NOAA IID IB. SURVEY DATA PROCESSING ANALYSIS AND DISSEMINATION.

3.3 NOAA IID IB. SURVEY DATA PROCESSING ANALYSIS AND DISSEMINATION.

3.4 NOAA IID IB. SURVEY DATA PROCESSING ANALYSIS AND DISSEMINATION.

3.5 NOAA IIB 2B. NAVIGATION CHARTING

3.6 COASTAL STATES BUR. OF FISHING

3.7 COMM. + SPORT FISHING, IND.

3.8 GT. LAKES STATE BUR. OF FISHING

3.9 GT. LAKES FISHING INDUSTRY

MARINE 4.MONITOR THE HEALTH OF THE GLOBAL OCEANS BY SURVEYING MARINE ORGANISMS, AND BY SURVEYING THE SOURCE, DISTRIBUTION, AND MOVEMENT OF THE MAIN POLLUTANTS IN THE MARINE ENVIRONMENT.

4.1 USGS IV C4. STUDY OF DISTRIBUTION AND MOVEMENT OF TRACE ELEMENTS IN MAJOR ESTUARIES

4.2 USGS VB6. DATA COLLECTION STUDIES OF CURRENTS AND DISSOLVED AND SUSPENDED SOLIDS OF SPECIFIC ESTUARIES.

4.3 USDI-NPS IA1. MANAGEMENT OF SEASHORES AND LAKE SHORES

4.4 USDI-BSFW II 4C. ALASKA PIPELINE, MARINE TERMINAL STUDIES IN PRUDHOE BAY AND PRINCE WILLIAM SOUND

4.5 USDI- BSFW III1. DETERMINE CONDITION OF HABITAT INCLUDING EFFECTS OF POLLUTION.

4.6 NOAA II B5A. GREAT LAKES RESEARCH

4.7 NOAA II B 2B. RESEARCH ON STRUCTURE, VELOCITY, AND EXTENT OF OCEAN CURRENTS TO FACILITATE BETTER PREDICTION OF WATER, HEAT, POLLUTANTS, PLANKTON, AND FISH TRANSPORT.

4.8 EPA IB2. WATER POLLUTION ABATEMENT AND CONTROL

4.9 USACE IA4. SPECIAL STUDIES TO RESOLVE UNIQUE OR ESPECIALLY COMPLEX WATER RESOURCES PROBLEMS.

4.10 COASTAL STATES WATER RESOURCES COMM.

4.11 GREAT LAKES STATES WATER RESOURCES COMM.

MARINE 5. SURVEY AND MONITOR HAZARDS TO NAVIGATION ON THE HIGH SEAS, SUCH AS SEA ICE, ICEBERGS, AND SEVERE WAVE CONDITIONS.

5.1 NOAA IA7. MARINE ENVIRONMENT FORECAST

5.2 NOAA IA7. MARINE ENVIRONMENT FORECAST

5.3 GREAT LAKE STATES

5.4 GREAT LAKES STATES, COASTAL STATES NAV. COMM.

5.5 ALASKA, MARINE NAVIGATION COMM.

WATER 1.SURVEY AND INVENTORY THE VOLUME AND DISTRIBUTION OF SURFACE AND GROUND WATER TO ASSESS AVAILABLE SUPPLIES FOR URBAN AND AGRICULTURAL CONSUMPTION.

1.1 USACE IA4. SPECIAL STUDIES TO RESOLVE UNIQUE WATER RESOURCES PROBLEMS.

1.2 USDI-BIA-IAG. OPERATION AND MAINTENANCE OF LIVESTOCK WATER FACILITIES.

1.3 ARS-IA1G. IMPROVE SOIL, STUDY HYDROLOGIC PROBLEMS

1.4 SCS IIIA . SMALL WATERSHED PROJECT INVESTIGATIONS AND PLANNING

1.5 SCS VA. GREAT PLAINS CONSERVATION PROGRAM

1.6 SCS IIA1. COMPREHENSIVE FRAME WORK SURVEYS

Table 3.2-2. Representative User/Mission/Tasks (Continued)

1.7 SCS IIA2- COMPREHENSIVE DETAILED SURVEY

1.8 SCS IIA3- COOPERATIVE RESOURCES STUDIES WITH STATES AND LOCAL ORGANIZATIONS.

1.9 USGS-IA2-EVALUATION AND PROJECTION WATER RESOURCES

1.10 NPS IC2- LAND AND WATER RESOURCES STUDIES.

1.11 BR ID1A- WATER SUPPLY AUGMENTATION AND CONSERVATION

1.12 SCS IB2 - SNOW SURVEY TO DEVELOP STREAM FLOW FORECASTS IN WESTERN STATES

1.13 SCS IVA3- AGRICULTURAL WATER MANAGEMENT

1.14 SCS VIA3- CARRY OUT CONSERVATION MEASURES FOR WATER SHED PROTECTION AND FLOOD PREVENTION.

1.15 USGS VA2- REGIONAL RESOURCE APPRAISALS INCLUDING GROUND-WATER STUDIES.

1.16 BLM IA4 - SOIL AND WATERSHED CONSERVATION

1.17 BR IA6- REGIONAL PLANNING SERVICE

1.18 BR ID 16- WATER QUALITY MANAGEMENT STUDIES.

1.19 USFS IB1- FOREST AND RANGE MANAGEMENT STUDIES

1.20 BR IA2 - RECONNAISSANCE STUDIES OF SPECIFIC PROJECTS DEALING WITH ASPECTS OF MULTIPURPOSE DEVELOPMENT

1.21 BR IA3- BASIN SURVEYS

1.22 BR ID1A- WATER SUPPLY AUGMENTATION AND CONSERVATION

1.23 SCS V A- GREAT PLAINS CONSERVATION PROGRAM

1.24 STATE WATER RES. AGENCY

1.25 AGRIBUSINESS

WATER 2.MONITOR RESERVOIR LEVELS TO MANAGE THE RELEASE OF WATER THROUGH HYDROELECTRIC POWER GENERATOR FACILITIES.

2.1 BR-IA2- RECONNAISSANCE STUDIES OF SPECIFIC PROJECTS (MULTI-PURPOSE) DEVELOPMENT

2.2 BSFW III1- ENVIRONMENTAL IMPACT STUDIES

2.3 TVA

2.4 STATE POWER COMM.

2.5 STATE WATER COMM.

2.6 POWER CO'S

WATER 3.SURVEY AND MAP THE GREAT LAKES' ICE COVER AND TYPE TO DETERMINE THE PASSIBILITY OF NAVIGATION CHANNELS, THE OPTIMUM ROUTING OF LAKE SHIPPING, AND THE ACCESSIBILITY OF PORTS.

3.1 NOAA II B2B. RESEARCH ON STRUCTURE, VELOCITY, AND EXTENT OF OCEAN CURRENT TO FACILITATE BETTER PREDICTION OF WATER, HEAT, POLLUTANT, PLANKTON, AND FISH TRANSPORT

3.2 CG 100 C.

3.3 ST. LAWRENCE SEAWAY CO.

3.4 GT. LAKES STATES DEPT. OF COMMERCE

3.5 SHIPPING IND.

WATER 4.SURVEY AND MONITOR THE QUALITY OF SURFACE WATER THROUGHOUT THE U.S. AND SURROUNDING COASTAL ZONES WITH PARTICULAR ATTENTION TO: LAKE EUTROPHICATION LEVELS; AGRICULTURAL AND URBAN SOURCES OF WATER POLLUTION; SUITABILITY FOR RECREATIONAL USE, FISH, AND WILDLIFE; LEVELS OF POLLUTANT DISCHARGE INTO THE COASTAL ZONES.

4.1 NPS IA1. MANAGEMENT OF PARKS AND OTHER AREAS

4.2 NPS IC2. LAND AND WATER RESOURCE STUDIES (ACQUISTION PROGRAM)

4.3 USGS IA2. EVALUATION AND PROJECTION OF WATER RESOURCES

4.4 USGS VA1. ACQUISITION, ANALYSIS, STORAGE, AND DISSEMINATION OF DATA ON STREAM FLOW.

4.5 BSFW IF1 . FISH ECOSYSTEM RESEARCH

4.6 BSFW II2. SMALL WATER SHED PROGRAM

4.7 BLM IA4. SOIL AND WATER SHED CONSERVATION

4.8 BR IA2E. WATER QUALITY CONTROL

4.9 BR IA3. BASIN SURVEYS

4.10BU REC. IDIC. WATER RESOURCES PLANNING

4.11 SCS III A. SMALL WATER SHED PROJECT INVESTIGATIONS AND PLANNING

4.12 SCSIV A7. POLLUTION ABATEMENT THROUGH STREAM FLOW REGULATION

4.13 EPA IB2. WATER POLLUTION ABATEMENT AND CONTROL

4.14 USACE IA4. SPECIAL STUDIES TO RESOLVE UNIQUE OR COMPLEX WATER RESOURCE PROBLEMS.

4.15 USACE IB4. INTERNATIONAL WATER STUDIES

4.16 STATE WATER RES. COMM.

4.17 STATE PUBLIC HEALTH COMM.

WATER 5. SURVEY AND MONITOR SURFACE WATER, SNOW COVER, GLACIERS, AND GROUND WATER LEVELS AND MOVEMENT TO IDENTIFY POTENTIAL FLOOD CONDITIONS AND TO TRACE THE MOVEMENT OF FLOODWATERS.

5.1 USDI-GS VB4- FLOOD HAZARD MAPPING

5.2 SGS II4- FLOOD HAZARD ANALYSES OF INDIVIDUAL COMMUNITIES

5.3 SGS II4- FLOOD HAZARD ANALYSES OF INDIVIDUAL COMMUNITIES

5.4 SGS IV A2- FLOOD PREVENTION

5.5 SGS IV B- FLOOD PREVENTION OPERATION

5.6 USACE IB5- FLOOD PLAIN MANAGEMENT SERVICES.

5.7 USACE IID 1- CONSTRUCTIONS OF RESERVOIRS FOR FLOOD CONTROL AND OTHER PURPOSES

5.8 USACE IV A- EMERGENCY FLOOD CONTROL AND SHORE PROTECTION.

5.9 USACE IA1- NAVIGATIONAL AND FLOOD CONTROL STUDIES TO DETERMINE NEED AND ECONOMIC JUSTIFICATION FOR PROPOSED WATER AND RELATED LAND RESOURCE DEVELOPMENT.

5.10 NOAA IA 13- RIVER AND FLOOD FORECASTS AND WARNING

5.11 USACE III B- FLOOD CONTROL PROJECTS

5.12 BR III D- GENERAL ENGINEERING AND RESEARCH

5.13 USGS II A2- HYDROLOGIC INVESTIGATIONS

5.14 US BM IIA1- DRAINAGE OF ANTHRACITE MINES

5.15 BR IA2- RECONNAISSANCE STUDIES OF SPECIFIC PROJECTS DEALING WITH MULTI-PURPOSE DESIGN.

5.16 BR IA 3- BASIN SURVEY

5.17 III C BR- SOIL AND MOISTURE CONSERVATION

5.18 STATE DEPT. OF AGRICULTURE

WATER 6. SURVEY AND MONITOR THE SURFACE WATER VOLUME AND INDICATOR SPECIES OF VEGETATION IN WETLANDS AND ESTUARIES TO EVALUATE THE ECOLOGICAL PRODUCTIVITY AND DEVELOPMENT POTENTIAL OF WETLAND AREAS.

6.1 USDI-NPS-IA1- MANAGEMENT OF PARKS AND OTHER AREAS

6.2 USDI-BSFW-IB1- MANAGEMENT OF WILDLIFE REFUGES

6.3 USDI-BSFW-II1- ENVIRONMENTAL IMPACT STUDIES FOR WATER RESOURCE PROJECTS, FACILITIES, CONSTRUCTION, DREDGING ETC.

6.4 USDI-BLM-IA6C- ENHANCEMENT OF WILDLIFE HABITAT

6.5 USDI-BLM-IA6G- AQUATIC HABITAT MANAGEMENT PLANS

Table 3.2-2. Representative User/Mission/Tasks (Continued)

6.6 USDA-SCS-VA

6.7 USDC-NOAA IB4- COASTAL ZONE MAPPING AND SERVICES

6.8 USACE-IA4- SPECIAL STUDIES TO RESOLVE UNIQUE OR ESPECIALLY COMPLEX WATER RESOURCES PROBLEMS

6.9 USDI-BSFW-IF3- ACQUISTION OF MANAGEMENT INFORMATION PERTAINING TO WILDLIFE ECOLOGY ON PUBLIC LANDS

6.10 USDI-BLM-IA7A- ACTIVITIES INCIDENT TO ISSUANCE OF RIGHT-OF-WAY AND ASSOCIATED PERMITS (ALASKA PIPELINE)

6.11 USDI-BSFW-ID3- ANNUAL SURVEYS TO DETERMINE ABUNDANCE, DISTRIBUTION AND TRENDS IN MIGRATING GAME BIRD POPULATIONS AND THEIR HABITATS.

6.12 USDA-SCS-IVA5- FISH AND WILDLIFE DEVELOPMENT

6.13 USDA-SCS-VI3- CONSERVATION MEASURES FOR WATERSHED PROTECTION AND FLOOD PREVENTION

6.14 STATE DEPARTMENT OF WILDLIFE AND FISHERIES

The various requirements of each of the representative 285 user/tasks have been collated into a requirements data base. This data base contains the information shown in Figure 3.3-1 for each user task organized into the general categories of:

Observation coverage

Measurements

Pre-Processing

Extractive Processing

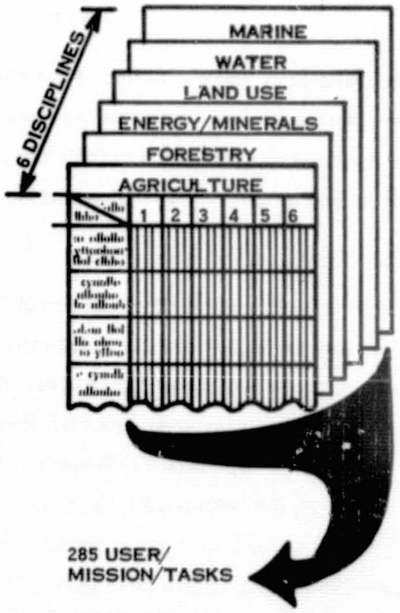
Output Products

The complete data base is presented in Appendix A, User's Mission and System Requirements Data, of this TERSSE report (due to its physical size, approximately 300 pages, Appendix A is separately bound as TERSSE report Volume 8). Figure 3.3-2 contains the data base entries for the Agriculture 1.1 user/mission/task as an example.

Care must be exercised when using this data base that undue significance is not placed on any single data item. It is the general trends and groupings of the data which are meaningful and which were used in this study. The data items contained in the data base were determined without extensive user interaction and iteration. Although no attempt has yet been made to rank or prioritize the user tasks the data base their large number will provide aggregate answers to the question of overall system architecture which are not seriously biased.

IDENTIFICATION:
USER/MISSION/TASK

OBSERVATION COVERAGE: LOCATION, AREA, LATITUDE, FREQUENCY, DURATION	PRE-PROCESSING: GEOMETRIC, RADIOMETRIC
MEASUREMENTS: TIME OF DAY, RESOLUTION, OBLIQUITY, CHARACTERISTICS, SPECTRAL BANDS, ACCURACY, AUXILIARY MEAS.	EXTRACTIVE PROCESSING: INFO TYPE, TECHNIQUE, BANDS USED
	OUTPUT PRODUCTS: FORMAT, INFO. GRID, TIMELINESS, UPDATE CYCLE, DURATION



- INCLUDES 285 SPECIFIC USER/MISSION/TASKS IN 30 BASIC MISSIONS IN 6 PRIMARY DISCIPLINE CATEGORIES
- NO ATTEMPT MADE YET TO RANK OR PRIORITIZE—REQUIRES WORTH/IMPORTANCE/BENEFIT INFORMATION
- REPRESENTS BEGININGS OF STANDARDIZED USER DATA BASE—REFINEMENT AND ITERATION NOW POSSIBLE
- EXPERIENCE AND JUDGEMENT NECESSARY IN ORDER TO APPLY TO SPECIFICS

Figure 3.3-1. User Task Requirements Data Base

```
MISSION/USER NUMBER: AGRICULTURE 1.1
MAJOR MISSION: SURVEY U.S. CROPLANDS TO PREPARE STATISTICAL SUMMARIES AND PRODUCTION FORECASTS FOR MAJOR CROPS.

SPECIFIC USER TASK: USDA-ASCS-B- OPERATION OF SUPPLY ADJUSTMENT, CONSERVATION AND PRICE SUPPORT PROGRAMS

GEOGRAPHIC COVERAGE:
    LOCATION: U.S. AGRICULTURE REGION
    AREA (KM**2): 5.0 X 10**5 /// 1.4 X 10**6                    LATITUDE: WITHIN 27.5 - 52 DEGREES

COVERAGE:
    FREQUENCY: 1 DAY EVERY 14
    DURATION: MAY-JUL MIDWEST /// JAN-DEC CAL,TEX,FLA

MEASUREMENTS (REMOTE):
    TIME OF DAY: 1200                                   OBLIQUITY: ANY (VIS-IR) 30 DEGREES OFF NADIR (MW)
    RESOLUTION-HIGH FREQ: 10 METERS                     RESOLUTION-MICROWAVE: 100 METERS
    DISTINGUISHING CHARACTERISTICS: SPECTRAL SIGNATURE            TEMPORAL SPECTRAL SIGNATURE
                                    SCATTERING CROSS SECTION (MW)

    HIGH FREQ SPECTRAL BANDS (MICRONS): .51-.55 .62-.66 1.0-1.4 1.5-1.8 2.0-2.6 9.5-11.5

    MICROWAVE BANDS: X,L RADAR
    RADIOMETRIC ACCURACY: N/A                                                      * SUN ANGLE > 30 DEG

AUXILIARY MEASUREMENTS:     | SOIL MOISTURE           | DEGREE DAYS              | PLANT LEAF AREA INDEX | RAINFALL HISTORY
    GCPS FOR GEOM REGIS     | ATMOSPHERIC VISIBILITY  | ENRGY DIFF/ENERGY TOTAL  |                       |
    TRAINING SET LOCATIONS  |                         |                          |                       |

DATA PROCESSING:
    GEOMETRIC PREPROCESSING: LOCAL MAP GRID ROTATED (E.G. LARS APPROACH)
    RADIOMETRIC PREPROCESSING: 1B - RELATIVE ATMOSPHERE CALIBRATION TO INTERNAL STANDARD (FRAME TO FRAME)

EXTRACTIVE PROCESSING:
    INFO TYPE: 1.1 CROP INVENTORY                 | 1.1 CROP INVENTORY
    TECHNIQUE: 3B-SUP PAT RCG (SPC,SPA,TEM)       | 5B-ESTIMATORS (SPC,SPA,TEM)
    BANDS:     2 VIS-IR  3 MIR  1 TH              | 2 VIS-IR  3 MIR  1 TH
    INFO TYPE:
    TECHNIQUE:
    BANDS:
    INFO TYPE:
    TECHNIQUE:
    BANDS:
    INFO TYPE:
    TECHNIQUE:
    BANDS:
    INFO TYPE:
    TECHNIQUE:
    BANDS:

OUTPUT PRODUCTS:
    FORMAT: C3 RECORDED STAT ANALYSIS OUTPUT /// C5 RECORDED STAT ANALYSIS OUTPUT /// B1 MAPS (HAND AND/OR MACHINE)
    [illegible] TRACT                                /// OWNERSHIP PARCEL            /// TRACT
    TIMELINESS [illegible] DAYS
    [illegible]
    [illegible] /// [illegible]

[illegible] NUMBER: AGRICULTURE 1.1
```

Figure 3.3-2. Computer Data Base Example

The general trends and clustering of the requirements can be readily observed when the raw data is compiled in the form of histograms. A few of the requirements for which this was done are shown in the figures below where four of the key requirements are individually discussed. These four key requirements are: (1) Coverage cycle, (2) Spatial resolution, (3) Sun illumination angle, and (4) Duration of coverage.

Coverage Cycle

The distribution of user task requirements for coverage cycle are shown in Figure 3.3-3 to range from several times per day through every few weeks to only once (ever). Coverage cycle is that requirement parameter which specifies the required frequency of observation (number of observations per time interval). It should be noted that coverage cycle is not synonymous with frequency of overflight; external interveening factors such as cloud cover can easily cause a significant difference. Two significant points to note are (1) the significant number of user tasks (70 out of 285) who have a requirement for a single observation once. Second, the presence of a bureaucratic rhythm which shows up as weekly, monthly, and quarterly observation requirements. This rhythm is a direct result of most user's need to publish various resource reports on a regular (calendar oriented) basis.

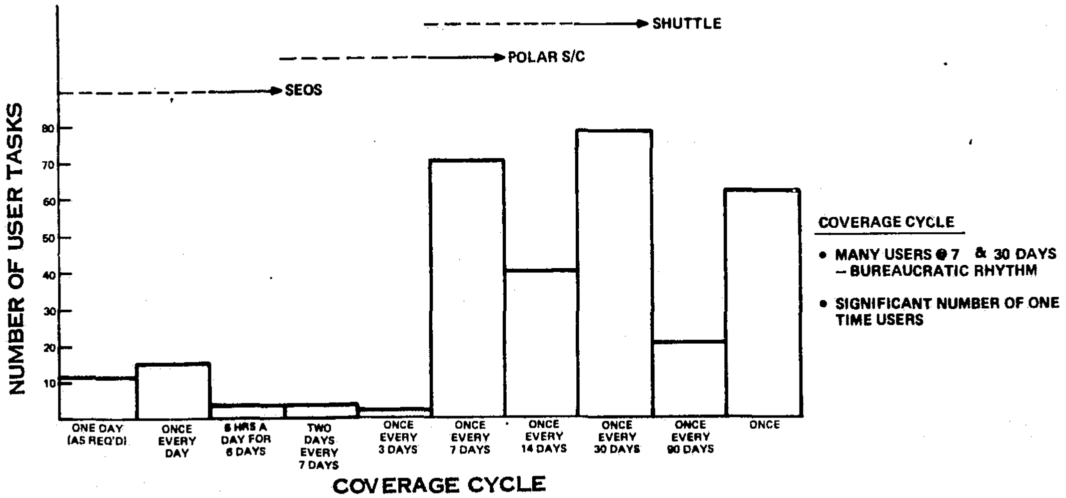


Figure 3. 3-3. Coverage Cycle Requirements

Spatial Resolution

The distribution of user task requirements for spatial resolution are shown in the histogram of Figure 3. 3-4. Those requirements are seen to range from 1 meter to 1000 meters IFOV with the largest cluster by far in the 50 to 100 meter category. A smaller, yet still significant group of user tasks have requirement for spatial resolution in the 5 to 10 meter range.

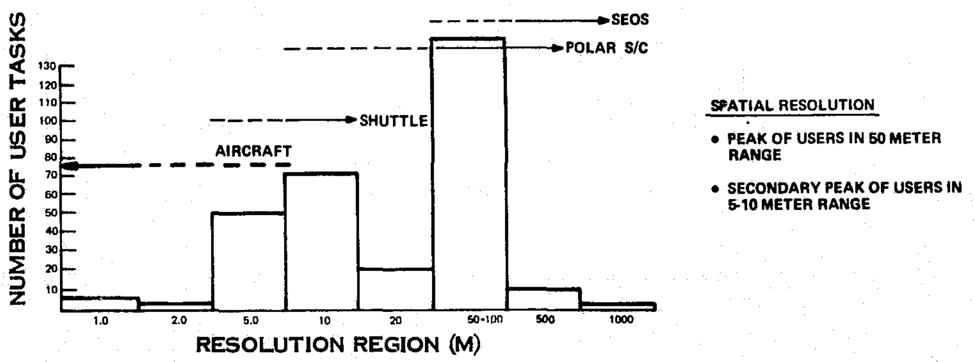


Figure 3. 3-4. Spatial Resolution Requirement

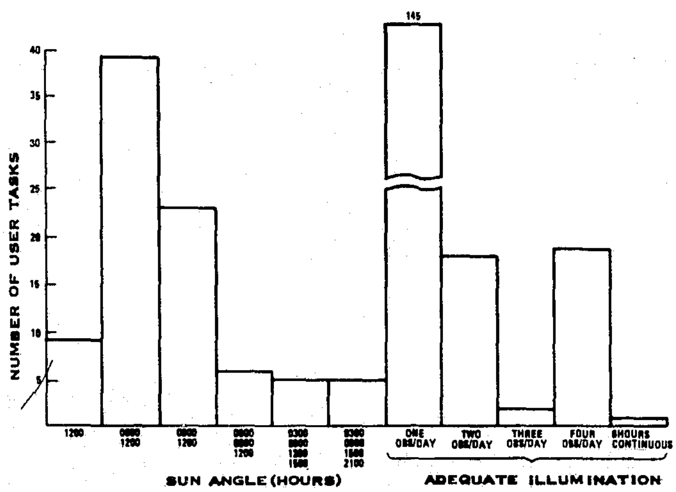
Superimposed with the histogram are the four basic categories of remote sensing platforms. The solid and dashed arrows with each platform provide a rough guideline of that platforms utilization in the TERSSE. The solid portion indicates a definite capability/need while the dashed portion indicates a possible but usually impractical or uneconomical realm of operation.

Sun Illumination Angle

The distribution shown in Figure 3.3-5 expresses the user task requirements for the various sun illumination angles. This solar illumination requirement is expressed in terms of time-of-day of the observation (close to the nodal crossing time for sun synchronous orbits). It is readily apparent from this distribution that about half of the user tasks have no specific illumination requirements (as long as adequate illumination is available). Another point of note is that the mid-day (1200 hour) observation will serve all user tasks with a single daily observation requirement and will contribute to almost all of the multiple observations per day requirements.

Duration of Coverage

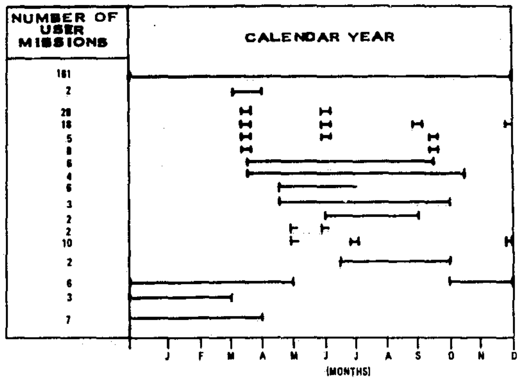
The summation of requirements shown in Figure 3.3-6 depicts the distribution of the user task's observation coverage requirements throughout the year. It is readily apparent that over half of the user tasks require year round coverage and thus are not seasonal in nature. The remainder of the user tasks have intermittent coverage requirements which a spread throughout the year. There is a discernable peak of user tasks (primarily from the Agriculture resource management discipline area) who require early Spring (March), early Summer (June), and late Summer (September) observation coverage.



SUN ANGLE

- **1200 HR ACCEPTABLE FOR MOST**
- **0600, 0900, 1200**
- **NOT CRITICAL (ADEQUATE LIGHT) FOR ABOUT HALF**

Figure 3.3-5. Solar Illumination Requirements



DURATION

- **HALF ARE YEAR ROUND**
- **PEAKS IN MARCH, JUNE, SEPT.**

Figure 3.3-6. Duration of Coverage Requirements

3.3.2 MISSION/SYSTEM REQUIREMENTS TRANSLATION

As noted from the previous section, the mission requirements are expressed in terms of user (resource manager) oriented parameters and requirements. In order to develop a system such as TERSSE, these parameters must be translated into system requirement parameters useful to the system designer. What is necessary is a quantitative structure which will serve as an effective translator between what the informational needs of the Resource Manager are and what the system design requirements of the TERSSE designer are.

This translator must be capable of defining the users needs in the designers terms. This translation is not an easy one, for it must simultaneously be responsible to a wide variety of mission requirements and reflect the series of performance parameters which dominate the system design. The translation structure used for TERSSE is shown here in Figure 3.3-7.

Many of the system requirements involve multiple mission requirements and of necessity require considerable juggling to arrive at an optimal solution. For example, consider the determination of the number and type of remote sensing platforms. As shown on the figure, there are six mission requirement parameters (Observation - location/area, coverage cycle, duration, sun angle, obliquity, and Sensor resolution) which must simultaneously be considered in order to determine the true system characteristics. By way of contrast, other systems requirements are relatively straight forward; for example, the extractive processing throughput (a major driver of the ground system) is a direct function of the type of processing and the number of pixels involved.

3.4 MISSION INFORMATION FLOWS

For each of the 30 TERSSE missions the flow of information through the data system to the users was determined. This information flow includes the preprocessing and extractive processing required, the use of auxillary data, both ancillary and in-situ, and the flow of output product to the users. These information flows thus represent a requirement on the ground system configuration.

SYSTEM REQUIREMENTS

MISSION REQUIREMENTS	PLATFORMS			SENSORS					PREPROCESSING		EXT. PROC	USER MODELS	OUTPUT PROD.	
	TYPE/NO	REPEAT CYCLE	NODE TIME	TYPE	RESOLUTION	BANDS	PRECISION/ ACCURACY	FOV	RAD T'PUT	GEOM T'PUT	T'PUT BY TYPE	NUMBER BY TYPE	TYPE	OUTPUT RATE
OBSERVATION														
- LOCATION/AREA	X								X	X	X	X	X	
- COVERAGE CYCLE	X	X						X	X	X	X			
- DURATION	X								X	X	X			
- SUN ANGLE	X		X											
- OBLIQUITY	X													
SENSOR														
- RESOLUTION	X				X			X	X	X	X			
- BANDS						X			X	X	X			
- DIST. CHAR.				X										
- PREC ACC							X							
- IN-SITU MEAS														
PREPROCESSING														
- GEOM. CO										X				
- RADIOM. CORR									X					
EXTRACTIVE PROC														
- ANCILLARY DATA														
- TECHNIQUE											X			
- OUTPUTS											X			
USER MODELS														
- TYPE												X		
- ANCILLARY DATA														
- OUTPUTS														
OUTPUT PRODUCT														
- FORMAT													X	X
- TIMELINESS													X	X
- UPDATE CYCLE													X	X

Figure 3. 3-7. From Mission to System Requirements

These 30 information flows, one for each mission, are included as Appendix C to this TERSSE report Volume. One of the 30, the Water 1 mission, is shown here in Figure 3. 4-1 as an example. These information flows are a unique output of the TERSSE study. They present in one place the complete flow of remotely sensed data as it progresses thru the various data processing to the eventual users.

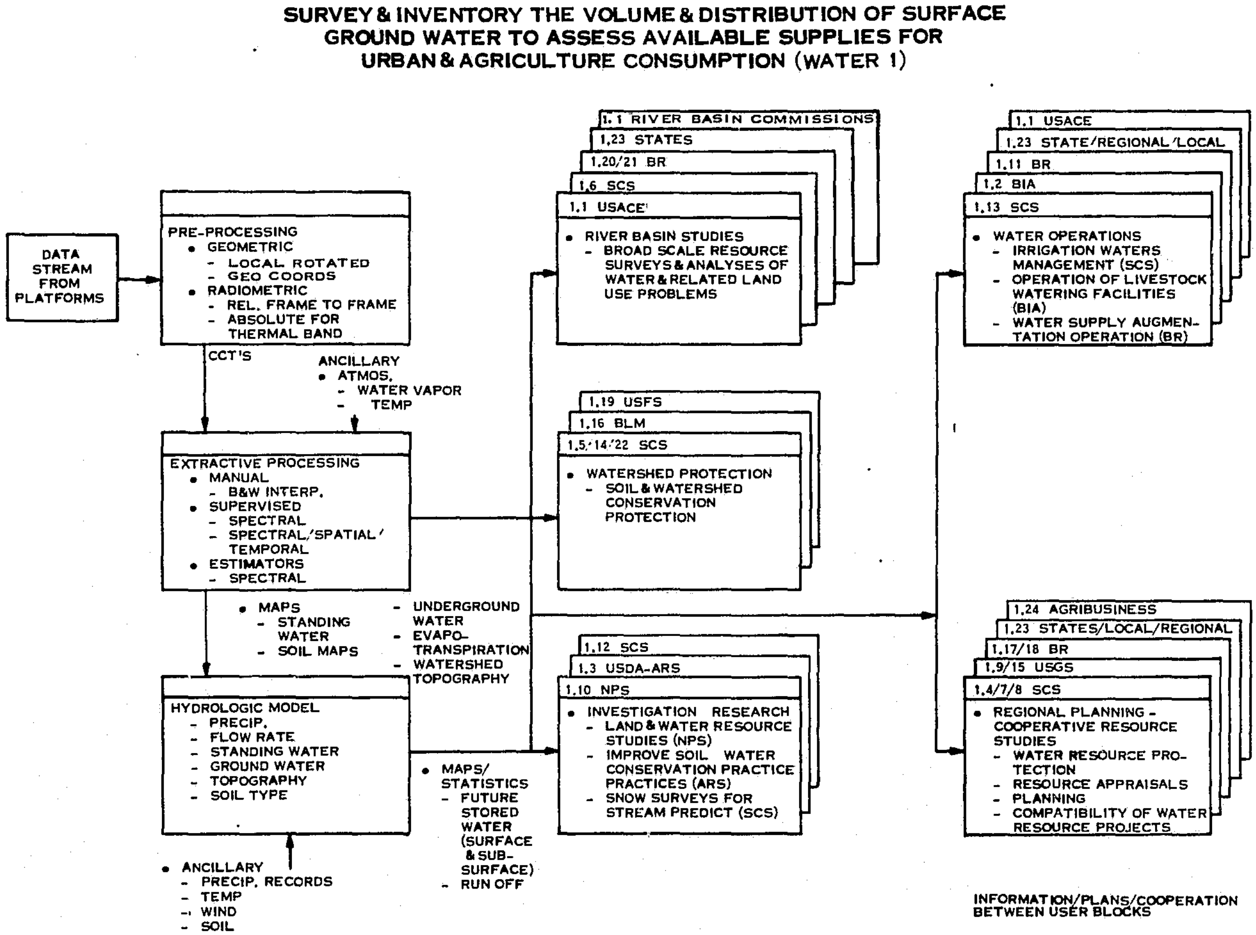


Figure 3.4-1. Information Flow - Water 1 Mission

SECTION 4

REMOTE SENSING PLATFORMS

Automated spacecraft, Shuttle sortie flights and aircraft are the principal means of gathering remotely sensed information for the earth resources management functions. No single observation platform can provide the required information while operating with the following constraints:

Cost

Sensor power, weight, volume, thermal stability, data handling

Resolution, spatial and spectral

Frequency of observation

Sun illumination

Cloud cover

Therefore a set of seven remote sensing platforms were derived from the user requirement data base in order to provide the required information. The seven TERSSE types are shown in Figure 4-1; these are:

1. Earth Synchronous

2. Predawn Sun Synchronous

3. Morning Sun Synchronous

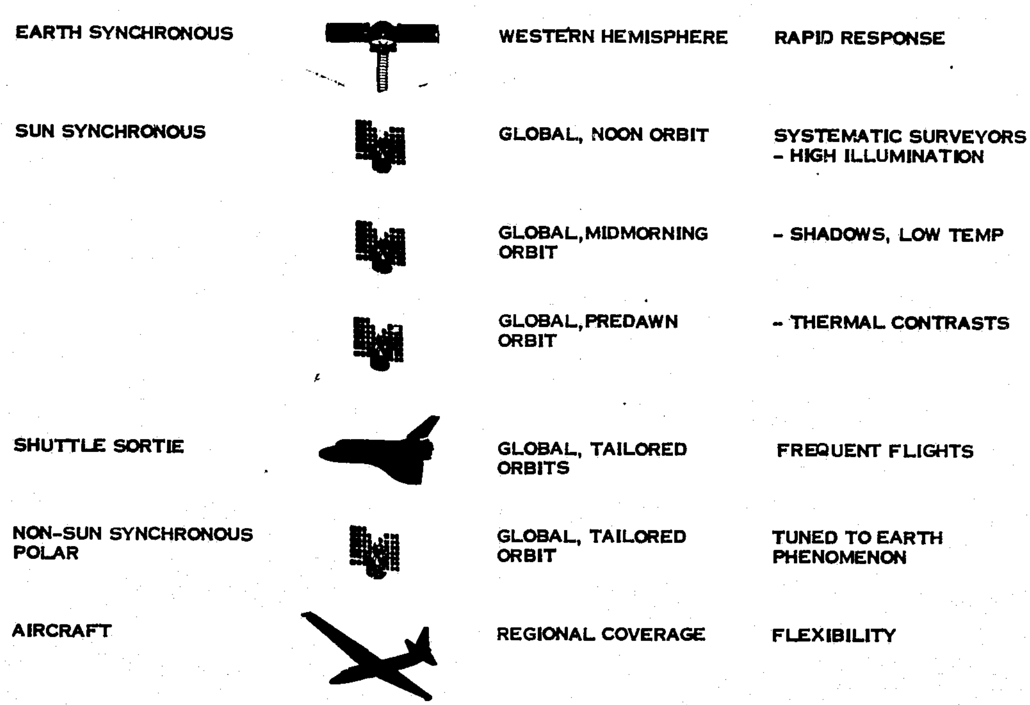


Figure 4-1. Seven TERSSE Platform Types

4. Mid-day Sun Synchronous

5. Shuttle Sortie

6. Non Synchronous Spacecraft

7. Aircraft

4.1 SELECTION OF PLATFORMS

The data base of the 30 TERSSE missions (Section 3.3) was used to determine the specific platforms required. The inputs used were:

1. Location/Area

2. Coverage Cycle

   Nodal Time

4. Duration

5. Obliquity

6. Resolution

The location determines such things as whether one Earth Synchronous satellite can be used (above 57° latitude the large oblique viewing angles cause distortion in the data). The area determines whether an aircraft or a spacecraft should be used, considering the economics of using multiple aircraft as compared to a single spacecraft. The coverage cycle determines such things as whether a Shuttle sortie can be used on a once every 30 days repeat cycle, or the repeat cycle of Sun Synchronous satellites vs. swath width is required.

The observation duration determines whether a continuous observation is required where an Earth Synchronous, Sun Synchronous, or Non Sun Synchronous satellite platform should be used or whether for shorter observation durations aircraft or Shuttle sortie is more adequate. Obliquity determines whether more than one oblique viewing angle is required per target of observation (for stereo photographs, etc), thus, for example, limiting the Earth Synchronous satellite mission where it can only provide one viewing angle only.

The spatial resolution parameter takes into account the present and near future (1980's technology) sensor capabilities as a function of observation platform altitude. For example a 50 meter scanner in a geosynchronous orbit, a 10 meter scanner in a solar orbit, a 5 meter scanner in a Shuttle orbit and a 1 meter high altitude aircraft are all technologically achievable sensors. This parameter therefore determines what platform is required to carry what sensor to provide the required spatial resolution. Figure 4.1-1 shows the platform selection screen for the seven types of platforms.

The four histograms shown in Figure 4.1-2 are typical of the use made of the data base, facilitating the selection of the TERSSE platforms. The four subjects presented include spatial resolution, coverage cycle, coverage duration and observation sun angle.

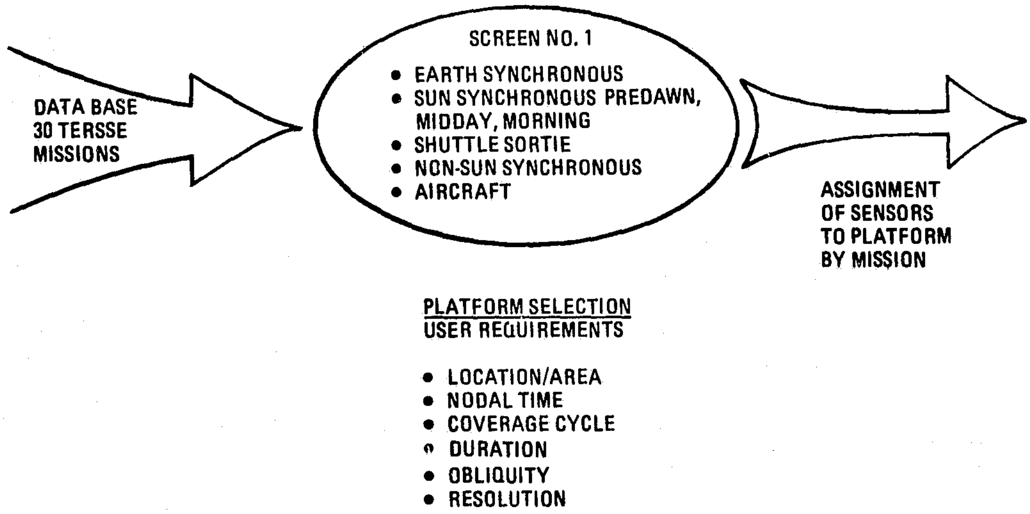
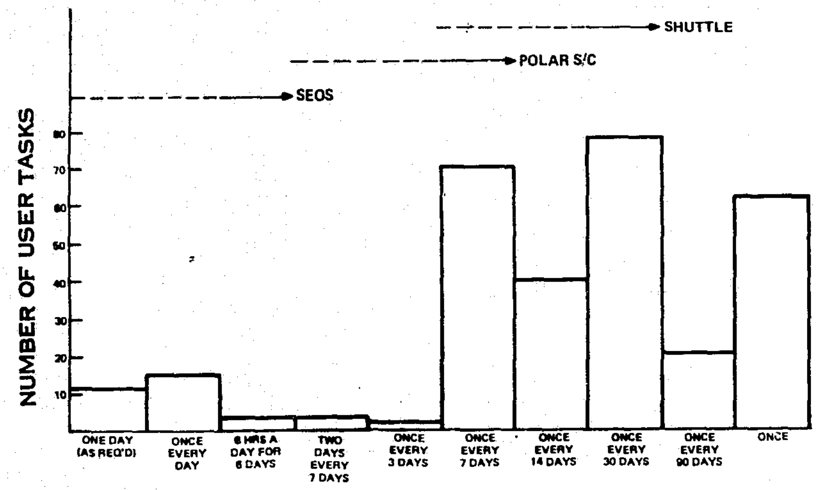


Figure 4. 1-1. System Requirement Development Platform Selection

4. 2 ASSIGNMENT OF MISSIONS TO PLATFORMS

The mission requirements of the 30 basic mission statements, as represented by the 285 user tasks, were used to establish the basic platforms set for TERSSE. As a result of analyzing the platform-related mission requirements using the computerized data base it was determined that seven specific platform types would satisfy all the identified missions with respect to remote sensing. The seven platform types required are identified in Figure 4. 2-1.

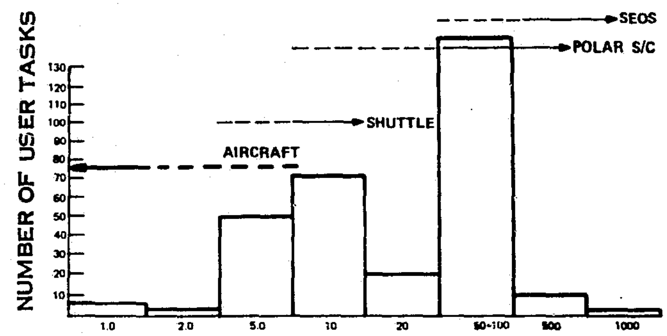
The specific platform characteristics used to allocate the thirty resource missions to the various platforms are shown in Table 4. 2-1. These characteristics were iterated with the mission assignments for three different cases of spatial resolution. The earth synchronous satellite is the only one that has a location limitation of $\leq 57°$ latitude due to the distortion created by large oblique viewing angles at higher latitudes. Nodal crossing time is a restriction upon Sun-Synchronous, Shuttle Sortie, and Non Sun Synchronous spacecraft to a single observation of the target at a constant time for Sun-Synchronous spacecraft and variable observation at different times for Shuttle Sortie and Non Sun Synchronous, due to different target observation times. The coverage cycle is a restriction to a seven day repeat cycle for Sun-Synchronous, one observation per target for a Shuttle Sortie and seven to fourteen day repeat cycle for a Non-Sun Synchronous spacecraft. Due to the limit of time that Space Shuttle can remain in orbit (7 to 30 days), the duration of earth target observation is intermittent. Therefore space shuttle can best be used to observe objects of interest on non-repetitive basis which require a single observation. The Earth Synchronous satellite is capable of providing only one angle of observation of the target due to its constant stationary geosynchronous point.



COVERAGE CYCLE

- MANY USERS @ 7 & 30 DAYS – BUREAUCRATIC RHYTHM
- SIGNIFICANT NUMBER OF ONE TIME USERS

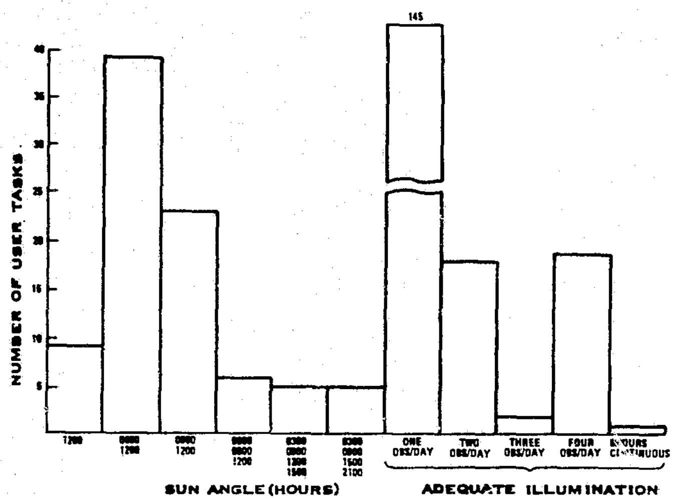
COVERAGE CYCLE



SPATIAL RESOLUTION

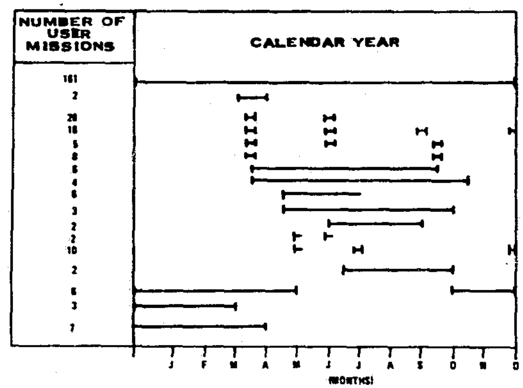
- PEAK OF USERS IN 50 METER RANGE
- SECONDARY PEAK OF USERS IN 5-10 METER RANGE

RESOLUTION REGION (M)



SUN ANGLE

- 1200 HR ACCEPTABLE FOR MOST
- 0600, 0900, 1200
- NOT CRITICAL (ADEQUATE LIGHT) FOR ABOUT HALF



DURATION

- HALF ARE YEAR ROUND
- PEAKS IN MARCH, JUNE, SEPT.

Figure 4.1-2. Mission Requirements – Platform Summarization

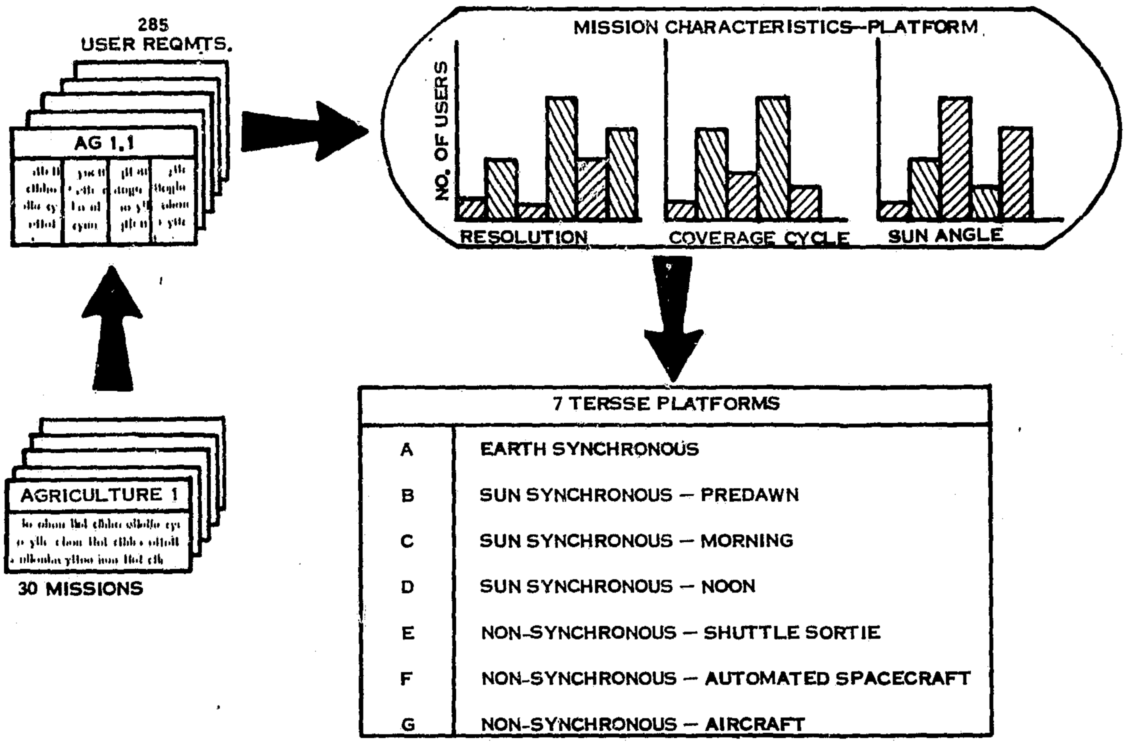


Figure 4.2-1. Determination of TERSSE Platforms

Table 4.2-1. Platform Assignment Characteristics

	EARTH SYNCHRONOUS	POLAR (SUN-SYNC.)	SHUTTLE SORTIE	AIRCRAFT	POLAR (NON SUN SYNC.)
LOCATION	≤57° LAT	ALL	ALL	ALL	ALL
NODAL TIME	ALL	SINGLE CONSTANT	VARIABLE	ALL	VARIABLE
COVERAGE CYCLE	ALL	7 DAY	ONCE EACH	ALL	>7 DAY
DURATION	ALL	ALL	(ALL INTERMITTENT)	ALL	ALL
OBLIQUITY	SINGLE	ALL	ALL	ALL	ALL
RESOLUTION (SPATIAL)	50 METER	CASE I = 50 CASE II = 10 CASE III = 50	CASE I = 20 CASE II = 5 CASE III = 5	≥1	CASE I = 50 CASE II = 10 CASE III = 50

The spatial resolution takes into account the present and near future sensor technology. The Earth Synchronous platform with a 50 meter scanner is the maximum SEOS resolution under present consideration. Aircraft have the greatest advantage of providing high spatial resolution. The TERSSE data base indicates that there are several requirements for high (1 meter) resolution and frequent small area coverage, an ideal combination for the aircraft platform. The Sun-Synchronous, Non-Sun Synchronous and Shuttle Sortie platforms were assigned three resolution cases.

CASE 1: polar spacecraft with a mechanical scanner in a 700 to 900 nm orbit can achieve a 50m spatial resolution utilizing current technology. Shuttle sortie resolution of 20 m was assigned as the upper limit on the same basis.

CASE 2: polar spacecraft (with a push broom solid state detector array) in the same orbit can achieve a 10 m spatial resolution, while the Shuttle Sortie can achieve a 5 m resolution with the same technology.

CASE 3: polar spacecraft with a 50m resolution and a Shuttle Sortie with a 5m resolution provides the other extreme.

The CASE 1 approach maximizes the use of the Earth Synchronous satellite and the aircraft. CASE 2 maximizes the use of the polar spacecraft and the Shuttle Sortie. CASE 3 maximizes use of the Shuttle Sortie only.

By examination of the user requirements data base it can be seen that there are a large number of periodic (7, 14, 30 day) coverage cycles requirements at 10 meter spatial resolution, with durations of 6 months to 1 year. These form an ideal case for a polar spacecraft. There are also a large number of non-repetitive, short duration, coverage requirements at 5 meter resolution covering large areas of observation; these are ideal Shuttle Sortie opportunities. Therefore the most logical choice for platform assignment is CASE 2, a 10 meter Sun-Synchronous satellite and a 5m Shuttle Sortie. With respect to sensor availability, these resolution requirements are not unrealistic for the Shuttle era.

The computerized data base was filtered through the platform assignment characteristics of Table 4.2-1 using the case 2 platform resolution assignments. Additional screening requirement guidelines are the physical and economic constraints imposed on the observations by the platforms; these included:

1. Spacecraft for repeated observation missions are more cost effective than aircraft over large areas
2. A geosynchronous spacecraft is more effective than multiple polar spacecraft
3. Shuttle sortie missions are effective platforms for high spatial resolution requirements
4. Geosynchronous not appropriate for global coverage
5. Shuttle sortie missions should be unique (not appropriate for spacecraft)

This filter approach to platform assignment is depicted in Figure 4.2-2 where the various requirements, constraints, and guidelines are used to "set" the filter screen.

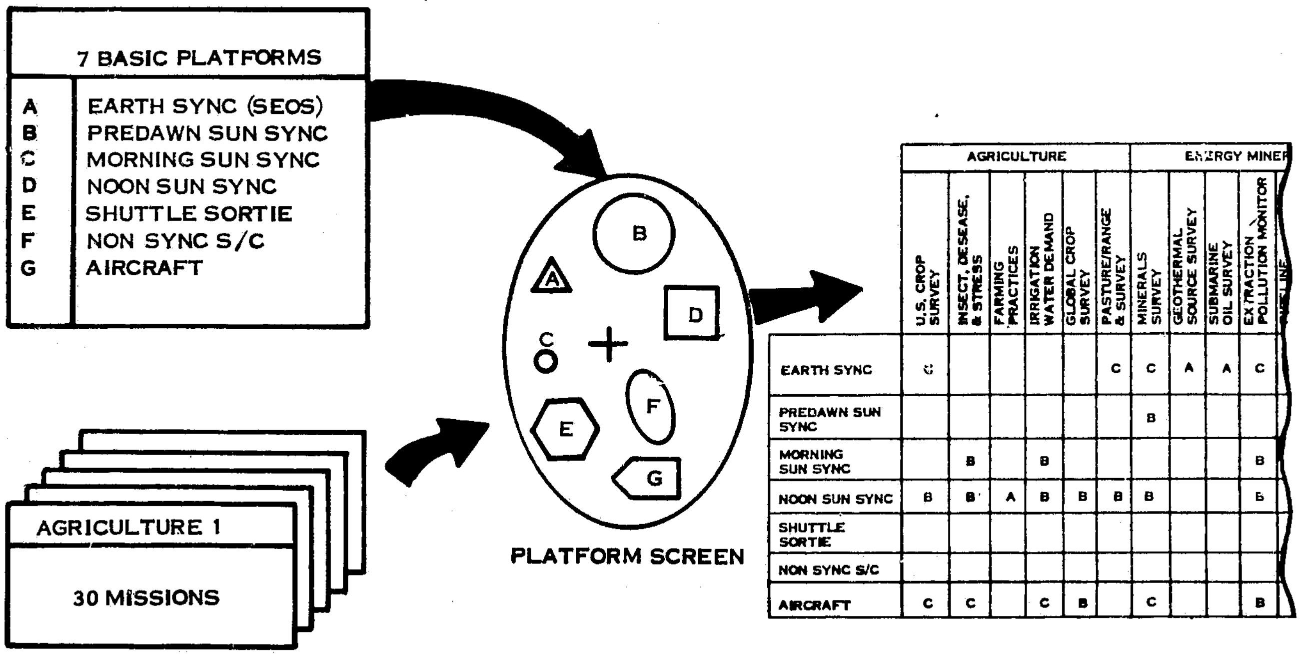
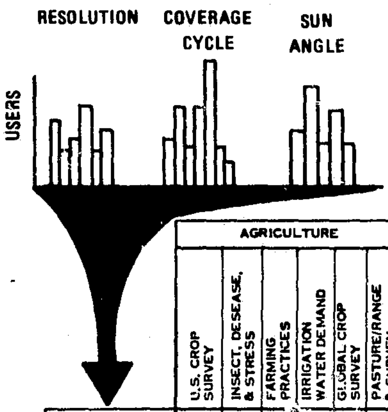


Figure 4. 2-2. Resource Missions Assigned to Platforms

The output of this filtration process is the assignment of each TERSSE mission to a specific remote sensing platform. This assignment was done, by computer, for each of the three resolution cases. The computer output for Case 2, the selected case, is presented as Appendix B to this TERSSE report. The results of the screening were then aggregated on a mission by mission basis, each mission being assigned to at least one (and in most cases several) of the seven TERSSE platforms.

These seven basic platforms together can satisfy all of the observation requirements of the TERSSE resource missions. Two degrees of satisfaction of a mission's requirements are indicated when the missions were assigned to the platforms. Figure 4. 2-3 shows the platform assignments for all 30 TERSSE missions. A platform having a mission assigned to it with either an A code (provides all or major part of data needs) is able to fully (or mostly) satisfy that mission's data collection requirements. The B code (partial satisfaction of data needs) signifies that the platform is able to satisfy some but not most of the mission's data collection requirements. Full satisfaction for such a mission can usually be accomplished with the aid of another platform.

When considering these mission/platform assignments (shown in Figure 4. 2-3) it must be borne in mind that this represents the mature operational TERSSE system. Prior to the availability of the entire TERSSE, many of the missions can be adequately (although not completely) served by alternate platforms. These mature assignments represent the optimal usage of all the TERSSE platform elements. This assignment does not indicate that other platforms should not be used in the intermediate time frame until all TERSSE elements are operational.



- SEVEN BASIC PLATFORMS REQUIRED
- MOST MISSIONS REQUIRI: MULTIPLE PLATFORMS
- ASSIGNMENT CHOICES DEPENDENT ON SYSTEM EVOLUTION RATE, FORM

	AGRICULTURE						ENERGY MINERALS							FORESTRY			LAND USE				MARINE				WATER					
	U.S. CROP SURVEY	INSECT, DESEASE, & STRESS	FARMING PRACTICES	IRRIGATION WATER DEMAND	GLOBAL CROP SURVEY	PASTURE/RANGE & SURVEY	MINERALS SURVEY	GEOTHERMAL SOURCE SURVEY	SUBMARINE OIL SURVEY	EXTRACTION POLLUTION MONITOR	PIPELINE MONITOR	OIL POLLUTION MONITOR	THERMAL POLLUTION MONITOR	TIMBER INVENTORY	INSECT, DISEASE STRESS	FIRE MONITOR & ASSESSMENT	U.S. LAND USE INVENTORY	LAND FORM & COVER MAPPING	COASTLINE SURVEY	GEOLOGICAL HAZARD MAPPING	OCEAN DYNAMICS MONITOR	FISH ENVIRONMENT & LOCATION	MARINE POLLUTION MONITOR	NAVIGATION HAZARD MONITOR	URBAN/AG SUPPLY INVENTORY	HYDROELECTRIC SUPPLY INVENTORY	GREAT LAKES ICE	WATER QUALITY MONITOR	FLOOD MONITOR	COASTAL WETLANDS MONITOR
EARTH SYNC	B					B	B	A	A	B								B				A	A		A		A	B	B	B
PREDAWN SUN SYNC							A								A															
MORNING SUN SYNC		A		A						A	A											A			A					
NOON SUN SYNC	A	A	A	A	A	A	A			A	A		A	B	A	B	B	A		A		A	B		A	A		A	A	A
SHUTTLE SORTIE	B		B		B		B			B			B	A		B	A	A	B					B						B
NON SYNC S/C																					A			A						
AIRCRAFT		B		B			B			A		A			B	A	A		A	A	B			B	B		B			

A – PROVIDES ALL OR MAJOR PART OF DATA NEEDS
B – PARTIAL SATISFACTION OF DATA NEEDS

Figure 4.2-3. Platform Assignments For Operational Missions

4.3 SPACE SHUTTLE AS A TERSSE PLATFORM

A full and complete discussion of the Space Shuttle is contained in TERSSE report Volume 4 entitled The Role of the Shuttle in the Earth Resources Program. This section will present the key features of that report as they relate to platform/mission assignment.

The Space Shuttle in its sortie mode of operation has four principal roles to perform as part of TERSSE. These four and their characteristics are:

1. Operational-intermediate area sizes, short duration mission.
2. ASVT Support - test platform, transitional time frame, lower cost.
3. Sensor development - test bed platform, timely availability.
4. Technique development - test data source, transitional time frame, lower cost.

The first item, operational, requires explanation because there are actually four slightly different operational roles. These four are:

1. Primary operational platform - the most effective platform to provide the data acquisition in satisfaction of a missions requirement.

2. Secondary operational platform - where the Shuttle is used to supply necessary supplemental data in addition to a mission's other platform requirements (e.g., periodic, high resolution data on world-wide test sites).

3. Partial mission fulfillment - whereby the Shuttle is used to fill the time gap before all of a mission's platforms are operational to satisfy a part of its mission objectives (e.g., urban land use data for the 56 largest US cities instead of for all US urban areas).

4. Partial data fulfillment - whereby the Shuttle gathers all of the required data but not to the full extent required by the mission (e.g., data collected every 6 or 8 weeks as opposed to the every 2 weeks required in the fully operational configuration).

The previous section identified three of the 30 TERSSE missions for which the Space Shuttle would serve as a primary operational platform. Each of these three appeared as an "A" (provides all or major part of Data Needs) in the mission/platform assignment matrix (Figure 4.2-3). These principal operational missions are:

Forest 1 - Survey and monitor forestland to prepare forecasts of timber production, classify areas according to productive status, and assess the efficiency and ecological soundness of timber production and harvesting operations.

Land Use 1 - Survey and map current land use patterns within the U.S. in support of State land use planning and the management of Federal lands.

Land Use 2 - Survey and map the natural vegetative cover, landforms, topography, underlying geology, and soil types of the U.S. land area.

In addition to these three principal operational utilizations there are many additional missions for which the Space Shuttle offers operational capability. These additional missions are shown in Figure 4.3-1 (together with the three principal missions). These additional missions arise from the Shuttle's ability to provide partial mission satisfaction and partial data satisfaction.

A more complete discussion of all the Shuttle modes (including ASVT, sensor development, and technique development) is contained in Volume 4 of the TERSSE report.

4.4 TERSSE PLATFORM TYPES

The five types of TERSSE platforms each provide different advantages and disadvantages. This section briefly describes each type of platform.

EARTH SYNCHRONOUS PLATFORM

To date, earth observation programs have concentrated on low-altitude platforms giving repetitive coverage of much of the earth's surface; but at non-varying intervals of time (e.g., ERTS-1, once every 18 days). Given the presence of an interfacing cloud cover, such low altitude satellites can result in very long intervals between successive images of a specific area.

	ARGRICULTURE						ENERGY MINERALS							FORESTRY			LAND USE				MARINE				WATER					
	U.S. CROP SURVEY 1	INSECT, DESEASE, & STRESS 2	FARMING PRACTICES 3	IRRIGATION WATER DEMAND 4	GLOBAL CROP SURVEY 5	PASTURE/RANGE & SURVEY 6	MINERALS SURVEY 1	GEOTHERMAL SOURCE SURVEY 2	SUBMARINE OIL SURVEY 3	EXTRACTION POLLUTION MONITOR 4	PIPELINE MONITOR 5	OIL POLLUTION MONITOR 6	THERMAL POLLUTION MONITOR 7	TIMBER INVENTORY 1	INSECT, DISEASE STRESS 2	FIRE MONITOR & ASSESSMENT 3	U.S. LAND USE INVENTORY 1	LAND FORM & COVER MAPPING 2	COASTLINE SURVEY 3	GEOLOGICAL HAZARD MAPPING 4	OCEAN DYNAMICS MONITOR 1	FISH ENVIRONMENT & LOCATION 3	MARINE POLLUTION MONITOR 4	NAVIGATION HAZARD MONITOR 5	URBAN/AG SUPPLY INVENTORY 1	HYDROELECTRIC SUPPLY INVENTORY 2	GREAT LAKES ICE 3	WATER QUALITY MONITOR 4	FLOOD MONITOR 5	COASTAL WETLANDS MONITOR 6
PRIME PLATFORM														X			X	X												
PARTIAL MISSION SATISFACTION		X	X	X	X		X	X		X			X	X	X	X	X		X		X			X	X			X	X	X
PARTIAL DATA SATISFACTION			X			X	X		X	X	X	X		X		X	X	X	X	X	X	X	X		X	X		X	X	

Figure 4.3-1. Shuttle Sortie as an Operational Platform

While current and planned programs will result in a number of such low altitude orbiting platforms, and one can postulate an appropriate observation sequence to partially alleviate this problem, there are many earth resources phenomena which exhibit such short term temporal behavior that they require an unacceptably large number of low altitude platforms (for example targets requiring multiple observations per day). In such cases, the only practical approach appears to be through the rapid response - interactive capability of a geosynchronous satellite (eg. SEOS).

It has been noted that natural disasters constitute one of four key problems involved in monitoring the global environment. Such disasters (hurricanes, tornadoes, forest fires, floods, frost and disease and insect crop damage) often involve temporal behavior requiring critically timed and/or near continuous observation. While it has been demonstrated that remote observation can materially aid in reducing the harmful effects of such disasters, it must also be noted that critical timing is the key to appropriate preventive or corrective action.

SHUTTLE SORTIE

The Space Shuttle appears to be uniquely suited for purposes of instrument development and for the study of short duration or infrequent phenomena as well as ASVT missions. Proposed sortie missions of seven to thirty days at 100 nm to 400 nm altitude are readily adaptable to Earth Resources Survey applications requirements. For such missions, experimental payloads may comprise both operational and developmental experiments. Operational experiments would include surveys of slowly varying phenomena such as river delta or coastal studies, forestry patterns, land use inventory, land form and cover mapping, agriculture, pollution monitoring and those requiring intermittent observations rather than constant surveillance. Short duration phenomena such as catastrophic events would require "contingency" missions which could be employed, but only under the most demanding circumstances.

The sortie mode will permit scientists from various earth resources disciplines to participate in target selection and sensor development on short duration missions. The capability of carrying a large payload will permit sensing over the entire pertinent electromagnetic spectrum at high spatial resolution, this will allow intercomparison of several types of sensors by the investigator, and will tend to assure the reliability of instrument performance. This mode is considered to be particularly useful where seasonal or less frequent sensing is desired, data is not available from other systems, on-board data processing or mission specialists are required, and/or few observations from low altitude orbit will provide sufficient data.

SUN SYNCHRONOUS

Polar spacecraft are the only means of remote sensing from space and achieving full global coverage. It is the only means of achieving low altitude sun synchronism, the advantage being that the node time is fixed providing repeating coverage and fixed time of day over the target. Figure 4.4-1 shows a plot of a 7 day repeat cycle for a Sun Synchronous platform as a function of longitude and day number of spacecraft at an altitude of 611 Km whereas Figure 4.4-2 shows the same plot for a 28 day repeat cycle at 833 Km. A plot of sensor swath width as a function of repeat cycle for two different altitudes is shown in Figure 4.4-3, for a 5% overlap at the equator. It can be seen that a swath width of 400 Km is required for a 7 day repeat cycle. The swath width is, when coupled with IFOV, a critical system driver.

Using the requirements data base a plot of spatial resolution vs. coverage cycle was made (Figure 4.4-4) in order to show the number of user tasks (numbers next to the circles showing clusters of points) satisfied by 1, 2, 3 ..... 10 polar spacecraft in orbit. For example for a 30 day repeat cycle at 10 m resolution at least two polar spacecraft are required to provide this type of coverage and 19 user tasks require this type of information. This plot is made for a 5% overlap at the equator. Other, more economically feasible solutions for this problem are to a) fly more than one sensor per spacecraft providing the increased swath width and decreasing the number of spacecraft or b) to offset-point the sensors where full coverage is not required.

NON-SUN SYNCHRONOUS SPACECRAFT

This particular satellite has the advantage of providing full global coverage at variable nodal crossing times, providing a variable time of day over the target. The main application of this platform in the study is for Ocean Dynamics Monitoring and Navigation Hazard Monitoring observation missions. An example of this platform under present consideration is the SEASAT program.

AIRCRAFT

Aircraft are the most versatile of all platforms. They can provide earth observation coverages at different times of day, continuous coverage and high resolution. The major disadvantage is the economic burden of providing large area coverage on a continuous basis. The aircraft considered for TERSSE are high altitude aircraft such as the U-2 or RB-57F. Aircraft have the capability of providing data as a primary platform for small area, high spatial resolution coverage. They serve many primary missions that require coverage during disasters, and also serve in many secondary supporting missions to spacecraft.

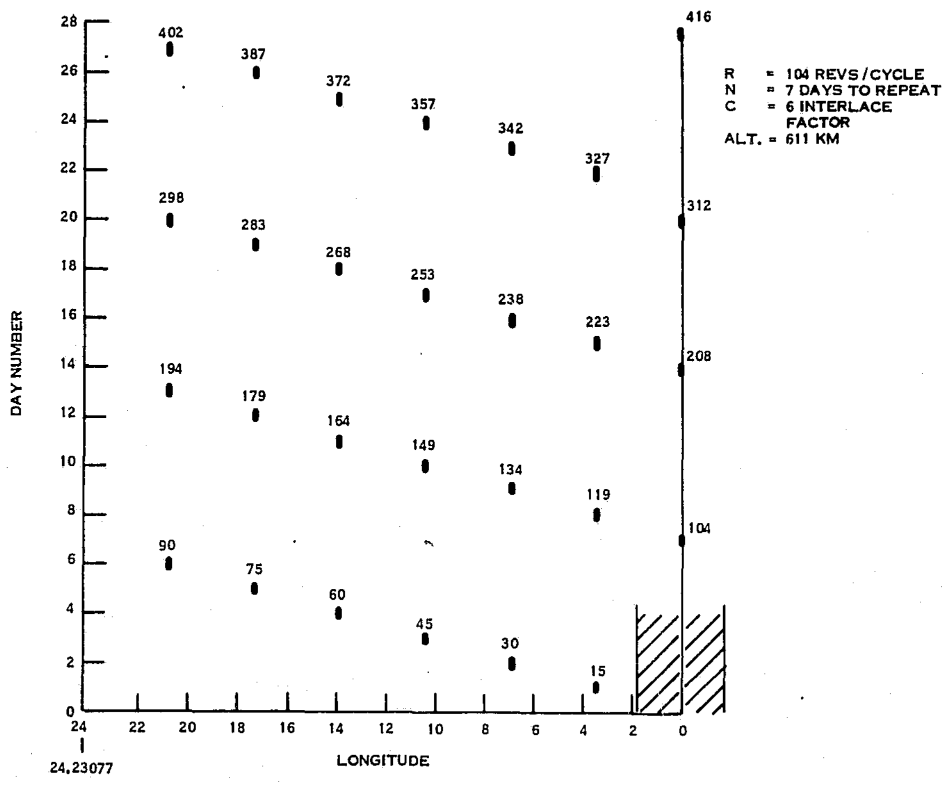


Figure 4.4-1. 7-Day Repeat Cycle Orbit

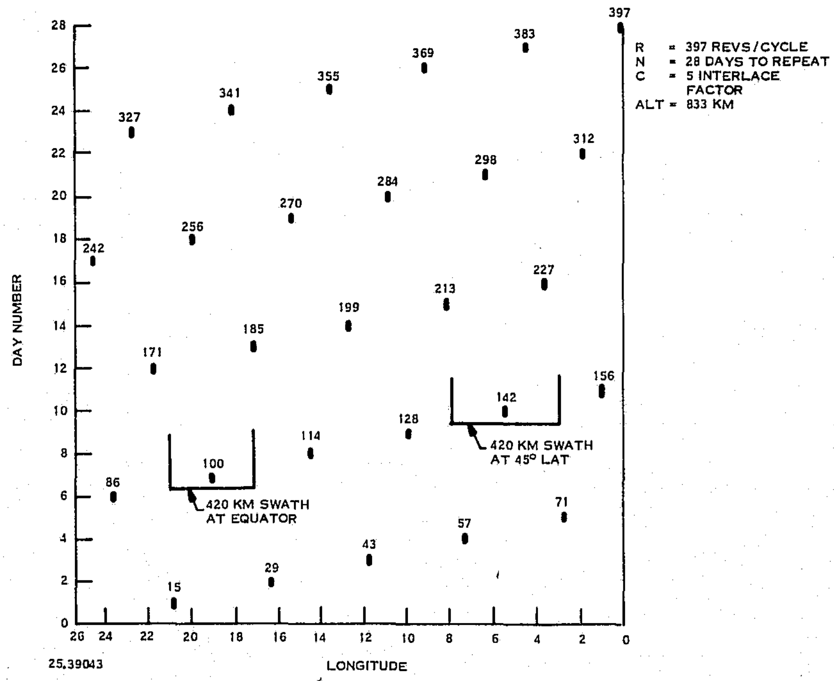


Figure 4.4-2. 7/14/28-Day Repeat Cycle Orbits

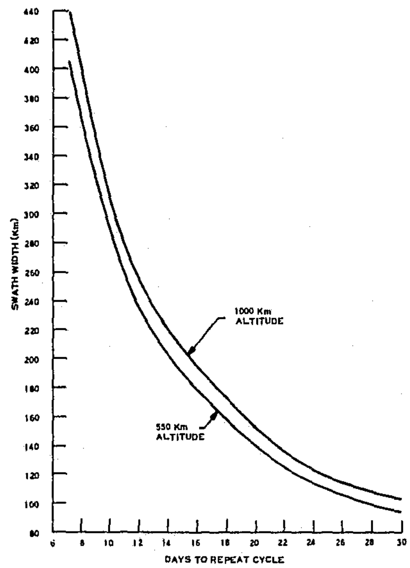


Figure 4.4-3. Swath Widths With 5% Sidelap at Equator

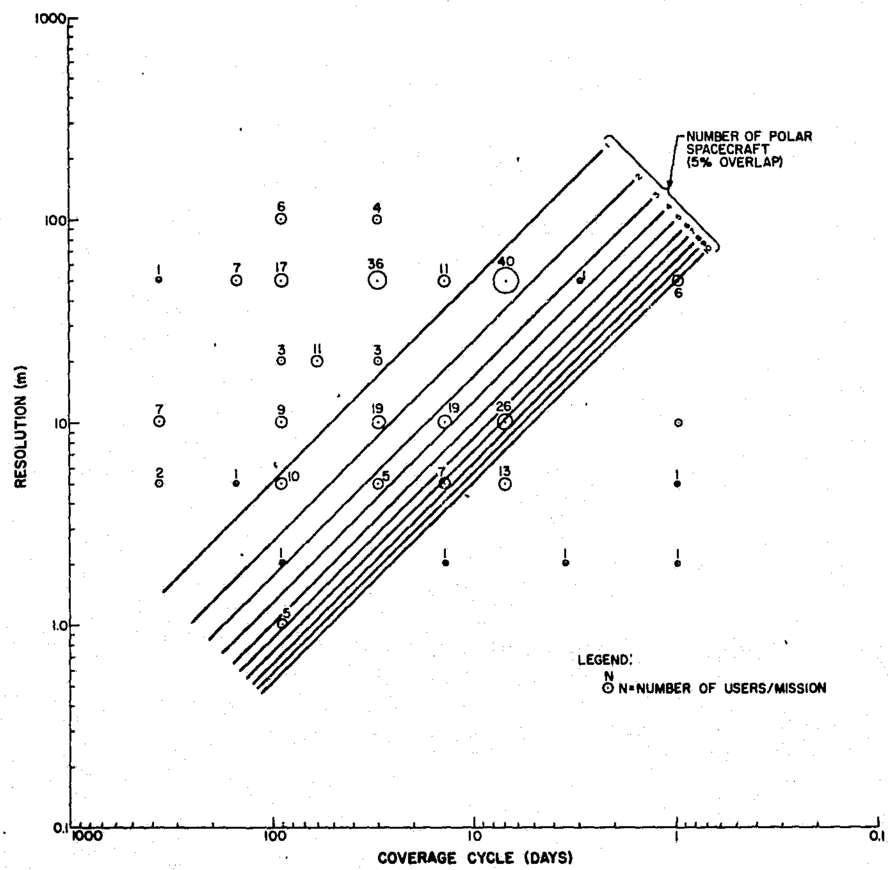


Figure 4.4-4. Plot of Spatial Resolution vs. Coverage Cycle

SECTION 5

REMOTE SENSORS

This section addresses the sensor portion of the overall TERSSE system. The other two major components of the TERSSE are the remote sensing platforms, discussed in Section 4, and the ground system, discussed in Section 6 of this report.

5.1 REMOTE SENSORS OVERVIEW AND CONCLUSIONS

The determination of the TERSSE sensors begins with an analysis of the resource managers requirements as represented in the mission and system requirements data base. The data base contains the spectral and spatial requirements for each of 285 representative user tasks. These disparate requirements were then processed through a sensor strategy in order to reduce the number of discrete sensors required. The results of this process, as depicted in Figure 5.1-1, is a set of twenty spectral band families which will satisfy all of the resource management missions.

Each of 30 basic TERSSE missions were then considered with the spectral and spatial categories so that a definite assignment could be made for each mission. This process is represented in Figure 5.1-2.

It will become evident in this section that, in order to maintain the number of discrete sensors at a reasonable level while satisfying all users, the number of missions served per sensor will have to be high. A general design goal

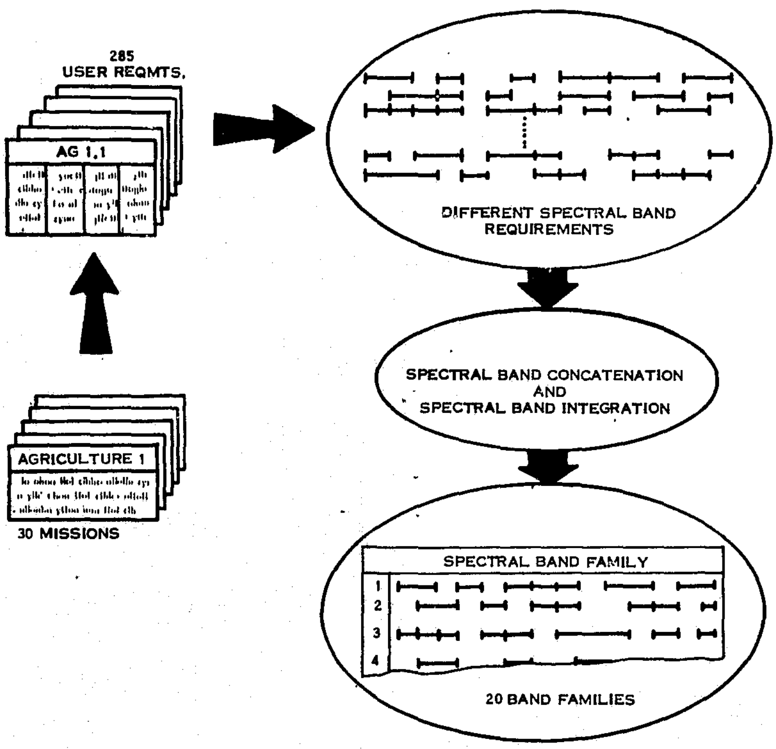


Figure 5.1-1. Determination of TERSSE Sensors

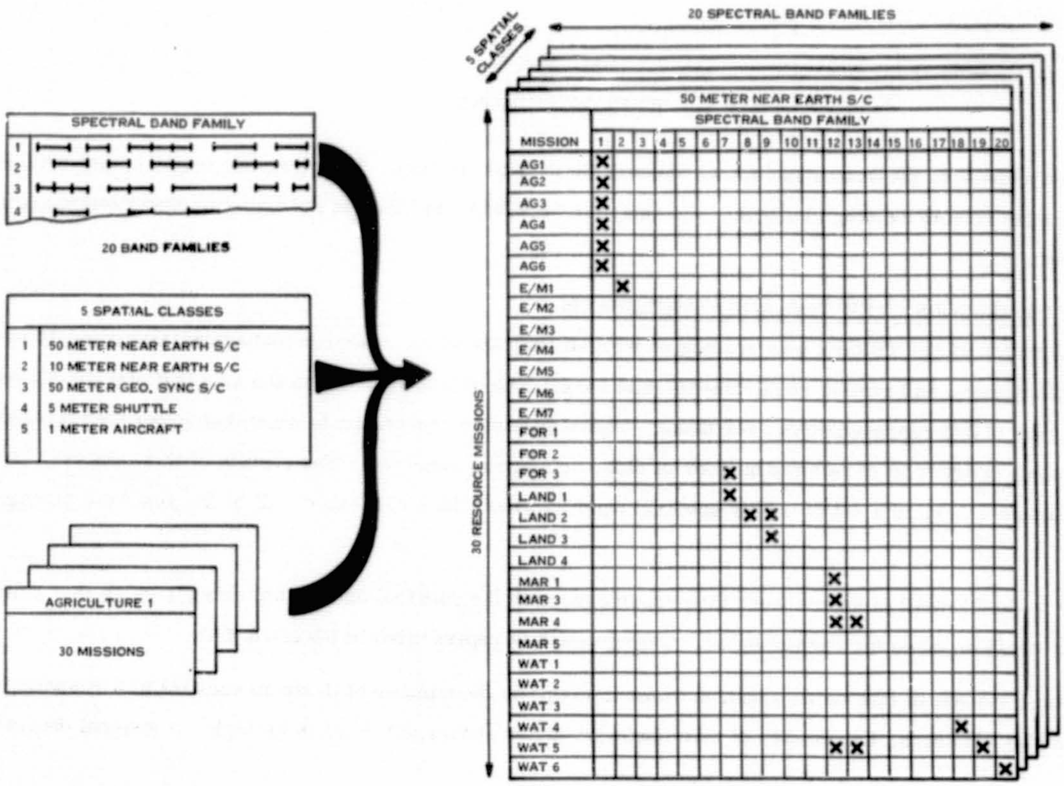


Figure 5. 1-2. Resource Missions Assigned to Sensors

therefore is for sensors to either (1) carry all bands potentially required or (2) have interchangeable band packages tailored to particular sets of missions. For those cases where the sensor will be conveniently physically accessible (aircraft and space shuttle) the second approach appears workable.

The spectral requirements in the IR-thermal region are not as variable as in the lower wavelength region and can probably be satisfied by a standardized sensor for that region. The visible-near IR region has more variable requirements which should be met with a multiband and modular design. The current state-of-the-art is such that development of these sensors can start now with a reasonable expectation of being achieved by the 1980's.

Microwave sensors can be considered in two categories; (1) those producing grid measurements such as scatterometers and radiometers, and (2) imagers such as synthetic aperture radars. The principal resource management disciplines which drive the microwave requirements are Water and Land Use diciplines. The Water discipline can make effective use of the grid measurement sensors for wind velocity and direction, wave height, and water salinity; the imaging sensor would be applicable for ice measurements. The Land Use discipline will utilize microwave grid measurements for soil moisture, snow depth, and snow moisture context; the imaging sensors have two applications (1) "cloud free black and white photography" and (2) the exploration of reflection emission properties (multiple parameter analysis).

With respect to spatial resolution, the key sensor development recommendation is the need for a 10 meter IFOV scanner from near earth polar orbit altitudes. The need for a relatively large number of spectral bands and large optics with respect to the field of view will require the utilization of advanced technology. Therefore, the availability of this sensor should not be expected before the mid 1980's. However, with slightly reduced constraints, the design could begin soon for a Space Shuttle borne version which would be available by the late 1970's or early 1980's.

The current limitation on the ability to apply automatic data processing techniques over large areas of multispectral data need to be overcome in order to achieve an efficient operational system. The current capability in automated processing requires that several training sites be used for each frame/swath processed. In order to reduce the number of training sites required two sensor developments appear appropriate; (1) atmospheric condition sensing capability, and (2) accurate spectrometry for calibration to allow signature extension.

In summary, the analysis of the user's sensor requirements in conjunction with the state-of-the-art determination and the driving sensor design parameters leads to the following conclusions:

1. Development of the following sensors is indicated:
    a. 1-2 m (Aircraft)
    b. 5 m (Shuttle)
    c. 10 m (Polar and Shuttle)
    d. 30-50 m (Polar)
    e. 50-100 m (Synchronous)
2. These sensor configurations must be designed to accommodate a larger number of spectral bands and to achieve higher spectral resolution and narrower bandwidths than are manifested in current sensor designs.
3. Final specification of the ultimate <u>operational</u> sensor/mission assignment for TERSSE will require advancement in the state of knowledge regarding:
    a. systems level sensor feasibility/cost as a function of the number of spectral bands
    b. refined user requirements and weighting factors as to relative importance to mission success
    c. relative importance of the particular user tasks
    d. specific decisions on the assignment of one or more missions to a sensor design

5.2 SENSOR/MISSION ASSIGNMENT METHODOLOGY

The sensor element of TERSSE is unlike either its platform or ground situations. In the platform case it was found that seven remote sensing platform types would satisfy the requirements of all 285 user tasks. However, the quantity and diversity of the spectral band requirements for the sensor case preclude a meaningful result without first reducing the number of different spectral band sets.

The various spectral requirements of the 285 user tasks appear at first glance to represent the need for several hundred different sensors (192 unique spectral band sets, 7 different spatial resolutions, with at least 3 different altitudes). The major contributor to this situation is the large number of unique spectral band sets required by all the users. The possibilities for dealing with these (without changing the requirements from those given) are:

1. leave the spectral requirements as is and design a unique sensor for each.

2. reduce the requirements to a lowest common denominator band set (approximately 25 separate bands) and design one sensor.

3. choose a middle approach and combine the band requirements where possible to reduce the number of different designs required.

The approach taken here in TERSSE was the latter, number 3, whereby the band requirements were combined and juggled in order to arrive at 20 unique band families (sets) which would satisfy all user tasks.

The approach taken and the various intermediate results are described in Section 5.4, Sensor Strategies, below. The result of this sensor strategy is a set of twenty spectral band families and five spatial resolution/altitude categories. At this point, the sensor requirements of each user task were considered and a sensor assigned.

5.3 SENSOR REQUIREMENTS

The user's sensor performance requirements are contained in the data base (refer to Section 3.3 of this report for a description) for each of the 285 representative user tasks. The sensor performance descriptive parameters included are spatial resolution, required spectral bands, and radiometric calibration accuracies. The radiometric calibration accuracies required were either two percent, five percent, or were unspecified. These values are within the state of the art and consequently are not sensor drivers. The driving sensor performance parameters based on the available mission requirement information are thus spatial resolution and spectral bands.

Adoption of these two descriptors, spatial resolution and spectral bands, for examination of the mission/system sensor requirements is not meant to imply their adequacy for sensor design specification; the more detailed analysis required for that, including specification of modulation transfer functions, noise statistics, linearity, etc., is a step beyond the requirements data base and is beyond the scope of the present TERSSE effort.

As with the other areas of TERSSE, it is assumed that the users requirements accurately reflect his true needs and are adequately reflected in their mission requirement specification. In other words, the initial working hypothesis was that to meet the data base specifications is to meet minimal necessary and sufficient conditions to ensure image product adequacy for the user. Adoption of this hypothesis allows the requirements to be analyzed and sensor systems to be formulated; it will be examined in retrospect later in this section.

The spatial resolution requirements specified by the various user tasks were 1, 2, 5, 10, 20, 50, 100, and 1000 meters. The relative distribution of these resolution requirements is shown in Figure 5.3-1 below. Note that the total number of resolutions indicated is greater than the number of user tasks (285) because some require multiple resolutions.

The spectral band requirements specified by each of the various user tasks are shown graphically in Figure 5.3-2. It can be observed by viewing this figure that quite frequently the same spectral band requirements are shared by several user tasks (usually different user tasks representing the same mission statement). The total number of resolution/band set configurations needed for the 285 tasks is 306.

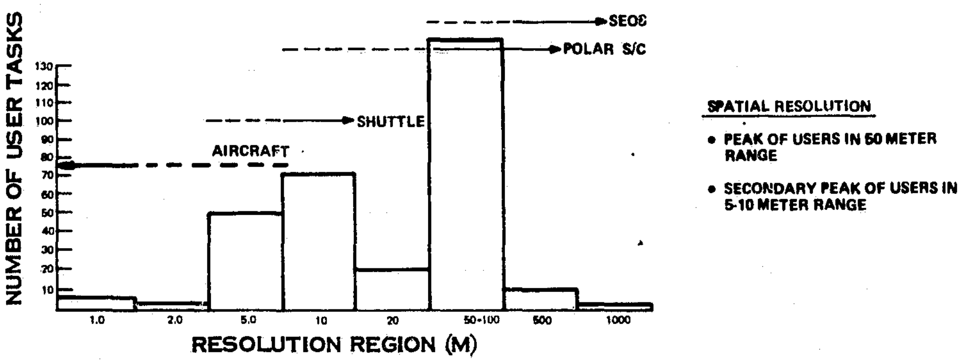


Figure 5.3-1. Spatial Resolution Summary

Given a set of sensor requirements for each mission, one might satisfy them by dedicating a sensor design to each set of mission requirements yielding a large number of instruments; or by specifying a single sensor with the versatility to satisfy all mission requirements. The optimal strategy sought probably lies between these two extremes; but the precise specification of that strategy is not immediately obvious. The following section is an examination of the available data and an attempt to provide a realistic and efficient sensor strategy.

5.4 SENSOR STRATEGIES

As discussed in the previous section, the two user requirements which serve as driving functions are spatial resolution and spectral band requirements. The resolution requirements fall into eight classes ranging from 1 meter to 1000 meters; the spectral band requirements on the other hand are much more diverse with nearly 200 different requirements initially specified. An iterative approach, shown in Figure 5.4-1, was undertaken in order to formulate a sensor strategy.

The large number of different spectral bands specified by the user tasks was considered. The cutoff frequencies to delineate the band limits were consistent in the greater than 1. micrometer wavelength region, but in the visible-near infrared region it was often found that one user specified, for example, .55-.65 mm while another specified .54-.64 mm. It was judged unlikely that these small differences in cutoff frequencies were "real" requirements;

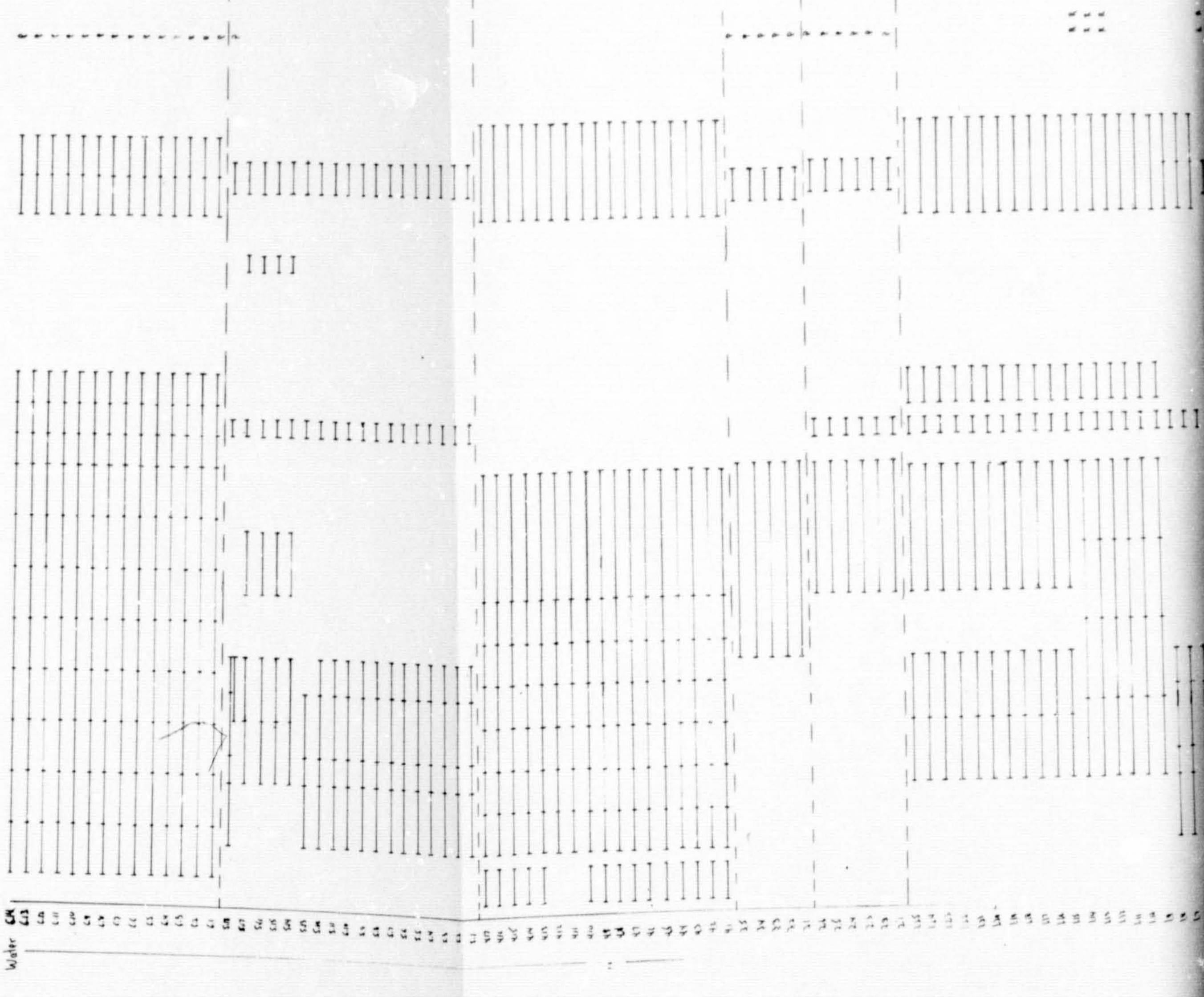
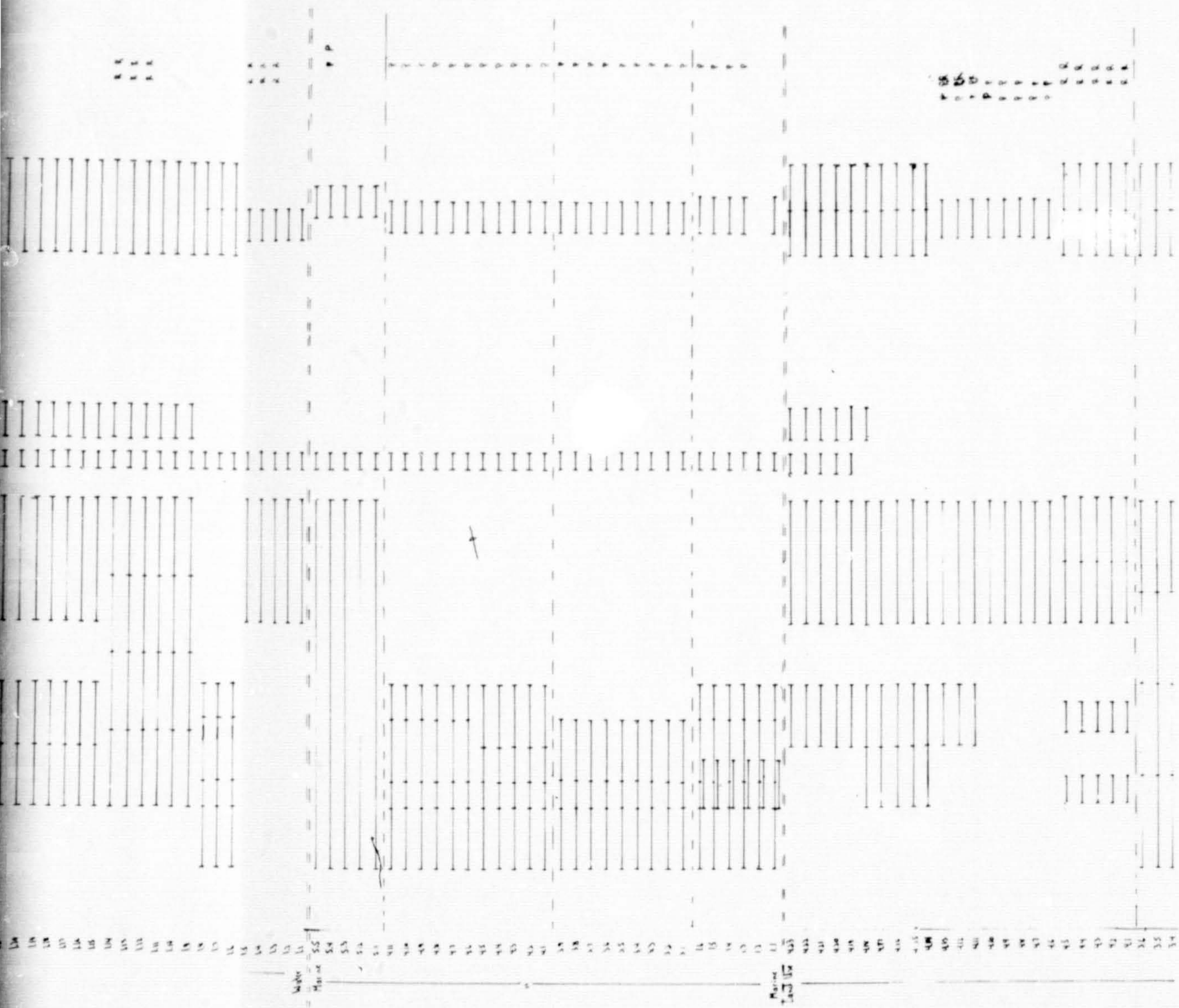
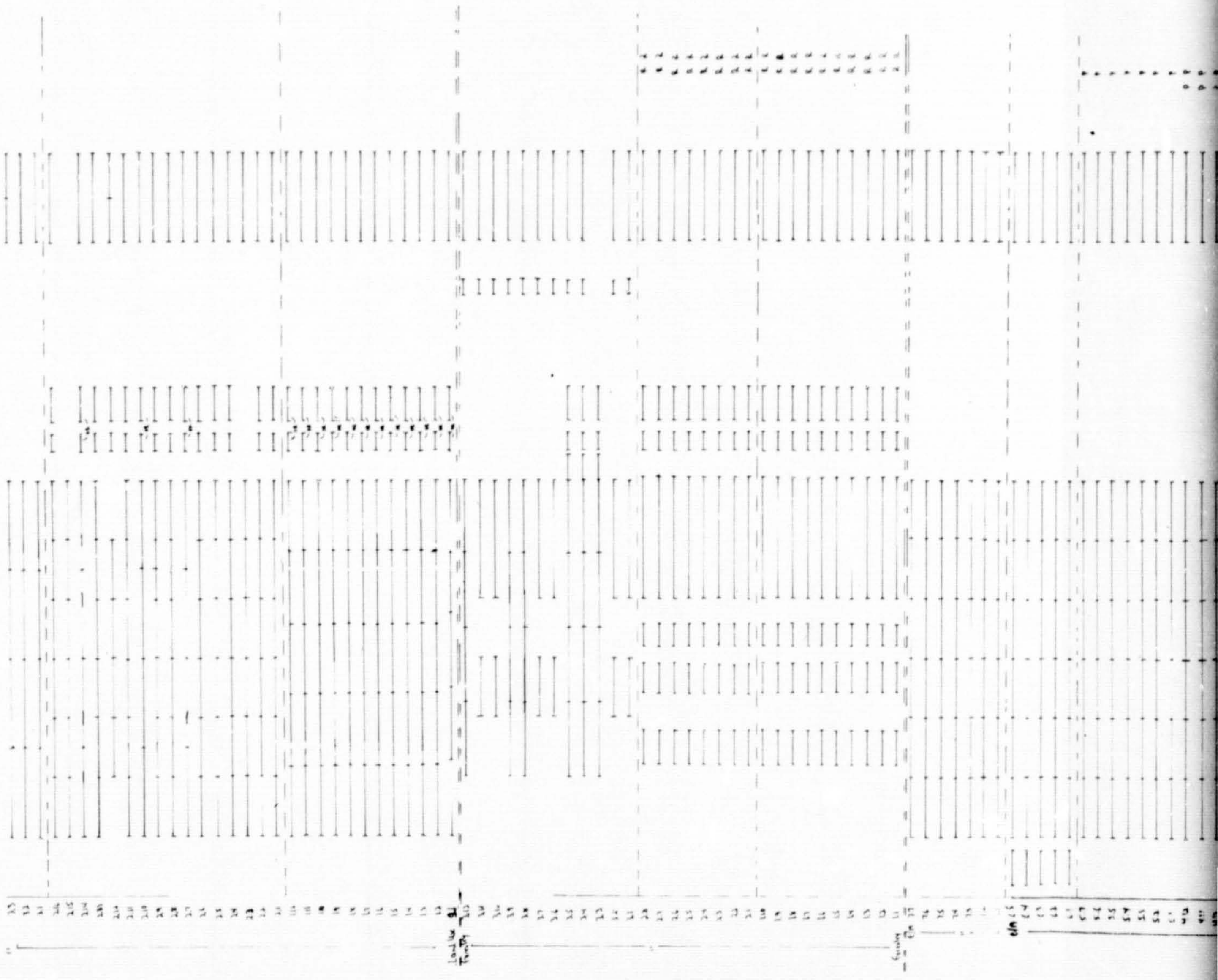


Figure 5.3-2. Spectral Channels Requirements
(Sheet 1 of 2)



FOLDOUT FRAME 2



FOLDOUT FRAME

Figure 5.3-2. Spectral Channels Requirements (Sheet 2 of 2)

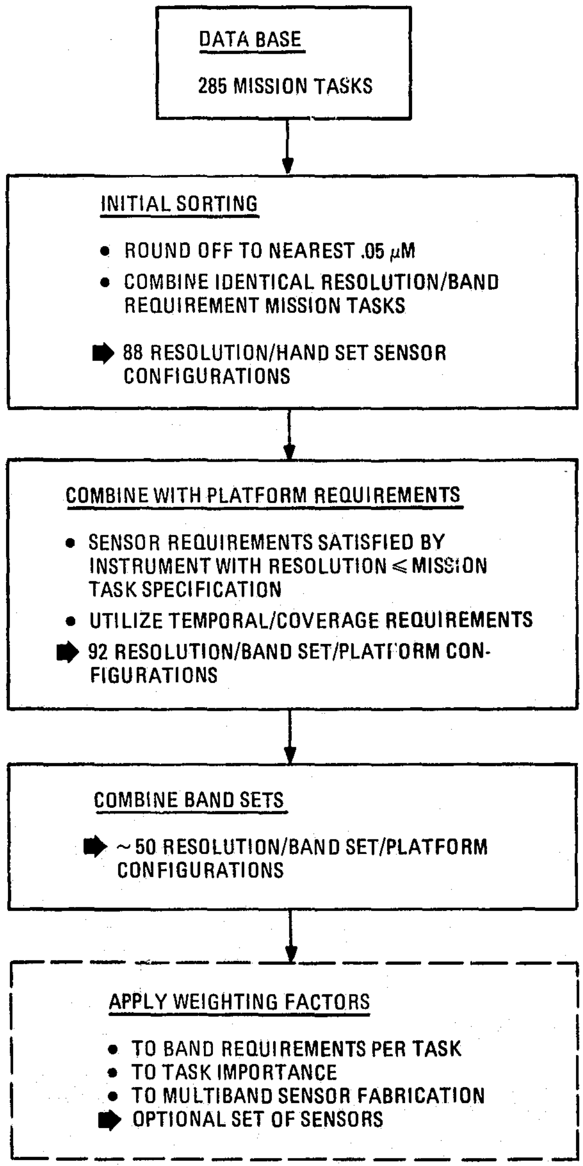


Figure 5.4-1. Formulation of Sensor Strategy

substituting one band for the other was thought to be unlikely to cause a signature to be lost. Consequently, the cutoff frequencies of the visible-near IR spectral bands were rounded off to the nearest 0. 05 mm which helped to reduce the magnitude of the problem.

The data base of sensor requirements was sorted according to resolution required. Under each resolution requirement, each unique set of spectral bands was listed, and for each unique resolution/band set, the individual user tasks which require that particular sensor configuration were delineated. The results of this initial sorting are summarized in Table 5. 4-1 and illustrated in Figure 5. 4-2. Simply by combining user tasks with identical requirements, the total number of configurations has been reduced from 306 to 88 at this point.

Table 5. 4-1. Sensor Requirements - First Sorting

Resolution	Number of Different (Unique) Spectral Band Sets	Total Mission Subtasks Satisfied
1. m	2	5
2. m	3	4
5. m	23	65
10. m	19	69
20. m	11	26
50. m	25	126
100. m	4	10
1000. m	1	1
	88	

Total Resolution/Bandset Configuration is 88.

At this point, the coverage and obliquity constraints were considered, and a set of resolution/platform requirements delineated. The postulate that any resolution specification is also satisfied by a higher resolution sensor was invoked (a user requiring 100. m resolution could accomplish his task if given 50. m resolution imagery). It should be noted that this is not a good general postulate for all cases because of the possibility for significantly increased data rates and data processing throughput requirements; it was therefore used in only a few cases and with considerable care. Combining this postulate with the resolution/platform requirements yielded a new set of sensor configuration requirements which are summarized in Table 5. 4-2 and Figure 5. 4-3.

The band requirements were then reexamined and it was found that by adding a band or two to certain unique band sets, several sets could often be combined thus reducing the total number of sensor configurations. That is, the band sets per resolution-platform configuration (Figure 5. 4-3) were combined in the most obvious ways while trying to keep the total number of bands per sensor reasonably small.

After each spectral band requirement was rounded off to the nearest . 05 micrometers it was subjected to the concatenation and integration process shown in Figure 5. 4-4 together with all the other band set requirements for each of the 5 platform classes. The concatenation step shows that if TERSSE provides the bottom band set on the figure, either of the two users whose individual requirements were concatenated can select his unique requirement from the

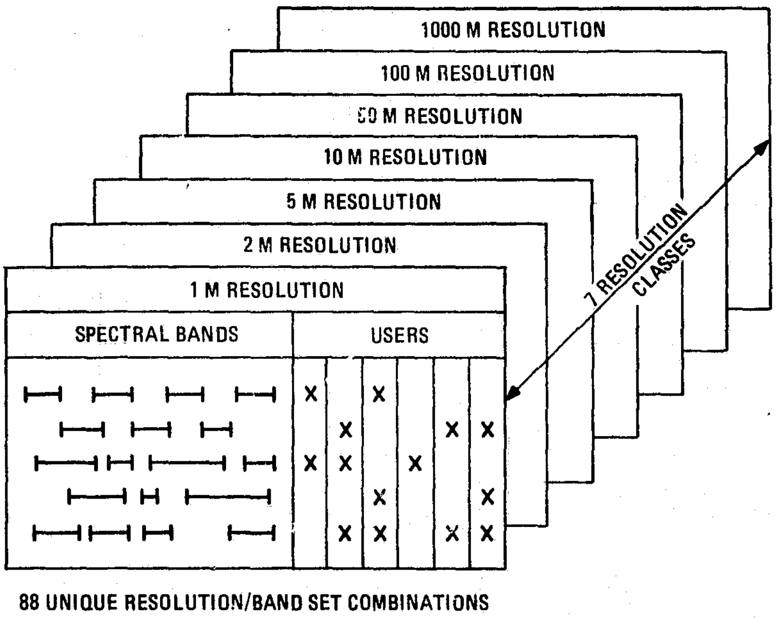


Figure 5.4-2. Sensor Requirements - First Sorting

Table 5.4-2. Sensor Requirements - Platforms Included

Resolution/Platform	Number of Different (Unique) Spectral Band Sets	Total Mission Subtasks Satisfied
1. m Aircraft	26	65
5. m Shuttle	6	20
10. m Polar	21	69
50. m Polar	18	88
50. m Sync.	21	99

Total Resolution/Band Set Platform Configuration is 92.

Note that some tasks could be satisfied by either a synchronous or polar platform. Such tasks appear under both resolution/platform headings in Table 5.4-2.

total. The integration step shows that some users require a spectral band which is really the sum of two or more bands required by another user. If TERSSE provided the bottom band set the second user could be satisfied by integrating the radiance measured in the second and third bands to form the total represented by his first band. In this manner it was possible to derive 20 unique spectral band families which satisfied all of the users without any compromise as to their original requirements.

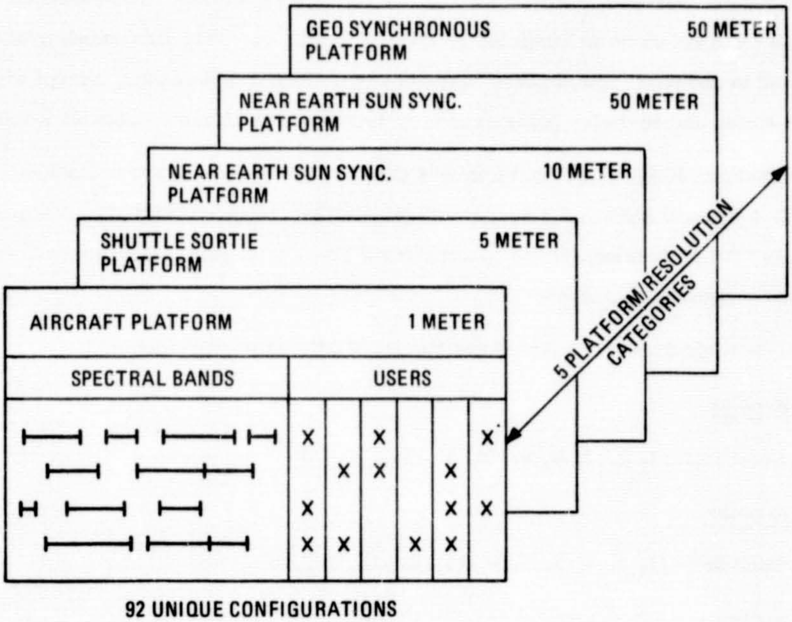


Figure 5.4-3. Revised Sensor Requirements

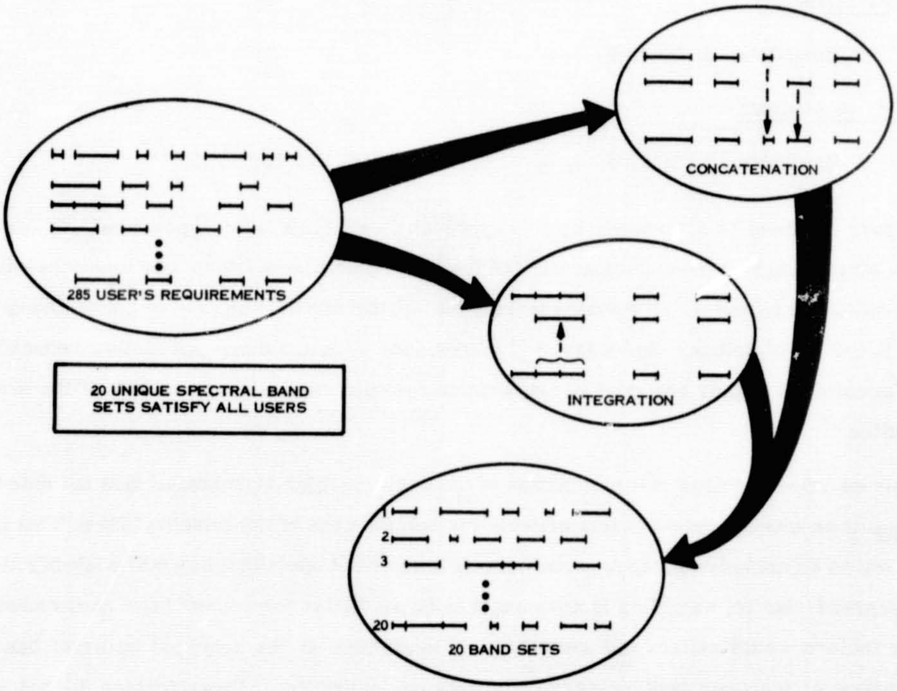


Figure 5.4-4. Spectral Band Requirements Resolved

It should be apparent that there is no single unique combination which will result from the above step; the results are dependent on the judgment applied during the combination process. The result of one such combination, which reduced the total number of unique band sets to twenty, is shown in Figure 5.4-5. The resolution/platform requirement to which each band set corresponds is also shown on the figure as a matrix. The particular spectral band families assigned to each platform class is tabulated in Table 5.4-3 below. The total number of discrete sensors required has been reduced to about 51. Each check mark in Figure 5.4-5 is a sensor, except where the same band is shown for both the 50 meter and 10 meter polar case — in this case the 10 meter version would satisfy both needs.

The results of this combination, 20 spectral band families (sets), and the five platform classes, were then used to assign (refer to Figure 5.4-6) each resource management mission to a sensor (defined as a spectral band family at a resolution). The assignment of missions to the spectral band families is shown in Figures 5.4-7 through 5.4-11 for each of the 5 platform - resolution classes.

Table 5.4-3. Sensor Band Family/Platform Requirements

1) <u>50. m polar</u>

   Band Sets: 1, 2, 7, 8, 9, 12, 13, 18, 19, 20

2) <u>10. m polar</u>

   Band Sets: 1, 3, 4, 5, 6, 7, 11, 12, 15, 16, 18

3) <u>50. m sync.</u>

   Band Sets: 1, 2, 3, 4, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

4) <u>5. m shuttle</u>

   Band Sets: 5, 7, 8, 9

5) <u>1. m Aircraft</u>

   Band Sets: 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 14, 15, 17

The number of sensors required as determined by this approach is still felt to be impractical. It is clear from Figure 5.4-5 that a single twenty-band sensor at each of the five resolution/platform combinations would yield a set of five sensors sufficient to satisfy all mission tasks. Recall that the combination of bands shown as band families in Figure 5.4-5 is not unique. One might add more bands here and there and further reduce the number of band sets. The question is simply how does one determine the optimal combination short of the twenty band universal configuration?

Consideration of this question requires re-examination of the basic working hypothesis: that the data base as given constitutes the <u>minimal</u> necessary and sufficient criteria for achievement of the mission tasks. That this hypothesis is strictly valid is felt to be unlikely. Rather, perturbations in the band specifications will probably affect different users to different degrees; that is, weighting factors ought to be applied to the sensor band requirements for each user task. Those factors would reflect the sensitivity of variations in the required spectral bands to the successful performance of the user task resource management objective. These factors do not exist at the

BAND SET No.	SPECTRAL BANDS (m)																					RESOLUTION/PLATFORM					MISSIONS SERVED					
	.3 -.35	-.4	-.45	-.5	-.55	-.6	-.65	-.7	-.75	-.8	-.85	-.9	-.95	-1.	-1.4	1.5 -1.8	2. -2.6	4.5 -5.5	9.5 -11.5	8. -11.	-14.	50.m POLAR	10.m POLAR	50.m SYNC.	5.m SHUTTLE	1.m AIRCRAFT	AGRICULTURE	ENERGY MINERALS	FORESTRY	LAND USE	WATER	MARINE
1					—	—	—				—	—	—	—	—	—	—		—	----		✓	✓	✓		✓	1-6					
2					—		—				—	—					—			—	—	✓		✓		✓		1				
3			—	—	—	—	—	—												—	—		✓	✓		✓		3,4				
4	—	—	—	—	—	—	—	—	—	—	—	—	—	—						—	—		✓	✓		✓		4-7				
5						—		—	—		—	—	—	—		—	—			—	—		✓		✓	✓			1,2			
6							—	—			—	—	—	—				—		—	—		✓			✓			3	4		
7			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	✓	✓		✓	✓			3	1		
8			—	—	—	—	—	—	—	—	—	—	—	—		—	—			—	—	✓		✓	✓					2		
9			—	—	—	—	—	—	—	—	—	—	—	—			—			—	—	✓		✓	✓	✓				2,3		
10					—		—				—	—	—	—						—	—					✓				4		
11					—	—	—	—			—	—	—	—		—	—			—	—		✓	✓		✓				4	1	
12			—	—	—	—	—	—								—			—	—	—	✓	✓	✓		✓					1,5	1,3,4
13			—	—	—	—	—	—								—			—	----		✓		✓							5	4
14			—	—	—	—	—	—	—	—	—	—	—	—		—			—	----				✓		✓						5
15											—	—	—	—		—			—	----			✓	✓		✓					1,2	
16					—	—	—	—	—	—	—	—	—			—	—		—	—			✓	✓							1	
17									—	—	—	—	—	—					—	----				✓		✓					3	
18	—	—	—	—	—	—	—	—	—	—	—	—	—	—					—	—		✓	✓	✓							4	
19					—	—	—	—			—	—				—		—	—	----		✓		✓							5	
20		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—		✓		✓							6	

—— IS BAND SPECIFIED IN DATA BASE

---- RECOGNIZES ATMOSPHERIC EFFECTS AND REPLACES THE 9.5 – 11.5 BAND WITH AN 8 – 11 BAND FOR ALL NON AIRCRAFT PLATFORMS

Figure 5.4-5. Twenty Spectral Bands

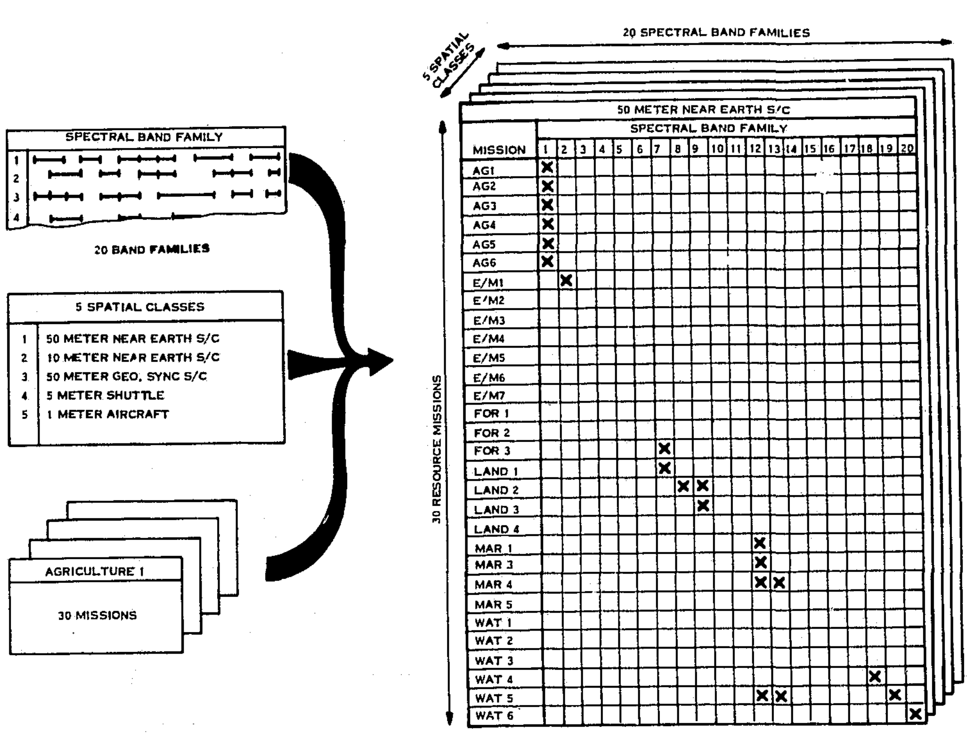


Figure 5.4-6. Resource Missions Assigned to Sensors

SPECTRAL BAND FAMILY	ARGRICULTURE 1 U.S. CROP SURVEY	ARGRICULTURE 2 INSECT, DESEASE, & STRESS	ARGRICULTURE 3 FARMING PRACTICES	ARGRICULTURE 4 IRRIGATION WATER DEMAND	ARGRICULTURE 5 GLOBAL CROP SURVEY	ARGRICULTURE 6 PASTURE/RANGE & SURVEY	ENERGY MINERALS 1 MINERALS SURVEY	ENERGY MINERALS 2 GEOTHERMAL SOURCE SURVEY	ENERGY MINERALS 3 SUBMARINE OIL SURVEY	ENERGY MINERALS 4 EXTRACTION POLLUTION MONITOR	ENERGY MINERALS 5 PIPELINE MONITOR	ENERGY MINERALS 6 OIL POLLUTION MONITOR	ENERGY MINERALS 7 THERMAL POLLUTION MONITOR	FORESTRY 1 TIMBER INVENTORY	FORESTRY 2 INSECT, DISEASE STRESS	FORESTRY 3 FIRE MONITOR & ASSESSMENT	LAND USE 1 U.S. LAND USE INVENTORY	LAND USE 2 LAND FORM & COVER MAPPING	LAND USE 3 COASTLINE SURVEY	LAND USE 4 GEOLOGICAL HAZARD MAPPING	MARINE 1 OCEAN DYNAMICS MONITOR	MARINE 3 FISH ENVIRONMENT & LOCATION	MARINE 4 MARINE POLLUTION MONITOR	MARINE 5 NAVIGATION HAZARD MONITOR	WATER 1 URBAN/AG SUPPLY INVENTORY	WATER 2 HYDROELECTRIC SUPPLY INVENTORY	WATER 3 GREAT LAKES ICE	WATER 4 WATER QUALITY MONITOR	WATER 5 FLOOD MONITOR	WATER 6 COASTAL WETLANDS MONITOR
1	X	X	X	X	X	X																								
2							X																							
3																														
4																														
5																														
6																														
7																X	X													
8																		X												
9																		X	X											
10																														
11																														
12																					X	X	X		X				X	
13																							X						X	
14																														
15																														
16																														
17																														
18																												X		
19																													X	
20																														X

Figure 5.4-7. 50 Meter Near Earth Spacecraft

SPECTRAL BAND FAMILY	ARGRICULTURE 1 U.S. CROP SURVEY	ARGRICULTURE 2 INSECT, DESEASE, & STRESS	ARGRICULTURE 3 FARMING PRACTICES	ARGRICULTURE 4 IRRIGATION WATER DEMAND	ARGRICULTURE 5 GLOBAL CROP SURVEY	ARGRICULTURE 6 PASTURE/RANGE & SURVEY	ENERGY MINERALS 1 MINERALS SURVEY	ENERGY MINERALS 2 GEOTHERMAL SOURCE SURVEY	ENERGY MINERALS 3 SUBMARINE OIL SURVEY	ENERGY MINERALS 4 EXTRACTION POLLUTION MONITOR	ENERGY MINERALS 5 PIPELINE MONITOR	ENERGY MINERALS 6 OIL POLLUTION MONITOR	ENERGY MINERALS 7 THERMAL POLLUTION MONITOR	FORESTRY 1 TIMBER INVENTORY	FORESTRY 2 INSECT, DISEASE STRESS	FORESTRY 3 FIRE MONITOR & ASSESSMENT	LAND USE 1 U.S. LAND USE INVENTORY	LAND USE 2 LAND FORM & COVER MAPPING	LAND USE 3 COASTLINE SURVEY	LAND USE 4 GEOLOGICAL HAZARD MAPPING	MARINE 1 OCEAN DYNAMICS MONITOR	MARINE 3 FISH ENVIRONMENT & LOCATION	MARINE 4 MARINE POLLUTION MONITOR	MARINE 5 NAVIGATION HAZARD MONITOR	WATER 1 URBAN/AG SUPPLY INVENTORY	WATER 2 HYDROELECTRIC SUPPLY INVENTORY	WATER 3 GREAT LAKES ICE	WATER 4 WATER QUALITY MONITOR	WATER 5 FLOOD MONITOR	WATER 6 COASTAL WETLANDS MONITOR
1	X	X	X	X	X	X																								
2																														
3									X	X																				
4										X	X	X	X																	
5														X	X															
6																X				X										
7																X	X													
8																														
9																														
10																														
11																				X					X					
12																					X	X	X		X				X	
13																														
14																														
15																									X	X				
16																									X					
17																														
18																												X		
19																														
20																														

Figure 5. 4-8. 10 Meter Near Earth Spacecraft

SPECTRAL BAND FAMILY	ARGRICULTURE 1 U.S. CROP SURVEY	ARGRICULTURE 2 INSECT, DESEASE, & STRESS	ARGRICULTURE 3 FARMING PRACTICES	ARGRICULTURE 4 IRRIGATION WATER DEMAND	ARGRICULTURE 5 GLOBAL CROP SURVEY	ARGRICULTURE 6 PASTURE/RANGE & SURVEY	ENERGY MINERALS 1 MINERALS SURVEY	ENERGY MINERALS 2 GEOTHERMAL SOURCE SURVEY	ENERGY MINERALS 3 SUBMARINE OIL SURVEY	ENERGY MINERALS 4 EXTRACTION POLLUTION MONITOR	ENERGY MINERALS 5 PIPELINE MONITOR	ENERGY MINERALS 6 OIL POLLUTION MONITOR	ENERGY MINERALS 7 THERMAL POLLUTION MONITOR	FORESTRY 1 TIMBER INVENTORY	FORESTRY 2 INSECT, DISEASE STRESS	FORESTRY 3 FIRE MONITOR & ASSESSMENT	LAND USE 1 U.S. LAND USE INVENTORY	LAND USE 2 LAND FORM & COVER MAPPING	LAND USE 3 COASTLINE SURVEY	LAND USE 4 GEOLOGICAL HAZARD MAPPING	MARINE 1 OCEAN DYNAMICS MONITOR	MARINE 3 FISH ENVIRONMENT & LOCATION	MARINE 4 MARINE POLLUTION MONITOR	MARINE 5 NAVIGATION HAZARD MONITOR	WATER 1 URBAN/AG SUPPLY INVENTORY	WATER 2 HYDROELECTRIC SUPPLY INVENTORY	WATER 3 GREAT LAKES ICE	WATER 4 WATER QUALITY MONITOR	WATER 5 FLOOD MONITOR	WATER 6 COASTAL WETLANDS MONITOR
1	X	X	X	X	X	X																								
2							X																							
3									X	X																				
4										X	X	X	X																	
5																														
6																														
7																														
8																		X												
9																		X	X											
10																														
11																				X					X					
12																					X	X	X		X				X	
13																							X						X	
14																								X						
15																									X	X				
16																									X					
17																											X			
18																												X		
19																													X	
20																														X

Figure 5. 4-9. 50 Meter Geosynchronous Spacecraft

SPECTRAL BAND FAMILY

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ARGRICULTURE	1	U.S. CROP SURVEY																				
	2	INSECT, DESEASE, & STRESS																				
	3	FARMING PRACTICES																				
	4	IRRIGATION WATER DEMAND																				
	5	GLOBAL CROP SURVEY																				
	6	PASTURE/RANGE & SURVEY																				
ENERGY MINERALS	1	MINERALS SURVEY																				
	2	GEOTHERMAL SOURCE SURVEY																				
	3	SUBMARINE OIL SURVEY																				
	4	EXTRACTION POLLUTION MONITOR																				
	5	PIPELINE MONITOR																				
	6	OIL POLLUTION MONITOR																				
	7	THERMAL POLLUTION MONITOR																				
FORESTRY	1	TIMBER INVENTORY					X															
	2	INSECT, DISEASE STRESS					X															
	3	FIRE MONITOR & ASSESSMENT							X													
LAND USE	1	U.S. LAND USE INVENTORY							X													
	2	LAND FORM & COVER MAPPING								X	X											
	3	COASTLINE SURVEY									X											
	4	GEOLOGICAL HAZARD MAPPING																				
MARINE	1	OCEAN DYNAMICS MONITOR																				
	3	FISH ENVIRONMENT & LOCATION																				
	4	MARINE POLLUTION MONITOR																				
	5	NAVIGATION HAZARD MONITOR																				
WATER	1	URBAN/AG SUPPLY INVENTORY																				
	2	HYDROELECTRIC SUPPLY INVENTORY																				
	3	GREAT LAKES ICE																				
	4	WATER QUALITY MONITOR																				
	5	FLOOD MONITOR																				
	6	COASTAL WETLANDS MONITOR																				

Figure 5.4-10. 5 Meter Shuttle Sortie

SPECTRAL BAND FAMILY

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ARGRICULTURE	1	U.S. CROP SURVEY	X																			
	2	INSECT, DESEASE, & STRESS	X																			
	3	FARMING PRACTICES	X																			
	4	IRRIGATION WATER DEMAND	X																			
	5	GLOBAL CROP SURVEY	X																			
	6	PASTURE/RANGE & SURVEY	X																			
ENERGY MINERALS	1	MINERALS SURVEY		X																		
	2	GEOTHERMAL SOURCE SURVEY																				
	3	SUBMARINE OIL SURVEY			X																	
	4	EXTRACTION POLLUTION MONITOR			X	X																
	5	PIPELINE MONITOR				X																
	6	OIL POLLUTION MONITOR				X																
	7	THERMAL POLLUTION MONITOR				X																
FORESTRY	1	TIMBER INVENTORY					X															
	2	INSECT, DISEASE STRESS					X															
	3	FIRE MONITOR & ASSESSMENT						X	X													
LAND USE	1	U.S. LAND USE INVENTORY							X													
	2	LAND FORM & COVER MAPPING									X											
	3	COASTLINE SURVEY									X											
	4	GEOLOGICAL HAZARD MAPPING						X				X	X									
MARINE	1	OCEAN DYNAMICS MONITOR												X								
	3	FISH ENVIRONMENT & LOCATION												X								
	4	MARINE POLLUTION MONITOR												X								
	5	NAVIGATION HAZARD MONITOR														X						
WATER	1	URBAN/AG SUPPLY INVENTORY											X	X			X					
	2	HYDROELECTRIC SUPPLY INVENTORY															X					
	3	GREAT LAKES ICE																	X			
	4	WATER QUALITY MONITOR																				
	5	FLOOD MONITOR												X								
	6	COASTAL WETLANDS MONITOR																				

Figure 5.4-11. 1 Meter Aircraft

present time and to develop them would constitute forming a new, more detailed data base beyond the present scope of this TERSSE study.

On the basis of the data which has been developed to date, without a better understanding of the relationship between spectral band variations and task performance, it can only be said that the number of sensors required lies somewhere between the 51 indicated in Figure 5.4-5 and five twenty-band sensors. Specification of the optimal sensor configuration strategy for the TERSSE shall require advancement in the state of knowledge of systems level sensor feasibility/cost as a function of number of spectral bands, and weighting factors on user/mission/task sensor requirement specifications. This information is necessary to cause the bounds on the sensor configuration which we have developed to converge to a single point solution.

5.5 SENSOR DEVELOPMENT RECOMMENDATIONS

The previous discussion has indicated that to attempt to satisfy all user tasks while maintaining reasonable limits on the number of sensor/platform configurations flown clearly requires that sensors be designed to maximize utility in terms of number of missions adequately served per platform, not maximized for a particular mission.

A general design goal is therefore for sensors to be able to either:

- Carry all bands potentially required, or
- Have interchangeable band packages tailored to sets of particular missions.

The first possibility is most attractive for inaccessible platforms - polar and synchronous. The second possibility is workable for aircraft and sortie platforms where a modular sensor design would allow band package interchange on the ground.

Looking at the spectral band cutoff points (refer back to Figure 5.3-2) one finds that there is greater variability in mission task requirements in the visible-near IR region than in the IR-thermal. Since the technical problems differ in the two regions, it is recommended that fabrication of a standard IR-thermal sensor be considered. Achievement in this wavelength region of the requisite resolution at acceptable signal-to-noise will require advancement of the state of the art.

The visible-near IR region sensor ought to be, as has been stated, multiband and probably modular. The state of the art is such that development of these sensors can start now and can be expected to be achieved by the 1980's. The driving design problems appear to be:

1. Signal-to-Noise Ratio — The scanning radiometers are noise limited in performance. As the number of spectral bands per wavelength range (spectral resolution) is increased, the signal per detector is decreased. To obtain acceptable signal-to-noise for higher spectral resolution sensors will require as a consequence either faster optics (larger aperture since focal length is constrained by detector size and resolution required) or lower detector noise (possibly achieved by cooling).

2. Focal Plane Configuration — Room is required for the hardware which partitions the energy into the spectral bands. In multiband sensors this might prove a driver in optical configurations and might provide a limit on the number of bands implementable.

A system driver (as opposed to a sensor driver) associated with implementation of the recommended sensor configurations is data rate, both short-term (communication link, storage (bits/sec)) and long-term (information processing, dissemination (bits/year). Increasing resolution, either spatial, spectral, or temporal, implies proportional data rate increase. Therefore, multiband sensors ought to have the capability of commandable utilization of only those bands required by the given users at a particular earth location. In addition, should for example a 50. m sensor be flown, but only 100. m resolution be required at a given earth area, the capability to onboard process the data to reduce the sensor capability to the restricted user requirement ought to be considered.

Finally, since we have emphasized spectral band requirements as a driving sensor design problem, it is appropriate to add a comment on the "resolution" criterion. Most users mean by "resolution" the smallest object from which they can extract useful radiometric information. A sensor design specification eventually ought to include expressions of the required modulation transfer function, the acceptable noise level (either S/N or perhaps additionally the noise power spectral density), the detector calibration accuracy requirement, and the scan accuracy requirement. The effect of these parameters on user extractive processing algorithms expected to be in use in the 1980's should be quantitatively studied and reflected in the instrument designs.

When considering the overall mission and system requirements of TERSSE, several specific sensor development requirements become evident. Figure 5.5-1 depicts five required sensor developments and relates them to the six discipline categories which contain the 30 TERSSE resource management missions.

The five required/recommended sensor developments are:

1. Modular, Tailored Scanners
2. All Weather Terrain Imaging
3. Microwave Sensors
4. Atmospheric Condition Sensing Capability
5. Accurate Spectrometry for Calibration

The time phasing of the required sensor developments is shown in Figure 5.5-2. The three time frames are:

1977-78	Current Technology
1980-82	Early Advanced Technology
1984 and on	Late Advanced Technology

The general trends indicated by this figure are for higher spatial resolution, greater numbers of spectral bands, and the use of modularity in sensor design.

The sensor development requirements/recommendations for the 10 meter IFOV resolution scanner are especially important and are shown here in Figure 5.5-3. The ultimately required capability, from polar spacecraft, will require the use of advanced technology and is not expected until the mid 1980's time frame. However, with slightly reduced constraints a Shuttle version can be achieved by the late 1970's or early 1980's (beginning of the Shuttle Era).

The need for microwave sensor capability is shown in Figure 5.5-4 together with the two driving resource management disciplines, Water and Land Use.

SENSOR	DEVELOPMENT REQUIREMENT	AGRICULTURE	ENERGY/MINERAL	FORESTRY	LAND	MARINE	WATER
SCANNERS	MODULAR, TAILORED SCANNERS WITH INCREASED SPECTRAL SENSITIVITY, NO. OF BANDS, CALIBRATION ACCURACY; TAILORED IFOV	✓		✓		✓	✓
RADAR	APPLICATION TECHNIQUES FOR "CLOUD-FREE B & W PHOTOGRAPHY." SIGNATURE DEVELOPMENTS FOR MULTI-CHANNEL USE	✓	✓	✓	✓	✓	✓
RADIOMETERS/ SCATTEROMETERS	SIGNATURES, FREQUENCIES, DESIGN FOR SOIL MOISTURE, SALINITY, SNOW DEPTH AND MOISTURE CONTENT	✓				✓	✓
ANCILLARY	ATMOSPHERIC CONDITION SENSING FOR CORRECTION; ACCURATE RADIOMETRY FOR CALIBRATION	✓		✓	✓	✓	✓

Figure 5.5-1. Mission Requirements/Sensor Recommendations

1977 – 78	1980 – 82	1984 →
CURRENT TECHNOLOGY	EARLY ADVANCED DESIGN	LATE ADVANCED DESIGN
5 BAND SCANNER 50M SPATIAL RESOLUTION SORTIE FAMILY VARIABLE ALTITUDE	(7-8) BANDS SCANNER 10M SPATIAL RESOLUTION SORTIE FAMILY VARIABLE ALTITUDE	(MULTI-BAND MODULAR) SCANNER (1) 10M SPATIAL RESOLUTION POLAR ORBIT FAMILY SINGLE ALTITUDE (2) 5M SPATIAL RESOLUTION SORTIE FAMILY VARIABLE ALTITUDE
2 – 6 BAND FILM CAMERA 5M SPATIAL RESOLUTION SORTIE FAMILY VARIABLE ALTITUDE	(7-8) BANDS SCANNER (1) 50M SPATIAL RESOLUTION POLAR ORBIT FAMILY (2) 1M SPATIAL RESOLUTION AIRCRAFT	(MULTI-BAND MODULAR) SCANNER 50M SPATIAL RESOLUTION GEOSYNCRONOUS FAMILY

Figure 5.5-2. Sensor Development Requirements

- POLAR S/C:
  - LARGE NUMBER OF BANDS
  - THERMAL CHANNELS
  - BIG OPTICS/FOV
  - SINGLE ALTITUDE

OPTIONS:
- MISSION-DEDICATED
- SINGLE AGGREGATED
- PARTITIONED

REQUIRES ADVANCED TECHNOLOGY → MID 80's

- SORTIE:
  - EASIER TO DO
  - MECHANICAL SCAN ACCEPTABLE
  - VARIABLE ALTITUDE

OPTIONS:
- MISSION-DEDICATED
- SINGLE AGGREGATED
- PARTITIONED

CAN START NOW WITH MODULAR DESIGN → LATE 70's/EARLY 80's

Figure 5.5-3. The 10 Meter Scanner

	GRID MEASURERS - SCATTEROMETERS - RADIOMETERS	IMAGERS - SYNTHETIC APERTURE
WATER	• WIND VELOCITY • WIND DIRECTION • WAVE HEIGHT → IMPLEMENT • SALINITY → DEVELOP	- ICE → IMPLEMENT
LAND	• SOIL MOISTURE • SNOW DEPTH • SNOW MOISTURE CONTENT → DEVELOP	- CLOUD-FREE B&W PHOTOGRAPHY → IMPLEMENT - EXPLORATION OF REFLECTION EMISSION PROPERTIES (MULTIPLE PARAMETERS) → DEVELOP

Figure 5.5-4. Microwave Sensors

The microwave sensors can be considered in two classes of capability: grid measurement and images as represented by spectrometers/radiometers and synthetic aperture sensors respectively.

Included with each recommendation is an indication as to whether the capability needs to be implemented or developed.

Figure 5. 5-5 summarizes, by platform type, the major sensor development recommendations. Note that "polar" refers to near earth orbit, sun synchronous spacecraft and that "synchronous" refers to Earth stationary or geosynchronous spacecraft.

AIRCRAFT	MODULAR VISIBLE/ NEAR IR; COMMON MID, THERMAL IR 0. 5 μM BANDWIDTHS (OR BETTER) 1 - 2 METER RESOLUTION
SHUTTLE	MODULAR VISIBLE/ NEAR IR; COMMON MID, THERMAL IR 0. 05 μM BANDWIDTHS 50M, 10M NOW (5M EVENTUALLY?)
POLAR	ULTIMATE AGGREGATED CAPABILITY ~15-18 BANDS 50M, NOW-10M, LATER
SYNCHRONOUS	DESIRED AGGREGATED CAPABILITY ~15-19 BANDS APERTURE MAJOR LIMIT → OPTIMIZE FOR MAX POSSIBLE APERTURE
SPECIAL PURPOSE	PREDAWN THERMAL WATER QUALITY OCEAN COLOR

Figure 5. 5-5. Scanner Development Recommendations

SECTION 6

GROUND SYSTEM

In R&D operations, remote sensed data is disseminated through discrete and controlled channels to experimenters and selected Federal Agencies. As operational systems come on line, and as user requirements broaden to include multi-disciplinary needs covering both remote sensed and other ancillary data, the data flow will increase and the single thread R&D approach will be unable to respond. A total systems approach is required to assure that the outputs of all earth resources data acquisition systems are readily accessible to all potential users whether they be technical or nontechnical, or whether they be part of Government, public, or private agencies.

This section presents the results of the Ground Systems portion of the TERSSE effort. The subjects covered include:

- 6.1 - Overview and Conclusions
- 6.2 - Data Acquisition
- 6.3 - Data Preprocessing
- 6.4 - Extractive Processing
- 6.5 - Auxiliary Data Processing Elements
- 6.6 - Ground System Configuration
- 6.7 - System Operation

6.1 GROUND SYSTEM OVERVIEW AND CONCLUSIONS

The Total Earth Resources System for the Shuttle Era, TERSSE, has been considered throughout this report as being comprised of three major elements; platforms, sensors, and ground systems. This section of the report addresses itself to those elements of TERSSE considered as part of the ground system. The expanded definition of the ground system used during the study is portrayed in Figure 6.1-1 and can be seen to include the elements of Ground Station, Preprocessing, Extractive Processing, User Models, and Users, as well as the overall System Operational considerations.

The ground system is the interface between the collection system (remote sensing platforms and sensors) and the user community. Existing ERS systems are adequate for the present needs because those needs are experimental, or R and D, in nature. The present needs can be characterized as being a thorough broadly oriented analysis of relatively limited quantities of data. This is in contrast to the needs of the TERSSE time frame where the users will be operational, requiring the routine and timely handling of large quantities of data (each for more narrowly oriented analysis). The TERSSE ground system must be developed to satisfy those needs within the overall context of the entire TERSSE system, including consideration of remote sensing platforms, sensors, communications, users' needs and capabilities, and the available technology.

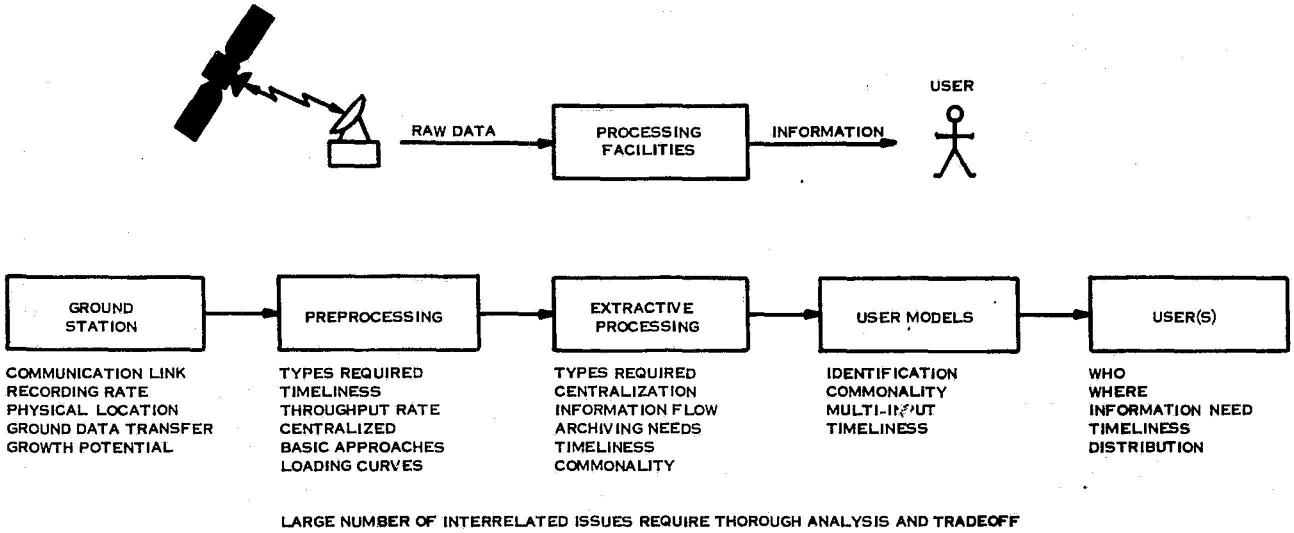


Figure 6.1-1. Ground System Requirements

The ground system design must take into consideration the growth and maturation of the TERSSE such that the costs and implementation are consistent with the users' ability to exploit the output information. The ground system must begin modestly and grow (evolve) in a planned manner in order that its capabilities are matched with its requirements. This evolution can be accomplished with greater efficiency if the overall design concept is kept in mind as incremental capability is added.

What is needed is an integrated data collection and dissemination system architecture which will systematically evolve into the capability to adequately provide for the impending change in mode of ERS usage: from R&D to operational. This system should be able to effectively channel the application of existing technologies into operational resource management applications. It is the projected growth in both the breadth and the depth of the operational applications which is potentially the most dramatic difference between TERSSE and the systems of today.

The important conclusions and recommendations developed throughout this Ground System section can be summarized as:

1. A single, Coherent and integrated ground data processing/distribution system was developed which will serve all TERSSE users.

2. The concept for the data processing function makes a distinction between the basic preprocessing needs which are allocated to a national center and the other functions (more user unique) which are allocated to several "lead Federal agencies."

3. The need for significant additional study in the realm of operations technology has been identified.

4. Multi-source data correlation is identified as the next major advance required in geometric preprocessing; film and digital data from different sensors at different times must be transformed into user tailored grids.

5. Photointerpretation and machine analysis are <u>not</u> competitive but are complementary techniques for extractive processing; fast interactive systems are the route to their joint usage and should be pursued by the ERP.

6. Data systems equipment and hardware technology is advancing rapidly without ERS assistance. The ERS system design must exploit this by focusing development and application on needed special purpose hardware.

7. The ERS ground system should parallel the user's structure. Terminus facilities should be mission oriented and co-located with users - not super regional satellite data centers serving all comers.

This section of the TERSSE report develops a ground system configuration which is responsive to these overall system requirements. Referring back to Figure 6.1-1, there are two elements depicted which are not addressed in this section. The ground system element labeled "User Models" is discussed at length in a separately bound TERSSE report volume; Volume 7 entitled, User Models: A System Assessment. The element labeled "Users" is explicitly addressed in the TERSSE report, Volume 1, entitled, Total Earth Resources Program Scope and Information Needs.

6.2 DATA ACQUISITION

The acquisition of data by the system may be accomplished through the use of any or all of the platform/communication paths shown in Figure 6.2-1. Of concern in the definition of the total system are the trade-offs among the various means of communication the data to different receiving sites: Aircraft or spacecraft direct to ground, and aircraft or spacecraft relayed through a synchronous satellite. This question has been the subject of a Task 3/4 analysis, the results of which are shown in graphical form in the following subsections.

The questions addressed by the analysis were not so much intended to provide the specific wattage or antenna size of a given satellite as they were to indicate the basic possibilities or impossibilities of doing a given data acquisition job a given way.

The observations possible from these efforts are:

1. A small (0.3 meter) fixed antenna for single frame coverage would minimize local ground antenna costs but would be prohibitive in its demands on spacecraft EIRP. A better approach is a small (3.0 meter) steerable dish which would both extend coverage to many frames and lessen the requirement on the polar spacecraft.

2. This same 3-meter dish could receive real-time 15 bit/sec data from a very modest transmitter mounted on an aircraft working in its region.

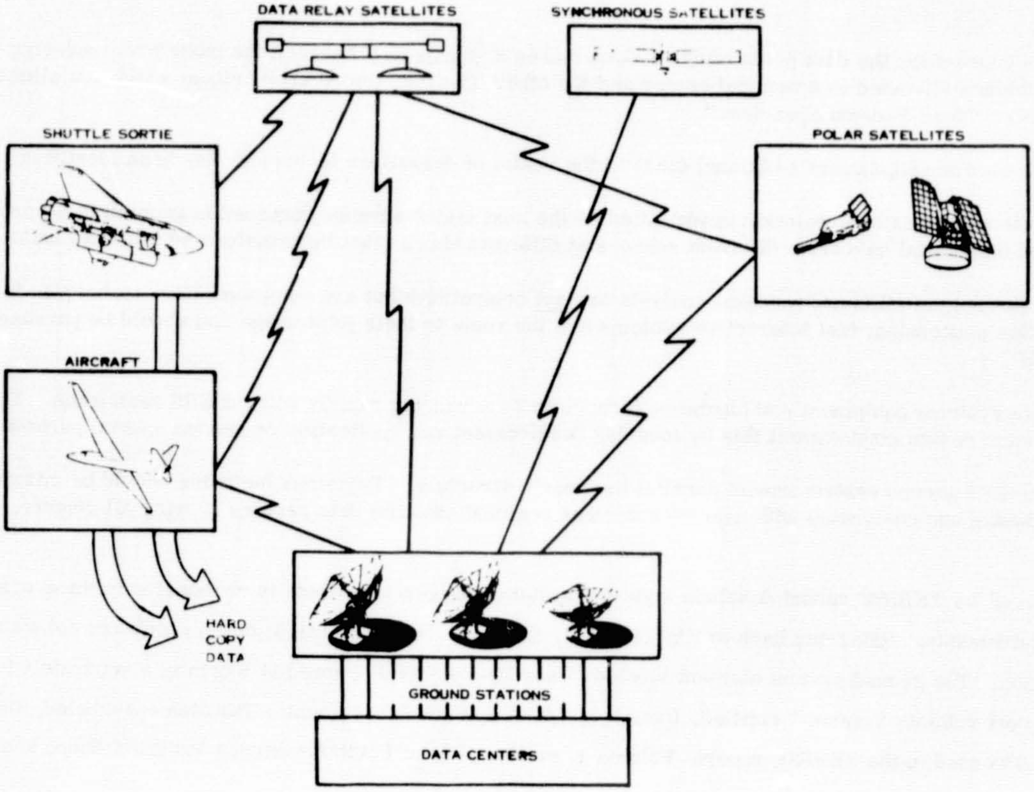


Figure 6.2-1. Data Acquisition Configurations

3. Data relay satellites at K-band, such as TDRS, are rather demanding of the polar spacecraft EIRP but do not require massive ground receive antennas. Multiple TDRS stations would not be excessively costly in an all-up system.

The topics covered in the following subsections are:

- 6.2.1 - Low Altitude Satellite EIRP Requirement (Major Ground Stations)
- 6.6.2 - Low Altitude Platform EIRP Requirement (Minor Ground Stations - S-Band)
- 6.2.3 - Satellite or Aircraft Power/Antenna Gain Combinations (S-Band)
- 6.2.4 - Low Altitude Platform EIRP Requirements (Minor Ground Stations - X-Band)
- 6.2.5 - Satellite or Aircraft Power/Antenna Combination (X-Band)
- 6.2.6 - EIRP Requirements for Low Altitude Satellite Through TDRS to Earth
- 6.2.7 - Satellite Power/Antenna Combination (Ku Band)
- 6.2.8 - Synchronous Satellite EIRP Requirement (Ku Band)

6.2.1 LOW ALTITUDE SATELLITE EIRP REQUIREMENTS (MAJOR GROUND STATIONS)

The first graph of the series, Figure 6.2-2 below, translates sensor bit rate into satellite effective isotropic radiated power (EIRP) at S or X band for major ground facilities such as the NASA network and the 30 foot dish to be operated at Sioux Falls by USDI.

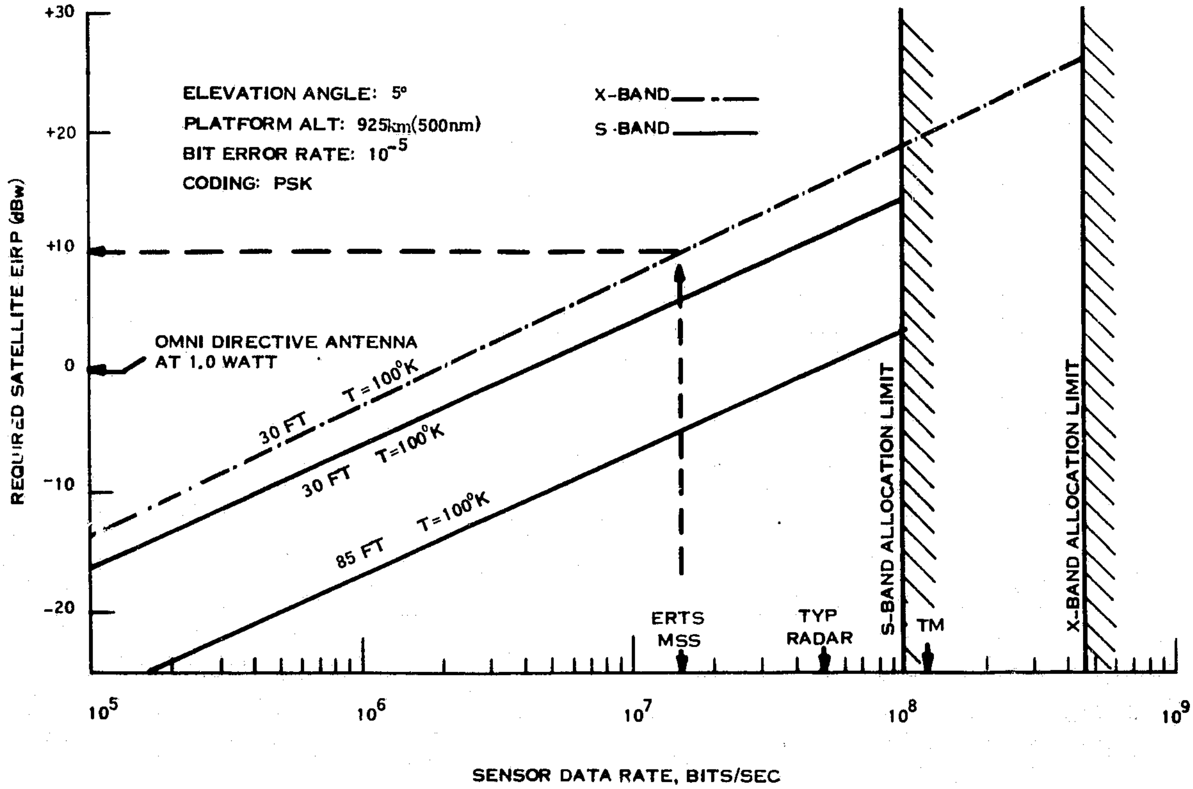


Figure 6.2-2. Major Ground Station EIRP Requirements

6.2.2 LOW ALTITUDE PLATFORM EIRP REQUIREMENTS (MINOR GROUND STATION - S-BAND)

Figure 6.2-3 illustrates aircraft and satellite EIRP required to communicate at S-Band with several types of minor ground stations at varying bit rates. The uppermost pair of lines refers to a 60° (full angle) ground antenna fixed in the vertical direction and should be read as the 60° elevation angle scale for EIRP. Sixty degrees was chosen as a beam angle corresponding to regional coverage, approximately 1850 km (1000 nm) in diameter.

The middle pair of lines refers to a steerable but small (0.3 m) dish and may be read from any EIRP scale to obtain EIRP for different elevation angles. It should be noted that a 0.3 m dish at S-Band, if fixed vertically, would provide coverage of approximately one ERTS frame (185 km 100 nm).

The lower pair of lines refers to a steerable 3 meter dish. The feasibility of performing operations with such ground stations may be assessed by comparing this graph with the following one.

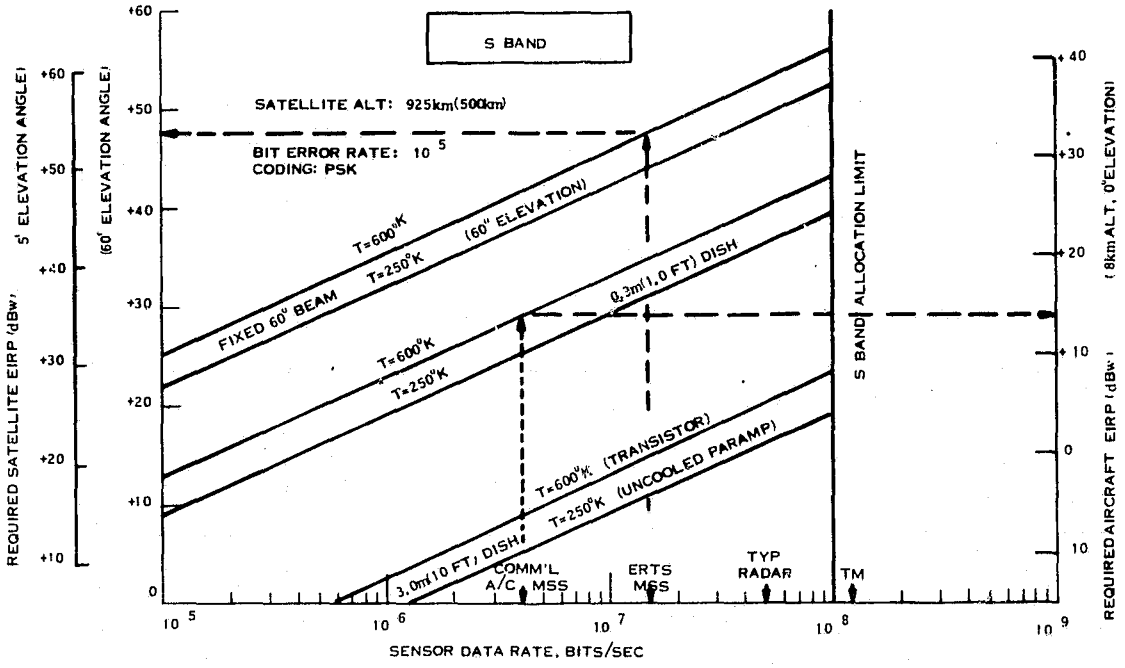


Figure 6.2-3. Minor Ground Station EIRP Requirements (S-Band)

6.2.3 SATELLITE OR AIRCRAFT POWER/ANTENNA GAIN COMBINATIONS (S-Band)

The graph below, Figure 6.2-4, may be used to obtain platform transmitter power required for various platform antenna sizes as a function of the required S-Band EIRP. For example the fixed 60° antenna referred to in the previous chart may be seen to require 48 dBw of satellite EIRP to transmit at 15 bit/sec resulting in, say, a 1.0 satellite antenna and a 1.0 m satellite antenna and a 120-watt transmitter.

6.2.4 LOW ALTITUDE PLATFORM EIRP REQUIREMENTS (MINOR GROUND STATION - X-BAND)

Figure 6.2-5 illustrates the X-Band EIRP required for three ground station cases analyzed earlier. It should be noted that the center set of lines no longer corresponds to a single frame of coverage, as the antenna cone angle is reduced by approximately a factor of four by the change from S- to X-Band.

6.2.5 SATELLITE OR AIRCRAFT POWER/ANTENNA COMBINATION (X-BAND)

Figure 6.2-6 may be used to obtain platform transmitter power required for various platform antenna sizes as a function of the required X-Band EIRP. The previously discussed example of a 60° fixed ground antenna receiving MSS data now requires approximately 62 dBw of EIRP, resulting in, say, a 300-watt transmitter and a 1.0 m dish.

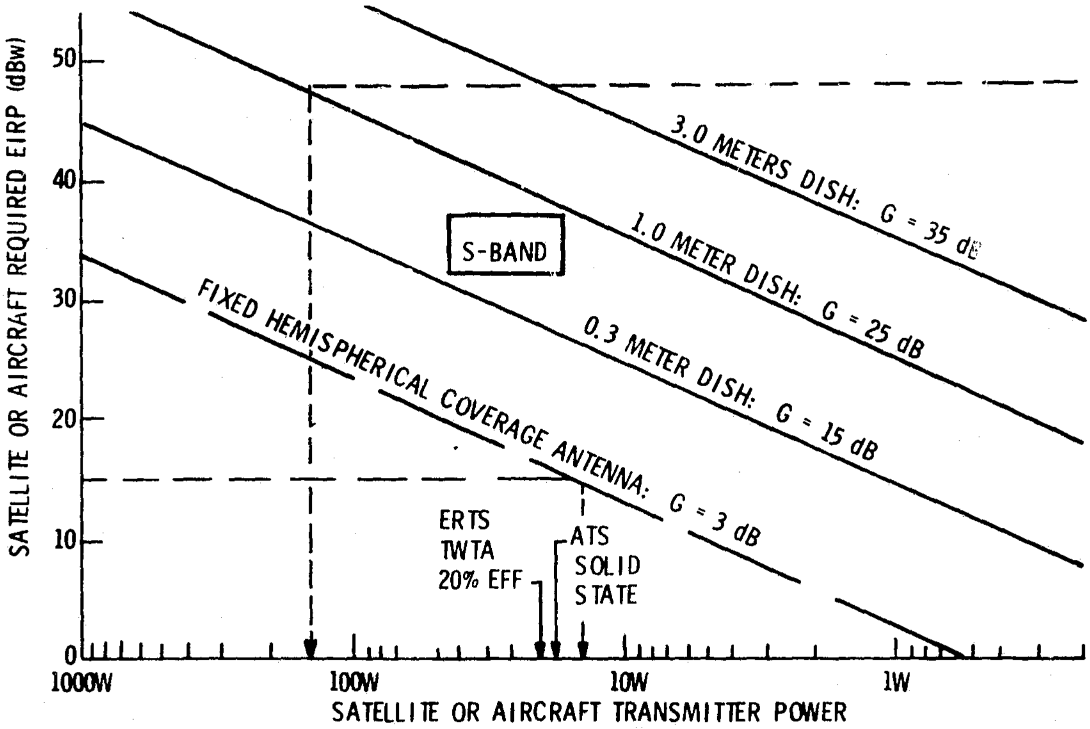


Figure 6.2-4. Power/Antenna Gain Combinations (S-Band)

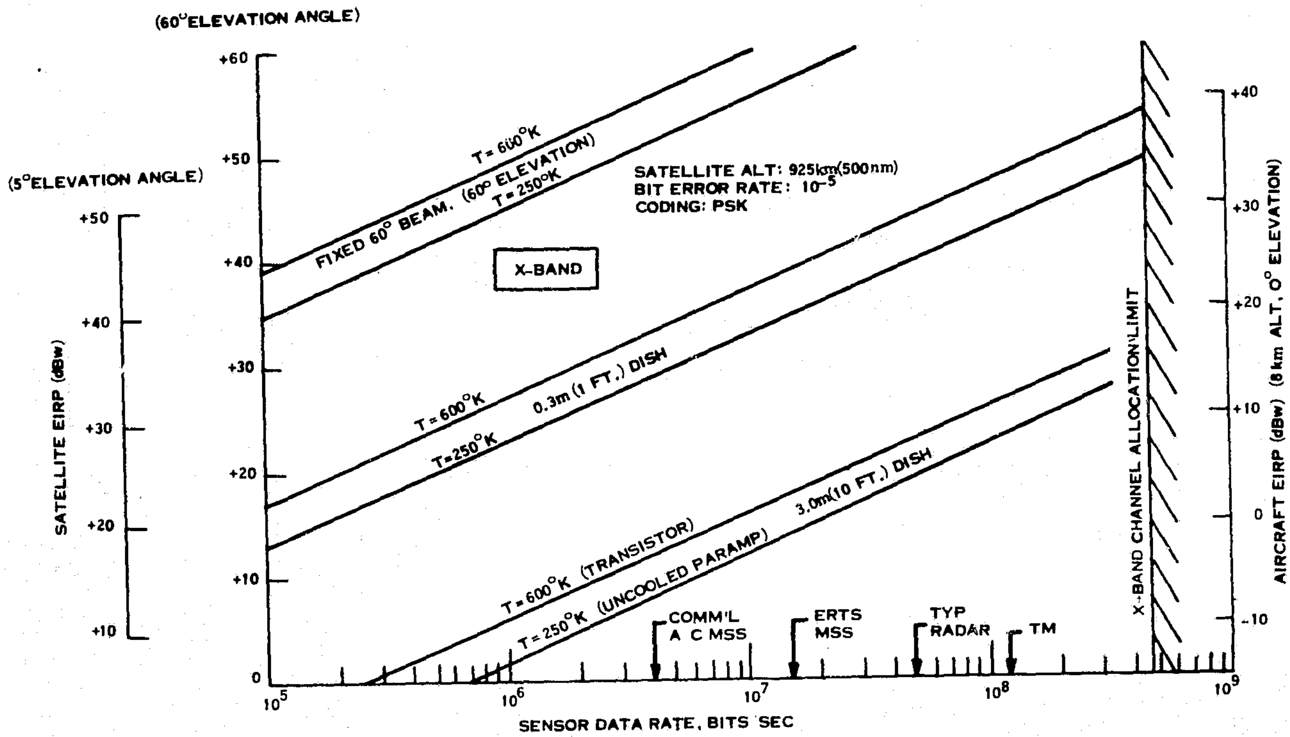


Figure 6.2-5. Minor Ground Station EIRP Requirements (X-Band)

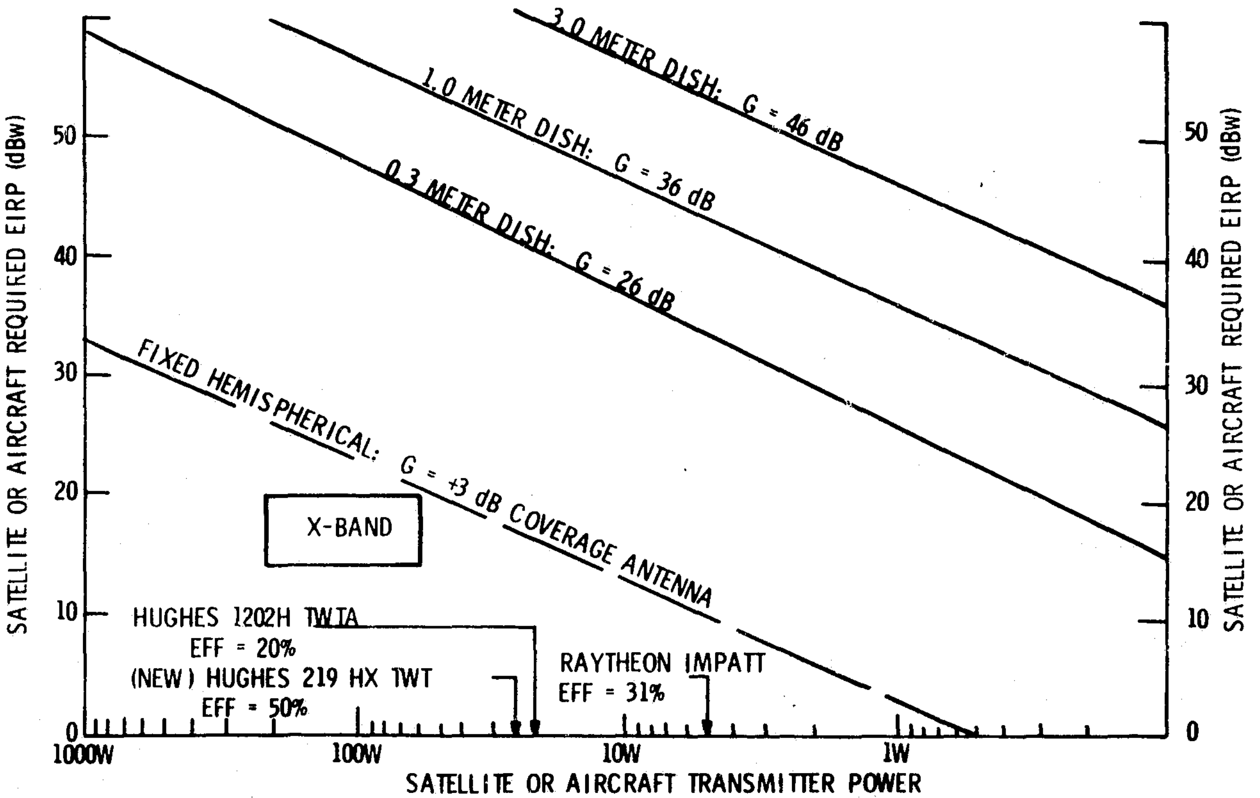


Figure 6.2-6. Power/Antenna Gain Combinations (X-Band)

6.2.6 EIRP REQUIREMENTS FOR LOW ALTITUDE SATELLITE THROUGH TDRS TO EARTH

Figure 6.2-7 illustrates the EIRP required to transmit at Ku Band to various Earth stations via a typical TDRS. The graph is characterized by two types of asymptotes: a sloping line defining the uplink limit case and vertical lines approached asymptotically by the different ground receiver curves as the downlink is reached.

It may be seen that substantial satellite EIRP is required (58 dBw) to transmit ERTS MSS data through this typical TDRS (which is similar to the current NASA baseline) but that a relatively modest ground antenna is required, say, a 3.5 m dish.

6.2.7 SATELLITE POWER/ANTENNA COMBINATION (Ku BAND)

Figure 6.2-8 may be used to obtain the satellite transmitter power required for various satellite antenna sizes as a function of required EIRP at Ku Band. The previous example of transmitting MSS data at 15 bit/sec through the TDRS is seen to require 55 watts of power transmitted through a 1 meter antenna to achieve the required 58 dBw EIRP.

6.2.8 SYNCHRONOUS SATELLITE EIRP REQUIREMENTS (Ku BAND)

Figure 6.2-9 illustrates the Ku-Band EIRP required of a synchronous observatory such as SEOS to communicate with various ground receivers. The previous curve, Figure 6.2-8, relating Ku-Band EIRP to antenna size and transmitter power may be used to obtain the latter parameters.

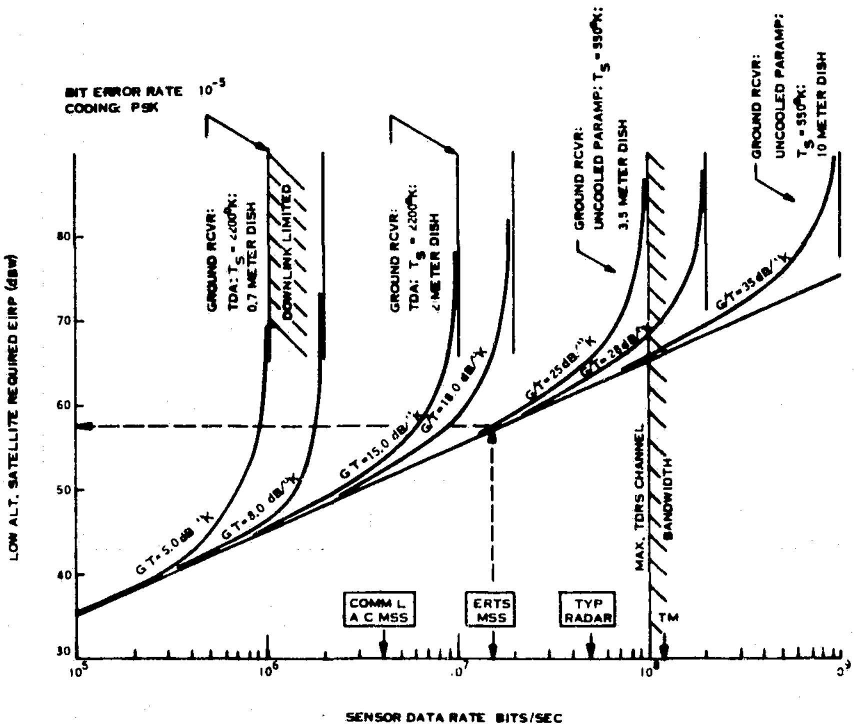


Figure 6.2-7. EIRP Requirements with TDRS

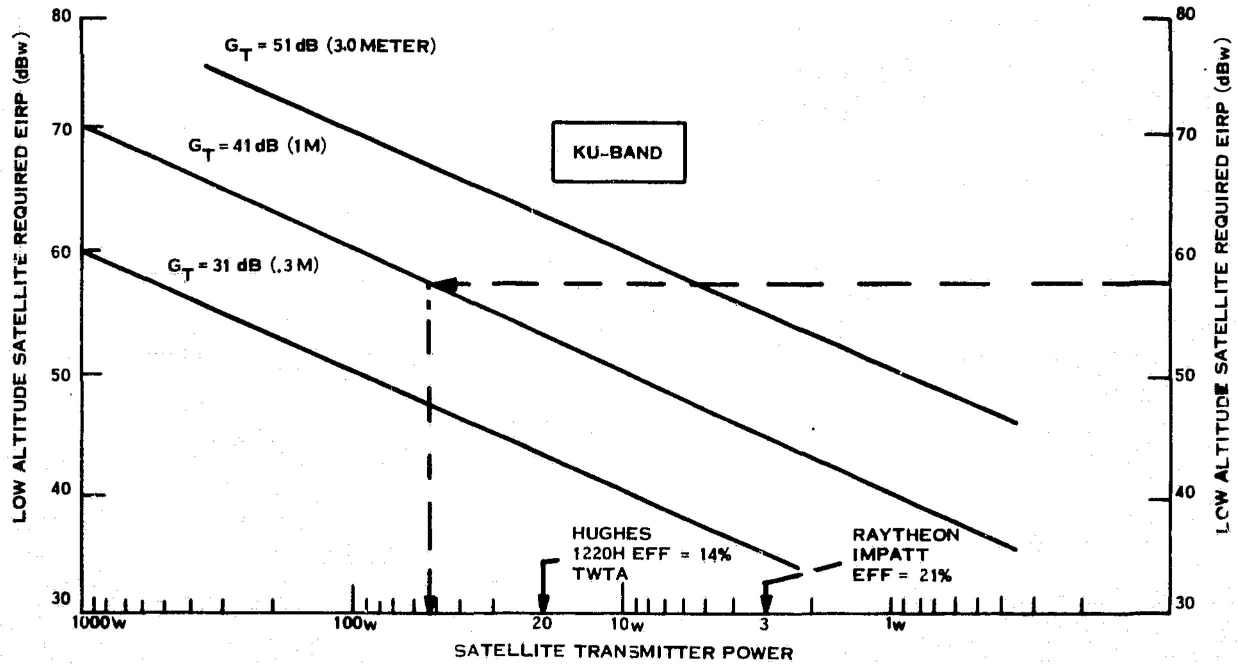


Figure 6.2-8. Power/Antenna Gain Combinations (Ku-Band)

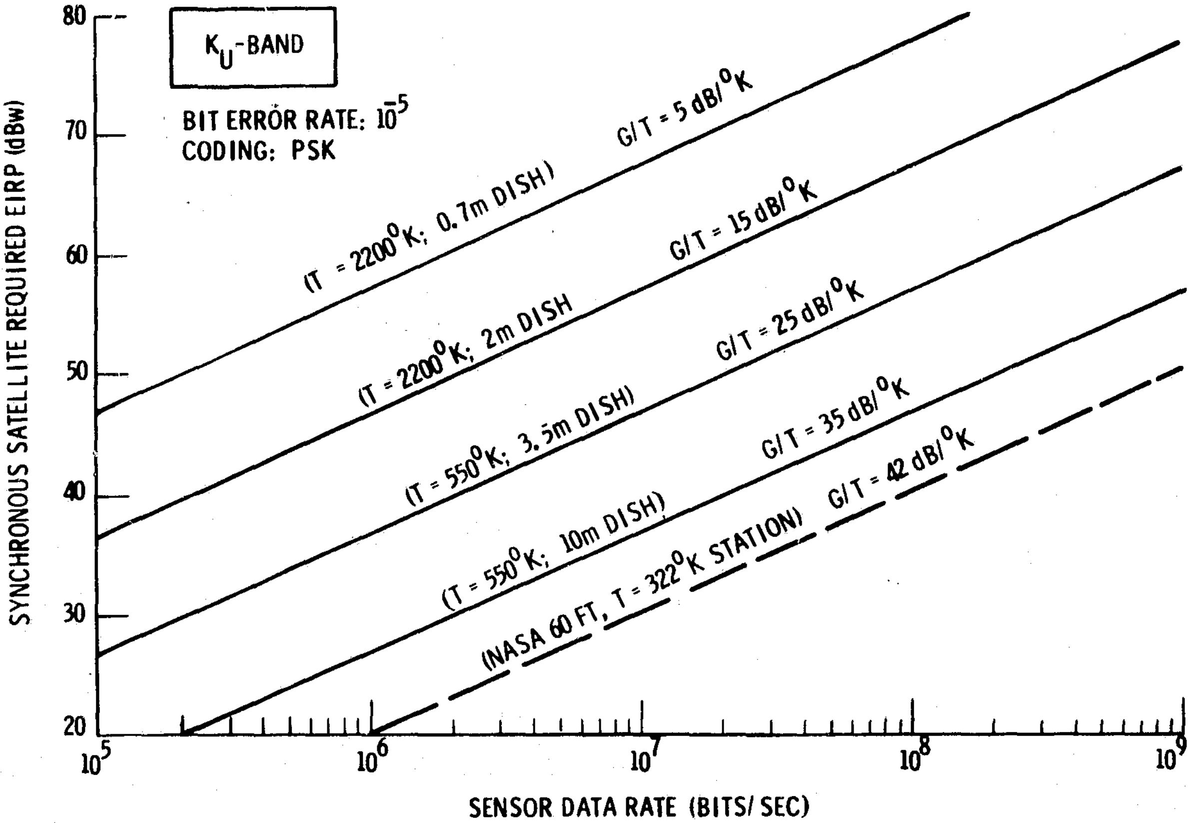


Figure 6.2-9. Satellite ERIP Requirements (Ku-Band)

6.3 DATA PREPROCESSING

Preprocessing includes all those operations which are necessary to retrieve the desired information (i.e., approximate distinguishing characteristics) from data which has been radiometrically and geometrically contaminated by "noise" during the collection process. A comprehensive discussion of the various preprocessing techniques and their degree of technological advancement is contained in the TERSSE report, Volume 2, An Assessment of the Current State of the Art. The purpose of this section is not to repeat that discussion but rather, to consider the preprocessing requirements of the various users/resource managers as a key part of the 1980's TERSSE.

One of the significant TERSSE conclusions which arose from this preprocessing investigation was the need to establish an integrated systems approach to data grids. Most ERS mission/users have their own frame-of-reference; in some cases this is a longitude/latitude geographic reference system, in others it is a different X-Y reference system. The source of the remotely sensed data (and the particular reference system within which it is collected) should not be of concern to the user; the TERSSE should adapt this data to the user's particular reference frame. As shown in Figure 6-3.1 there can be multiple data collection grids(two are shown on the figure as squares and circles) which must be converted to the users reference frame (shown on the figure as dashed lines).

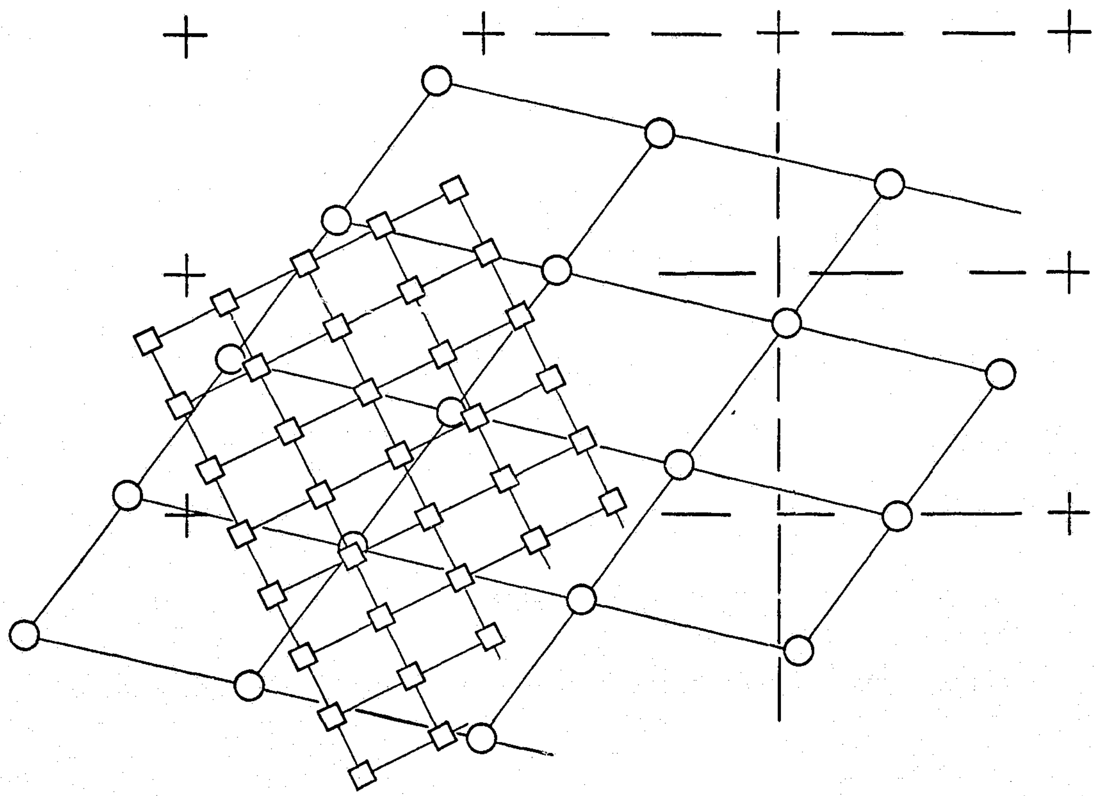


Figure 6.3-1. The Data Gridding Problem

The current and projected capabilities of special purpose digital hardware makes the digital manipulation of large volumes of individual pixels straight forward. This technology should be used in order to get multi-source data into the user's frame-of-reference. The correlation of multi-source data is the next major required advance in geometric preprocessing; both film and digital data from different sensors, acquired at different times, should be transformed to user tailored grids.

6.3.1 BACKGROUND AND TERMINOLOGY

The preprocessing subsystem receives multi-dimensional raw data from the data acquisition subsystem (i.e., sensors) and performs those functions which are necessary to quantitatively restore the original fidelity to the data and produce sufficiently accurate approximations to the desired distinguishing characteristics of the sensed materials. The function of image preprocessing is to retrieve desired information from data which has been contaminated, radiometrically and geometrically, by "noise" introduced during the collection process so as to make the data intelligible and useful for the user. No amount of processing can increase the information content of the data - it can only make the information that is already there more usable.

Images, in an earth resources context, are arrays of data elements (pixels, picture elements, or resels, resolution elements), which represent a record of events or conditions on the earth at a given instant of time. This data is generally used in one of three ways:

1. Inspection and analysis of the data (i.e., in photographic format) with the eye, where the precesion of the radiometry and geometry may be secondary. In fact, distortion of these quantities may enhance the capability of the eye/brain system to perform data extraction.
2. Automated numerical analysis and data extraction where the precision of the geometry and/or radiometry may be of paramount importance.
3. A combination of the foregoing two, where the automated analysis is used to enhance and expand the human visual operations and vice verse.

Preprocessing functions for conventional imaging sensors can be grouped into two major categories, vis, radiometric correction and geometric correction.

6.3.1.1 Radiometric Correction

The purpose of the radiometric correction function is to remove errors and anomalies in received radiance to allow the recovery of the reflectance distinguishing characteristics. As shown in Figure 6.3-2 radiometric correction functions can be grouped into three general areas dealing with the removal of the effects from (a) the data collection instrument, (b) the viewing and illumination geometry; and (c) the atmosphere (down and up).

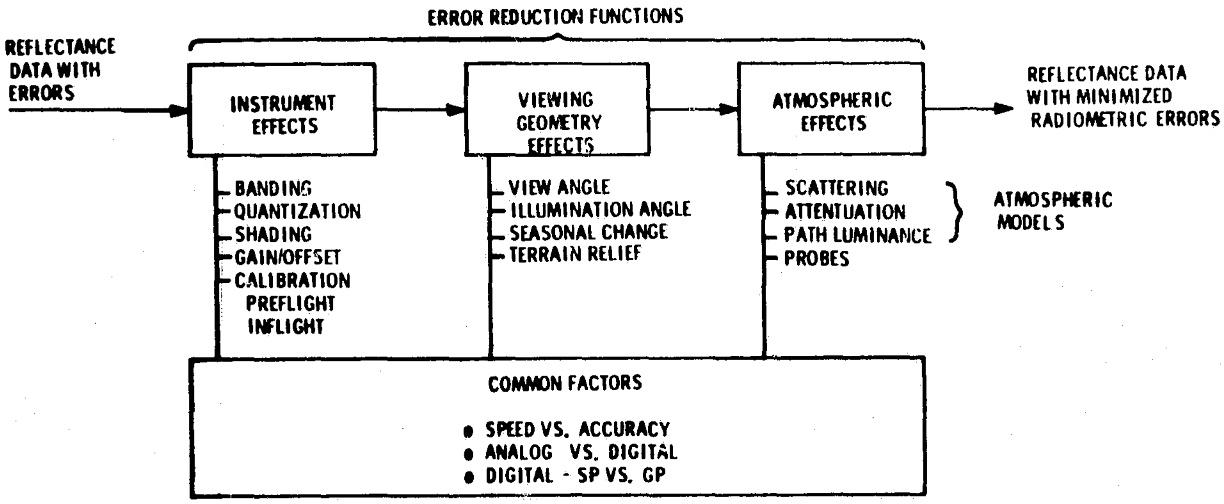


Figure 6.3-2. Radiometric Correction

Atmosphere

At present the radiometric quality of multispectral sensor data is limited not by sensor technology, or available flux, but rather by the degradation caused by the atmosphere. As spacecraft sensors become operational and the volume of data increases, it is important that suitable algorithms be developed which can be used to correct remotely sensed data for atmospheric effects.

Viewing and Illumination Geometry

The effect of viewing and illumination geometry on the calculation of multiplicative and additive correction functions to spectral reflectance has been shown to be very important under some circumstances. The solar altitude, elevation and azimuth look angle, as well as average background albedo have a significant effect on absolute reflectivity determination of an object. Corrections for viewing and illumination geometry may be made with a considerable degree of ease and accuracy. Many of the thrusts to arrive at the determination of atmsopheric effects on remote sensed Earth resources data have included the effects of viewing geometry.

Instrument Effects

The state of the art has advanced considerably in the area of correcting for radiometric errors in the data due to instrument effects. Removal of errors due to the instrument requires that extensive pre-flight calibration measurements be carried out. In certain instances periodic inflight calibration measurements are made and used to update corrections applied to the data. Camera calibration laboratories perform radiometric calibration and modulation transfer function definition of optical systems (e.g., lenses, filters, detectors, etc.) in order to reduce the residual error in resulting radiometric data. The calibration functions required vary considerably in both nature and complexity for different types of sensors.

In assessing the radiometric preprocessing requirements of the users for TERSSE, three "levels" or degrees of radiometric correction were established. These three are:

- 1A = Relative Atmospheric Correction (within a frame)
- 1B = Relative Atmospheric Correction (frame to frame)
- 2A = Absolute Radiometric Calibration (atmospheric effect removal)

Relative Atmospheric Correction (within a frame)

This degree of radiometric correction causes each pixel within a frame to exhibit the proper radiometric spectral intensity with respect to the other pixels in the same frame. The two principal effects which are to be corrected are the detector to detector variations along the sensor array and the lower order radiometric differences from the frame center to the edges of the frame caused by viewing geometry.

Relative Atmospheric Correction (frame to frame)

This level of radiometric correction causes all pixels, including those displaced in time and distance from each other, to exhibit the proper relative spectral intensity with respect to each other. The principal differences between this correction and the previous one, within a frame, is that now larger effects of time (multiple images taken of the same area over a long period of time) and distance (images taken at different areas separated by hundreds of kilometers) must be included. The principal new effect which must now be included in the correction process is the variation of atmospheric and illumination effects.

Absolute Radiometric Calibration

This degree of radiometric correction allows the radiometric spectral intensity of each pixel to be known in times of absolute measureable units such as milliwatts/square centimeter/micrometer of spectral range. This correction is necessary where the actual ground radiance is of the essence in the measurement (primarily for those applications utilizing theoretical models developed in absolute terms).

6.3.1.2 Geometric Correction

A key requirement of an automatic multidimensional analysis system is the availability of a set of congruent measurements for each resolution element in the image. Multiple measurements from each image resolution element offer a means of improving the accuracy of recognition of the properties of the scene over that attainable using one dimension. Measurements of reflectance and radiance from microwave, thermal, and reflective infrared, through the visible wavelengths and into the ultraviolet region, can be utilized for analysis of each image point if congruence of these measurements can be achieved.

The necessity for geometric correction is generated primarily due to (1) uncertainty in platform position and motion (ephemeris, attitude and attitude rates), (2) sensor-induced distortions (aberrations, smear, boresighting, etc.) and (3) geometry of the imaging process (rotation of the earth, terrain elevation, viewing perspective). An additional and paramount requirement stems from the need to correlate pixels from multiple sources which produce X-Y pixel arrays or images which are not colinear with each other.

Many of these sources of geometric error can be minimized by calibration measurements of the sensors and associated electronics prior to and during the flight, measurement and/or control of platform dynamics and knowledge of the viewing geometry. In many remote sensing systems, measurement of the internal distortions related to the sensor is easily accomplished.

The requirement for ground registration accuracy is determined by the application of the data. A user who wishes to do only manual photo interpretation for purposes of change detection or geologic applications does not require very stringent absolute geometric accuracy. However, for mapping purposes or for automated information extraction, the geometric accuracy of the preprocessed data should be to at least within a picture element and probably to sub-pixel accuracy. This requires either very accurate knowledge of the parameters which affect geometric accuracy or the use of ground references. If the data system concept is to preprocess, store and correct all data from a given source or sensor to a single geometric accuracy, then the most stringent requirement will determine that accuracy.

In order to accomplish the task of being able to precisely register to sub-pixel accuracies data from different sensors, time periods and sources, the data must be fit to some absolute reference grid or projection (e.g., the latitude/longitude grid using a specific reference spheroid, the UTM projection, etc.). This requires that the position of each point with a given radiance value be precisely determined and then moved to that point (hybrid approach) or the radiance value for a specific location on the reference be determined from a knowledge of adjacent radiance values from the data (digital approach).

The accuracy of applying geometric correction without ground control is primarily limited by the platform position and dynamics, and the geometry of the imaging process (e.g., curved earth, terrain elevation, viewing perspective). Sensor induced errors due to observatory, non-linear sweeps, boresighting, etc. can generally be minimized by measurement and calibration of the sensors and associated electronics. In most remote sensing systems, this is easily accomplished.

The geometric correction process, regardless of the method of implementation, involves the completion of three basic functions which are: registration, correction function calculation, and rectification. These are depicted in Figure 6.3-3.

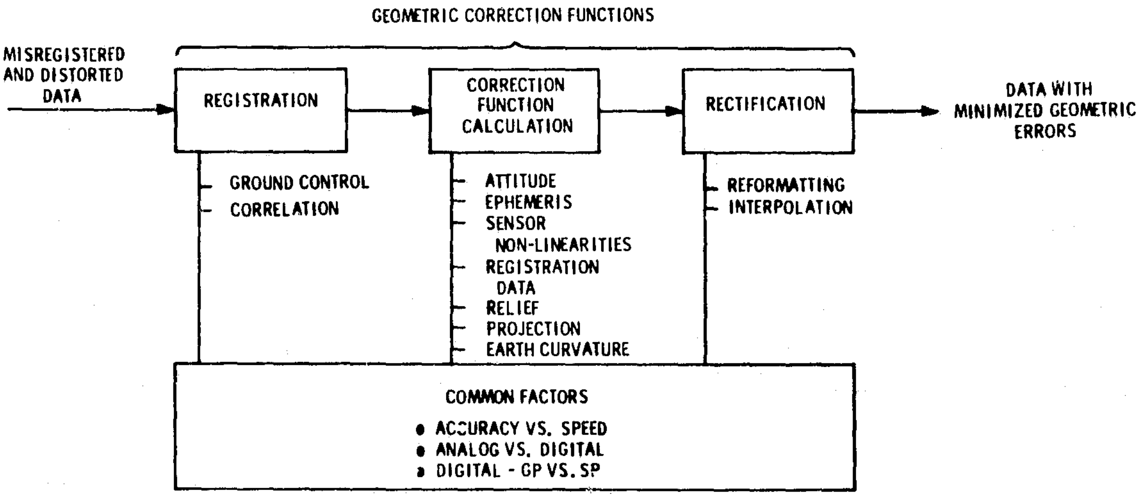


Figure 6.3-3. Geometric Correction

The registration function involves the identification of reference or control points or areas in the data and the measurements of their location to sub-pixel accuracy.

The correction function calculation process involves the determination of the x and y correction necessary at every point in the data in order to remove the distortions present and fit it to the actual location in some desired projection or reference grid system.

The rectification process implements the calculation corrector fit by reformating the individual pixels (i.e., rubber sheet stretch) to make them correspond to their actual location. The reformating involves interpolation in all but the simplist schemes. Interpolation is carried out by weighted averaging in the neighborhood of the "new " pixel according to one of several schemes such as $\frac{\sin x}{x}$ or linear weighting.

In assessing the geometric preprocessing requirements of the users for TERSSE, three "levels" or degrees of geometric correction were established. These three are:

- 1 = Local Map Grid
- 2 = Local Map Grid Rotated
- 3 = Remapped into Geographic Coordinates

Local Map Grid

The Local Map Grid level of corrections applies a "local" sensor oriented reference grid to the radiometric intensity data. No effort is made to orient this data reference grid with respect to any other reference grid or coordinate system. The correction supplied with "bulk ERTS" geometric preprocessing would be an example of this degree of preprocessing.

Local Map Grid Rotated

The Local Map Grid Rotated type of correction is quite similar to the previously described Local Map Grid in that the convenient "local" sensor reference frame is the basis. However, in this scheme the image frame and the scan lines are rotated so as to be in alignment with a North-South reference. In other words, "up is North". Note, however, that this correction only applies a rotational correction to the image frame, translational correction for full geographic correction is still not present. The geometric correction associated with the "LARS" approach would be an example of this degree of preprocessing.

Remapped into Geographic Coordinates

When an image frame has been "Remapped into Geographic Coordinates" that indicates that it has undergone complete rotational and translational correction such that it is referenceable to an established coordinate system, usually established by the user. This correction includes the annotation of the image data so that any pixel, picture element, can be referenced via a longitude, latitude geographic coordinate system. The correction referred to as "ERTS precision" is a partial example of this degree of preprocessing; it is a partial example because the image is referenceable only as a whole - not on a pixel by pixel basis.

6.3.2 USER MISSION REQUIREMENTS

Each of the 285 User Tasks (specific subdivisions of the 30 basic TERSSE missions) were analyzed as to their specific preprocessing requirements. This was done for both the geometric corrections and the radiometric corrections necessary in order to extract the required information from the remotely sensed data. The specific requirements for each User Task are detailed in the computerized data compilation of Appendix A.

One way to examine this data is to plot it in the form of histograms showing the number of User Tasks which require each type of correction technique. These histograms are shown in Figures 6.3-4 and 6.3-5 for the geometric and radiometric corrections respectively. The same data is shown in tabular form in Table 6.3-1.

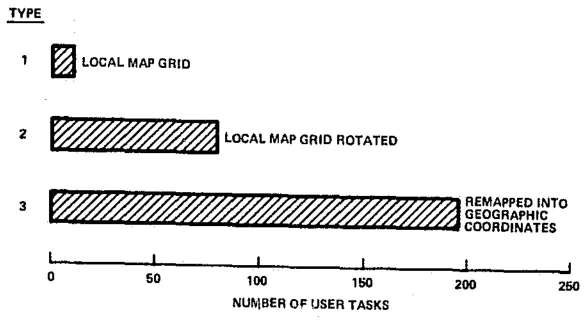


Figure 6.3-4. Distribution of Geometric Preprocessing Requirements

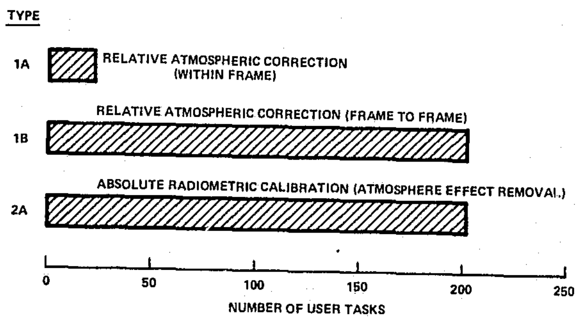


Figure 6.3-5. Distribution of Radiometric Preprocessing Requirements

Table 6.3-1. Number of User Tasks Requiring Preprocessing by Type Required

Resource Discipline	Geometric			Radiometric		
	1	2	3	1A	1B	2A
Agriculture	4	10	21	0	25	24
Energy & Minerals	0	22	27	0	49	49
Forest	7	4	19	11	18	8
Land Use	0	4	51	0	56	22
Water	0	41	44	0	57	70
Marine	0	1	34	11	0	31
	11	82	196	22	205	204

Geometric: 1 = Local Map Grid (e.g., bulk ERTS)
2 = Local Map Grid Rotated (e.g., LARS approach)
3 = Remap into Geographic Coordinates (e.g., ERTS precision)

Radiometric: 1A = Relative Atmospheric Correction -- within frame
1B = Relative Atmospheric Correction -- frame to frame
2A = Absolute Radiometric Calibration -- atmospheric effect removal

When viewing these plots it must be kept in mind that this approach treats all User Tasks equally; no distribution is made as to relative worth or importance. It can, however, be useful for detecting clusters or trends in the distribution. Note that the sum of the distributions exceed the number of User Tasks; this situation arises because some User Tasks extract more than one class of information from the data, and thus may use more than one type of preprocessing. This data reflects the number of User Tasks and does not include the number of spectral bands of each; as such it indicates the distribution of requirements.

The data is not weighted by the number of spectral bands to be processed for each User Task. For example, a rough count of the spectral bands for radiometric preprocessing showed twice as many (about 1300) for type 1B than for type 2A (about 650 bands) corrections; a significant difference when the User Tasks count are the same (205 and 204).

The last two factors which need to be considered in order to compare the relative volumes of preprocessing corrections by type of correction are the area and frequency of coverage. Different User Tasks cover different amounts of geographic area at different repeat cycles; therefore they are expected to have quite different volumes of data to be preprocessed. A User Tasks which cover most of the United States every two weeks represents a substantially different system loading from a User Tasks which covers only the Great Lakes four times a year. This overall loading by preprocessing type was not investigated as part of this TERSSE study.

6.4 EXTRACTIVE PROCESSING

Information extraction, extractive processing, can be defined as the process of converting image data into parametric information such as the identification and classification of wheat fields from a multi-spectral image. Specifically it is the process of converting n-channel spatial array data (ie., an image from any sensor in any spectral band) into user-oriented parameters. A comprehensive discussion of the various extractive processing techniques and their degree of technological advancement is contained in the TERSSE Volume 2 report, entitled An Assessment of the Current State of the Art. The purpose of this section is not to repeat that discussion; but rather, will consider the extractive processing requirement of the various users/resource managers as a key element of the TERSSE.

6.4.1 BACKGROUND AND TERMINOLOGY

As seen in the following generic depiction, Figure 6.4-1, of an Earth Resources data system, extractive processing.

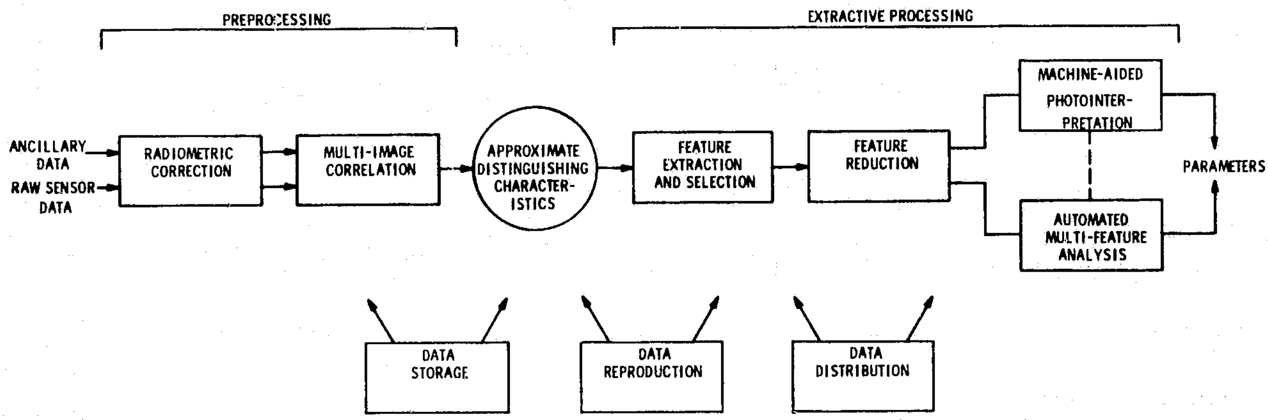


Figure 6.4 -1. Generic Earth Resources Data System

Figure 6.4-1, Generic Earth Resources Data System includes all those operations which convert the approximate distinguishing characteristics into user oriented parameters. The sequential functions in information extraction are shown in Figure 6.4-2. They include:

- Feature selection/extraction: obtaining the features or characteristics of the scene which can be used to identify points or objects in the scene.
- Feature reduction: a linear transformation of the features obtained above to gain, hopefully, a minimum optimal set of features which will be sufficient to identify objects or points in a scene.
- Feature classification/estimation: the conversion of feature measurements into user oriented parameters (i.e., corn yield, soil moisture, etc.)

These functions are briefly described in subsequent paragraphs.

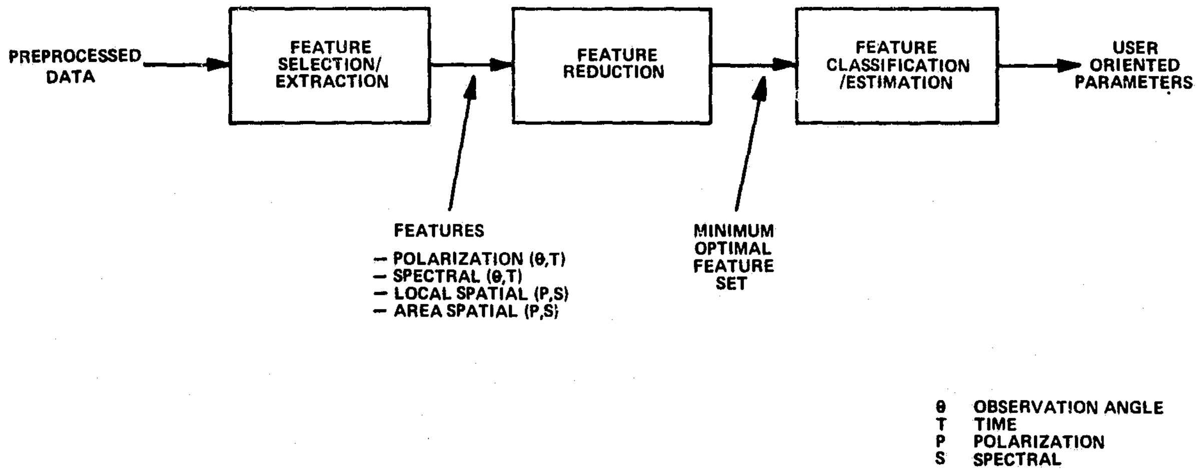


Figure 6.4-2. Information Extraction Functions

6.4.1.1 Feature Selection/Extraction

Feature selection/extraction (Figure 6.4-3) is the initial and most critical step in any machine-aided information extraction approach because subsequent extractive processing functions must utilize these features to achieve the desired result.

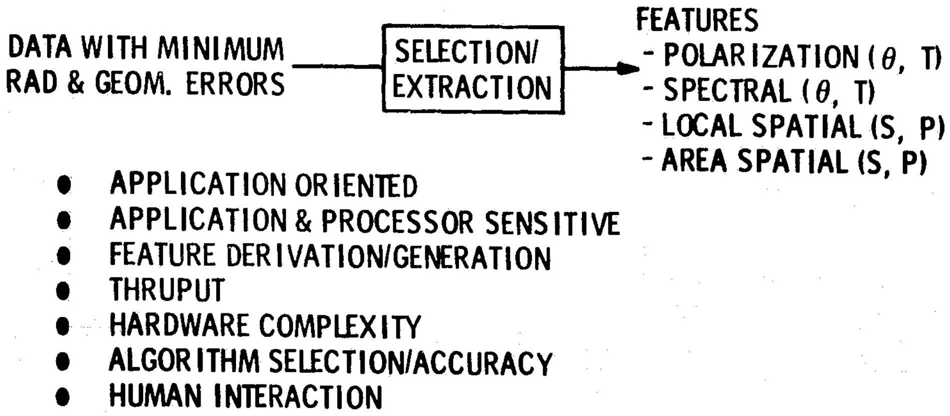


Figure 6.4-3. Feature Selection/Extraction

The purpose of feature selection/extraction is to identify and generate those features which can contribute to the recognition and/or separation of classes of objects. Effort to date has been concentrated in the visible and near IR and has been primarily spectral analysis. Additional development work is required to bring the spatial and temporal areas up to the current level of spectral techniques.

Table 6.4-1 lists the various techniques utilized in the feature selection/extraction process. Each of the four major categories of techniques are briefly described below.

Table 6.4-1. Feature Selection/Extraction Techniques

1. Discrete Point Measurements - Polarization - Spectral Band (X-ray to Radar) - Spectral and Polarization Combinations Vs. Observation Angle and Time	3. Spatial Measurements On N x N Gridded Areas - Transformation (Hadamard, Fourier, Karhune Loeve) - Geometric Measurements Area, length, perimeter, aspect ratio, Spatial moment, texture measurements - Radiometric Measurements (Expected value, variance)
2. Local Spatial Features Derived From the Above Measurements - MxM Window Filters (M = 5-10) Operating on Each Pixel Smoothing, Laplacian, Gradient, Correlation Filter & Filter Sets - Bilevel Image Extraction via Thresholding	4. Function of Discrete Point Measures - Ratioing - Normalization - Ratio of Ratios

Discrete Point Features. The radiometric image data that is recorded in a spectral channel is a function of (1) the energy in a spectral band; and (2) the energy with a particular polarization as received by the sensor. If during the preprocessing the illumination, atmosphere and sensor radiometric errors have been reduced or eliminated, then the intensities in the data are a function of the properties of the object in the scene. Thus the radiometric intensities in a channel can be considered a feature which is useful in identifying points or objects in the scene. The n-channel radiometric image data can be considered as n-feature where each feature channel can have a different value for each point in the image.

If images acquired at different times and observation angles for a given scene are corrected to the same reference frame via geometric preprocessing, then the polarization and spectral features can be a function of the observation time (t) and angle (θ). For each value of t and θ there are a new set of n-features (one for each channel of the n-channels of radiometric image data for a given time and observation angle). Hence the number of features expand rapidly as the spectral/polarization bands and the number of observation times/angles increase.

A unique characteristic of the above features is that each feature or channel has a value for every point in the image which is only a function of the radiometry at that point features.

Local Spatial. The previous discussion was limited to those features (one channel of image data) which were a function of the radiometry at each point in the image, i.e., the spatial radiometric variations (variations between adjacent picture points in the image x-y plane) were not considered. The determination of variational characteristics between adjacent picture points for each point in an image is referred to as immediate neighborhood spatial feature extraction. These features are similar to the discrete point radiometric features in that each feature has a value for each point in the image. Examples of these features are spatial features derived from:

1. Spatial filtering of discrete point features, i.e., n-channel gradient, Laplacian, smoothing, high and low pass filter, match filter sets, etc.
2. Bi-level image obtained by thresholding the above features.

The gradient and Laplacian type operators followed by selected thresholding have recently been used to extract boundaries and homogenous training areas for both supervised and unsupervised learning. Matched filter sets have been used to extract line segment, arcs, and other simple geometric slopes from gray level images.

Area Dependent Spatial Features. The features discussed so far have the characteristic that the feature (channel) have a value at every point in the scene. Area dependent spatial features are different in that there are only feature values for each array of picture elements in the scene. The array can be a small segment of an image or the total scene. Arrays can be square (N x N pixels), polygons, or any arbitrary shape. The array can be pre-defined (i.e., a N x N segment of an image) or derived from the discrete point features of the scene via spatial filtering and thresholding, classification, or other techniques. Examples of area dependent spatial features are:

1. Transformations (i.e., Fourier, Hadamard, Karhune Loeve) of N x N pixel arrays.
2. Area, length, perimeter, aspect ratio, expected value, variance, spatial moments, texture measurement, etc. of each array.

Most of the recent work with remote sensing applications has centered around transformation or texture measurement for predefined N x N pixel segments in a grided gray level image.

Function of Descrete Point Measure. These functions consist of the ratioing of features or the normalization of features. Normalization of features is used to represent the division of each feature by the average value of a feature for a given observation time or angle. These functions have several benefits: (1) they further reduce radiometric error not removed during the preprocessing step; (2) they can reduce the number of features by one; (3) most importantly, they can produce new features which are more representative of the object of interest in the scene. These funtions have been incorporated into several multispectral analysis systems which are near operational on an experimental basis.

6.4.1.2 Feature Reduction

Feature reduction techniques (Figure 6.4.-4) attempt to reduce the number of features to the minimum number which can sufficiently recognize and/or separate given classes of objects. This reduction in the number of features can significantly reduce the time and effort required to classify sets of objects for a given application.

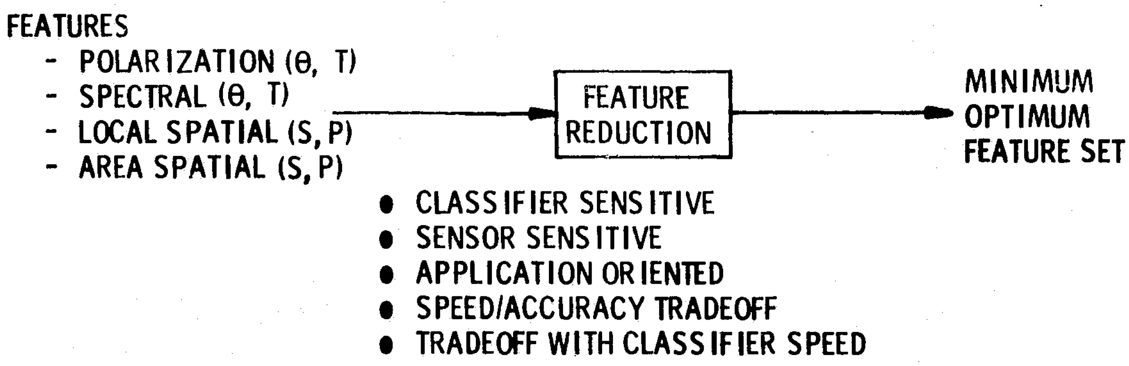


Figure 6.4 -4. Feature Reduction

From the discussion on Feature Selection/Extraction it was shown that many features could be measured or derived for a particular ground scene. Consider the case of overflights, with 4 spectral bands, each of a given ground scene. When consideration of spatial and ratioed features is included we could have the following situation:

16 Descrete point features - 4 bands, 4 overflights
x6 Spatial and ratioed features extracted for each discrete point feature
96 Features or Channels

Each of these 96 channels/features could consist of 10 million picture elements (pixels) of 6-16 bit dynamic range, and could be useful in identifying objects or points in the scene. To try to process the quantity of data would be very time consuming, even with high-speed special purpose hardware. It is thus desirable to select the minimum subset of features or linear combination of features which will produce satisfactory object recognitions or classifications. The reason for using new features that are linear combinations (transforms) of the original features is that in most cases fewer transformed features are required to obtain the same degree of classification accuracy.

Ideally, the optimum set of new features would be obtained by selecting the minimum set of transformed features that would produce the desired classification accurately with the classification algorithm being used. However, this apparently straightforward method is usually not practiced because the time to select the optimum features would be longer than the time to classify using the original features. Thus a whole family of feature reduction algorithms have been developed which show some degree of optimality under certain conditions. These are listed in Table 6.4-2 in approximate order of increasing effectiveness and computation time.

Table 6.4-2. Reduction Techniques

1.	Select input channel with largest variance
2.	Maximum or minimum eigen values of multi-class cluster
3.	Maximize (1) inter - to intra-class scattering or (2) distance - function using subset of original channels
4.	Minimize error using subset of original channels by use of a linear classifier
5.	Maximize (1) inter - to intra-class scattering or (2) distance - function using the best subspace of the original channels
6.	Minimize error using the subspace by use of a linear classifier
7.	Minimize error in subspace using the best available classifier

The final two methods are one function of the composite class distribution and as such do not guarantee an optimal separation of the classes. However, these are the only methods of feature reduction that can be applied prior to clustering type classification, because in the clustering approach no a priori individual class distributions are known. The remaining approaches can only be applied when a training site (supervised) machine training approach is used. In addition, approaches 3 through 7 utilize optimization techniques which require an interactive solution and as such can require a long solution time for the many channel, many class problem.

6.4.1.3 Feature Classification/Estimation

Feature classification/extraction (Figure 6.4-5) algorithms transform sensor oriented radiometric data (features) into user oriented parameters or themes needed to produce application information (e.g., user model inputs, statistical summaries, etc.).

The speed and accuracy with which this function can be performed is very dependent upon the validity of the minimum "optimum" feature set. Then classification techniques are well into the implementation stage but require additional developments in rapid throughput mechanization. Estimation techniques again are lagging even though the basic physics is understood. Development is required in relating the features analyzed to the desired output parameters.

Given an optimal set of spectral, polarization, temporal, angular and/or spatial features, these features must be used to classify or estimate points or objects in a scene in order to obtain user oriented parameters.

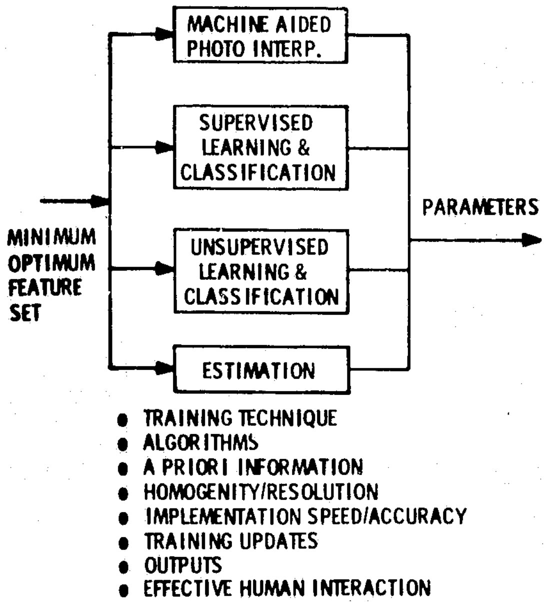


Figure 6.4 -5. Feature Classification/Estimation

The relation between the features and parameters can vary from deterministic to statistical. If this relationship is deterministic, i.e., the parameter is a monotonic function of the n-features, then the parameter can be estimated from the features. These functions are referred to as parameter estimation techniques and are in an early experimental state. Though the basic physics indicates that many of these deterministic relationships should exist, the models relating features to a particular parameter have been derived for only a few cases. These estimation models are very specific in that each model applies only to particular parameters (i.e., water depth for clean water).

On the other extreme, a statistical relationship may exist between the parameter and the features. In this case a given set of feature values will correspond to a given parameter. The process of determining a given parameter from one of a set of feature values is called classification. A graphic representation of estimation and classification is shown in Figure 6.4-6.

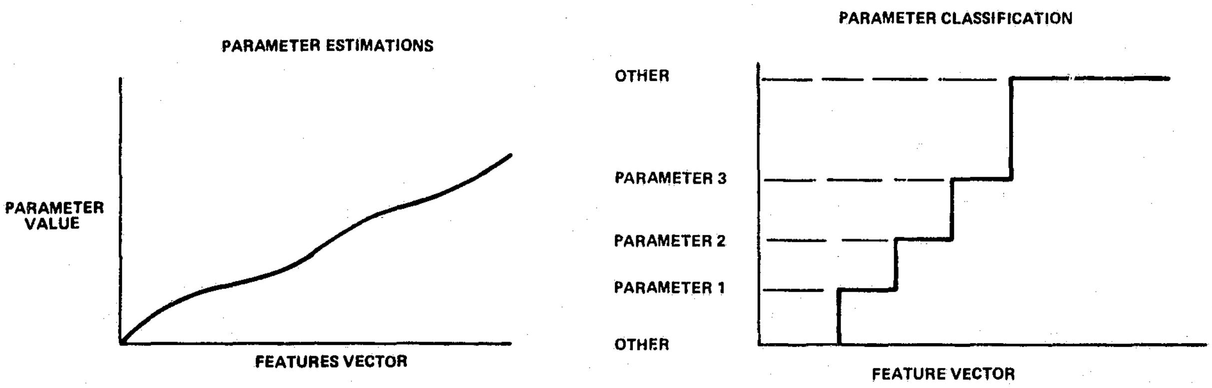


Figure 6.4-6. Parameter Estimations

Between the above two extremes is a method which can be considered to be classification followed by estimates of the value of the classified parameter. This is shown graphically in Figure 6.4-7. From a classification viewpoint this method can be considered as a continuous subclassification of a particular class or mixture of classes. The complex mixture algorithm for subpixel interpolation falls into this category.

The various classification and estimation techniques available are shown in Table 6.4-3.

Table 6.4-3. Classification/Estimation Techniques

Machine Aided
Gamma stretching
Color X-Function
Level slicing
Rationing
Clustering
Local spatial operations
Area spatial operations
Supervised
Training sites
Training sites plus unsupervised update
Unsupervised
Spectral clustering
Spatial/spatial clustering
Spatial derived training areas
Estimation

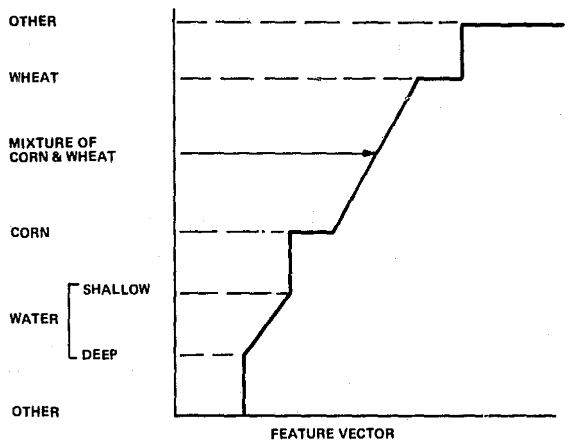


Figure 6.4-7. Continous Subclassification of Particular Classes

6.4.2 DEFINITION OF TERSSE EXTRACTIVE TECHNIQUES

In assessing the extractive processing techniques required for TERSSE a comprehensive set of techniques was considered. These techniques are listed in Table 6.4-4 below; a brief description of each follows.

Table 6.4-4. Extractive Processing Techniques

TECHNIQUE	DESCRIPTION
Manual Interpretation 1A - Color Additive Viewing 1B - Black & White Image Interpretation	Visual extraction of parameters from film or electronic images without special enhancement or interactive processing
Simple Enhancement 2A - Color Composite Ratio 2B - Color Level Slice 2C - Black & White Ratio	Involves simple manipulations of image data to enhance basic radiometry, such as color-coding black-white scale (color level slicing) or ratioing adjacent channels to highlight non-common information
Supervised Pattern Recognition 3A - Spectral Features - 3B - Spectral-Spatial-Temporal Features	Machine processing of pixel data to obtain statistically-derived classes of parameters; class boundary decisions made totally or partially by operator
Unsupervised Pattern Recognition 4A - Spectral Features 4B - Spectral-Spatial-Temporal Features	Machine processing of pixel data as above; class boundary decisions made by one of several machine-implemented approaches
Estimation 5A - Spectral Features 5B - Spectral-Spatial-Temporal Features	Calculation of a parameter value, such as water depth, from a known (monotonic) relationship between the parameter and one or more features; deterministic process, as opposed to statistical pattern-recognition processes.

6.4.3 USER MISSION REQUIREMENTS

Each of the 285 User Tasks (the specific representations of the 30 basic TERSSE mission statements) were analysised for their specific extractive processing requirements. These requirements were considered in terms of the eleven techniques discussed in the previous section (Section 6.4.2) and listed in Table 6.4-4, previous. The complete and specific requirements of each user task are contained in the computerized data base of Appendix A (TERSSE Volume 8, User's Mission and System Requirements Data.)

One way to examine this data is to plot it in the form of histograms which show the number of user task requiring each type of extractive technique. Figure 6.4-8 shows the total number of user tasks for each of the eleven extractive techniques. Figure 6.4-9 is a similar presentation; however only the five major categories of extractive techniques are used. In Figure 6.4-10 the composition of the user task requirements can be ascertained with respect to the six resources management areas. The detailed tabulation of user task requirements for each of the thirty resource management missions is shown in Figure 6.4-11.

When considering these histograms it should be kept in mind that this approach treats all user tasks equally; no distinction is made as to their relative worth or importance. This approach is useful for detecting trends or clusters in the distribution of requirements. It will be noted that the sum of the extractive processing requirements exceeds the number of user tasks. This situation arises because some user tasks extract more than one class of information from the data, and thus may use more than one type of processing or may use the same type of processing more than once.

Two significant factors which should be considered when comparing the relative number of requirements for each extractive technique are area of and frequency of coverage. Different user tasks cover different sizes of geographic area at different repeat cycles (and at different spatial resolution). Thus the various user tasks are expected to have quite different volumes of data to be extractively processed. A user task which must consider the entire Great Lakes area twice a week represents a different magnitude of volume than a user task which considers a single city twice a year.

Referring to the histograms, several points can be made with respect to the extractive processing requirements:

1. No user tasks have expressed a requirement for the Unsupervised Pattern Recognition technique.
2. The requirements for the use of Estimation and Supervised Pattern Recognition techniques are significantly greater (more than an order of magnitude) than the other required techniques.
3. The requirements for Estimation and for Supervised Pattern Recognitions are approximately equal in magnitude.
4. The requirements for use of spectral features are considerably greater (approximately three to one) than for spectral-spatial-temporal features for both the Estimation and the Supervised Pattern Recognition techniques.

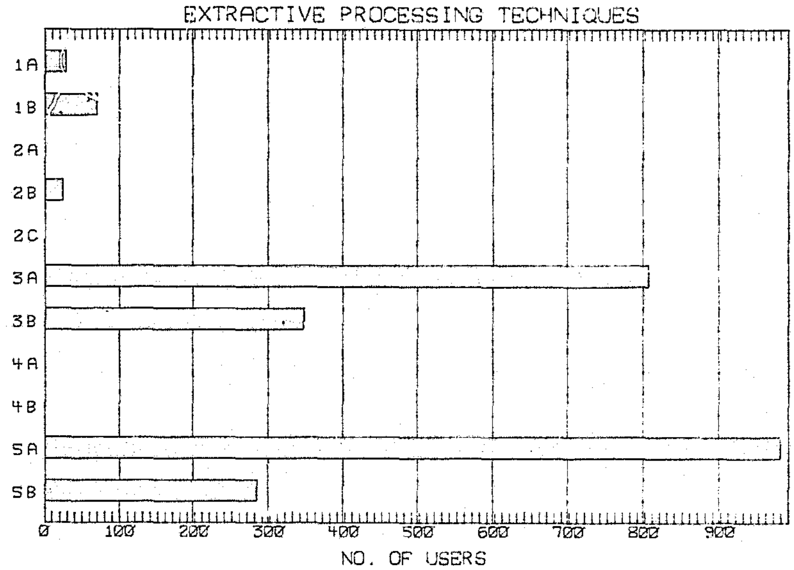


Figure 6.4-8. Distribution of Extractive Processing Requirements

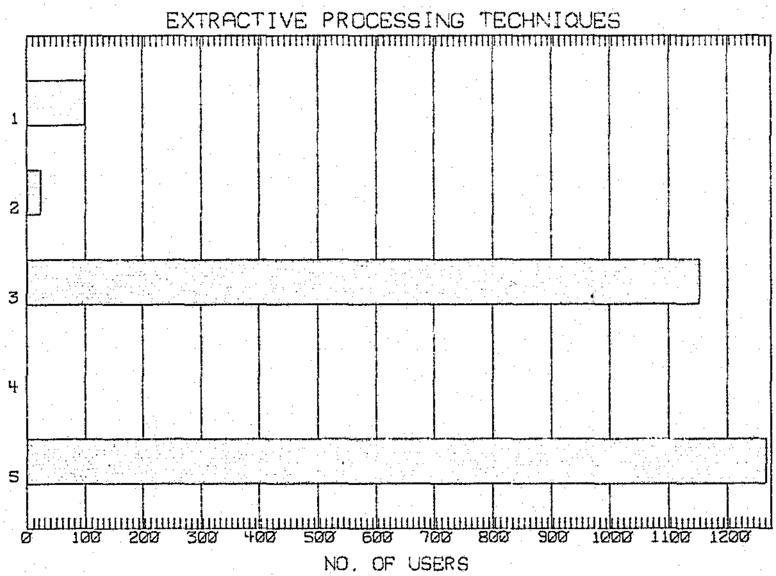


Figure 6.4-9. Major Categories of Extractive Techniques

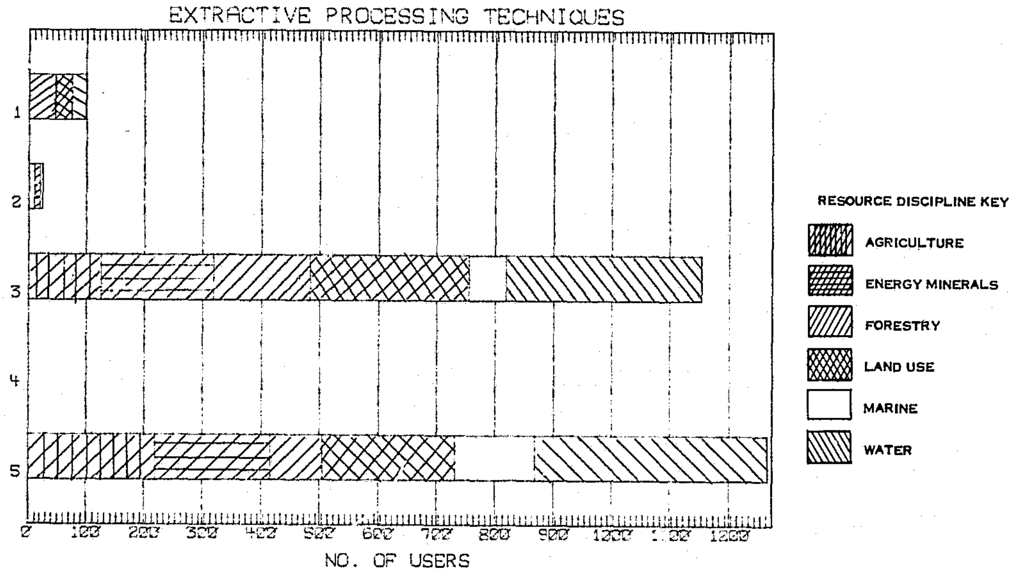


Figure 6.4-10. Extractive Processing Requirements by Resource Management Area

Extractive Technique		Agriculture: U.S. Crop Survey 1	Agriculture: Insect, Disease, & Stress 2	Agriculture: Farming Practices 3	Agriculture: Irrigation Water Demand 4	Agriculture: Global Crop Survey 5	Agriculture: Pasture/Range & Survey 6	Energy Minerals: Minerals Survey 1	Energy Minerals: Geothermal Source Survey 2	Energy Minerals: Submarine Oil Survey 3	Energy Minerals: Extraction Pollution Monitor 4	Energy Minerals: Pipeline Monitor 5	Energy Minerals: Oil Pollution Monitor 6	Energy Minerals: Thermal Pollution Monitor 7
1	A													
	B													
2	A													
	B			10										
	C													
3	A						5	50	15	4	42	21	10	14
	B	10	36	35		8	30	25	10					
4	A													
	B													
5	A	15	24	30	30	12	20	13	20	4	43	35	10	35
	B	19	30	5	6	4	20	27	10					

Extractive Technique		Forestry: Timber Inventory 1	Forestry: Insect, Disease Stress 2	Forestry: Fire Monitor & Assessment 3	Land Use: U.S. Land Use Inventory 1	Land Use: Land Form & Cover Mapping 2	Land Use: Coastline Survey 3	Land Use: Geological Hazard Mapping 4
1	A	20						
	B	10		15	7	3		19
2	A							
	B			10				
	C							
3	A	60	8	40	38	62	19	87
	B	20	32	5	6	9	4	47
4	A							
	B							
5	A	30	8	10	20	30	38	54
	B	20	16	5	13	15	3	54

Extractive Technique		Marine: Ocean Dynamics Monitor 1	Marine: Fish Environment & Location 3	Marine: Marine Pollution Monitor 4	Marine: Navigation Hazard Monitor 5	Water: Urban/Ag Supply Inventory 1	Water: Hydroelectric Supply Inventory 2	Water: Great Lakes Ice 3	Water: Water Quality Monitor 4	Water: Flood Monitor 5	Water: Coastal Wetlands Monitor 6
1	A					3				5	
	B					14				1	1
2	A										
	B				4						
	C										
3	A	2	20	31		112	24		76	11	54
	B		3	3	5	22				5	30
4	A										
	B										
5	A	30	62	45		186	6	10	80	68	21
	B					14				2	2

Figure 6.4-11. Tabulation of Extractive Processing Requirements

6.4.4 OUTPUT PRODUCTS

There is a wide range of output product types required by the various resource managers in order to successfully fulfill their functions. As part of the TERSSE study, these output product requirements were investigated. A comprehensive list was developed to categorize the product types (see Table 6.4-5) and each of the 285 representative user tasks were assessed with respect to this list. It should be noted that in many cases a single user task requires several output products of different types; therefore, the total number of output products is larger than the 285 user tasks.

Table 6.4-5. Output Product Type

A. Photographic:
- A1 Images (Thematic)
- A2 Overlays
- A3 Images (Non-Thematic)

B. Map-Like:
- B1 Maps wholly rendered by hand and/or machine
- B2 Photomaps
- B3 Overlays

C. Recorded:
- C1 Images
- C2 Physical Measurements (Spectral)
- C3 Output of Statistical Analysis (Correlations, Estimates, etc.)
- C4 Signature Histograms
- C5 X/Y Coordinates
- C6 Physical Measurements - Other (Streamflow, Temperature, Crop Acreages, etc.)

D. Linear Graphic:
- D1 Signature Histograms
- D2 Functional Relationships (e.g., Time Series)
- D3 Descriptive Statistics (Usually Histograms)

E. Tabulated:
- E1 Raw Data (e.g., Physical Measurements)
- E2 Analyzed Data (e.g., Coefficients, Ratios, etc.)

F. Verbal: (Typical)
- F1 Instructions
- F2 Warnings

G. Alphanumeric: (Typical)
- G1 Data Summaries (e.g., Streamflow Readouts)
- G2 Reports (e.g., Hydrological Evaluation)

As was done for the preprocessing and extractive processing requirements, the results of this investigation into output product requirements are shown in both histogram and tabular form. These results are presented in Figures 6.4-12 through 6.4-15. Again, the detailed requirements of each user task are contained in the computerized requirements data base (Volume 8 of the TERSSE report). As was true before, the histograms represent number of user tasks requiring an output product and thus should not be misrepresented as an accurate measure of output product quantities.

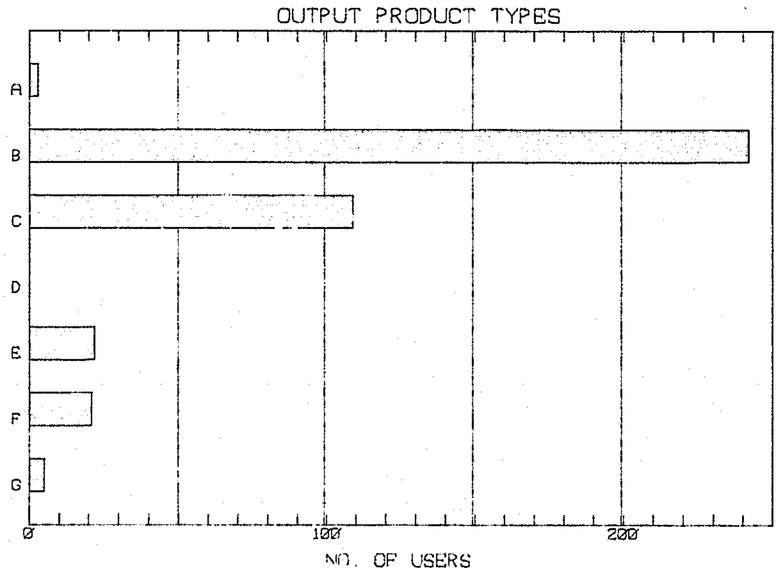


Figure 6.4-12. Major Categories of Output Products Required

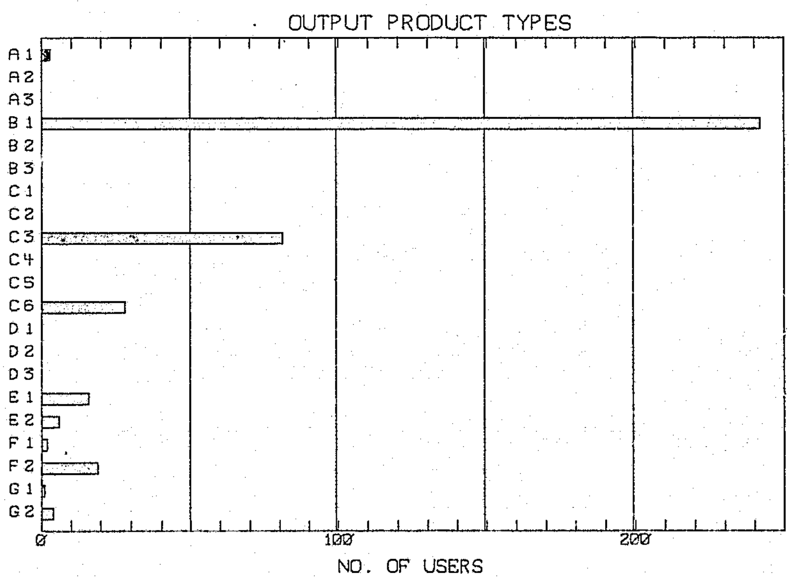


Figure 6.4-13. Specific Types of Required Output Products

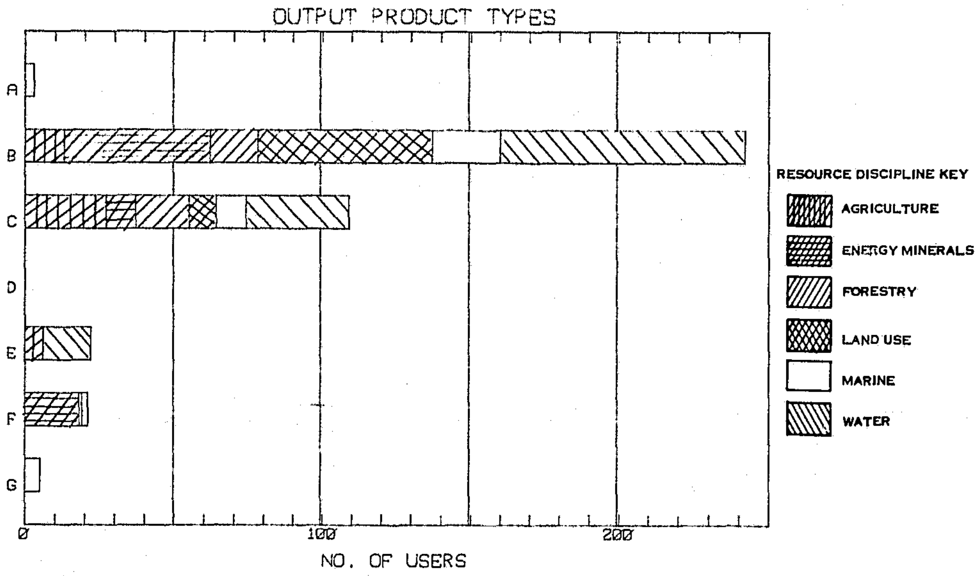


Figure 6.4-14. Output Products Required by Resource Management Area

		Agriculture						Energy Minerals						
		U.S. Crop Survey 1	Insect, Desease, & Stress 2	Farming Practices 3	Irrigation Water Demand 4	Global Crop Survey 5	Pasture/Range & Survey 6	Minerals Survey 1	Geothermal Source Survey 2	Submarine Oil Survey 3	Extraction Pollution Monitor 4	Pipeline Monitor 5	Oil Pollution Monitor 6	Thermal Pollution Monitor 7
A	1													
	2													
	3													
B	1	1	8	4				9	5	4	12	7	5	7
	2													
	3													
C	1													
	2													
	3	6	10	2		4	5							
	4													
	5													
	6							7						3
D	1													
	2													
	3													
E	1													
	2				6									
F	1													
	2										8	6	4	
G	1													
	2													

		Forestry			Land Use				Marine				Water					
		Timber Inventory 1	Insect, Disease Stress 2	Fire Monitor & Assessment 3	U.S. Land Use Inventory 1	Land Form & Cover Mapping 2	Coastline Survey 3	Geological Hazard Mapping 4	Ocean Dynamics Monitor 1	Fish Environment & Location 3	Marine Pollution Monitor 4	Navigation Hazard Monitor 5	Urban/Ag Supply Inventory 1	Hydroelectric Supply Inventory 2	Great Lakes Ice 3	Water Quality Monitor 4	Flood Monitor 5	Coastal Wetlands Monitor 6
A	1											3						
	2																	
	3																	
B	1		2	14	12	19	7	21	6	9	8		22	5	6	17	18	14
	2																	
	3																	
C	1																	
	2																	
	3	10		2		4		5					1				18	14
	4																	
	5																	
	6		6							8	2		2					
D	1																	
	2																	
	3																	
E	1												10	6				
	2																	
F	1											2						
	2							1										
G	1										1							
	2										2	2					18	

Figure 6.4-15. Tabulation of Specific Output Product Requirements

Some of the points that can be observed by considering the various histograms with respect to the Output Product requirements include:

1. The vast majority of required products are either of the map-like or the recorded type.
2. No user task currently indicates a requirement for the Linear Graphic type of output products.
3. The requirement for map-like output products is greater than all other output products combined.

It should be noted that the term "Map-Like" as used throughout this section has a far broader meaning than the strict definition of cartography used today by todays mapping community. Rather map-like includes almost any 2 dimensioned array of information keyed to a geographic reference system and printed on a paper base.

6.4.5 HUMAN VS. MACHINE ANALYSIS

The two extremes of implementing the extractive processing system element can be represented by human photointerpretation at one end and fully automated machine analysis at the other. Photointerpretation and machine analysis should not be considered as competitive but rather as complementary techniques. The development and implementation of fast interactive man-machine systems represent the route to the synergistic usage of these two extremes.

Photointerpretation uses the interactive and pattern recognition powers of the human operating on a visual display (either electronic or film) of a scene. The output of this process is able to be both qualitative in nature (e.g., the detection and anotation of geologic fault lines in the Earths structure) or quantitative (e.g., deliniation and measurement of field sizes). In general the human operates on a lower level of "information" per scene then the machine because of his limitations in spatial and spectral resolution (e.g., human cannot distinguish 64 distinct gray levels - spectral resolution).

Machine analysis, on the other hand, is ideally united to apply numerical and analyitical analysis techniques to digital representations of a scene. The output of this process is purely quantitative or analytical in nature (e.g., identification and enumeration of all pixels in a scene with a given spectral characteristic). In general, machine analysis is capable of operating on all the "information" in a scene but in a more limited, less flexible manner than the human.

Current practice, with few exceptions, is to use these two techniques separately. What is required to better exploit them both are extractive processing techniques which draw on the best characteristics of each. The interactive usage of a man-machine system need not be restricted to "training" but, if properly excuted, can become a major photointerpretative tool by extending and enhancing the range of the human visual channel. The initial steps in this area have been taken by such systems as the GE Image 100 on which machine-aided photointerpretation/enhancement as well as operator-aided machine analysis is possible. But much remains to be done to fully develop the synergystic capabilities of the two complementary approaches.

6.5 AUXILIARY DATA PROCESSING ELEMENTS

This section contains a brief, but relevant, discussion on those issues which relate to the overall data processing and ground system problems yet which are not included elsewhere in this report.

6.5.1 ARCHIVAL STORAGE

At the appropriate point in the overall data processing stream the data must be recorded, stored, indexed, and maintained for later reference; this is referred to as archival storage. The two principal needs for archival storage are (1) for temporal analysis and (2) for later historical analysis not initially perceived at the time of data collection.

One basic issue to be considered is the sheer volume of data (in physical terms) that is generated in the course of a year. Figure 6.5-1 illustrates for various sensor duty cycles the number of bits of data created in one year of operation as a function of sensor bit rate. This value is important in defining system archiving requirements such as the point in the processing cascade at which data is archived and the method for storage and access.

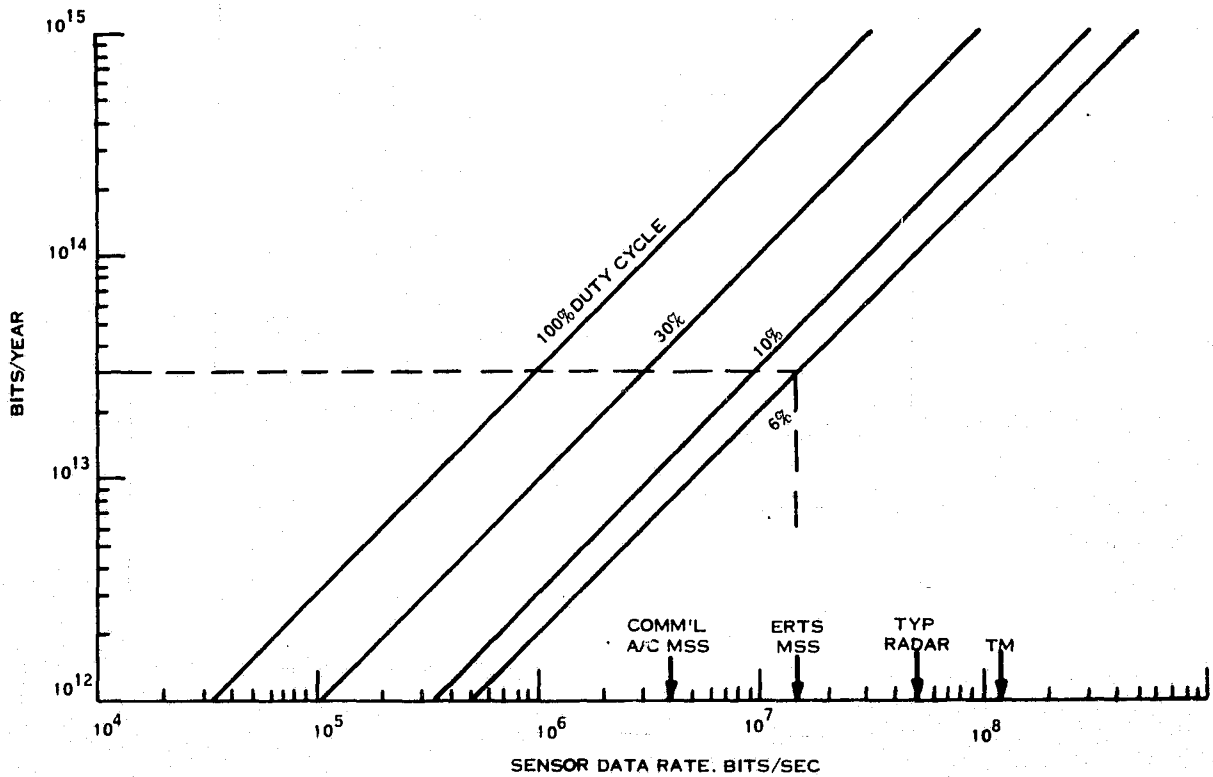


Figure 6.5-1. Archival Storage Requirements (Bits/Year)

Figure 6.5-2 may be used to convert the data generated, in bits/year, to required floor space, storage volume, or tape reels. Storage volume is the actual displaced volume of the storage medium and does not take into account storage reels, packing spacing, shelf or aisle space; nor does it include that necessary for the attendant access and retrieval equipment.

A currently available example of the state-of-the-art with respect to data storage and retrieval is shown in Figure 6.5-3. This system stores, searches, and retrieves data stored on microfiche cards.

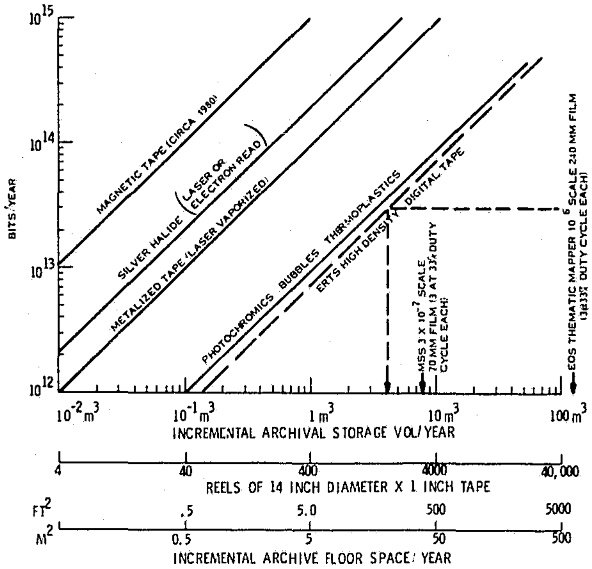


Figure 6.5-2. Archival Storage Requirements (Physically)

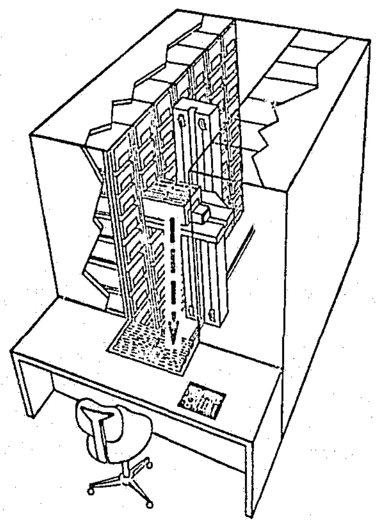


Figure 6.5-3. Current SOA Example

6.5.2 OPERATIONS TECHNOLOGY

The term "operations technology" refers to the broad range of actions, issues, problems, and tasks associated with coordinating, controlling, and operating the entire ERS system. The TERSSE ERS system is a complex multi-element system, refer to Figure 6.5-4; the control and operating problems associated with this system will represent a magnitude not previously encountered by the NASA nor Earth Resources communities. This problem, represented by the increase in magniture, was briefly addresses as part of the TERSSE study; this section presents a dexcription of the problem and makes the recommendation that the problem be studied further as the system takes shape.

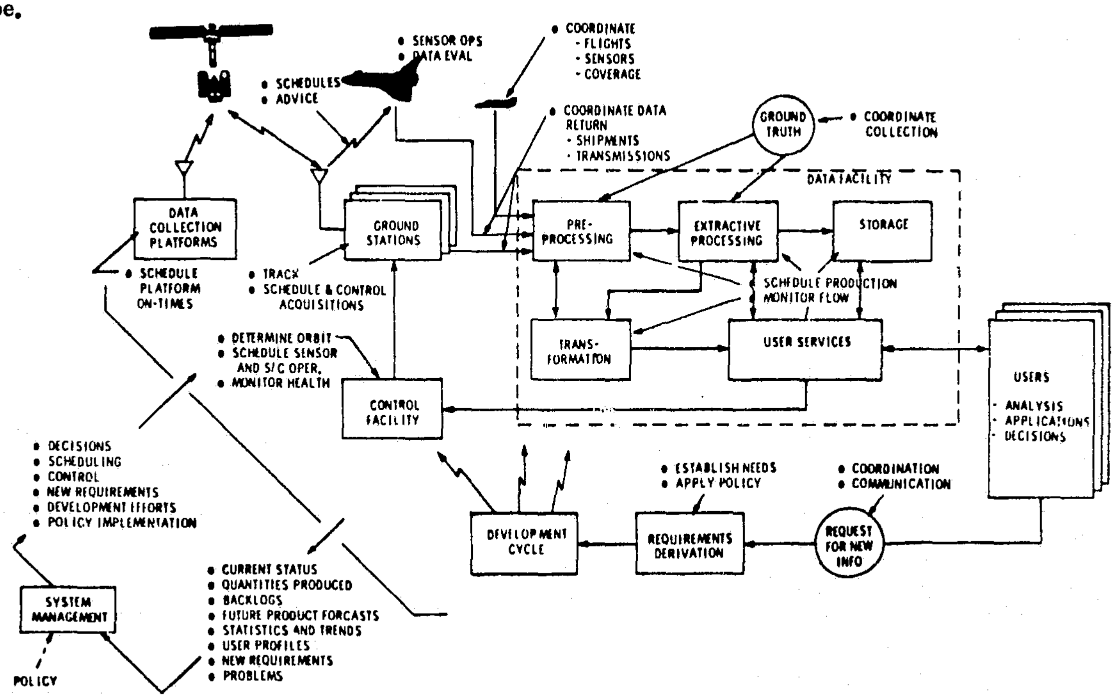


Figure 6.5-4. ERS Operations Technology

In general, the issue of operations technology can be treated in two categories:

1. Internal adaptivity and reconfiguration
2. External responsivity

Each of the points addressed in these categories, refer to Figure 6.5-5, will be addressed.

In the internal category, a significant item is the multiple uses to which key system elements will be put. It is expected that each of the remote sensing platforms will serve several users. In the operations context this represents a problem in the scheduling of data acquisition and in the distribution of common data to several users simultaneously. The centralized preprocessing and archival facility is another example of a key system element which will serve multiple (almost all)users. The internal scheduling and coordination of its operations must be balanced to adequately serve all requirements.

INTERNAL ADAPTIVITY AND RECONFIGURATION	EXTERNAL RESPONSIVITY
• MULTIPLE USES OF KEY SYSTEM ELEMENTS • FILL FROM INVENTORY VS NEW DATA • MERGE DATA FROM MULTIPLE SOURCES • INTER-PLATFORM SUPPORT • ACCEPT AND USE IN-SITU DATA • REAL-TIME USE OF MET SYSTEM - PLANNING, PROCESSING	• TURN ON WHEN ASKED - COLLECT WHAT'S NEEDED • RESOLUTION OF PRIORITIES • STANDING ORDERS - SPECIAL REQUESTS • ENABLE USER TO USE MULTI-SOURCE MULTI-TIME DATA • COPE WITH MULTIPLE REACTION TIMES

OPERATING COMPLEX MULTI-ELEMENT SYSTEMS REQUIRES A SIGNIFICANT ADVANCE IN OPERATIONS TECHNOLOGY - THE PROBLEM SHOULD BE STUDIED AS THE SYSTEMS TAKE SHAPE.

Figure 6.5-5. The 1980's ERS: An Operations Challenge

As the TERSSE becomes operational the acquisition and accumulation of remotely sensed data will reach unprecedented volumes, there will often be cases where a decision must be made, relative to a new data request, whether to attempt to satisfy that request (perhaps only partially) from data currently available in the archives or whether to acquire that specific data (sometimes anew). Several characteristics of the nature of the user's request will influence this decision including:

1. Need for fresh or current data
2. Need for simultaneous multisource data
3. Need for completeness in requested data

The projected ERS system indicates that most Earth resources missions will require multiple data sources in order to satisfy their data needs. These multiple sources will include not only several remote sensing platforms but also several ancillary and in situ data sources as well. The operational requirement to merge those separate sources and their separate data elements in an integrated and routine manner represents a significate improvement over that of todays system.

A slightly different aspect of the multiple platform system will be the real-time integrated usage of these separate platforms operating together as a system. For example, the presence of cloud cover, as indicated by the meteorological satellites, should influence the collection of data from other ERS elements. Pointable sensors can be, and should be, controlled so as to maximize their ability to obtain cloud-free data. When an opening is detected in a cloud cover pattern, the pointable sensor can be programmed to take advantage of the opportunity and collect data. Similarly, when data from one remote sensing platform is obscured by clouds the possibility of obtaining the necessary data from another platform (at a different but close point in time) is one which should be considered.

In the category of external responsivity the challenge to operations technology will stem from the needs of many separate and different users. The TERSSE must be responsive to both the routine or standing requests of those users as well as the special, exploritory, or one-time requests for data. A mechanism must be developed to resolve potential conflicts in requests; for example, different locations at the same time from a pointable sensor, or different spectral bands from a selectable band sensor. Procedures must be developed to establish priorities for user requests so that these inevitable conflicts can be resolved.

As the ERS system transitions from an R&D or experimental system into an operational system consideration must be given to the volume and nature of the data collected. The TERSSE should only collect data that is needed for specific users; the wholesale collection of unmanageable volumes of data will no longer be desirable or economically warrented. The system should turn on when requested (and not otherwise) and collect what is needed.

6.5.3 DATA SYSTEMS HARDWARE

During the technology state-of-the-art investigation (reported in TERSSE Volume 2, An Assessment of the Current State-of-the-Art) it was determined that the SOA for the data systems storage, reproduction, and distribution elements was well advanced. This is shown in Figure 6.5-6 where it can be seen that all five elements have reached the operational state. In general the hardware technology of data systems equipment is advancing rapidly without ERS assistance. The TERSSE should exploit this technology by focusing its development activities only on the specialized or unique hardware and systems that are peculiar to ERS.

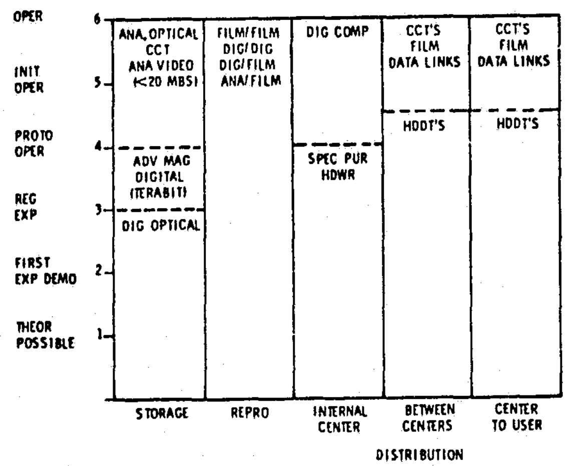


Figure 6.5-6. Data Systems Storage/Reproduction/Distribution

Two particular developments which have been identified in this vein are (1) a new CCP (Computer Compatible Product) storage device, and (2) low cost interactive remote terminals.

The volume of data which can be expected from the operational TERSSE will be large. It will be necessary to develop a storing medium which is not only capable of storing this data in a high-density, rapid-access manner, but which is also standardized to be compatible with computer-based processing systems. The current standard of 800 BPI magnetic tapes will not be adequate for the TERSSE.

The overall architecture for the data processing and distribution system (discussed in Section 6.6.6) requires that the operational terminus of the TERSSE be colocated within the user's organizational structure. This terminus must range in capability from a fully-interactive extractive processor control/display to a passive, receive-only product copier. With regard for the former, which is more demanding of technology, it was notable that special purpose classifiers are ideal candidates for time-shared systems where the classifier is connected to and supports many user-located terminals. Typical speed differentials of 20-100:1 exist between the classification of a TV screen of data into 8 themes (< 1 sec) and the setup of training site selection or interpretation of results (> 20 sec). In addition, the data rates between the classifier and the remote control/display need not be excessive, as it is only the altered CRT pixels which must be transmitted.

6.6 GROUND SYSTEM CONFIGURATION

As was discussed earlier at the beginning of this section, Section 6.1, and as is represented by the following figure, Figure 6.6-1, the total concept of the ground system includes all those elements necessary to get the raw data from the remote sensing platform, process the raw data into useable information, and then deliver that information to the user. The major elements involved are:

1. Ground Station
2. Preprocessing
3. Extractive Processing
4. User Models
5. Users

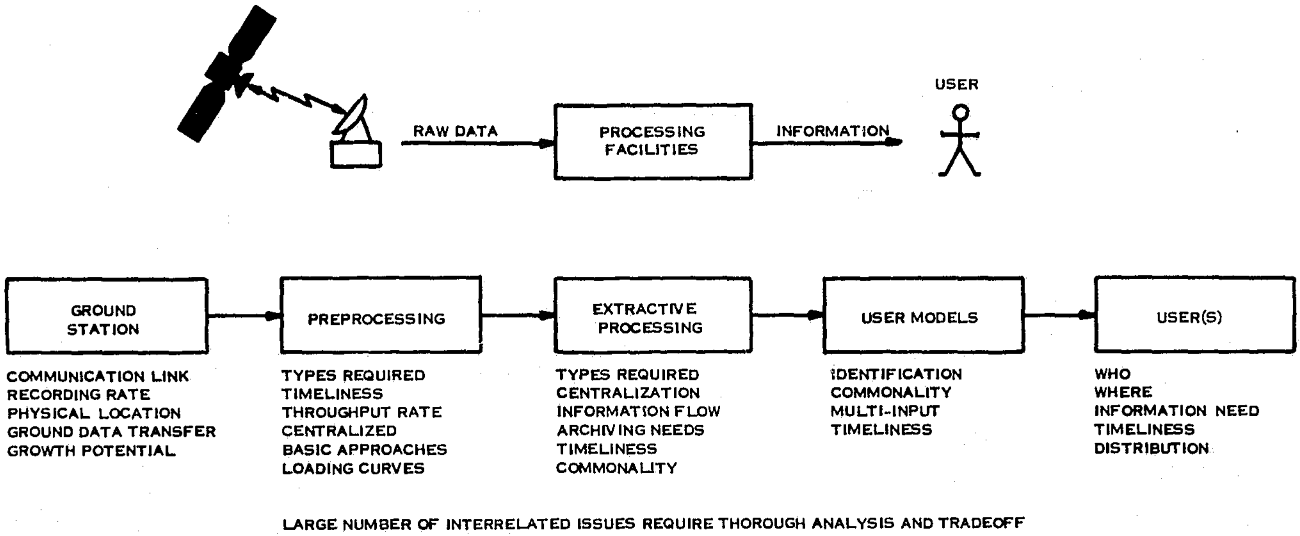


Figure 6.6-1. Ground System Requirements

As indicated on the figure, each of these elements have several important requirements and issues; all of which are generally interrelated and require tradeoffs in order to establish an optimal solution.

Inasmuch as the Ground Stations and downlink communications areas represent relatively established state-of-the-arts; and further, the user models and users are separately discussed elsewhere, this section of the TERSSE effort has concentrated on the "center box", data processing and distribution portion, of the system.

The approach taken with this study was to begin by establishing preliminary guidelines, requirements and other significant design criteria. Several different alternative system configurations were then developed and considered with respect to the initial criteria. The topics discussed in this section include:

- 6.6.1 - Parametric Approach to System Configuration
- 6.6.2 - Alternate Approach to System Configuration
- 6.6.3 - Ground System Selection Criteria
- 6.6.4 - System Selection Methodology
- 6.6.5 - Results of Weighted Criteria Approach
- 6.6.6 - The Selected Ground System Configuration

This procedure resulted in the development of nine basic ground system configurations which will be described in this section.

As will be seen, this portion of the TERSSE effort has evolved a single ground system configuration which satisfies the needs and selection criteria of all identified missions and uses. This selected configuration, titled "Lead Federal Agency - Information Analysis Center", provides sufficient flexibility and capability to serve the diverse requirements of the various users while maintaining sufficient centralization to remain efficient.

6.6.1 PARAMETRIC APPROACH TO SYSTEM CONFIGURATION

Perhaps the most rigorous methodology towards system configuration (when a pure analytical optimization solution is not feasible) is that of parametric variation. In the parametric approach the various dimensions of variability and the feasible points of variation along the dimensions are determined first. Then, systems are formulated by parametrically combining all combinations of feasible points. Finally, each of these "systems" can then be evaluated against the overall requirements, guidelines and other criteria. For example, assume that the two dimensions of a system were its color and its size. Further, assume that each dimension has only two possible values; the color is either black or white, and the size is either large or small. The parametric combination of these values will produce four "systems"; large-black, large-white, small-black, and small-white.

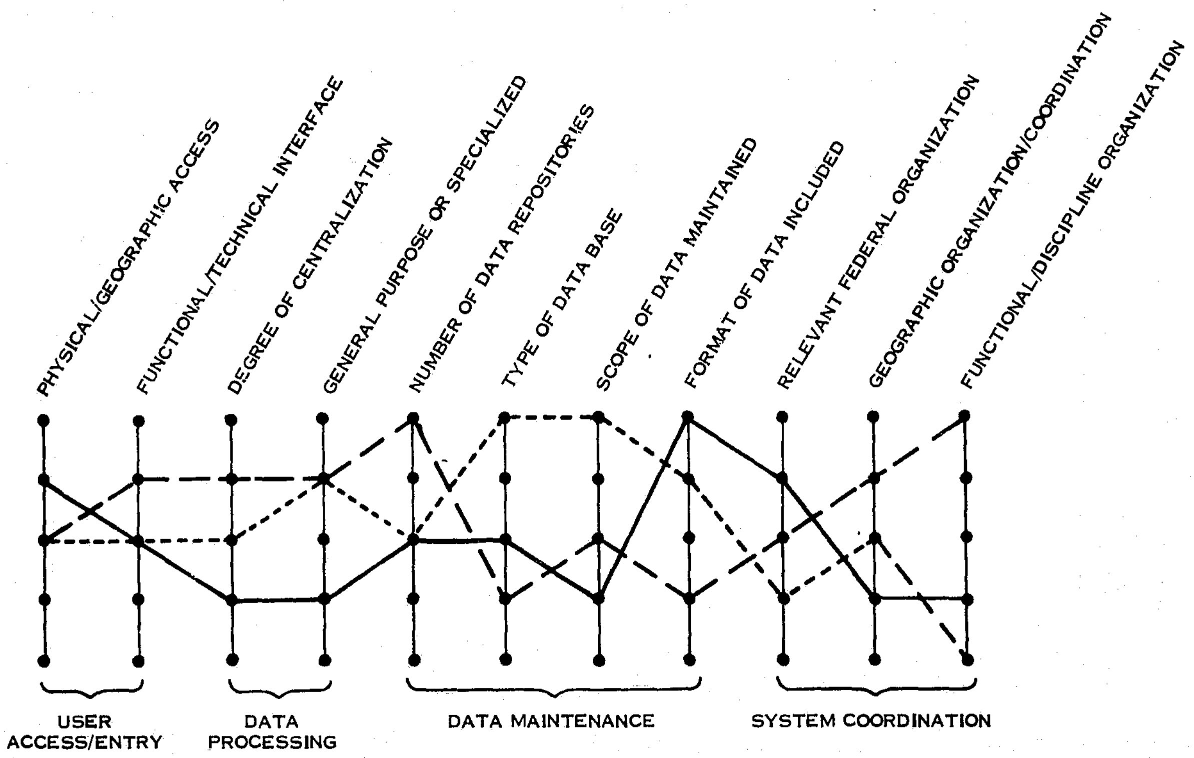
In the present case, overall configuration of a ground data processing and distribution system, there are several key dimensions which result in a large number of possible system designs. For this problem, a total of eleven key dimensions of variability have been identified. These eleven dimensions, tabulated in Table 6.6-1 below, fall into four general categories:

1. User Access/entry
2. Data processing
3. Data Base Maintenance
4. System Coordination

On the average, each of the eleven dimensions have approximately five quantifiable feasible points (i. e., for dimension number one, users' physical/geographic access to system, there are :

1. Hundreds of local centers
2. Several dozen state centers,
3. Few dozen regional centers
4. Several/few teritorial centers, and
5. Single national center

Therefore, the total number of tentative systems (see Figure 6. 6-2) arrived at by this parametric approach is 5^{11} or nearly 50 million different configurations. Obviously, there are too many to do justice to each.



11 DIMENSIONS OF VARIABILITY WITH 5 LEVELS OF QUANTIFICATION EACH WOULD GENERATE 50 MILLION CONFIGURATIONS

PARAMETRIC APPROACH IS INEFFICIENT

Figure 6. 6-2. Variable Dimensions of Ground System Configuration

Table 6.6-1. Dimensions of Ground System Configuration Design

		Extreme	Description	Extreme
User	1	Local User Center Convenient Responsive Specialized Quick Access	User's physical/geographic access to system	National user center Focused Coordinated No Duplication Optimally sized Equally accessible
	2	General Purpose Interface Lower Cost No Duplication Simplified communications	Users' functional/technical interface to system	Functionally specialized interface Technical Expertise In-depth capability "Talks own language"
Data Processing	3	Highly Distributed Local Access Faster Response More direct communication	Extractive processing capability - where located	Single ER Center More sophisticated equipment On Site expertise Centralized resources
	4	General Purpose Inter-functional expertise Generalized capability Cross functional analysis Functionally synergistic	Extractive processing capability - How organized/conducted	Functionally specialized Intra-functional expertise Specialized responses Incremental approach
Data Base	5	Multiple Faster specific access Simplier linkages Geographicaly dispersable Segregated for security	Number of data bases maintained	Single Lower total volume Central location No redundency
	6	General Purpose Cross functionally linked Growable for new functions	Type of data base	Functionally specialized Faster access per user Simplier linkages Controllable access
	7	All relevant earth resources data Everything accessable ancillary data available In-sitsu data available Complete cross reference	Scope of data base	Remotely sensed data only Simpler cataloging Directly linked Fewer ownership problems
	8	Multiple Format Data Complete information center Primary sources retained Data fidelity maintained Lower storage volume	Format of data base	Digitized Data only Easily communicable Directly computer compatible Simpler to archive Less error prone
Coordination	9	Present Federal Structure Maintains proprietory interest Fosters competions Inherent self interest Direct applicability	Structure of system at federal level	New "US Dept of Earth Resources" Focuses responsibility Reduces redundency Simplifies interfaces No charter conflicts Phrocial promoter
	10	Federated System - National, Regional, State, Local Local self interest specialized services	Geographic Organization/Coordination	OAE National System Simplifier Interfaces Few redundencies Better communications
	11	Lead Agencys Provides focal points Friendly competition Traceable responsibility	Functional/Discipline Organization	No Special No new bureauracy No lead time required Lower profile

6.6.2 ALTERNATE APPROACH TO SYSTEM CONFIGURATIONS

Considering the unmanageable number of parametric possibilities discussed in the previous section it is evident that what is required is an approach which will rapidly eliminate those configurations which exist mathematically but which are not technically valid. The application of experience and engineering knowledge can produce a manageable number of viable alternatives which include all important configuration variations. These few configurations represent the significant extremes and thus bound the set of alternative configurations. The applications of this approach to the present problem produced a total of nine alternative system configurations for the ground data processing and distribution system.

These nine alternative configurations are shown in block diagram form in Figures 6.6-3 through 6.6-11. Corresponding to each system block diagram is an example, Figures 6.6-3A through 6.6-11A, of the information flow through that system concept. Table 6.6-2 summarizes the key features of each configuration concept together with some of the applicable strength and weaknesses of each concept.

6.6.3 GROUND SYSTEM SELECTION CRITERIA

In order to select from among the several systems configurations, specific selection criteria were developed in accordance with the general system performance requirements. These requirements and the specific criteria are summarized in Table 6.6-3; the following paragraphs provide a narritive discussion on each of the thirteen criteria:

1. System Acceptability - No system of national scope which crosses several discrete organizational boundaries, potentially impinges on existing charter responsibilities and requires Executive Branch and Congressional approval for its implementation can afford to overlook the real life environment in which the system must survive. Although quantitative technical system parameters can readily be developed and evaluated, it is much more difficult to factor in the qualitative environmental considerations on which eventual system implementation may really depend. Listed below are some typical considerations included in the design and selection process. Each of which must be fully evaluated when choosing between systems which represent the best trade-offs in technical compliance versus those which can do an adequate job--but more importantly--provide good prospects of being accepted and implemented.

    a. A lead federal agency exists for each area of earth resources management

    b. Establishment of a department of natural resources improves/strengthens management focus

    c. Lead agencies technically competent (and parochial) in data acquisition and extractive processing

    d. Historically, federal agencies resist external programs which threaten infringement on established activities

    e. Poor track record to date for implementing national super-systems, e.g.,

        --National Environmental Data System (Dingell Bill)
        --National Environmental Center (Muskie-Baker Bill)
        --RALI (DOI)
        --National Environmental Data Analysis System (EPA)

f. Technically sophisticated users already access appropriate federal and other availa data sources

g. Prime system requirements could evolve from growth of other potential users

2. System Cost - From a practical standpoint, one major factor in the implementation of any system is its overall cost, and the competitive relationship of these costs with other prioritized budget items. The approach, for now, is to assume that the lower the system cost the better its chances will be for implementation; the costs of each can be considered an independent factor in the selection process. At this stage of design, system costs will best be addressed in terms of estimated relative costs for each of the concepts considered; e.g.., cost of simplest and least complex system = X; System of estimated twice complexity = 2 X.

3. Response Volume Capability - The network shall be capable of responding to the projected volume of user inquiries in the 1978-1982 time period. Some key parameters in defining this workload are:

a. Source, number, and type of requests

b. Type of data and/or information required

c. Inquiry response sources

d. Response timing and corresponding communication networks required

e. Response efforts in terms of man hours; types of personnel required and available computer capability

4. Response Time - Data and/or information shall be made available to users in required format, on a demand or standing order basis, in accordance with the timing required to influence earth resource management decisions. Such timing--from the sensing of a dynamic event or the measurement of a static phenomenon--can range from near real time--e.g., 1/2 hour or less in the case of forest fire control to months or even longer intervals for geological surveys. In no case should the information network be the limiting factor in satisfying user response schedules.

5. Flexibility - The vast volume of data acquired through remote sensing will require a corresponding increased useage of automated processing techniques to assure that these data can be effectively and currently applied to the solution of earth resources management problems. Accordingly, archieved data must be disseminated in a form suitable for automated pre-processing, information extraction, analysis, and generation of output products to user requirements. Further, the system must be sufficiently flexible to provide a variety of data fromats compatible with a multiplicity of user techniques and equipment.

6. Scope of Output - The data and/or information required to contribute to a factual basis for earth resources management decisions should incorporate the best available inputs from all appropriate sources. The growth of remote sensing is expected to increasingly supplement, reinforce and otherwise beneficially impact--and in some cases supersede--the data available from in-situ or other ground based sensing and measurement techniques. Accordingly, any response to the user requests must integrate both remote sensed and all other auxillary data bases.

7. System Security - The network must provide adequate protection of the data files integrity of participating organizations by preventing usage by unauthorized personnel and by shielding the privacy of both the source and user.

8. System Adaptability - The network configuration and capability shall be sufficiently flexible and/or easily modified to respond in a timely manner to changes in the user population, user requirements, data sources, technology, economics, sociopolitical influences and all other changes in the operational environment which affect system functions and effectiveness.

9. Output to Users - The primary requirement of the Earth Resources Information Network is to satisfy known and forecasted direct and indirect user information requirements across all disciplines of interest and across all organizational boundaries within the United States.

Potential users range from technically sophisticated scientific personnel at the Federal agency, scientific and academic levels to non-technical laymen involved in localized business problems. The network shall have the capability of satisfying the information needs of both extremes of users, as well as all in-between gradations. For the technically sophisticated personnel, the information required may range from raw digital data to annotated photographic images. In the case of non-technical laymen, available data may require considerable extractive processing and interpretation in order to present the resulting information in an easily understandable format.

10. System Evaluation - The network shall be capable of evolutionary growth in scope, capability, and structure over time as network capability is demonstrated and accepted and user demands for services increase.

11. Interactive Capability - All elements of the network shall be interconnected and interactive to the extent necessary to assure that a user request for information at any entry point in the network will be satisfied by an appropriate and timely response, regardless of where the data exists in the network. The network operation shall be sufficiently flexible and responsive to permit users to alter, modify, or otherwise change initial requests if the user deems this action necessary to improve the quality of the information required.

12. Self-Monitoring - The network shall include a "housekeeping" capability to monitor system performance so that operations managers will have continual feedback in order to properly control and improve the network and its operations.

13. System Elements Improvement - Although conformance with design constraints and performance specifications will establish the major criteria for an acceptable ground system concept, recognition must be accorded to the fact that nearly any eventual configuration will represent a melding of new and existing system elements. Many existing elements--such as computerized data banks, other data repositories, and data processing facilities--in their present form will almost certainly not be fully compatible with each other in an integrated system, and will require modifications and improvements to assure an efficient and effective information management network. Provisions should be made in any system concept for some mechanism which addresses these problems and provides for their solution as the system evolves. Listed below are some of the system elements which have been identified as prime candidates for improvement:

a. Improve consistency of data bases format, quality, standard, and scales

b. Improve data base cataloging

c. Improved interaction of information processing efforts

d. Minimize duplicate data storage

e. Eliminate conflicting/non-objective data storage

f. Provide for R&D on:

--Imagery processing
--Data reduction techniques
--Microfilm development
--Modeling techniques
--Hardware compatibility
--Software adaptability
--Display modes
--Communication techniques
--Mass Data Storage

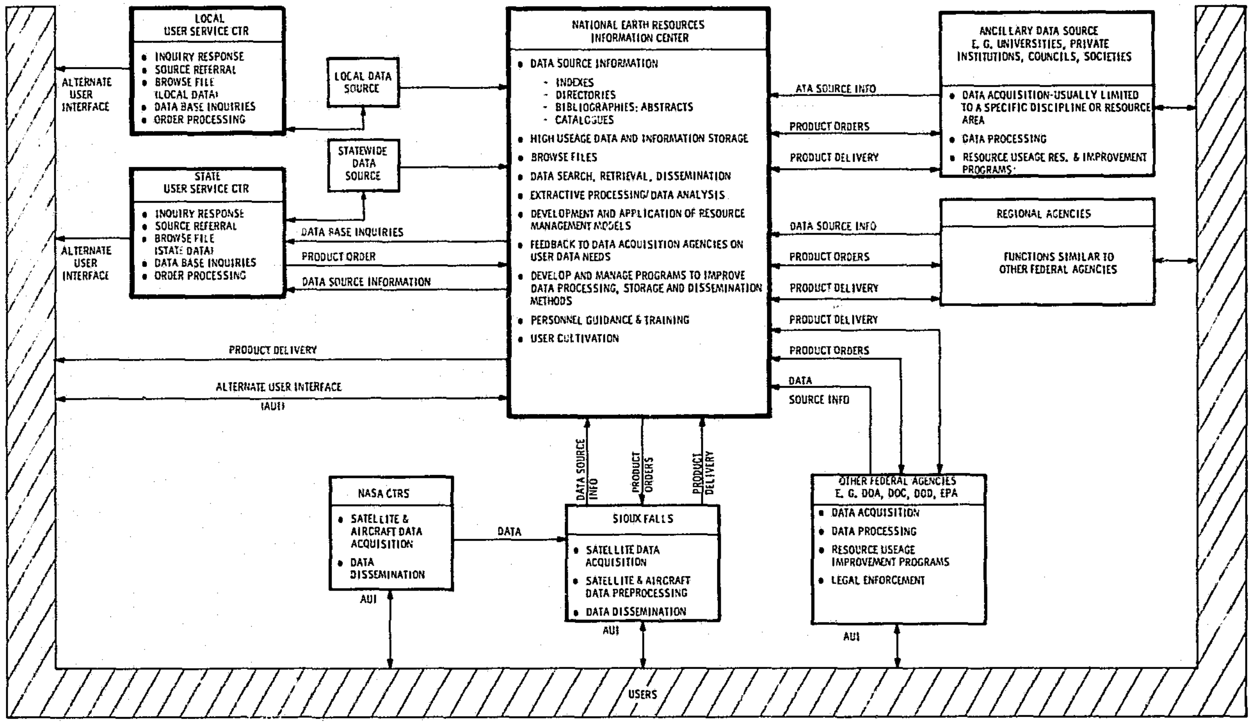


Figure 6.6-3. Configuration 1 Centralized NERIC

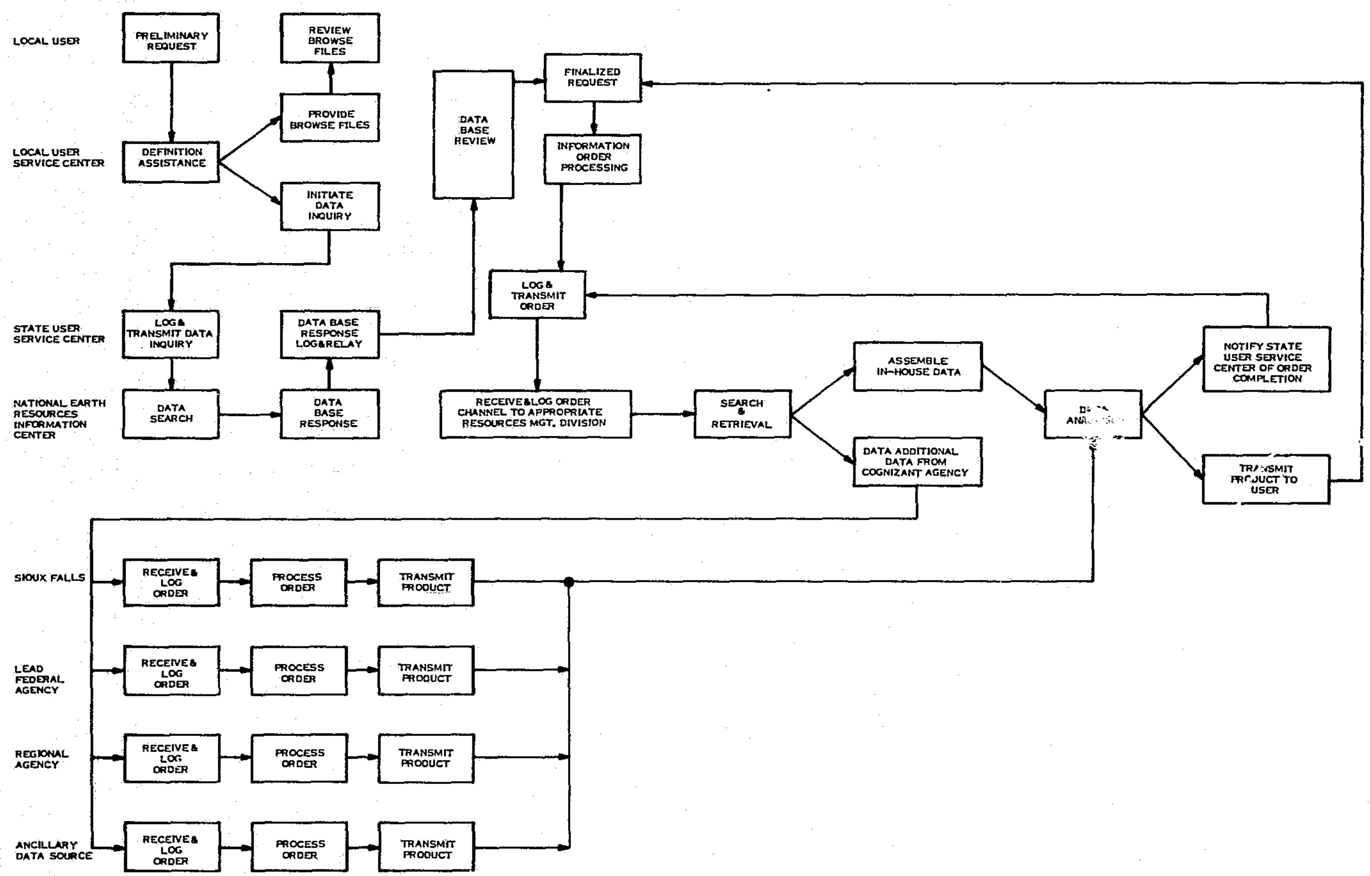


Figure 6.6-3A. Configuration 1 Sample Activities Flow Chart - Local User Level (Local Through National Scope Requests)

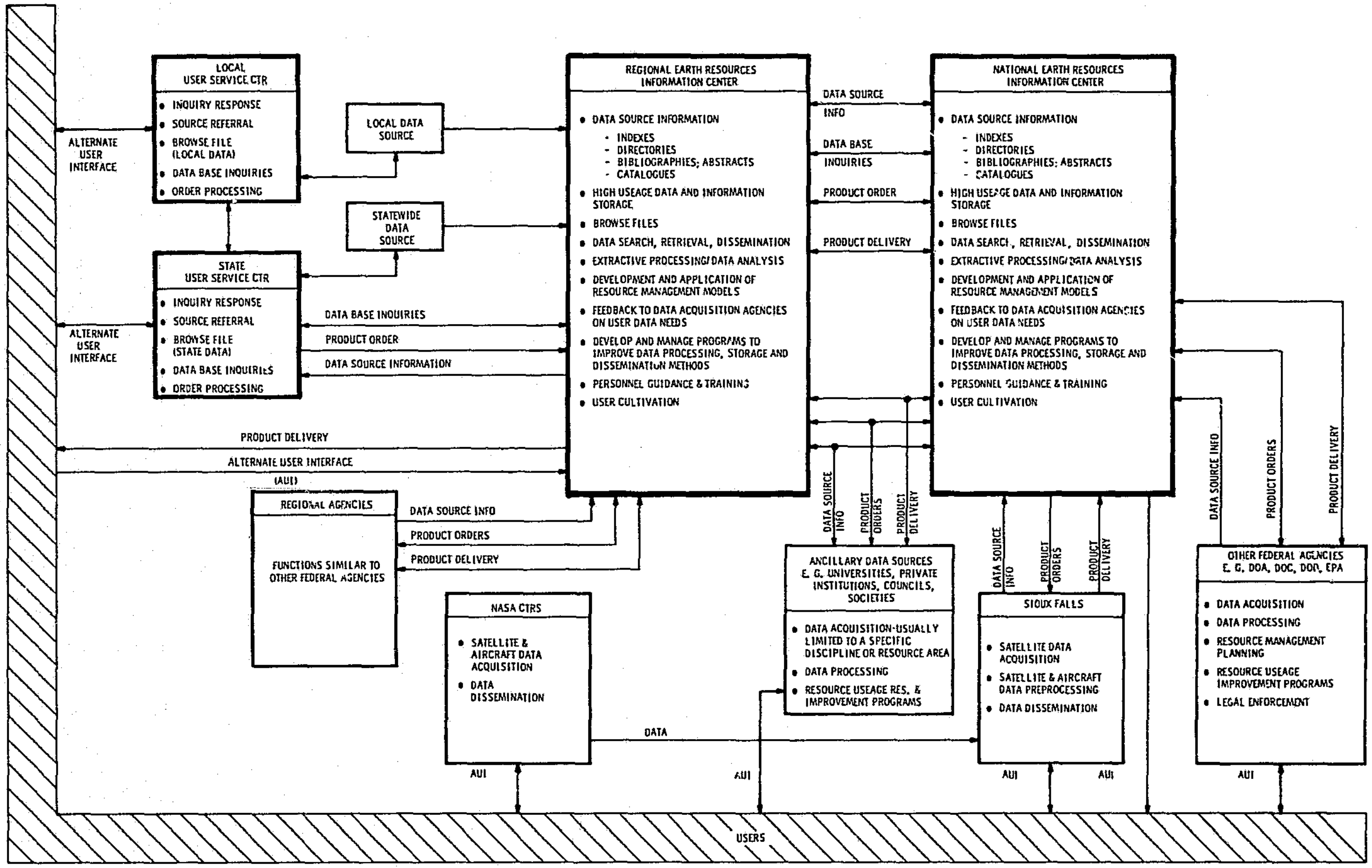


Figure 6. 6-4. Configuration 2 Federated NERIC/RERIC

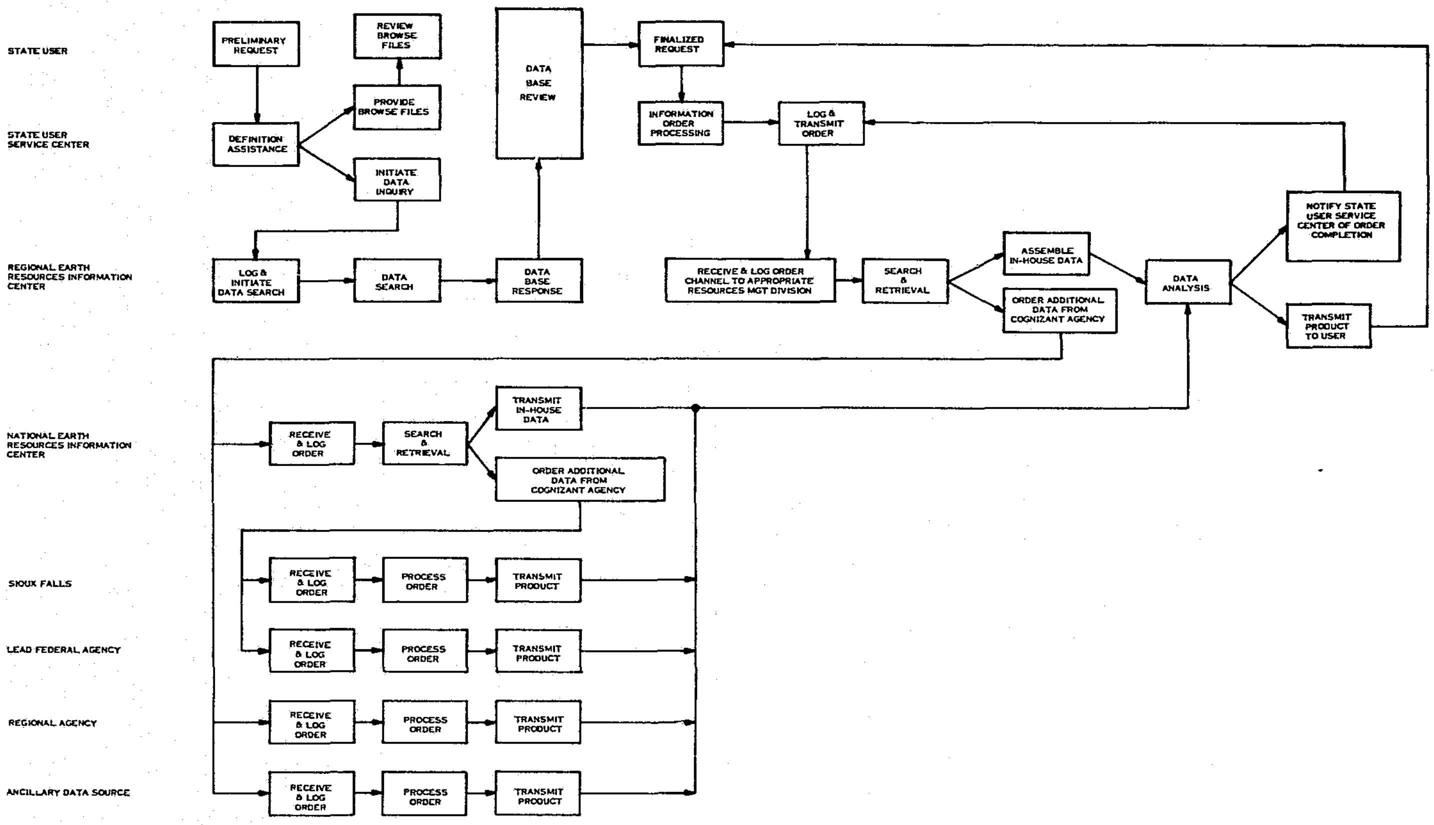


Figure 6.6-4A. Configuration 2 Sample Activities Flow Chart - State User Level (State Through Regional Scope Requests)

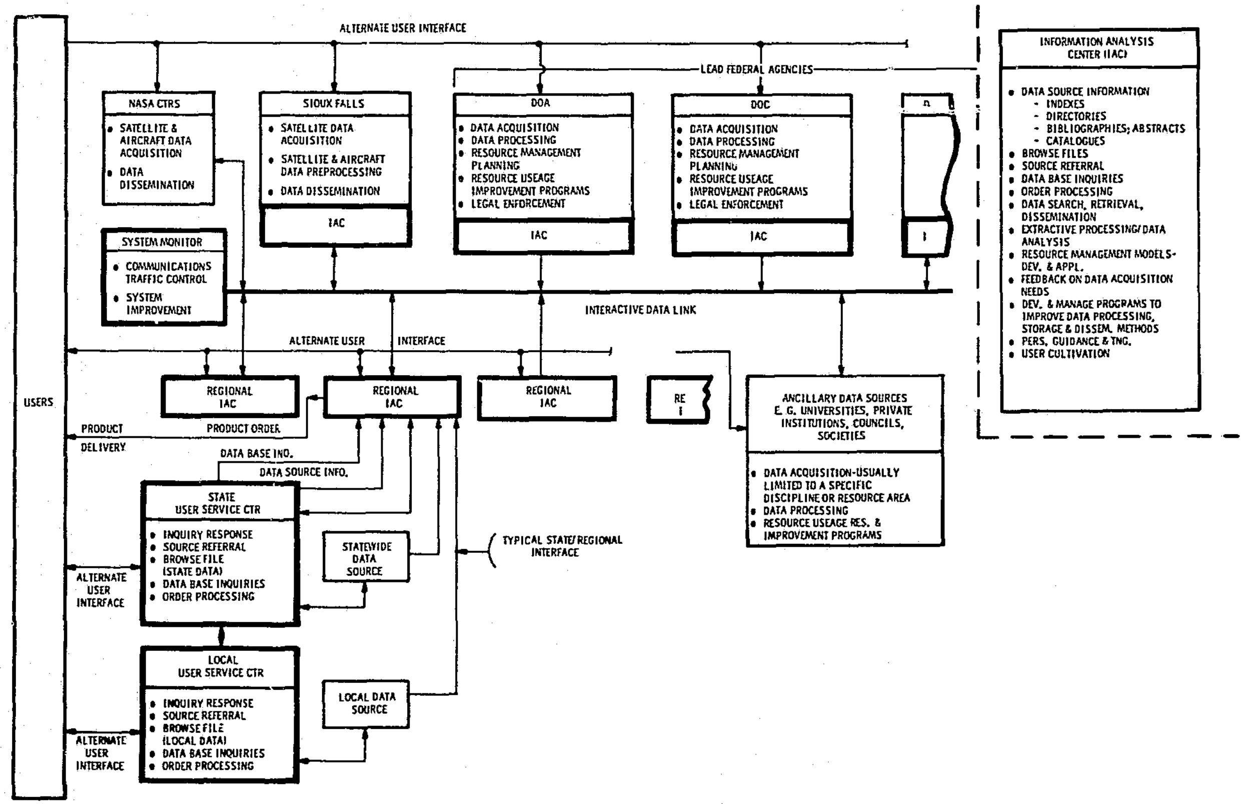


Figure 6. 6-5. Configuration 3 Lead Federal Agency

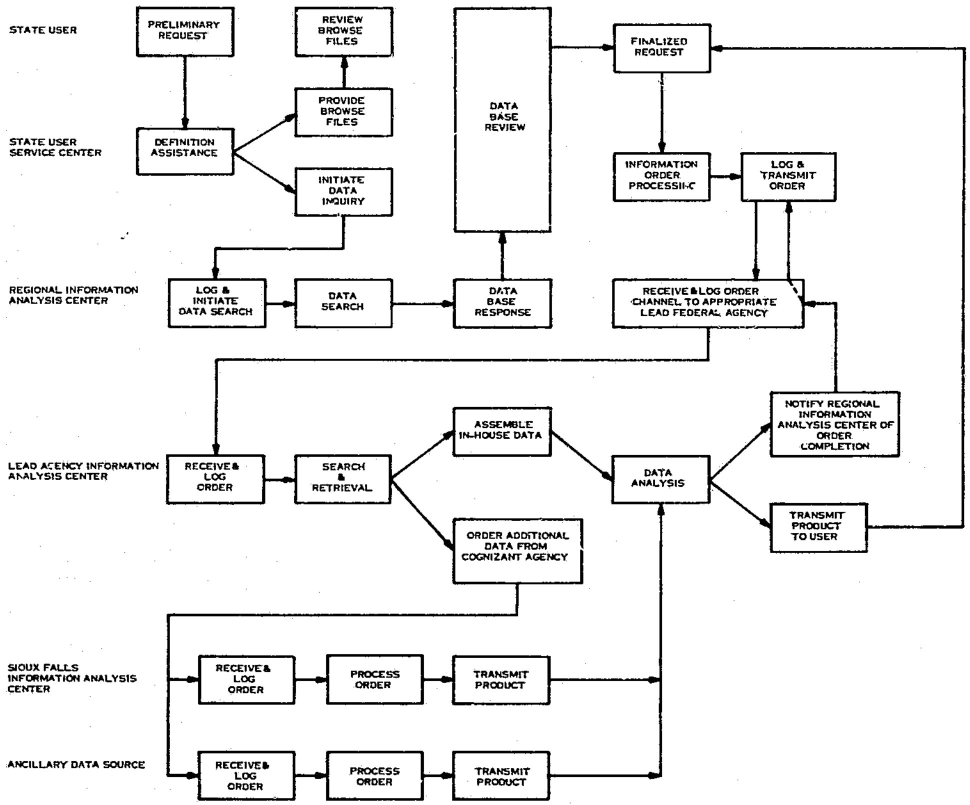


Figure 6.6-5A. Configuration 3 Sample Activities Flow Chart - State User Level (National Scope Requests)

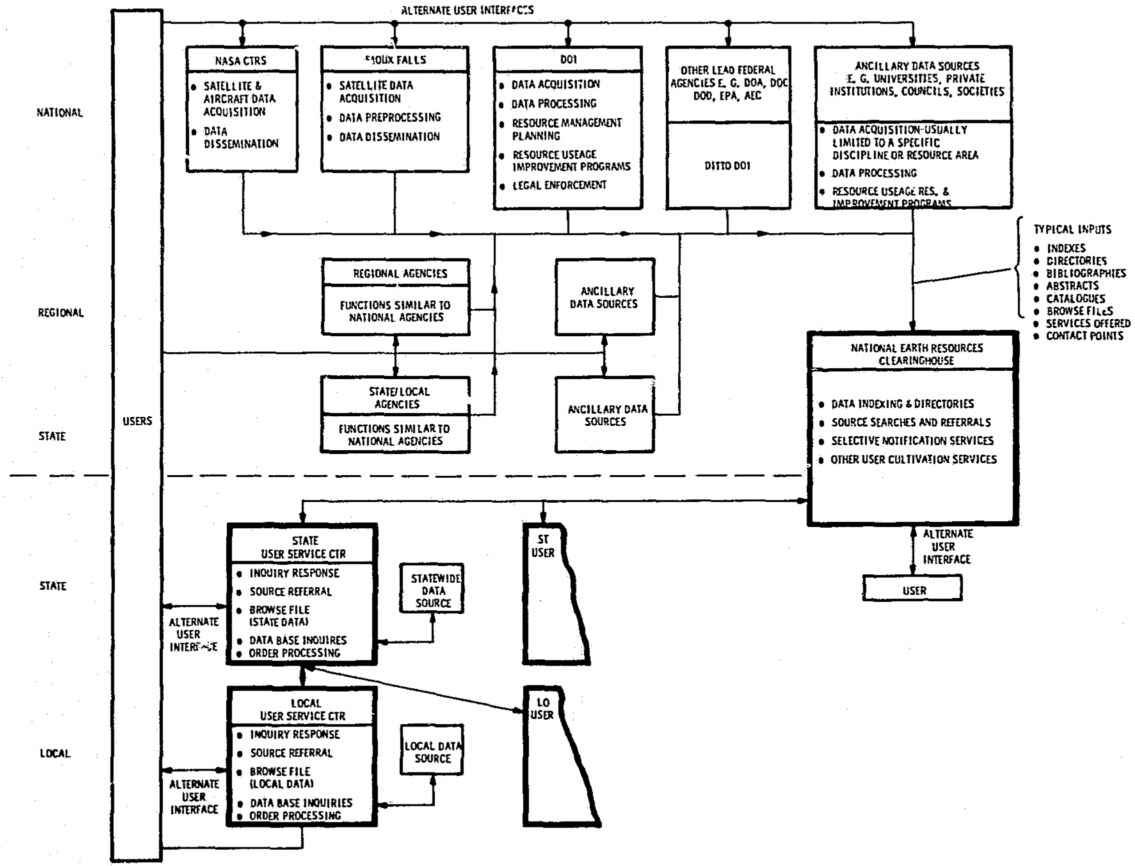


Figure 6.6-6. Configuration 4 National Clearinghouse

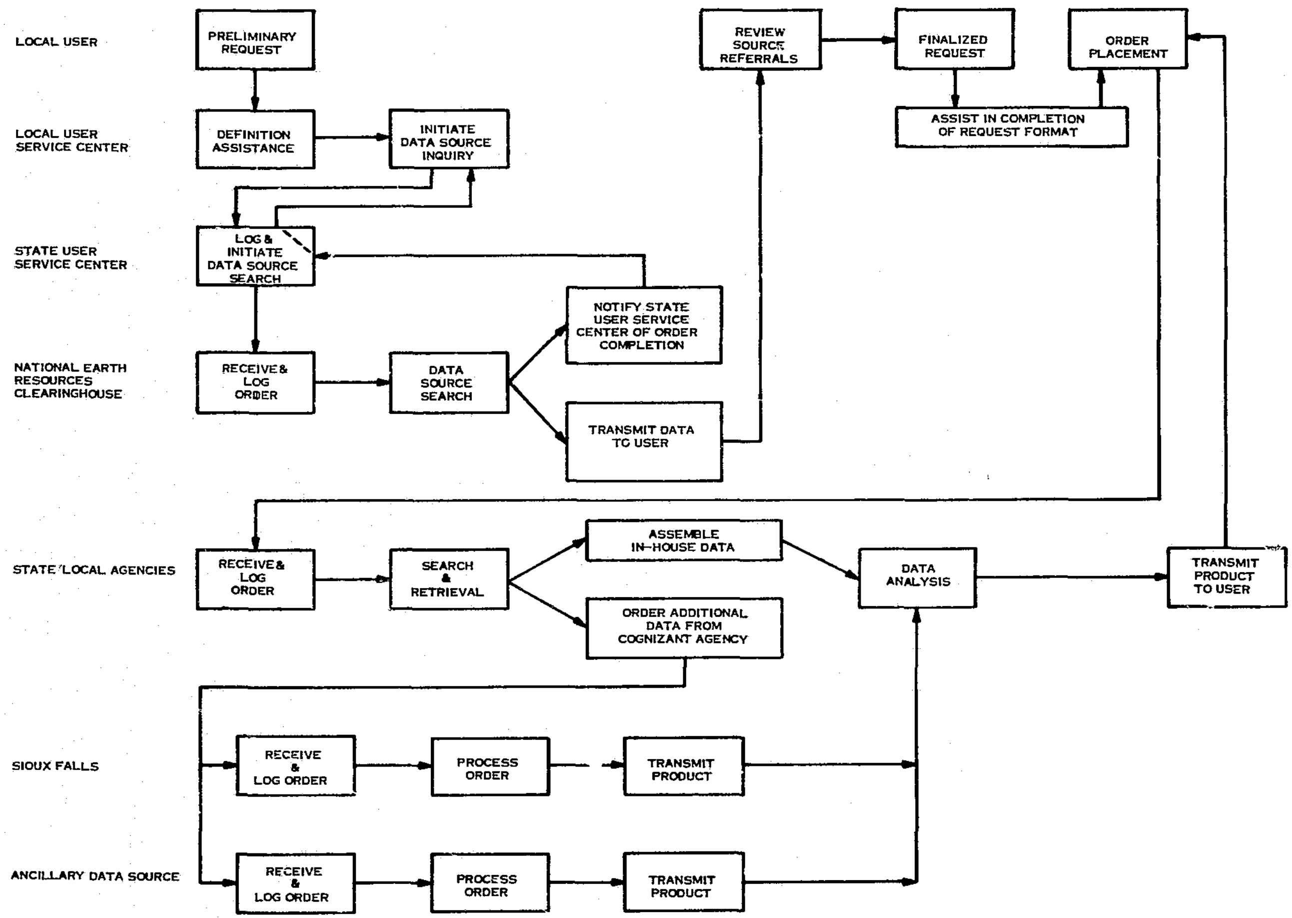


Figure 6.6-6A. Configuration 4 Sample Activities Flow Chart - Local User Level (State Scope Requests)

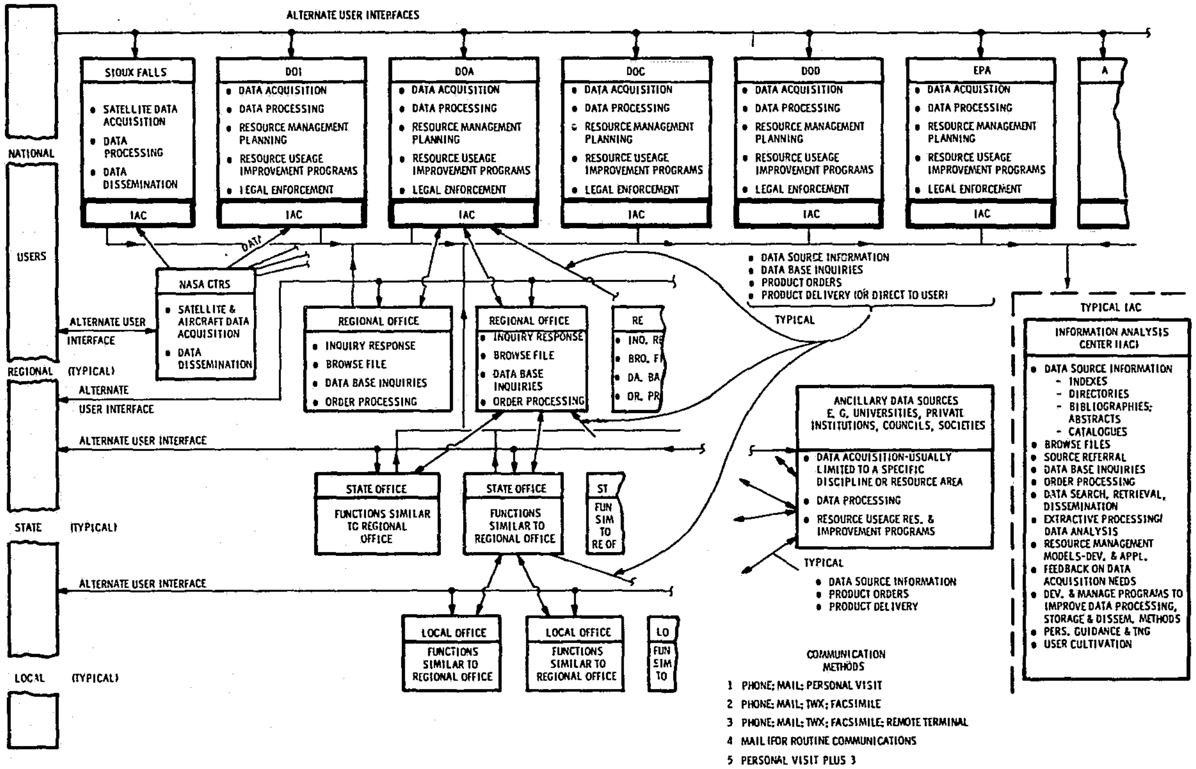


Figure 6. 6-7. Configuration 5 Federal Agency IAC

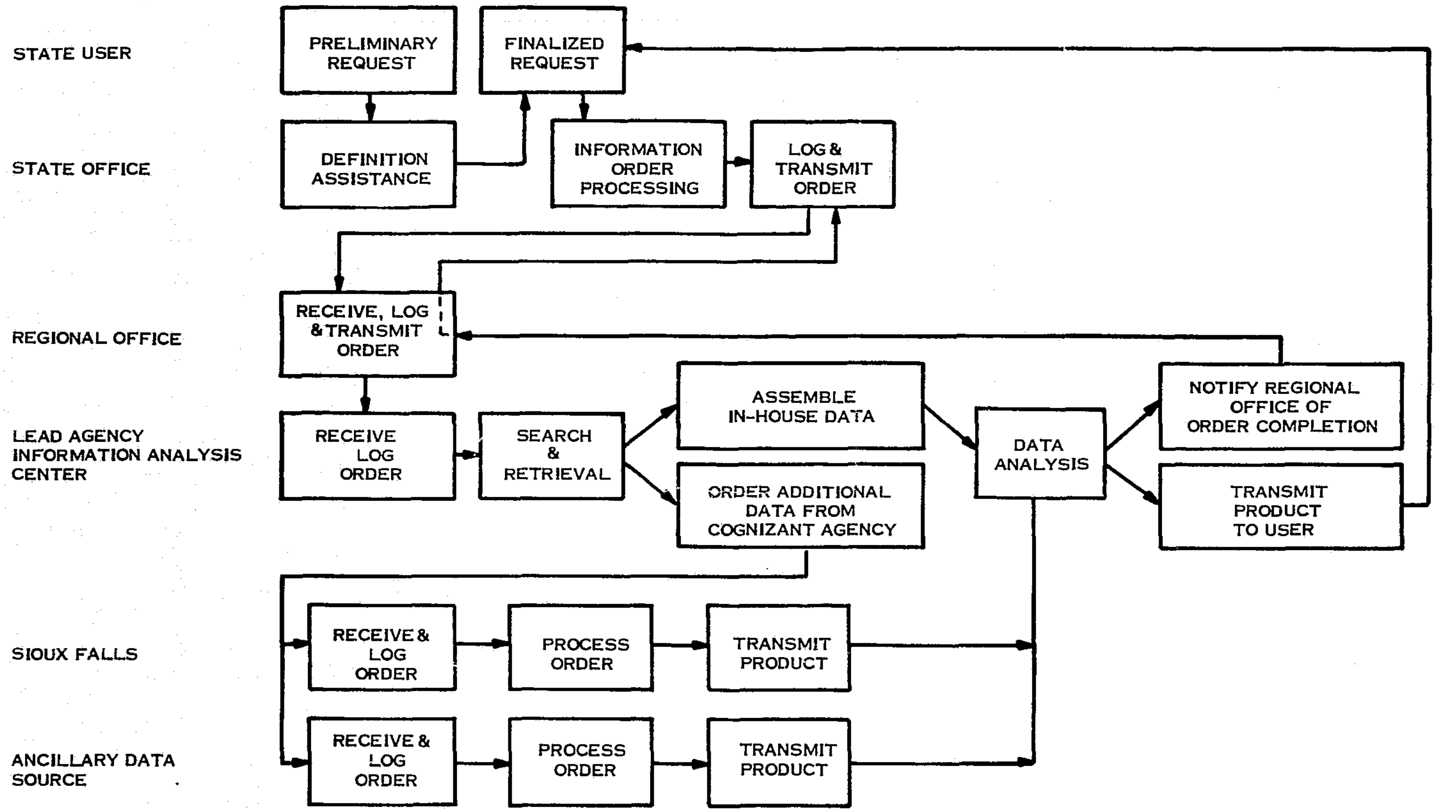


Figure 6.6-7A. Configuration 5. Sample Activities Flow Chart - Local User Level (State Through National Scope Requests)

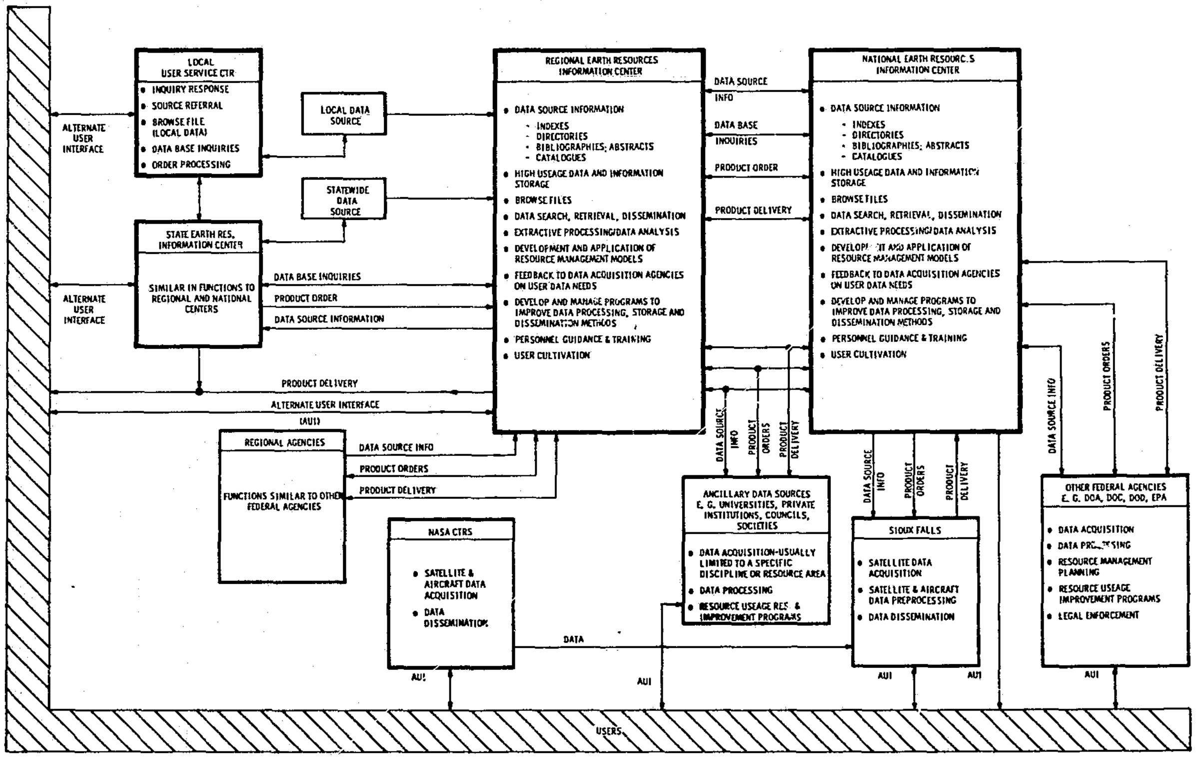


Figure 6.6-8. Configuration 6 Three Level Information Center

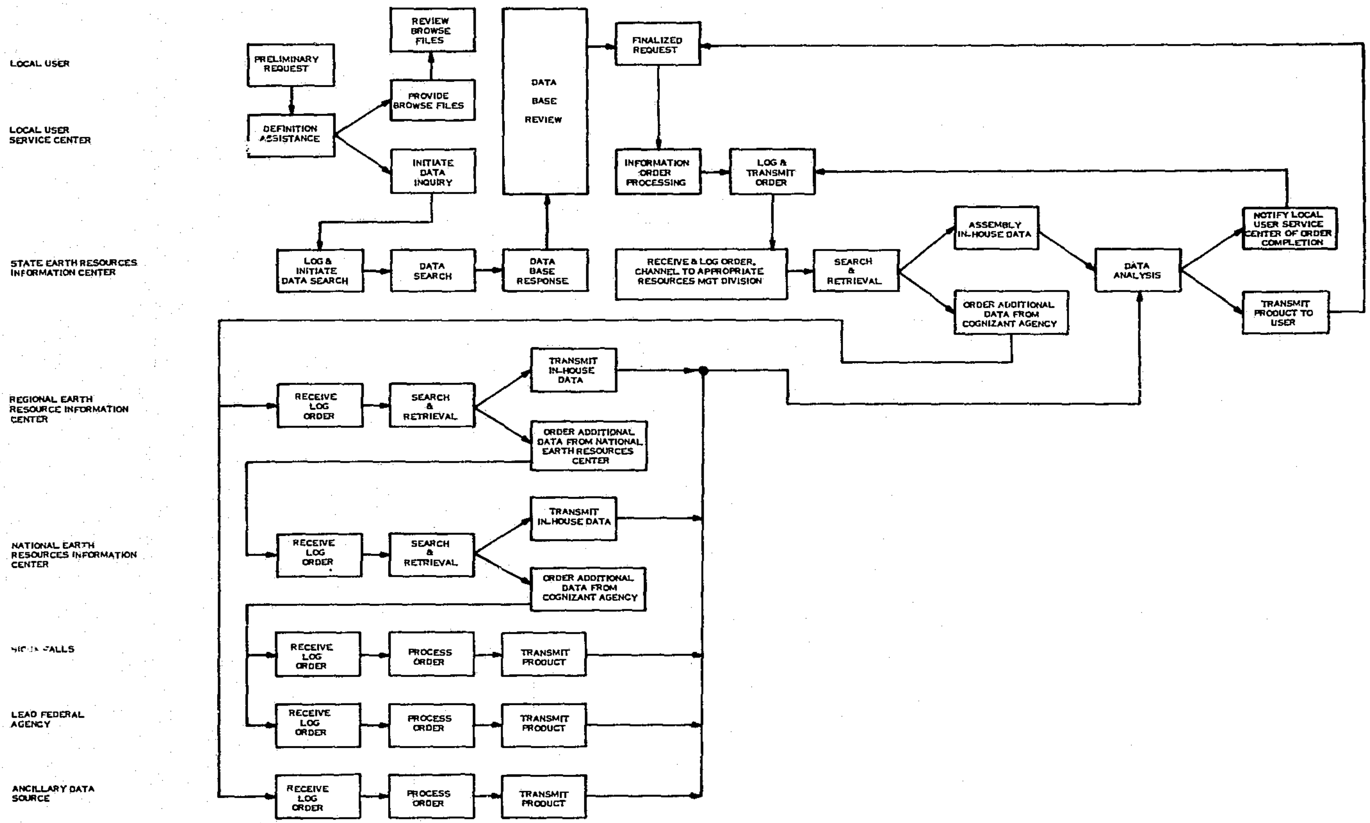


Figure 6.6-8A. Configuration 6 Sample Activities Flow Chart - Local User Level (Local Through State Scope Requests)

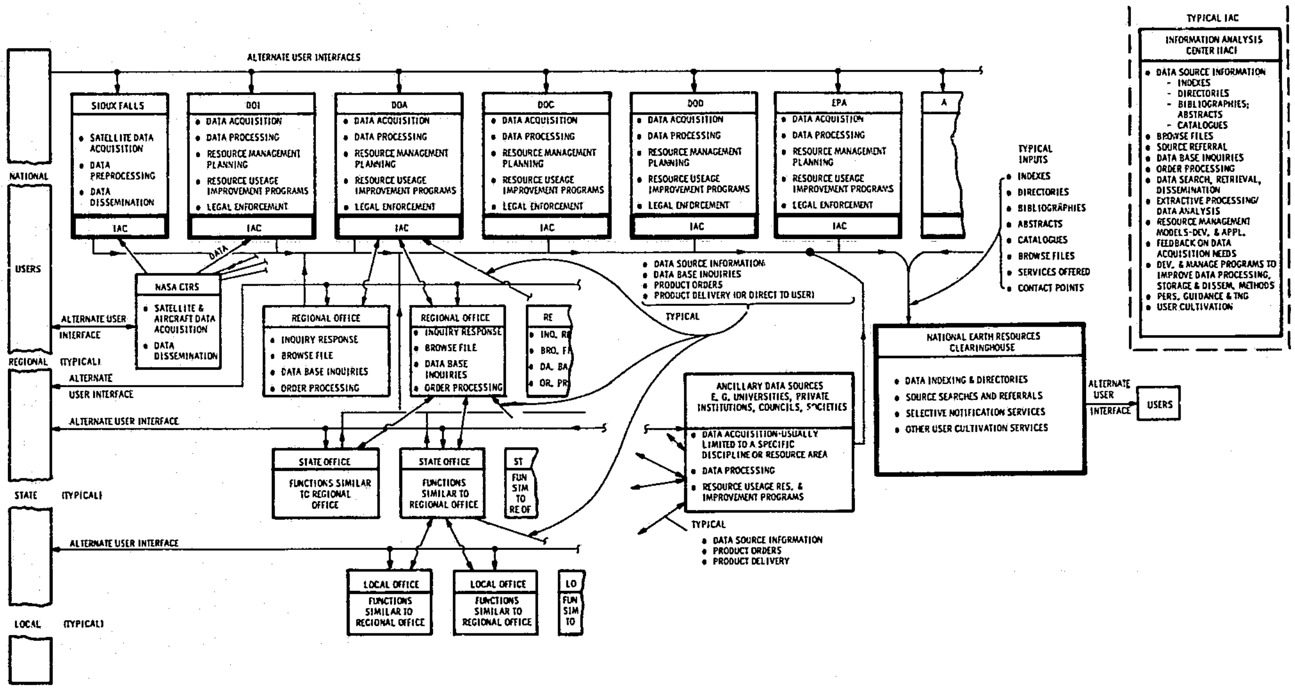


Figure 6. 6-9. Configuration 7 Federal Agency IAC with NERC

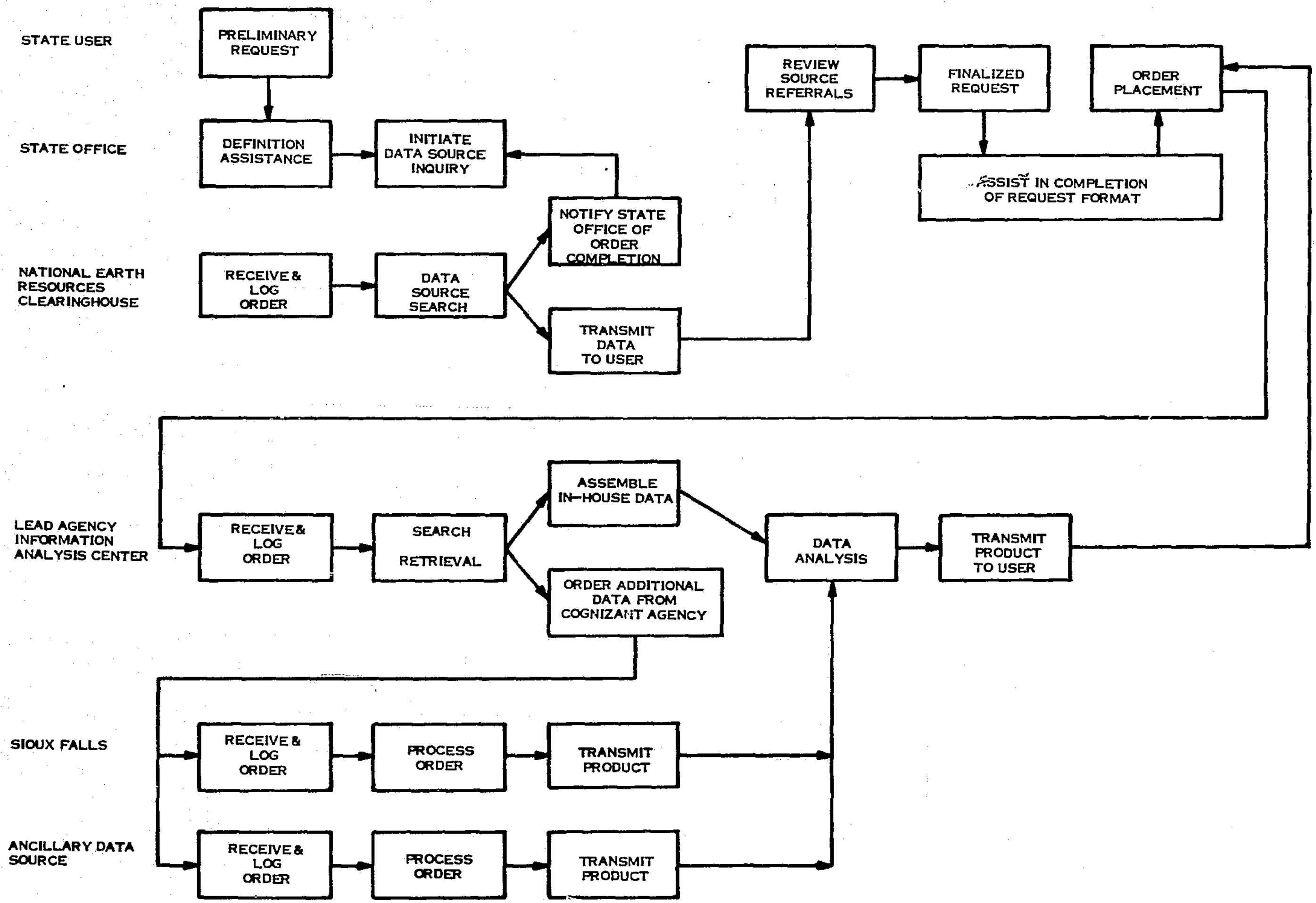


Figure 6.6-9A. Configuration 7 Sample Activities Flow Chart - State User Level (Regional Through National Scope Requests)

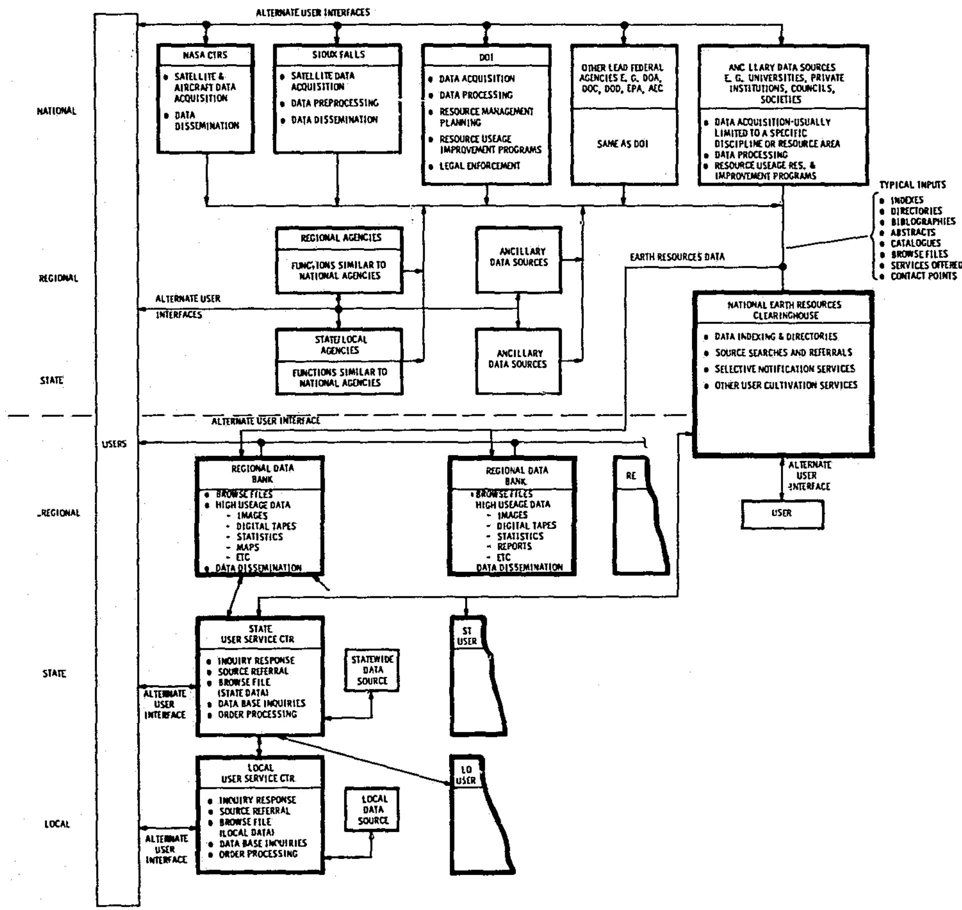


Figure 6.6-10. Configuration 8 NERC and Regional Data Banks

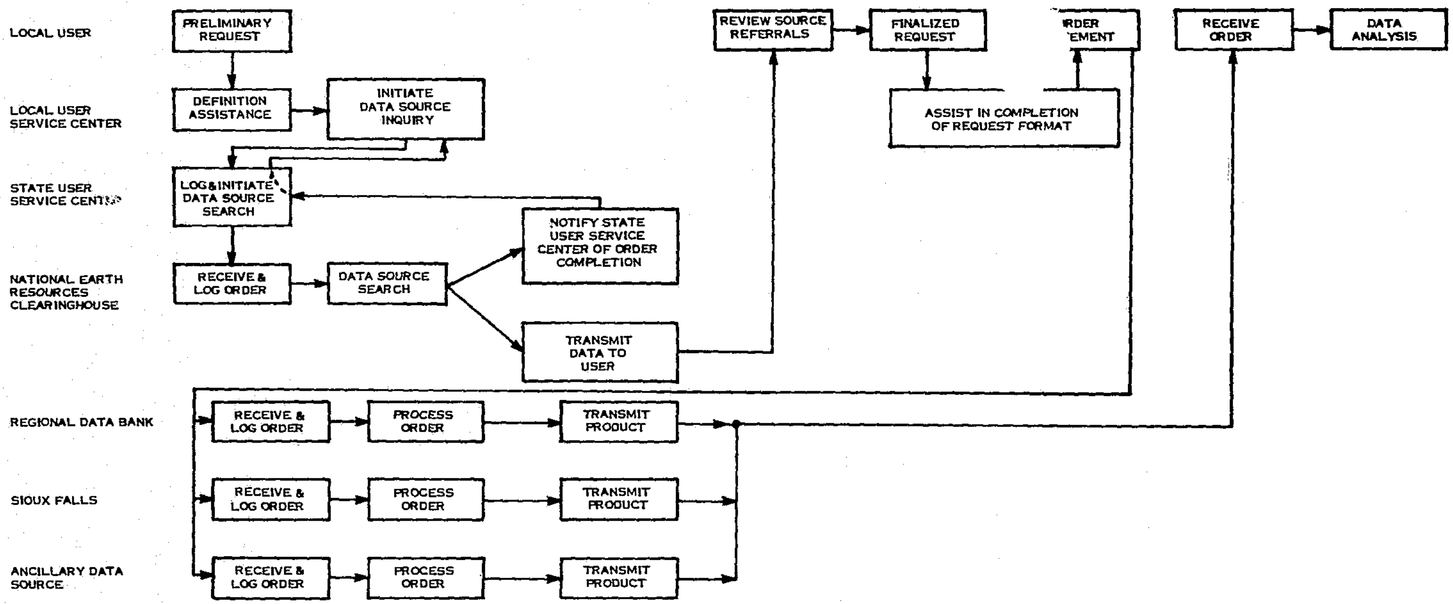


Figure 6.6-10A. Configuration 8 Sample Activities Flow Chart - Local User Level (Regional Scope Requests)

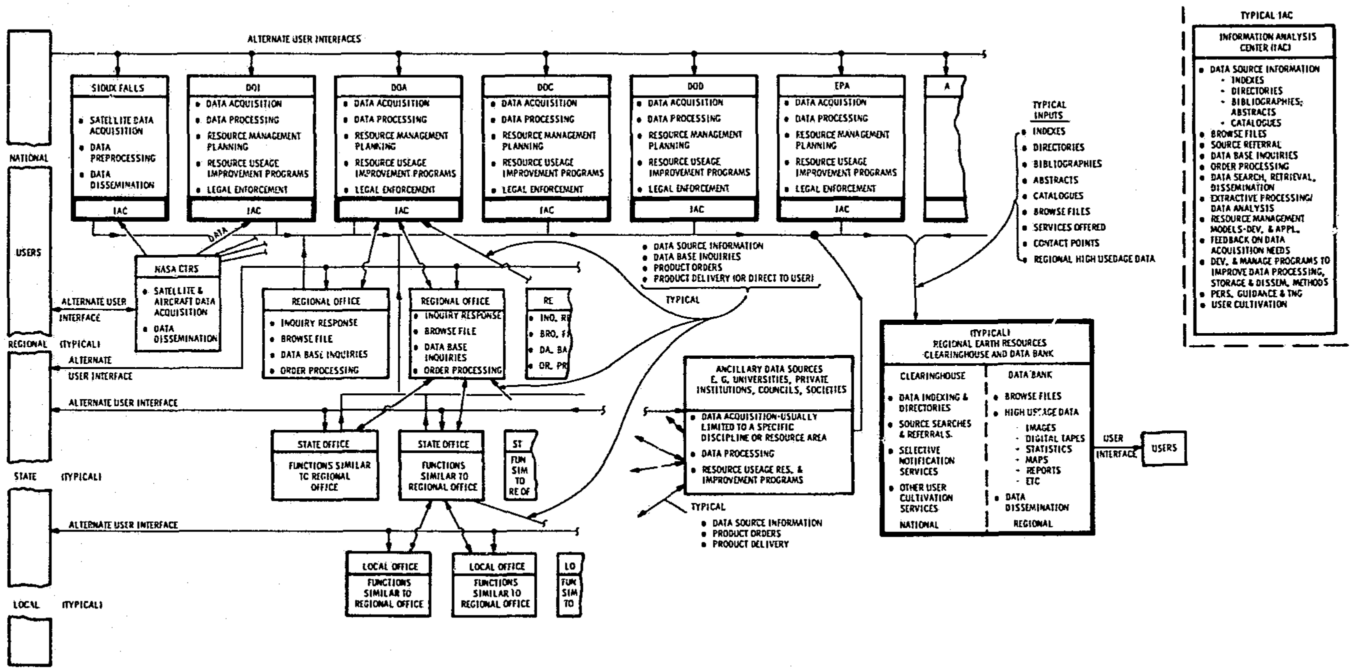


Figure 6. 6-11. Configuration 9 Distributed Center System

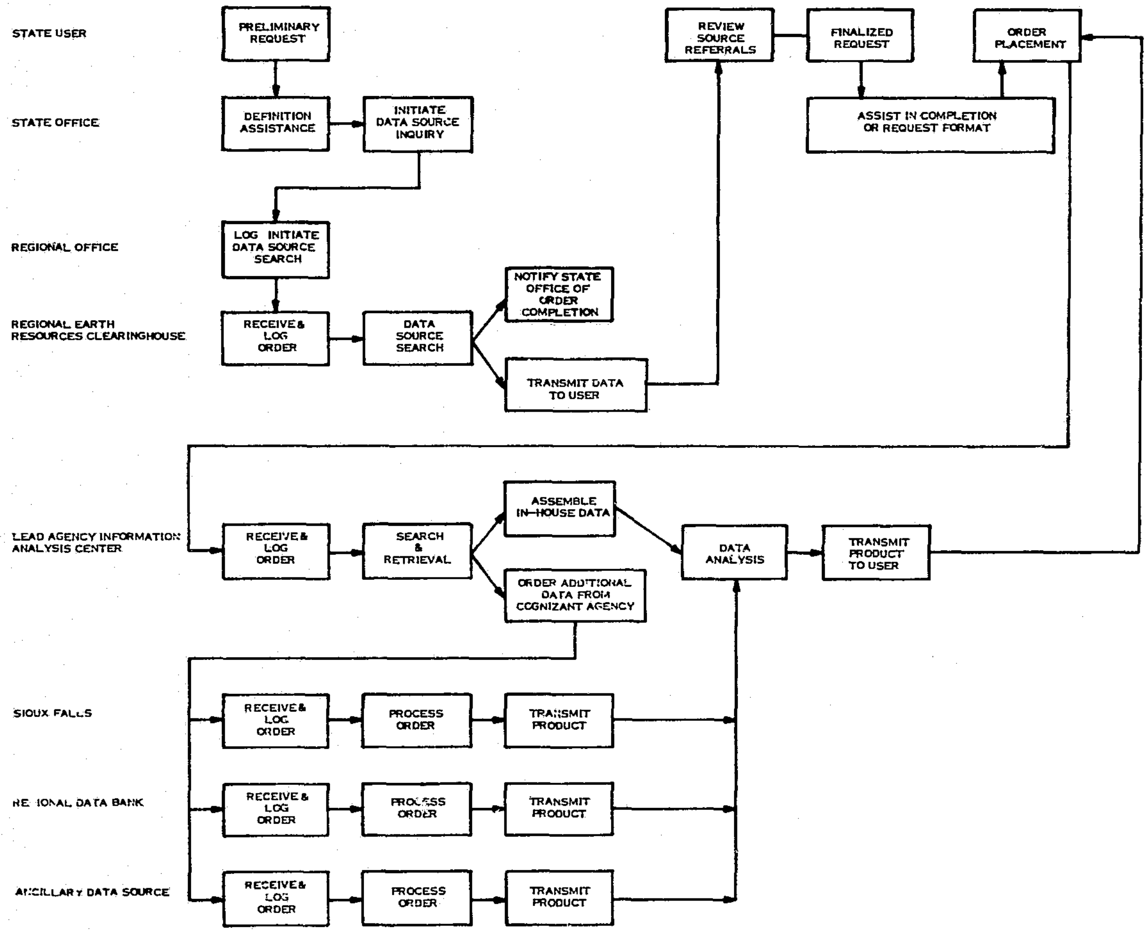


Figure 6. 6-11A. Configuration 9 Sample Activities Flow Chart - State User Level (Regional or National Scope Requests)

Table 6.6-2. Alternate System Configurations

No.	Title	Description	Major Strengths	Major Weaknesses
1	Centralized NERIC	Single NERIC satisfies the multidisciplinary data/information needs for all users. Configured/chartered so as to not duplicate nor conflict with existing agencies. Interactive data links with all major data sources. Communication links with User Service Centers at State and local level.	• all new, ground-up super system • single focal point • conceptually simple/straight forward • centralized resources	• requires close integragency coordination • all new, ground-up super system • remote from users • scheduling/priority conflicts
2	Federated NERIC/RERIC	A combination of an NERIC serving national users and RERIC (Regional) serving regional (state user with two discrete levels: (1) national, (2) combined Regional/State	• more rapid & comprehensive response to users at two discrete levels (focused) • fixed hierarchy of capability	• increased complexity/cost in communication links • increased costs of facilities, equipment, operating personnel
3	Lead Federal Agency	Lead Federal Agency is defined for each discrete area of Earth resources management. They will then expand their scope of interest and facilities as volume of user requests increases. Multiple Information Analysis Centers (regional scope) are established to process orders from User Service Centers. All linked together through an interactive computer network	• takes advantage of existing agencies paradoxical interests • highly responsive to users	• large complex computer network • potential charter conflicts • wasteful redundancy probable
4	National Clearinghouse	Similar to No. 3 (Lead Federal Agency) where existing agencies, now not restricted to Federal level, will expand their scope and facilities as required. No new analysis centers are created. A National Earth Resources Clearinghouse is established to provide indexing and source referrals.	• little required in way of new structures • minimum initial commitment	• highly fragmented system • potential charter conflicts • wasteful redundancy probable
5	Federal Agency IAC (evolved)	No new super system. Lead Federal Agencies encouraged to expand scope and facilities with an IAC for each. Users are geographically focused through regional, state, and local offices of the agency.	• minimum initial investment • agency oriented structure for access and visibility • focused to needs (administratively) • established through evolution	• potential charter conflicts • overlaping disciplines • redundency in expertise • lack of geographical focus
6	Three Level Information Center	Hierarchical system of national (NERIC) regional (RERIC), and state (SERIC) information centers structural to focus on geographical needs of user	• fast in-depth response • focused to user needs (geographically)	• large capital system investment • complex data/information exchanges • lack of disciplinary depth
7	Federal Agency IAC with NERIC	Similar to No. 5 (Federal Agency IAC-evolved) with the addition of a National Earth Resources Clearinghouse to provide data indexing and user referral	• provides selective notification services on National basis • Federally administratively focused • established mostly through evolution	• NERC redundant with agency services • discipline capability overlaps • geographically centralized
8	NERC and Regional Data Banks	The basic concept of a National Earth Resources Clearinghouse is expanded to include regional Data Banks which provide data to State and local user service centers.	• geographically distributed to users • rapid access to high usage data • geographically distributed data bank	• highly fractionated facilities • little centralized capability • redundancy in data banks • difficult for national users
9	Distributed Center System (evolved)	In combination with the evolved Federal Agency IAC incorporate Regional Earth Resources Clearinghouses and Data Banks	• maintains Federal Agencies as focus • established partly through evolution • focused response to user queries	• potential charter conflicts • probable data base redundancy • little national multidiscipline scope • no interagency coordination

NERIC = National Earth Resources Information Center
RERIC = Regional Earth Resources Information Center
IAC = Information Analsysis Center
USC = User Service Center
NERC = National Earth Resources Clearinghouse

Table 6.6-3. Selection Criteria/Performance Requirements

No.	Title	Performance Requirement	Selection Criteria
1	System Acceptability	System must be acceptable to all affected participants as a useful adjunct to existing or planned federal, regional, and state capabilities	System will engender a high degree of acceptability with all affected participants
2	System Cost	Cost must be within achievable funding	System ranking inverse to estimated relative costs (i.e., highest relative cost system receives lowest ranking).
3	Response Volume Capability	Meets projected needs of federal, public, academic, and private sectors	System is capable of responding in a timely manner to the projected volume of user requirements
4	Response Time	Sensing/Measurement to user inquires range from near real time to months	Capability is, or easily can be, provided to meet user response schedules for data and/or information ranging from near real time to protracted intervals.
5	Flexibility	Archival data suitable for automated preprocessing, information extraction, analysis, and generation of output products must be compatible with user techniques and equipment	System provides capability to format and disseminate archived data products compatible with a multiplicity of user's automated processing equipment and techniques.
6	Scope of Output	Remote and/or auxiliary data/information	Capability is provided to effectively locate, retrieve, and integrate both remote-sensed and related ancillary data in response to user requests.
7	System Security	Maintenance of data base integrity; source and user privacy protection are required.	The system incorporates the capability to invoke security provisions which adequately protect the integrity and privacy of communications between sources and users.
8	System Adaptability	The system should be responsive to changes in user mix; user requirements; data sources; technology; economics; socio-political influences	The system shall be readily adaptable or modifiable to conform to changes in the operational environment which affect network functions and effectiveness.
9	Output to Users	Data and/or information formats responsive to total spectrum of user requirements	Data and/or information outputs can be provided in a variety of formats responsive to the total spectrum of user requirements.
10	System Evolution	Built-in growth capability will be required	The system readily permits expansion or modification to accommodate growth in input/output requirements.
11	Interactive Capability	System responds to user requests at any entry point. Accommodates changes in requests prior to completion of response	System provides a multiplicity of user entry points with flexible inquiry/response capability.
12	Self-Monitoring	"Housekeeping" capability for operations control and improvement is necessary	The system incorporates provisions for performance monitoring to facilitate operational control and improvement.
13	System Elements Improvement	Functions and incentives are provided to improve each of the system elements	System capability is provided to promote and abet planned system element improvements.

6.6.4 SYSTEM SELECTION METHODOLOGY

The selection of a specific system configuration from the nine postulated was accomplished by using the approach of "weighted criteria". The weighted criteria method consists of first establishing the relative importance of the specific criteria with respect to each other by assigning each criteria a weighting factor. Then for each candidate configuration, the candidate is evaluated for each criteria and a numerical score assigned for that criteria. These raw scores are then weighted by the appropriate weighting factor and summarized to form the total score for that candidate. When all of the candidate configurations have been similarly evaluated their total scores can be compared and a selection made.

To initiate this process, the preliminary design constraints listed below have been formulated to define the boundaries of any eventual system solution. Each constraint represents a go-no/go criteria for configuration acceptability, and non-conformance with any one constraint is cause for rejection of the configuration under consideration.

1. Satisfy user requirements with the U.S.
2. Avoid/minimize duplication of other system capabilities
3. Avoid infringement on existing agency responsibilities
4. Operational feasibility baseline--1978-1982
5. Net Annual operating costs consistent with project budgets
6. Conform to all legal requirements

Each of the concepts selected for further evaluation was first measured against the above constraints and was determined to be within acceptable limits. Examination of the last two constraints did present unusual difficulties in that quantitative system costs and project budgets are undefined at this time, and that any system of the scope proposed could incur situations involving the legal liability of both source and user with regard to the use of the data. However, it was decided to defer deletion of any feasible concept pending the future determination of more definitive costs; budget and legal liability parameters were not within the scope of this study.

In contrast to design constraints which establish relatively inflexible go-no/go design and selection parameters, the system performance requirements define a set of design goals--each of which has relative importance and many of which are interdependent to various degrees. These requirements, together with other system goals and qualitative considerations, form the basis for the initial set of system selection criteria.

The individual criteria have been compared and have been judgmentally weighted with respect to each other to proportionalize the impact of any one criteria on the acceptability of the overall concept. Each configuration will be evaluated and measured against each individual criteria in order to evaluate the degree of conformance of that configuration to that criteria. Numerical factors (scores) have been assigned to both the conformance and weighting factors so that an overall numerical rating can be obtained for each criteria for each concept. Summation of the numerical ratings will then determine a prioritized listing of concepts in order of desirability, --No. 1 having the highest numerical rating.

Each of the selection criteria impacts on the acceptability of an overall concept to varying degrees. The degree of impact itself is also a variable depending on the environment existing at the time of concept evaluation and how accurate the evaluator's interpretation is of that environment. Further, the weighting factors must be selected to assure that the correct degrees of differences are assigned to each criteria so that the final numerical summations are sufficiently spread to assure that concept priorities are clearly defined. Listed below in Table 6.6-4 is the result of several iterations in prioritizing and weighting the selection criteria developed above. Weight is based on a scale of 1 to 50.

Each of the selection criteria represent system goals to which each of the concepts conform to in varying degrees. As with criteria weighting, it is important to assign the numerical factors so that the final summations result in clear delineations of order. The following conformance factors have been assigned on a rating spread of 0 to 10:

Conformance Factor	Numerical Rating
High degree of conformance	10
Very nearly conforms	8
Partially conforms	5
Barely acceptable	2
Does not meet	0

6.6.5 RESULTS OF WEIGHTED CRITERIA APPROACH

The results of applying the above criteria, with the weighting factors given, are shown in Table 6.6-5 below. For each of the nine candidate system configuration concepts, described above, the table contains two columns, one with the individual conformance scores and one with the weighted total. The overall summation of these results are shown in Table 6.6-6; configuration concept number five received the highest total score.

Two alternative criteria weighting factors schemes were also considered. In alternate scheme number one the relative importance of the first two criteria (System Acceptability and System Cost) is increased with respect to the other criteria by doubling their criteria weighting factors (to 100 and 50 respectively). In alternate scheme number two the relative importance of all criteria are the same (each has a weighting factor of one). Note that these alternatives only effect the total source, and ranking of concepts, by changing the criteria weights; since

Table 6.6-4. Baseline Conformance Criteria and Weighting Factors

Criteria Rank	Criteria	Weighting Factor
1	System will engender a high degree of acceptability with all affected participants	50
2	System ranking inverse to estimated relative costs (i.e., highest relative cost system receives lowest ranking)	25
3	System is capable of responding in a timely manner to the projected volume of user requirements	10
4	Capability is, or easily can be, provided to meet user response schedules for data and/or information ranging from near real time to protracted intervals	10
5	System provides capability to format and disseminate archived data products compatible with a multiplicity of user's automated processing equipment and techniques	10
6	Capability is provided to effectively locate, retrieve, and integrate both remote-sensed and related ancillary data in response to user requests	10
7	The system incorporates the capability to invoke security provisions which adequately protect the integrity and privacy of communications between sources and users	10
8	The system shall be readily adaptable or modifiable to conform to changes in the operational environment which affect network functions and effectiveness	10
9	Data and/or information outputs can be provided in a variety of formats responsive to the total spectrum of user requirements	7
10	The system readily permits expansion or modification to accommodate growth in input/output requirements	7
11	System provides a multiplicity of user entry points with flexible inquiry/response capability	5
12	The system incorporates provisions for performance monitoring to facilitate operational control and improvement	5
13	System capability is provided to promote and abet planned system element improvements	5

Table 6.6-5. Results Using Baseline Weighting Factors

		Candidate Configurations																	
		1		2		3		4		5		6		7		8		9	
	Selection Criteria	Criteria Weight	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total
1	System Acceptability	50	2	100	2	100	5	250	10	500	10	500	0	0	10	500	10	500	10	500
2	System Cost	25	2	50	0	0	0	0	8	200	10	250	0	0	8	200	5	125	2	50
3	Response Volume Capability	10	5	50	8	80	10	100	5	50	10	100	10	100	10	100	10	100	10	100
4	Response Time	10	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100
5	Flexibility	10	10	100	10	100	5	50	2	20	5	50	10	100	5	50	2	20	2	20
6	Scope of Output	10	10	100	10	100	10	100	5	50	5	50	10	100	5	50	5	50	8	80
7	System Security	10	10	100	5	50	2	20	10	100	10	100	2	20	10	100	5	50	2	20
8	System Adaptability	10	10	100	8	80	5	50	2	20	2	20	5	50	2	20	5	50	5	50
9	Output to Users	7	10	70	10	70	10	70	5	35	5	35	10	70	5	35	5	35	5	35
10	System Evaluation	7	10	70	10	70	5	35	5	35	5	35	8	56	5	35	5	35	5	35
11	Interactive Capability	5	5	25	8	40	10	50	10	50	10	50	10	50	10	50	10	50	10	50
12	Self-Monitoring	5	10	50	10	50	2	10	0	0	0	0	10	50	0	0	0	0	0	0
13	System Elements Improvement	5	10	50	10	50	2	10	0	0	0	0	10	50	0	0	0	0	0	0
				965		890		845		1160		1290		746		1240		1115		1040

Table 6. 6-6. Summary Ranking of Concepts
(Based on Baseline Weighting Factors)

Rank	Concept No.	No. Points	% of No. 1
1	5	1290	-
2	7	1240	96
3	4	1160	90
4	8	1115	86
5	9	1040	80
6	1	965	75
7	2	890	69
8	3	845	65
9	6	746	58

the system configuration concepts and the criteria themselves are the same the basic score is unchanged for the alternatives. The overall summation for these alternatives are shown in Table 6. 6-7 and 6. 6-8 for alternatives one and two respectively.

The results of all three weighting schemes are shown comparitively in Table 6. 6-9. Note that the only difference in ranking between the baseline scheme and alternative scheme one is that the seventh and eight place concepts switch places; the rank of all other concepts remains unchanged. However, alternative scheme two does produce a completely different ranking of concepts from the other two schemes.

In addition to considering the absolute ranking (first, second, etc) it is fruitful to look at the spread between the rankings. That is, a first place rank position is more meaningful if the second ranked concept is far removed than it is if the second place choice is quite close. Figure 6. 6-12 graphically displays this "spread" for the three weighting factor schemes considered. From this figure it can be observed that for the two schemes which involve wieghted criteria (baseline and alternative one) configuration number five is the highest ranked. But, it is not a clear head and shoulders selection; for the baseline weighting scheme it is only 4% above its closest "competitor" and for alternative weighting scheme number one it is only 7% above the second choice. Alternative scheme two is seen to provide a better clustering and spread between it "winners" and its "loosers", but it is based on each criteria having equal weight which is not a reasonably valid hypothesis upon which to rank the alternative configurations.

Table 6.6-7. Summary Ranking of Concepts - Alternate 1
(Based on Doubling the Criteria Wts. for Criterias 1 & 2)

Rank	Concept No.	No. Points	% of No. 1
1	5	2040	-
2	7	1940	93
3	4	1860	91
4	8	1740	85
5	9	1590	78
6	1	1115	55
7	3	1095	54
8	2	990	49
9	6	746	37

Table 6.6-8. Preliminary Ranking of Concepts - Alternate 2
(Based on all Criteria of Equal Weight

Rank	Concept No.	No. Points	% of No. 1
1	1	104	-
2	2	101	97
3	6	95	91
4	5	82	79
5	7	80	77
6	3	76	73
7	4	72	69
8	8	72	69
9	9	69	66

Table 6.6-9. Comparison of Concept Rankings

Concept No.	Baseline Rank	Alt. 1 Rank	Alt. 2 Rank
1	6	6	1
2	7	8	2
3	8	7	6
4	3	3	7
5	1	1	4
6	9	9	3
7	2	2	5
8	4	4	8
9	5	5	9

In summary, the best system configuration in terms of the selection criteria considered is configuration number five, Federal Agency IAC---evolved, (no new super system, evolved lead agencies, addition of information analysis centers). However, the determination of this selection is not so clearcut and definite that a strong position is warranted. For example the difference in ranking between it and concept number seven, Federal Agency IAC with NERC, is directly attributable to the cost of the NERC. It may vary well be, that the increased cost will be more than offset by increased benefit in other areas which were not accounted for by the thirteen selection criteria.

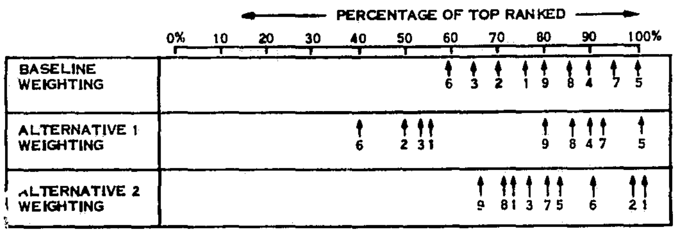


Figure 6. 6-12. Relative Ranking of Concepts

6. 6. 6 THE SELECTED GROUND SYSTEM CONFIGURATION

As developed over the preceeding several sections the selected ground system configuration for TERSSE is: Configuration 5, Federal Agency Information Analysis Center. This concept, shown again in Figure 6. 6-13, features a distribution of the information analysis functions among the several "lead" Federal agencies which now carry out the resource management tasks in the absence of a TERSSE. The interfaces between the outside users and the "system" exist through the geographically organized networks of offices of the various Federal agencies involved. An overall summary of these key elements of this configuration is shown in Figure 6. 6-14.

The study investigations into the architectural structure of the TERSSE ground system have led to the conclusion that the ground system structure should be mission tailored and parallel the user's organizational structure. Some missions are naturally centralized (e. g. , Global Crop Survey); however, most have a decentratized and geographically distributed user network, even those with heavy Federal involvement. A second recurring feature is the existence of a tiered hierarchial structure (local, district, state, regional) present in the organization of those users.

The TERSSE ground system architecture is designed to be structured along resource management mission lines and to be convient for user access at its terminus. This recommended approach produces a structure for an operational TERSSE which is in contrast to a recommendation by the Applications Summer Study and others for large regional satellite data centers. The satellite data center concept is not felt to be desirable unless modified, for two principal reasons: First, large regional centers will not be mission-oriented and geographically convient to the users; the TERSSE study team feels that mission orientation and convient user access is a major requirement for the operational ground data system. Second, the concept of a Satellite Data Center makes difficult the tailored integration and application of multi-source data to a specific resource management problem. The TERSSE study has shown that most missions will require the integrated usage of several data sources together with considerable amounts of ancillary and in situ data.

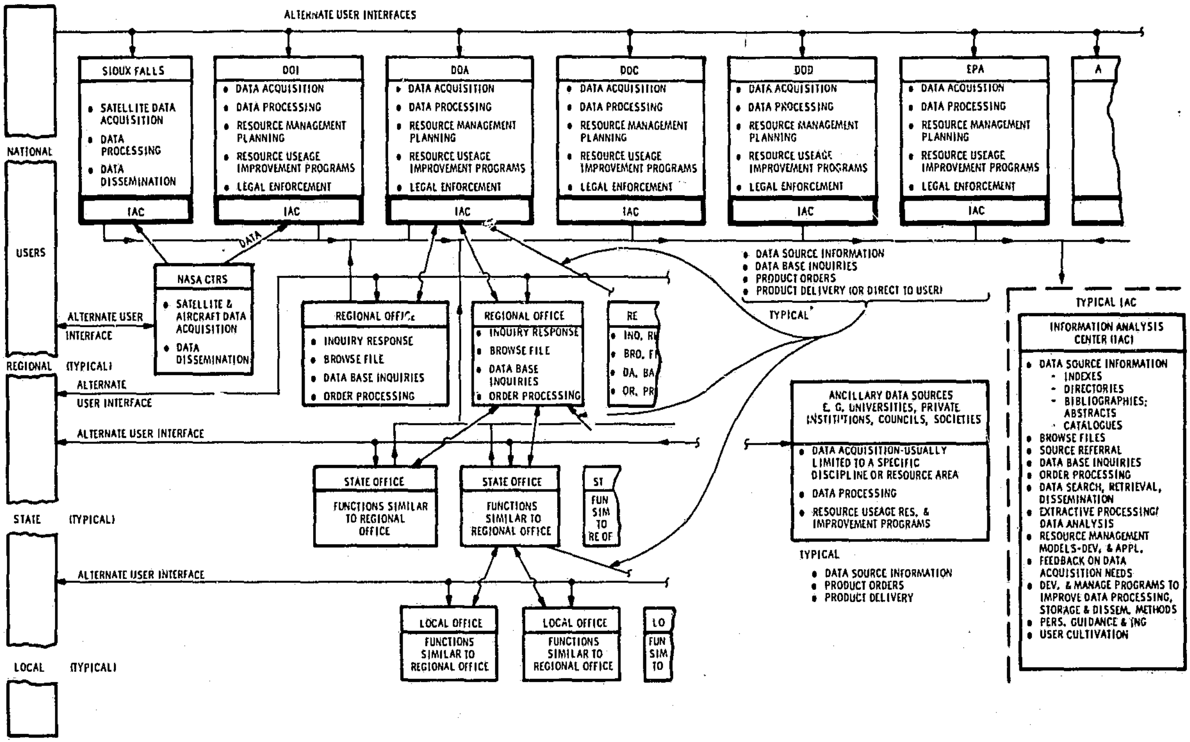


Figure 6.6-13. Ground Data System Configuration 5 Federal Agency IAC

- LEAD FEDERAL AGENCIES
  - OPERATES AN IAC
  - FUNCTIONAL DATA CENTRALIZATION
  - RESOURCE MANAGEMENT PLANNING
  - LEGAL ENFORCEMENT
  - RESOURCE IMPROVEMENT PROBLEMS
- REGIONAL/STATE/LOCAL OFFICES
  - USER CONTACT POINT
  - INQUIRY RESPONSE
  - INSTITUTE ORDERS

EACH LEAD AGENCY SYSTEM:
- PROBABLY DIFFERENT
- DEVELOPS AS REQUIRED
- FOCUSED ON OWN NEEDS

- IAC (INFORMATION ANALYSIS CENTER)
  - DATA SOURCE INFORMATION:

    INDEXES/DIRECTORIES/CATALOGS/BIBLIOGRAPHIES/ABSTRACTS
  - FUNCTIONAL DATA FOCUS:

    BROUSE FILES/SOURCE REFERRAL/FUNCTIONAL ARCHIVE/DATA UTILIZATION FEEDBACK/DATA BASE INQUIRIES
  - USER CULTIVATION:

    PERSONAL GUIDANCE/TRAINING PROGRAMS/COLLATE DATA NEEDS
  - EXTRACTING PROCESSING:

    INFORMATION EXTRACTION/DATA ANALYSIS/SPECIAL & STANDARD REQUESTS/ORDER HANDLING
  - RESOURCE MANAGEMENT MODELS:

    MODEL DEVELOPMENT/APPLICATION/IMPROVEMENT
  - INTERAGENCY COOPERATION:

    MODEL EXCHANGE/APPLICABLE JOINT EFFORTS/DATA INTERCHANGE

Figure 6.6-14. Elements of Federal Agency IAC Configuration

The recommended TERSSE ground system architecture provides for a mission-tailored hierarchial structure of user interfaces focused around several "Lead Federal Agencies". At the lower levels of the hierarchial structure the system interfaces are to be co-located with the users. In order to accomplish this co-location of the terminus, a series of low cost interactive remote access terminal devices connected to the next higher hierarchial level are needed. The nature of current advanced extractive processing systems (high ratio of user involvement time to machine processing time) lends itself to this time-shared remote terminal concept.

The near term activity required in this area consists of refining and defining the remote terminal concept. What should the specification of this device be, and who are the appropriate initial users are initial issues to be addressed. The "Applications Concept Testing Facility" (ACT) concept being considered by NASA/GSFC (Contract Number NAS 5-24022 Mod 40) offers an excellent vehicle for addressing these near term issues. The objectives of the ACT concept should be expanded to include the definition of the TERSSE ground system remote terminal.

In addition to the specific features of the selected ground system configuration, discussed in the remainder of this section, there are several other overall aspects of the ground system, refer to Figure 6.6-15. These more general functions will be performed at a centralized National center prior to receipt of the data by the several lead Federal agencies. These centralized functions include, data preprocessing, data archiving, and initial data distribution to the lead agencies.

DATA RATE:	LIMITED BY FREQUENCY ALLOCATIONS (AT X BAND, 450 MHz; <1 GBPS)
PREPROCESSING:	ALL DATA WILL BE PREPROCESSED (GEOMETRIC & RADIOMETRIC) AT A SINGLE NATIONAL CENTER PRIOR TO DISTRIBUTION & ARCHIVING
ARCHIVING:	PREPROCESSED DATA WILL BE ARCHIVED AT A SINGLE NATIONAL ERS ARCHIVE (RAW DATA NOT ARCHIVED)
DATA DISTRIBUTION:	PREPROCESSED DATA WILL BE DISTRIBUTED VIA DOMSAT ON A PREDETERMINED SCHEDULE TO ALL INTERESTED RECIPIENTS (DATA OF LIMITED/RESTRICTED INTEREST WILL BE DISTRIBUTED VIA CCT'S OR LOWER CAPACITY CHANNELS)

Figure 6.6-15. Ground System - General/Overall

The centralization of these functions can represent a cost savings due to commality and specialization when the functions are common to many users and/or several systems. This is the case for data archiving, is generally true for geometric preprocessing, but is less true for radiometric preprocessing. During the evolution of TERSSE it may become appropriate to have a separate "national center" and operational control facility for each "system" within TERSSE (e.g., EOS, SEOS, SEASAT, CROPSATS, etc.). Initially however it is felt that the predominance of new users and evoluving applications will make a single national center the appropriate configuration. Therefore the use of a single national center has been postulated for the purposes of the discussion in this section. We recognize that as the TERSSE matures some decentralization and specialization will occur, however significant ties and inter-connection will still be required.

The raw data stream from the various remote sensing platforms will be received, via a TDRS, at the national center and preprocessed both radiometrically and geometrically to an "adequate" level. The exact specification of this "adequate" level remains to be determined. In general it will be the degree of preprocessing stipulated for the missions in Section 6.3. There will still be some users who because of their uniquely exacting requirement will have to do further preprocessing at their Information Analysis Center, IAC. For example, it may be determined that geographic preprocessing correction for most users can be adequately supplied by utilizing the real time, on board euphemeris estimations. In this case, geometric correction would be supplied, to that degree, by the national center for all data; and those users who require further correction (e.g., with updated euphemeris data and/or ground control points) would supply their own.

Once the data has been preprocessed to this "standard" level of correction by the national center it will then be both archived and redistributed by the national center. The data archived by the national center will be fully indexed and cataloged and then made available to all IAC's. The redistribution of the preprocessed data stream to the various interested user IAC's will be accomplished via a DOMSAT, Domestic Communications Satellite. The data stream will be rebroadcast, via DOMSAT, according to a prepublished schedule so that each IAC may 'tap' the flow for that data required by its functionally/discipline oriented requirements. Each IAC will thus be able to tune in and begin recording only those data types of specific interest to them; it is not expected that any IAC will require all the data, from all the sensors, for all the spectral bands, for all the areas covered all of the time.

A "lead" Federal agency will evolve for each major resource management discipline. The designation of an agency as "the" lead agency for a particular resource management area is expected to be an evolutionary process as opposed to an executive fiat or decree. Those agencies with the greatest self-interest in an area will tend to exert themselves through their "power" of knowledge and expertise and will thus assume a position of leadership with respect to that resource management discipline. A somewhat obvious example perhaps is that the US Department of Agriculture would be expected to be the lead agency for the resource management disciplines of Agriculture.

Each lead agency will serve as a functional or discipline oriented focal point for the centralization of activity related to their area of interest. Each will operate on Information Analysis Center, IAC, specialized for the needs and requirements of its users. Each will provide a centralized data repository, including both remotely sensed and auxillary (ancillary and in situ) data, for data items relevent to its domain. The lead agencies will provide the motivation and guidance for such discipline oriented activities as resource management planning, resource improvement programs, and specialized data processing technique development as they relate to the agencies discipline areas.

The various Information Analysis Centers, one for each lead agency, provide the centralized capability for the actual data processing, information extraction, and output product production. Data Source Information availability is achieved through the maintenance of all necessary indexes, directories, catalogs, bibliographies, and abstract. These are maintained not only for the IAC's own data base, but through cooperative exchanges for all other IAC's as well. These data source availability tools can then be used to access all previously archived data that may be needed for a particular use, reguardless of its type, source, or location. In a more particular sense, each IAC maintains a local functional archive of those data items normally relevent to its lead agencies functional role. For this local functional archive the IAC will provide for brouse files, data base inquires, and data base utilization feedback.

Through the functionally oriented concentration of data processing expertise the IAC will be able to handle both routine and special user requests. This will include not only the data analysis and information extraction functions per se; but also, the development and refinement of user models and applications. The IAC will be able to assist users by providing them with whatever guidance and training is appropriate; however, most of the direct user interface will occur through the geographically dispersed network of the lead agencies offices.

Each lead agency will utilize its existing network of Regional, State, and Local Offices inorder to provide a geographically decentralized mechanism for user access and interface. These offices will provide geographically convient points of contact for those users interested in an agencies functional discipline. These offices will respond to initial user inquiries and assist the user in properly formulating his problem in terms appropriate to the TERSSE (as implemented by that lead agency). The actual order for output products will be initiated by the appropriate office interfacing with the user. It is intended that when a hierarchy of offices exist (regional, state, local) the appropriate office will be that whose scope correlates with the users problem (e.g., a user with a state wide problem would approach the corresponding state, see Figure 6.6-16).

In summary, each lead agency will evolve a different implementation of this basic configuration as appropriate. Differences will occur due to the inherent differences in the various resource management disciplines including maturity of the discipline, number of different users, geographical dispersion of both the users and their problems, and the present degree of experience in the application of remote sensing to resource management.

Because of these differences, each agency will evolve their implementation as required to serve their users and their problems.

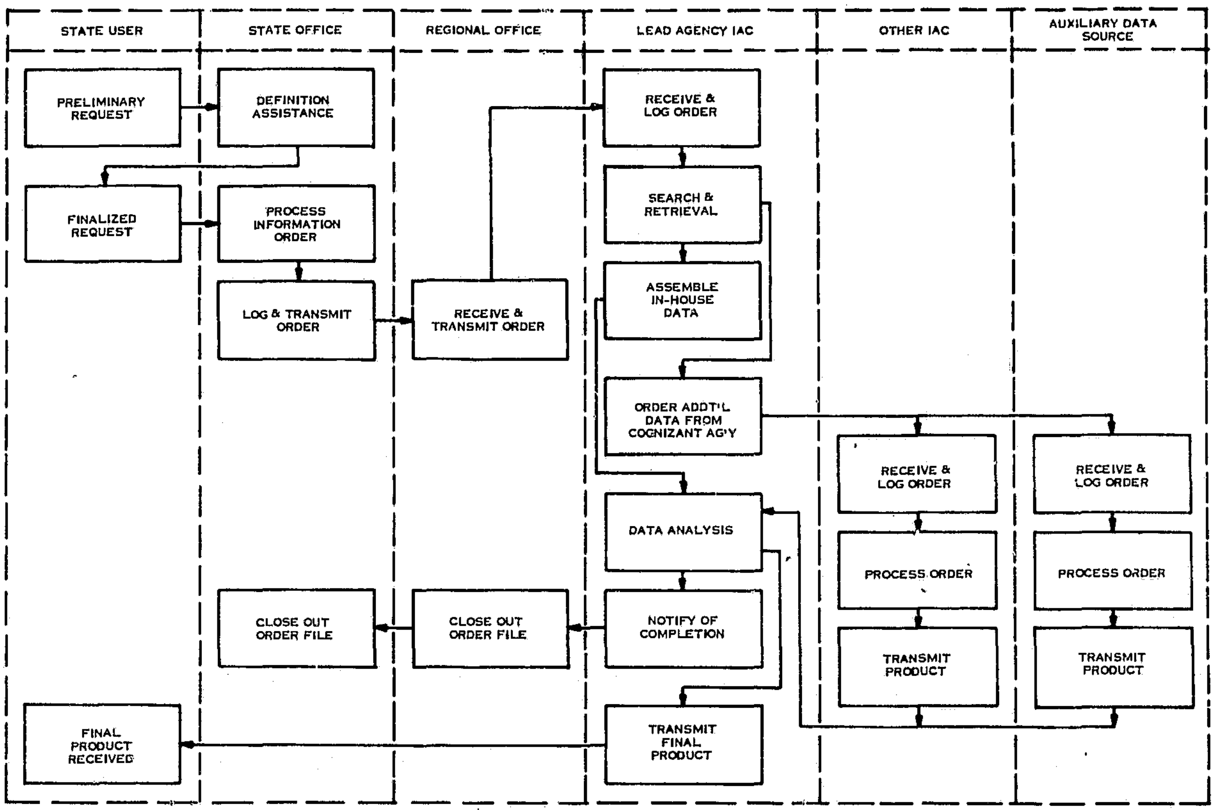


Figure 6.6-16. Example of User Request Flow

SECTION 7

SYSTEM CONFIGURATION

The preceding three sections have individually addressed the three principal TERSSE elements: Remote Sensing Platforms, Remote Sensors, and the Ground System. This section will address itself to the combination of these individual elements into an overall integrated system. Each of the 30 TERSSE resource management missions has its own "system" solution and the entire total system consists of the integrated sum of all 30 solutions.

7.1 THE TERSSE SYSTEM

Considering each of the missions singularly, there is a remote sensing portion and a ground portion which together represent the "system" for each mission. In Section 4 of this report the remote sensing platforms were discussed and each mission assigned to one or more specific remote sensing platforms. Those platform assignments are represented by Figure 4. 2-3 in Section 4 of this report. Similarly, the sensors were discussed and each mission was assigned specific sensors (specified as to spatial resolution and spectral band requirements) in Section 5 of this report. These sensor assignments are represented by Figures 5. 4-7 through 5. 4-11 in Section 5 of this report. The remote sensing portion of a mission's "solution" is determined by these platform and sensor assignments and is depicted in Figure 7. 1-1 with the Water 1 mission as the example.

For the example shown here, the Water 1 TERSSE mission, there were four platform types required to provide the necessary observation coverage. When these platform types, for the Water 1 mission, are used to index the sensor

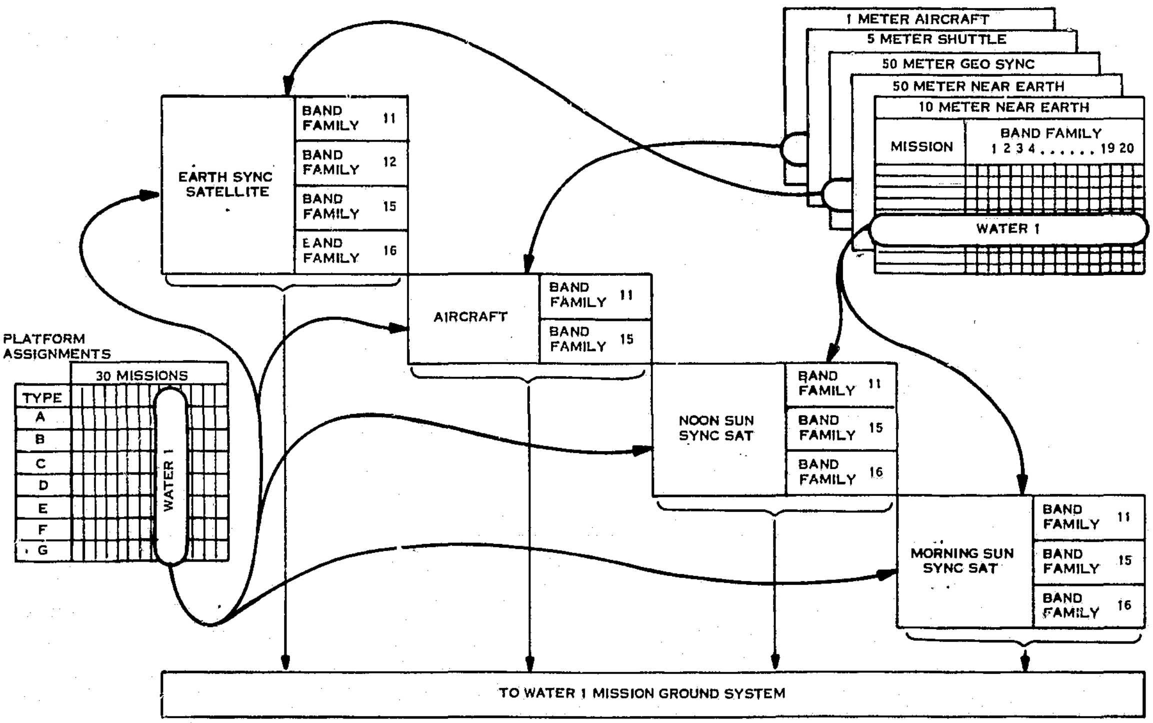


Figure 7. 1-1. Remote Sensing Portion of TERSSE (Water 1 Mission Example)

assignment tables the required sensor band families are thereby determined. These are then combined to establish the platform/sensor or remote sensing portion of the system (for the Water 1 mission).

The ground system element was discussed at length in Section 6 of this report. In that section and Section 3, specific information flow/processing diagrams were developed for each of the TERSSE missions; Figure 7.1-2 is an example of these for the Water 1 mission. In Section 6, a ground system concept was selected (the Lead Federal Agency Information Analysis Center concept) which can optimally implement all of the individual ground processes.

Shown in Figure 7.1-2 is an example of the Water 1 mission information flow; Water 1 is the survey and inventory of ground water for urban and agricultural consumption. The specific user tasks are identified by name and by a two place number system. For example, in the upper right-hand corner is "1.1 USACE". This is the US Army Corps of Engineers with user task number Water 1.1 (the first 1 is common throughout this example because this example is for the Water 1 mission).

The data and information flows include the type of preprocessing required (both geometric and radiometric) and the type of extractive processing required. The entry of ancillary and in situ data is indicated together with the format of the information where appropriate.

The entire system for each mission is then the sum of the remote sensing portion (Figure 7.1-1) and the ground portion (Figure 7.1-2). This is depicted in Figure 7.1-3 with the Water 1 mission as an example.

7.2 THE LEAD MISSION CONCEPT

As discussed above, the TERSSE is the sum of 30 separate systems each with different requirements and serving different users who have various degrees of readiness for the operational usage of remote sensing. The implementation of TERSSE should recognize and take advantage of these differences instead of attempting to be a one-time implementation of a singular "super system" that will serve all. The TERSSE approach which takes these differences into account is referred to as the "Lead Mission Concept".

Simply stated, the Lead Mission Concept indicates that a specific Earth resources management mission will be selected and the "system" for implementing it will be developed. As this specific mission's requirements are satisfied, the requirements for other (generally similar or related) resource management missions will be satisfied with little or no change to the specific system of the "lead" mission. It is through this process of selecting lead missions and implementing their systems that the entire TERSSE will evolve.

This concept focuses the system design and operation on critical system development steps and the implementation of cost effective solutions for promising missions. At the same time, the concept provides data to a maximum number of other emerging applications and missions. Thus, the Lead Mission Concept of system evolution will serve as the bridge between the exploratory investigation and the operational application of remote sensing to a resource management mission.

The selection of a particular resource management mission as a lead mission involves the consideration of four factors: benefits, users, technical, and ER Program. The benefits factor indicates that a lead mission should have a major identified benefits potential. The benefits can include both economic and social components and can be either national or global in scope. The users factor indicates that the user organization must be clearly

SURVEY & INVENTORY THE VOLUME & DISTRIBUTION OF SURFACE GROUND WATER TO ASSESS AVAILABLE SUPPLIES FOR URBAN & AGRICULTURE CONSUMPTION (WATER 1)

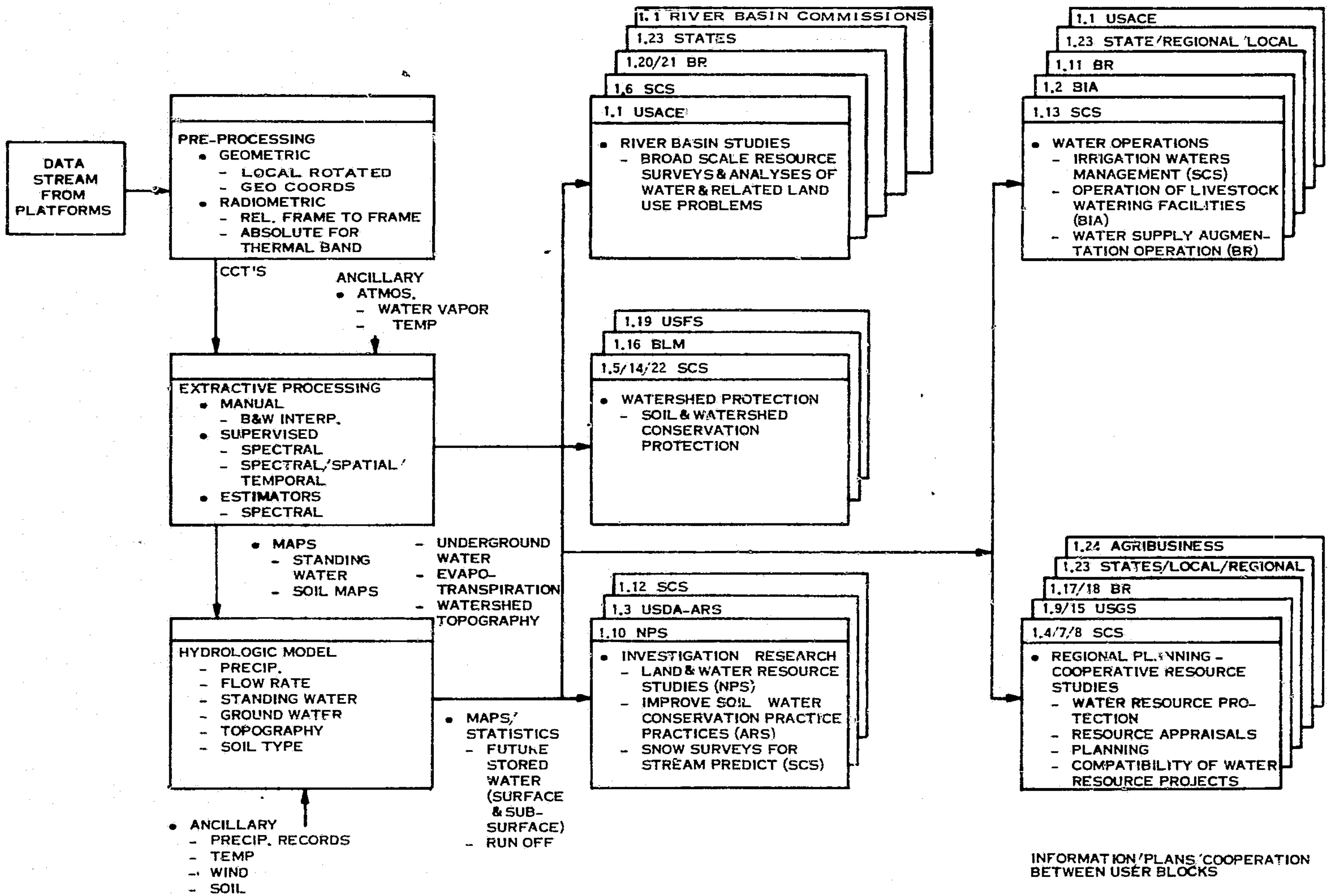


Figure 7.1-2. Information Flow – Water 1 Example

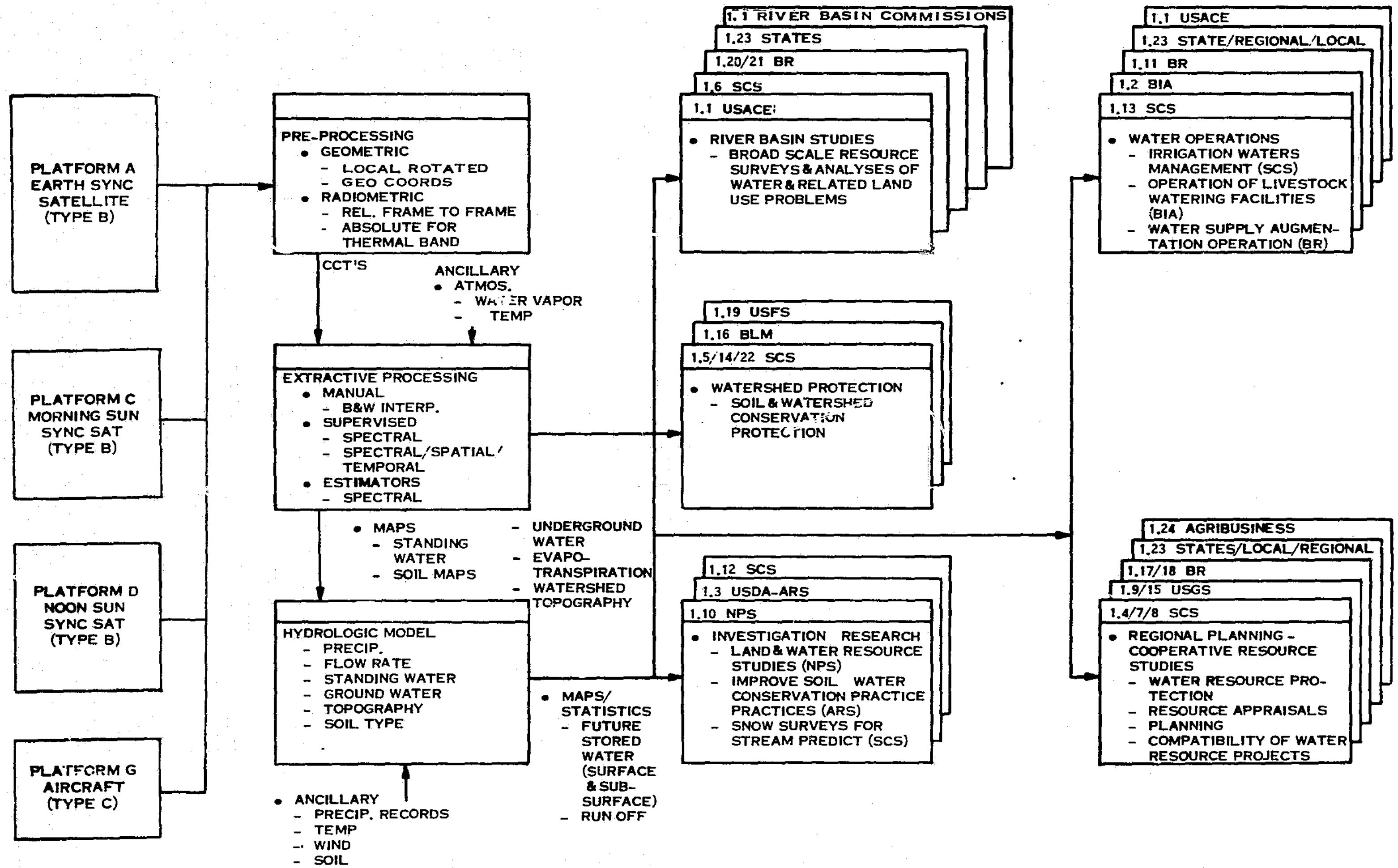


Figure 7.1-3. TERSSE Operational System (Water 1 Mission)

identified and must be willing to actively support the mission. The general public awareness of the user and his mission is also an influencing element of this factor.

The technical factor indicates that the necessary system developments are both identified and feasible. A clear plan for implementing the system should be available and should build upon the existing technology in a logical manner. The ER Program factor is an indication of the synergism that will accrue to the entire program from the particular lead mission under consideration. The capability for spinning off data useful to a maximum number of other applications that will produce widely applicable ERS advances should be considered.

As an example of the utilization of these four factors consider the rankings shown in Figure 7.2-1. Shown in this figure are nine alternative candidates for the "lead mission" for the ERTS-C satellite. Each of the candidates were evaluated with respect to the four factors and an overall ranking obtained.

ERTS-C CANDIDATE LEAD MISSION RANKING

	ECONOMIC		TECHNICAL		USER		ER PROGRAM	RANK
	COST/ EFFECTIVITY ASSESSABLE	HIGH BENEFITS	IDENTIFIABLE SYS. REQ'TS.	PROVIDES MAJOR ADV.	IDENTIFIED SUPPORTING ORG	PUBLIC SUPPORT		
WORLD CROP SURVEY	YES	YES	YES	YES	?	YES	YES	1
U.S. FARMING PRACTICES	NO	?	NO	?	NO	NO	YES	7
SURFACE WATER INVENTORY	YES	NO	YES	YES	?	NO	YES	2
WATER QUALITY MONITORING	NO	?	NO	NO	NO	?	NO	9
FLOOD MONITORING	YES	?	YES	NO	?	YES	?	3
COASTAL ZONE MONITORING	YES	YES	NO	NO	YES	?	YES	4
TIMBER INVENTORY	YES	NO	YES	NO	YES	NO	YES	5
U.S. LAND USE RESOURCES INV.	NO	?	YES	NO	NO	?	YES	6
LAND FORM & COVER MAPPING	YES	NO	NO	NO	NO	NO	YES	8

Figure 7.2-1. Example of Lead Mission Selection

SECTION 8

RELATED ISSUES

This section contains brief but relevant discussions on several TERSSE subjects. These subjects were considered at various times during the course of the study and are included here in this section; the subjects include:

- 8.1 Orbit Mechanics
- 8.2 Cloud Cover
- 8.3 Resolution
- 8.4 Aircraft vs. Satellite ERS Platforms
- 8.5 Coverage Cycle

8.1 ORBIT MECHANICS

This section provides a brief summary of orbital mechanics relevant to remote sensing for Earth Resources Survey missions.

8.1.1 LAUNCH AZIMUTH AND INCLINATION

There are two launch sites in the United States pertinent to TERSSE; the ETR (Eastern Test Range) at Cape Canaveral, Florida, and the WTR (Western Test Range) at Vadenberg, California.

The operational launch azimuths from these two launch sites and the orbital inclinations obtainable are shown in Figure 8.1-1. The figure indicates that at WTR if a satellite is launched at 140^{o} angle, the inclination would be 56^{o}. The WTR launch site would be used for launches of satellites to be put in a polar orbit.

The ETR launch site would be used for launches of satellites to be put in geosynchronous orbit, "figure 8 orbits," low inclination orbits and the 12 hour special purpose orbit.

8.1.2 LOW INCLINATION ORBITS

Low inclination orbits considered here are orbits with inclination less than 57^{o}. This class of orbit is primarily applicable to ETR missions. Inclination of the orbit to the Earth's equator is of significance for two reasons:

1. It determines the maximum latitude which can be viewed from the satellite.
2. It determines the amount of precession of the orbital plane caused by the oblateness of the earth.

Low inclination orbits, like any non-geosynchronous orbit, have the capability to provide two sightings per day for any latitude less than the inclination (Figure 8.1-2). They have the advantage to provide observations under

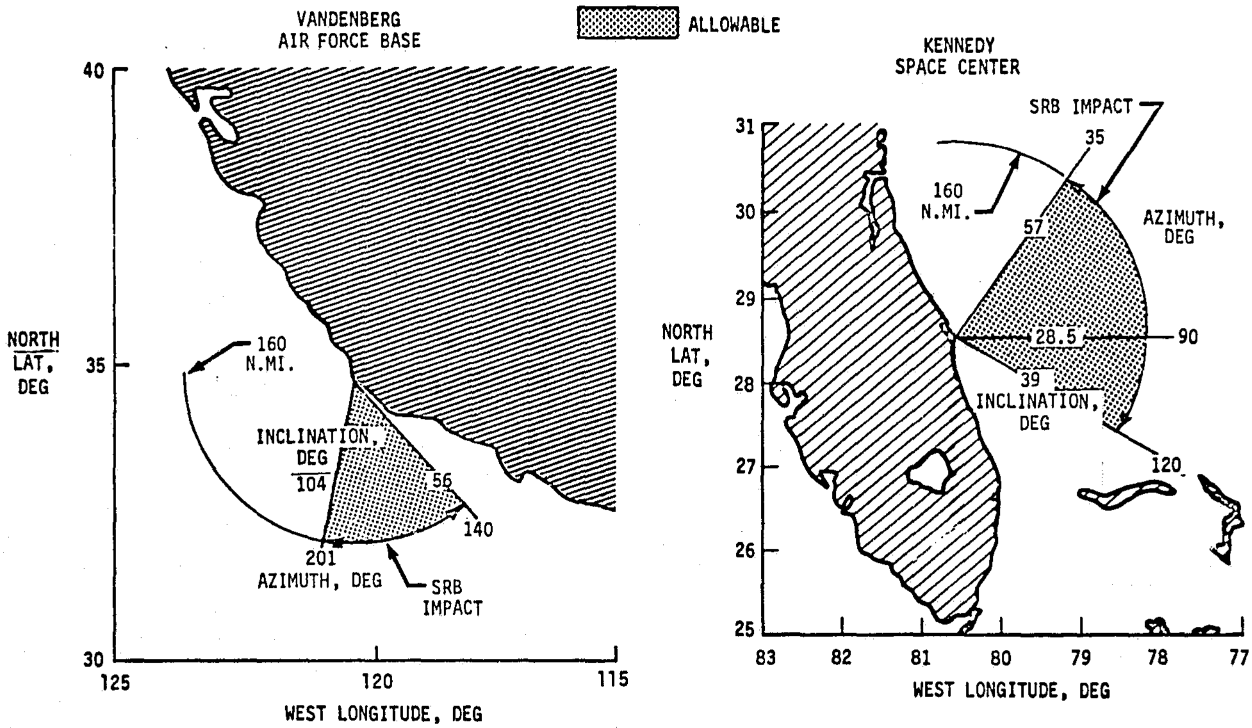


Figure 8.1-1. Launch Azimuth and Inclination Limits from VAFB and KSC

different sun illuminating conditions. It may be important to vary this parameter in a short time. Precession of the orbit around the earth at a constant rate depends on the altitude and the inclination angle of the orbit and is caused due to the oblateness of the earth. The earth's rotation and precession together with altitude and inclination of the orbit determine the rate of change of transit time. A change in transit time at a given site implies change in solar elevation angle. The rate of change of daily transit time in hours per week as a function of altitude and inclination of the low inclination orbit is shown in Figure 8.1-3.

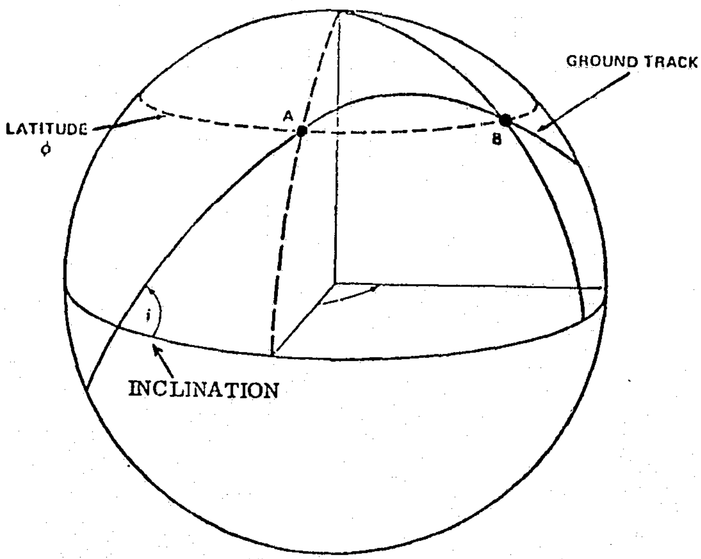


Figure 8.1-2. Geometry Showing Two Sightings A and B Per Day

8.1.3 POLAR ORBITS

Since the inclination of an orbit determines the maximum latitude which can be viewed from the satellite, polar orbits are an especially useful type as it is only with inclinations near 90° that the entire earth's surface comes into view of the satellite. Fortunately, it is the near polar orbits which also posses the capability for adjustment to sunsynchronism.

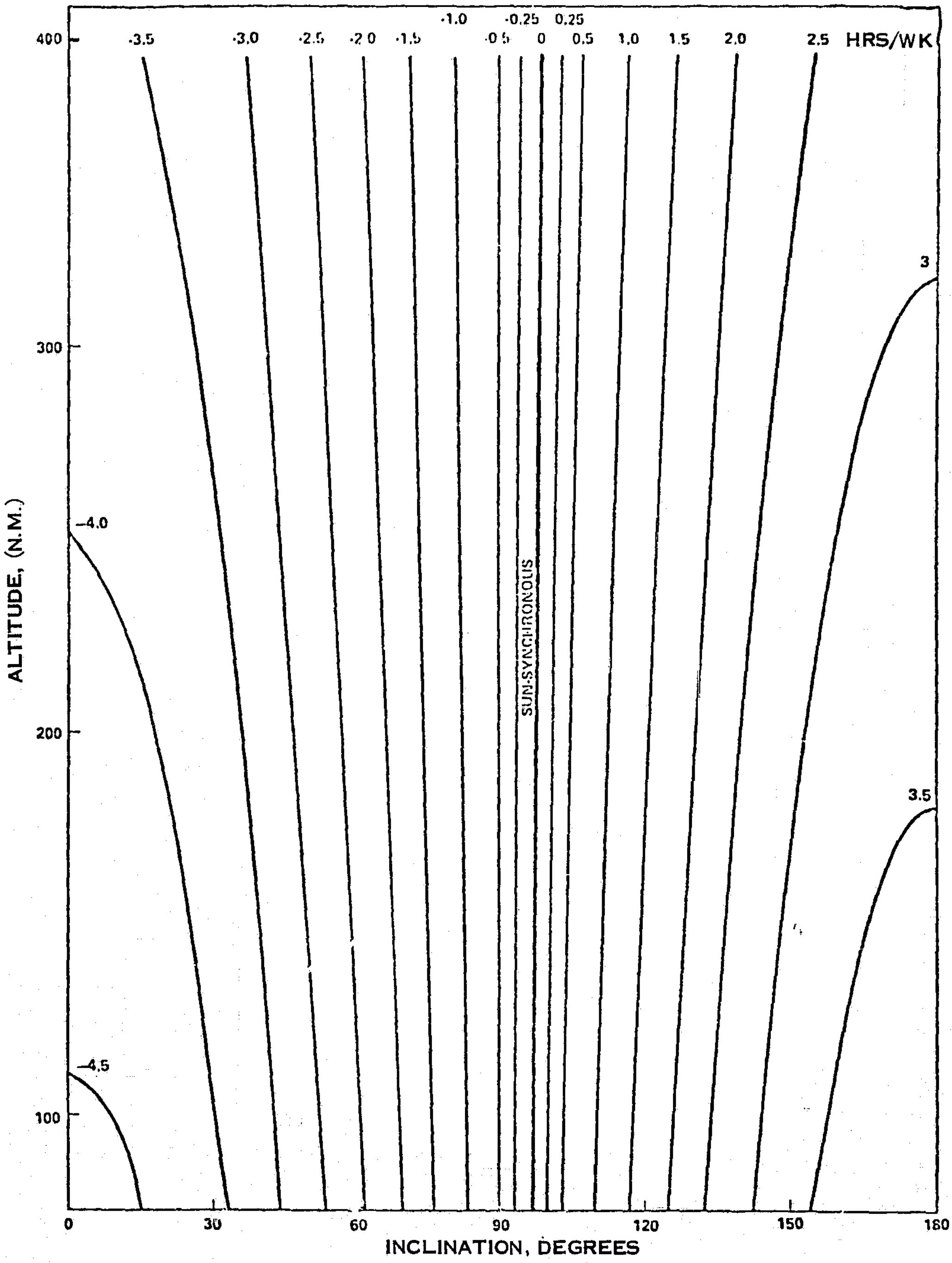


Figure 8.1-3. Rate of Change of Daily Transit Time (Hrs. /Wk.) vs. Altitude and Inclination

8.1.4 SUN-SYNCHRONOUS ORBIT

The oblateness of the earth causes long-term secular drifts of the orbital elements. The drift of the in-plane elements of a particular satellite are not of concern so long as they are known and accounted for.

The precession of the orbital plane itself, or the angular momentum vector, is much more important. The earth revolves around the sun at the rate of approximately 1°/day. If the orbit of the satellite can be made to precess at the same rate, the earth-sun line will always be contained in the orbit plane, and the local time of the ascending node is fixed. This is to say that the sun azimuth will always be fixed and the local time of the crossing of any latitude will remain constant for repeated crossing. Figure 8.1-4 shows the inclination required for various altitudes to obtain an orbital precessing rate equal to 360° per year. It may be seen that the inclination of such orbits, for the lower altitude, are approximately 90°, permitting global coverage. As can be seen, the higher altitude orbits are increasingly less polar in their sun-synchronous forms.

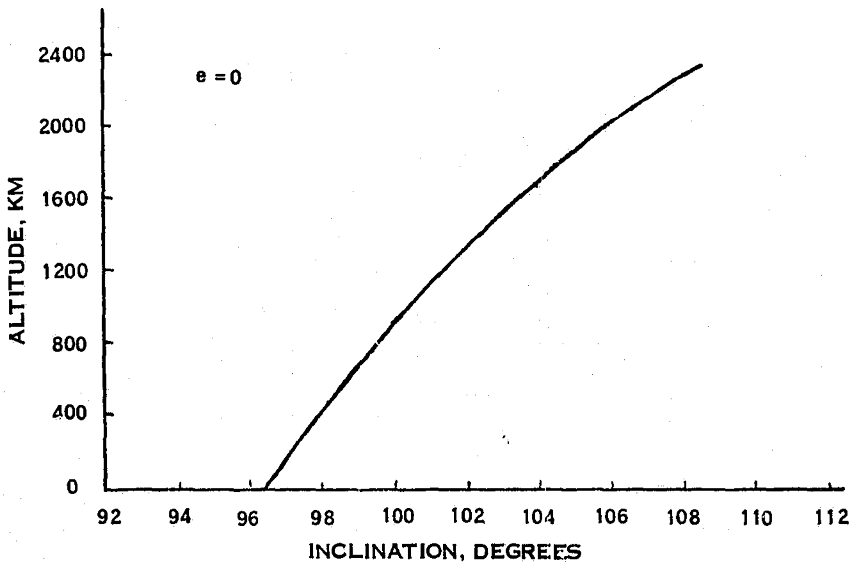


Figure 8.1-4. Inclination for Satellite Sun-Synchronism

8.1.5 SUN ANGLE CONSIDERATIONS

The local solar declination angle and azimuth are important to all types of remote sensing which rely on reflected solar radiation. To be considered are the magnitudes of the declination and azimuth as well as their variation in time. Solar declination angles less than 60° are generally required for most photography to provide adequate illumination. Specific declination angles and/or azimuths are required to achieve proper texture, relief and shadowing. Also of central importance are the variation of declination angle and azimuth, both from point to point in a single scene and from scene to scene in repetitive surveys.

The local solar declination varies with season, latitude and time of day. This variation of the nadir in time on a non-rotating earth's surface traces an oscillatory pattern which follows the expression:

$$\beta = 23.5^{\circ} \sin 2\pi y$$

where:

β = latitude of nadir

23.5° = Earth's inclination to the plane of the ecliptic

y = fraction of a year from vernal equinox

This variation is illustrated in Figure 8.1-5.

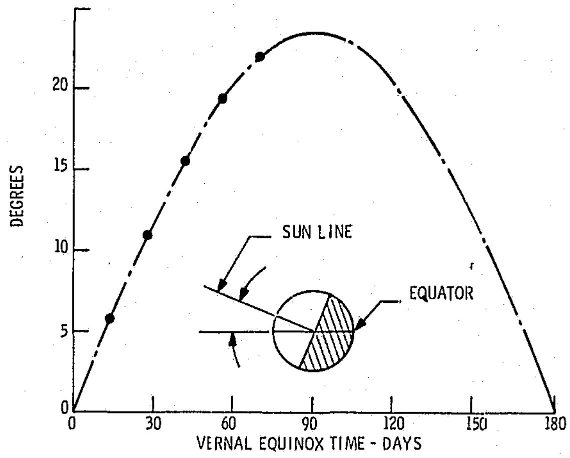


Figure 8.1-5. Variation of Nadir Point in Time, Non-Rotating Earth

When the rotating earth is considered, the nadir rotates about the small circular latitude β, completing a revolution in one day. Thus,

$$\text{LAT}(t) = \beta = 23.5^{\circ} \sin 2\pi y$$

$$\text{LON}(t) = 360^{\circ} d$$

where:

d = fraction of a day elapsed since noon at the zero degree meridian

Figure 8.1-6 illustrates the variation of β in Km/day.

At locations on the earth's surface other than the nadir, the declination angle is non-zero, ranging upward to 90° at the terminator, or greater-circle defining the boundary between light and darkness. A specific instance of interest is the value of the declination at noon as a function of latitude and season. From previous relationships, we may write

$$\gamma = \lambda - \beta = \lambda - 23.5^{\circ} \sin 2\pi d$$

In this case, the nadir is at the same longitude as the point of observation but at a different latitude. The variation of noon declination angles as a function of time and latitude is illustrated in Figure 8.1-7.

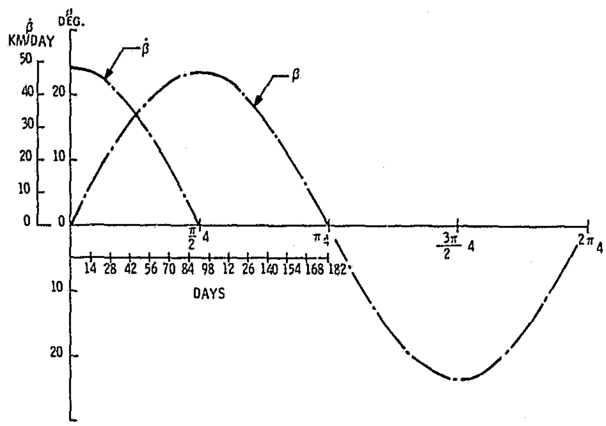


Figure 8.1-6. Variation of β and $\dot{\beta}$ with Time, Non-Rotating Earth

8.1.6 INTERLEAVED ORBIT

Interleaved means the orbits do not progress uniformly in one direction but alternate in a regular pattern which provides reduced access time. For example, a "2 day access" where the ground trace pattern is interleaved has the orbits on any given day located approximately midway between the orbits of the previous day.

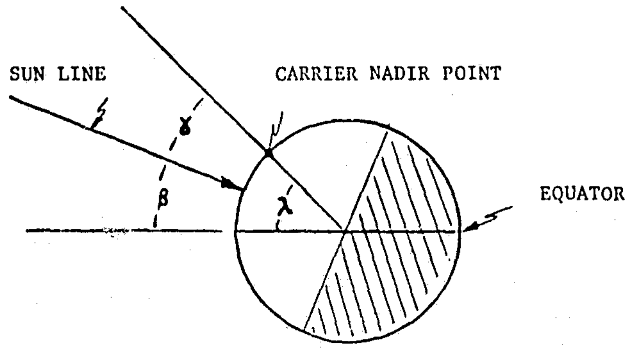
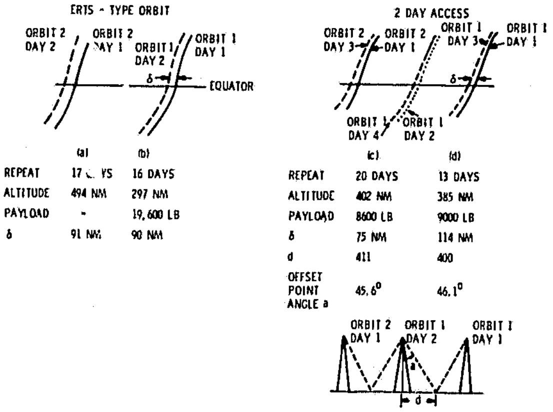


Figure 8.1-7. Geometry of Solar Declination at a Point on the Earth

By using an instrument with an off-nadir pointing capability equal to one-half the distance between adjacent orbits or two successive days, any given point on the earth can be observed every other day. This is illustrated in Figure 8.1-8. On the left of the figure is the familiar ERTS-type orbit with a westwardly daily progression and a between-orbit spacing of approximately 90 nautical miles. This pattern exists at both 494 and 297 nautical mile altitudes with repeat cycles of 17 and 16 days, respectively. Note that the Shuttle has zero payload capability at the higher altitude.

By contrast, the orbit on the right of the figure is a "2 day access" where the ground trace pattern is "interleaved" (interleaved means the orbits do not progress uniformly in one direction (westerly as on ERTS) but interleave in a regular pattern which provides the reduced access time). The two-day access pattern shown has the orbits on any given day located approximately midway between the orbits on the previous day.



	(a)	(b)
REPEAT	17 DAYS	16 DAYS
ALTITUDE	494 NM	297 NM
PAYLOAD	-	19,600 LB
δ	91 NM	90 NM

	(c)	(d)
REPEAT	20 DAYS	13 DAYS
ALTITUDE	402 NM	385 NM
PAYLOAD	8600 LB	9000 LB
δ	75 NM	114 NM
d	411	400
OFFSET POINT ANGLE a	45.6°	46.1°

Figure 8.1-8. Shuttle Compatible Orbits, Launch of Automated ER Spacecraft

By using an instrument with an off-nadir pointing capability equal to one half the distance between adjacent orbits or two successive days (d), any given point on the earth can be observed every other day. The two-day access pattern occurs with orbit altitudes of 402 and 385 nautical miles with 20-day and 13-day repeat cycles respectively. Shuttle payload capability ranges between 8600 and 9000 pounds at these altitudes.

8.1.7 GEOSYNCHRONOUS ORBIT

(Provides continuous coverage of a portion of the globe up to a given latitude determined by mission acceptability obliquity angles.)

In addition to the geosynchronous stationary 24-hour orbit (where the angle of inclination is equal to 0) whereby the satellite sits over a specific point of longitude on the earth's equator, there are a number of other options that may be considered which involve variations in (1) inclination of the orbital plane; (2) eccentricity of the orbit; and (3) the argument of perigee for the eccentric orbit (i.e., "ascending node" the location of the perigee point with respect to the equator crossing, Figure 8.1-9). The use of inclined orbit appears to have some potential attraction so that one may reach higher latitudes for nadir or near-nadir viewing. The employment of concentric orbits seems to offer some potential attractiveness in terms of providing lower altitude, and hence higher spatial resolution, coverage for a certain area and for certain times of the day.

Some examples are shown in Figure 8.1-10 for three different inclination angles in a circular 24 hour orbit, Figure 8.1-11 for two different inclination angles in an eliptical orbit and Figure 8.1-12 for a single inclination angle in an eliptical orbit with an argument of perigee angle of -30°.

With an argument of perigee of -90° and an eccentricity in excess of 0.1, the "figure 8" effect tends to be wiped out as seen in Figure 8.1-13.

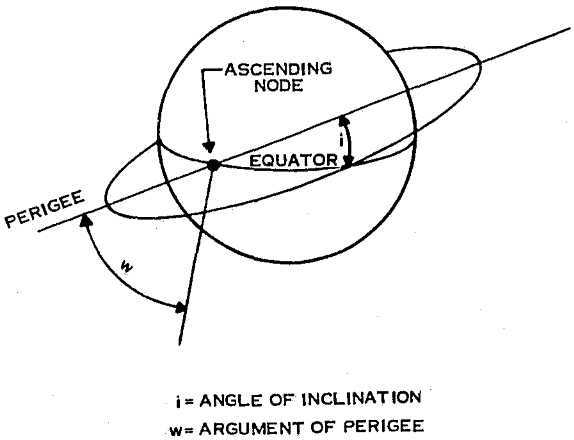


Figure 8.1-9. Orbit Geometry

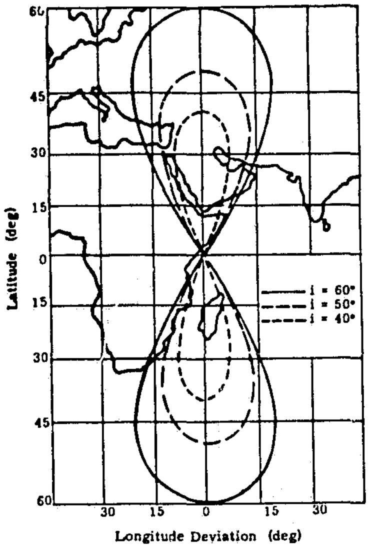


Figure 8.1-10. Ground Track of Circular 24-Hr. Orbits

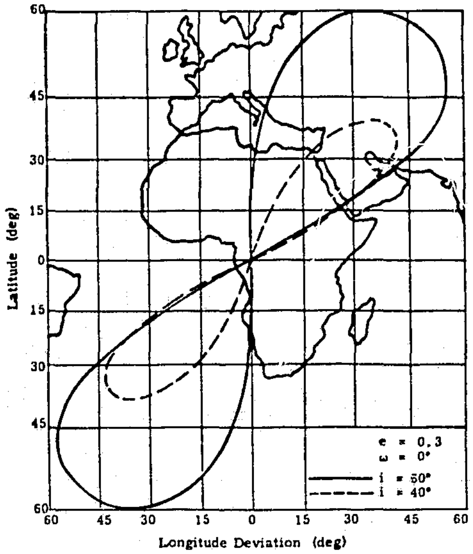


Figure 8.1-11. Ground Tracks of Elliptical 24-Hr. Orbits with Eccentricity and Inclination

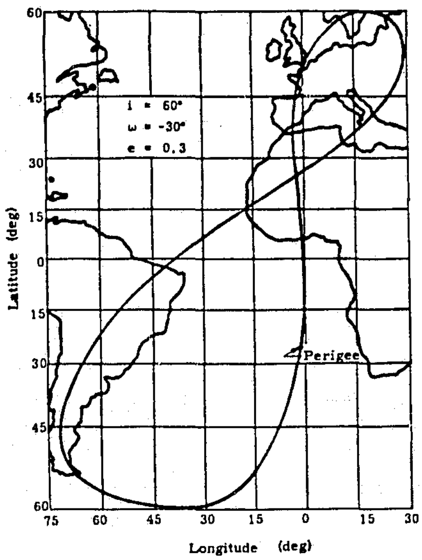


Figure 8.1-12. Ground Track on an Elliptical 24-Hr. Orbit with Eccentricity and Argument of Perigee and Inclination

There is a considerable price to be paid for both inclination and eccentricity. In case of inclination, one is faced with the regression of the nodes effect due to the earth equitorial bulge. This may be in the order of 5° a year. The price of eccentricity is a precession of the perigee at a rate which may be of the order of 15° a year. At an orbital inclination of 63.4° provides zero progression of perigee and may be a desirable configuration, if eccentricity seems to be worth it.

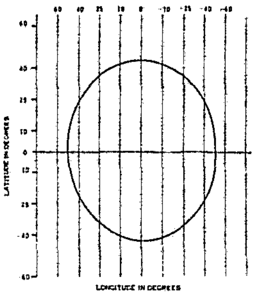


Figure 8.1-13. Ground Trace for High Eccentricity Orbit (0.5) with 45° Inclination and Argument of Perigee - 90° .

8.1.8 PLATFORM ACCESS TIMES

The two types of orbits primarily considered for long life Earth Resources missions are geosynchronous and sun-synchronous. The relationship between latitude and access time for these two orbit types is shown in Figure 8.1-14.

Sun-synchronous near-polar orbits provide access times ranging anywhere from one day to several weeks depending on latitude and field of view of the sensors. The "interleaving" of orbits with off-nadir sensor pointing capability can improve the access time at any point on the globe at the cost of observing at oblique angles.

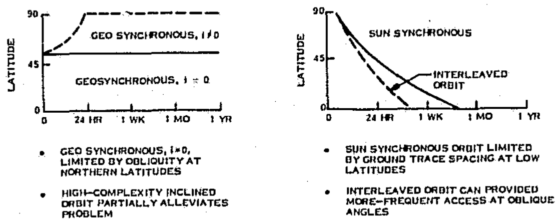


Figure 8.1-14. Platform Access Times

8.1.9 SHUTTLE COMPATIBLE ORBITS

The launch of automated low altitude ER spacecraft from a Space Shuttle requires special consideration. Some general constraints have been established which bound the range of useful orbits for low altitude Earth Resources spacecraft. The minimum altitude is limited by drag/orbit maintenance considerations; the maximum altitude by both sensor field of view/resolution and shuttle payload launch consideration. The constraints imposed on Shuttle launched automated spacecraft include:

- Most orbits are sun-synchronous - nearly all missions have visible/near IR sensors
- Minimum altitude: 300 nm - at lower altitudes drag requires numerous orbit adjustments
- Maximum altitude: 500 nm - shuttle direct payload delivery goes to zero at 500 nm. Initially consider direct placement only.
- Repeat cycles less than 20 days - strong user preference

There is a whole family of repeatable orbits between 300 and 500 nautical miles which are Shuttle compatible for the launch of ER spacecraft. Access patterns of 2, 3, 4 days are possible with offset pointing with the off-nadir distance decreasing as the access time increases. Reduced access time provides an alternative to multiple polar or synchronous satellites for the delivery of timely data which cannot now be fulfilled by the ERTS-type orbit. It is a realistic potential EOS and post-EOS operational capability.

8.1.10 SPECIAL PURPOSE ORBIT

Special orbits present special observation opportunities for Earth Observation experiments. During the course of this study, a quick look analysis was performed on the 12 hour elliptical orbit. This orbit (refer to Figure 8.1-15) would have an apogee of approximately 21,000 nm and a perigee of approximately 400-500 nm at inclination on the order of 60°.

The results of this analysis are presented below in the advantages and disadvantages of such an orbit.

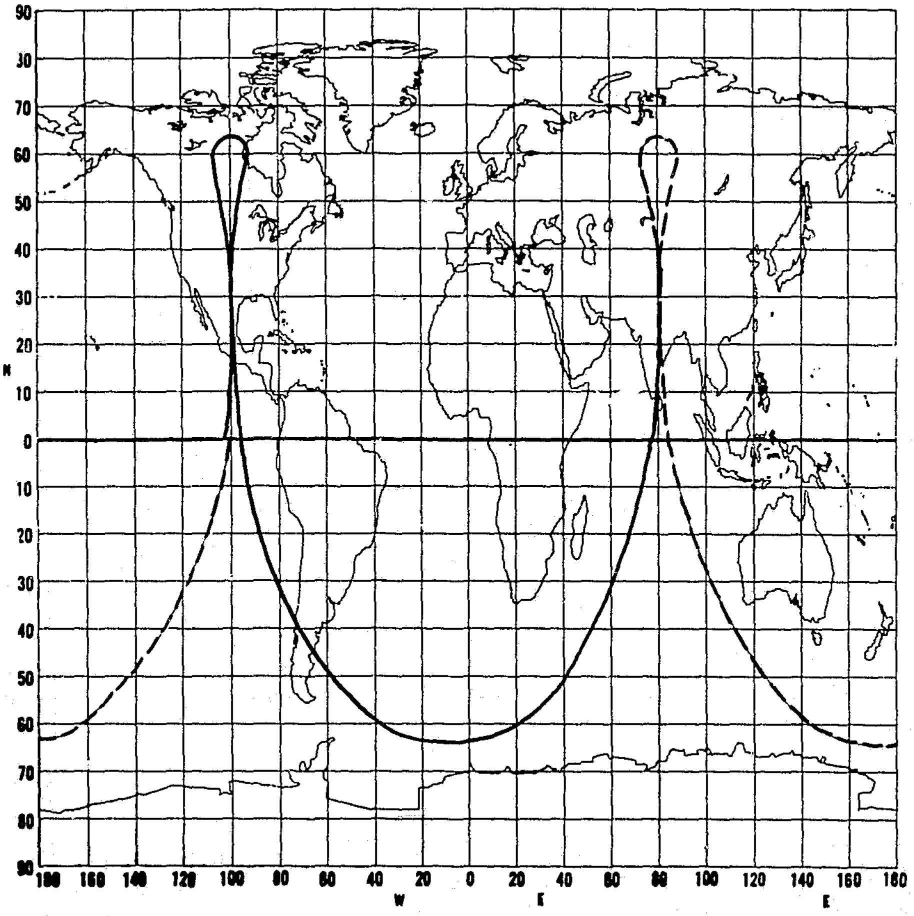


Figure 8.1-15. Ground Track of 12-Hr. Elliptical Orbit

Advantages

- Provides continuous daylight coverage over the same designated area
- Provides a capability for a ground station to receive real time data
- Provides data at a family of sun elevation angles
- Minimizes the effects of cloud cover
- Provides data at various look angles
- Provides a capability for concentrating on a specific large area
- Repeat cycles of approximately 1/week depending on precession rate
- Long duration mission

Disadvantages

- Loss in sensor resolution

8.2 CLOUD COVER CONSTRAINTS

Remote sensing by satellite has made great strides in technical capabilities since the early days of the satellite era. Yet despite these strides, the problem of cloud cover has continued to impede the utilization of satellite data in the burgeoning number of earth resources applications.

By reducing or eliminating visibility on a stochastic basis, cloud cover makes the performance of any non-earth stationary viewing system uncertain. Where reliable availability of data is of paramount importance, cloud cover can be fatal to an application.

The current problems with cloud obscuration can be expected to be alleviated to some degree in the future by two approaches. The first of these is simply shorter coverage cycles; repeating an orbit more frequently provides a greater number of possible observations opportunities. This will increase the probability of securing cloud free images. The second approach is the advent of pointable sensors (perhaps in conjunction with shorter repeat cycles). Those sensors are capable of being pointed, off-nadir, in order to take advantage of cloud-free opportunities such as holes or intermittent cloud coverage. These factors, in conjunction with better cloud cover predictability, and/or real time interactive cloud cover sensors, will provide some relief by the TERSSE era.

The data shown in Figures 8.2-1 through 8.2-3 exhibit the historical seasonal variation of cloud cover as a function of month-of-the-year for various areas of the world. These data were extracted from the "Global Atlas of Relative Cloud Cover (1967-1970)" and present the mean cloud cover for an afternoon (1400 to 1600 hours) local

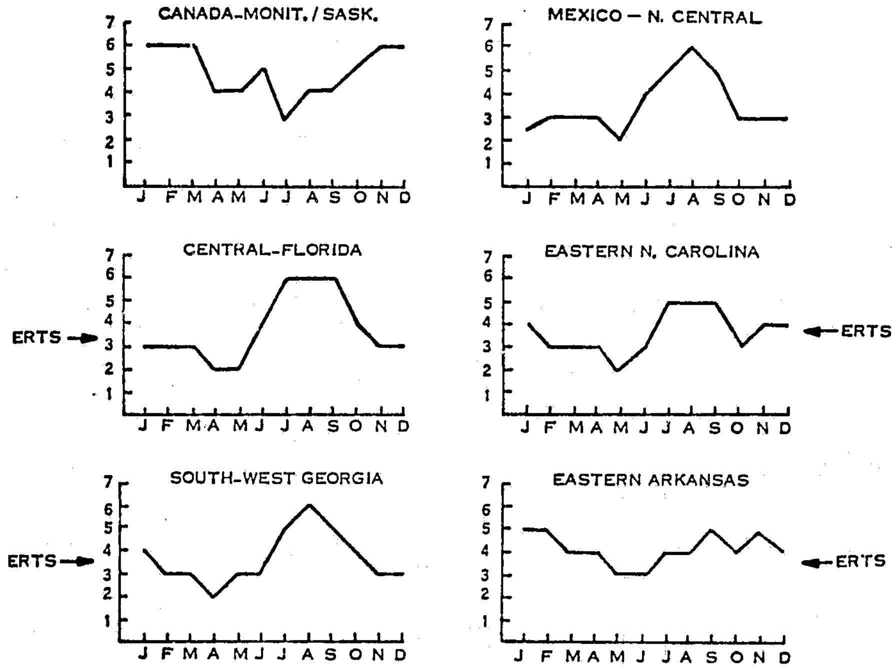


Figure 8.2-1. Mean Cloud Cover in Eighths vs. Month of Year

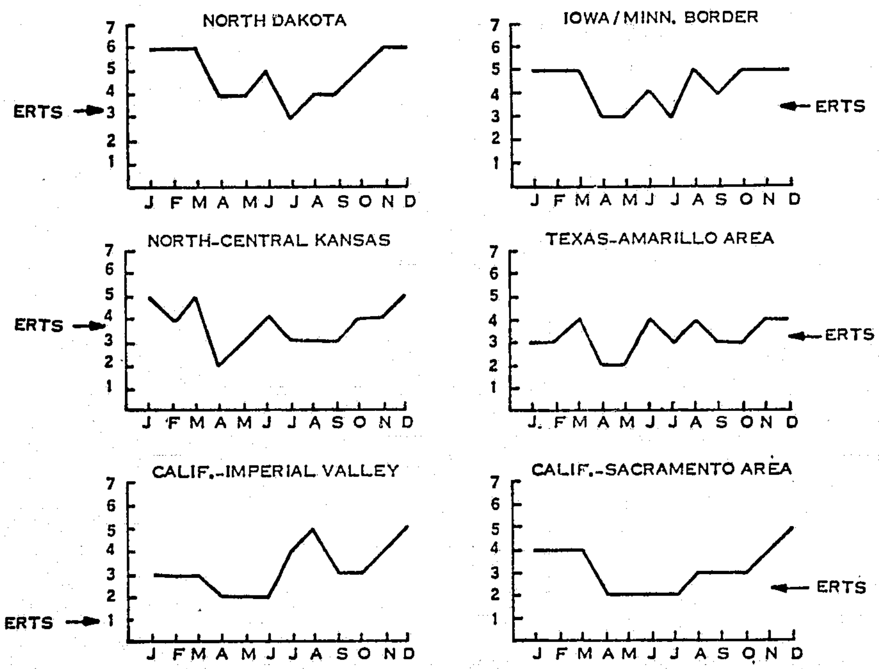


Figure 8.2-2. Mean Cloud Cover in Eighths vs. Month of Year

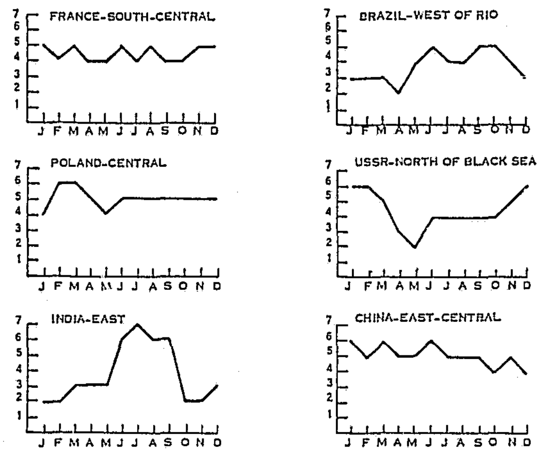


Figure 8.2-3. Mean Cloud Cover in Eights vs. Month of Year

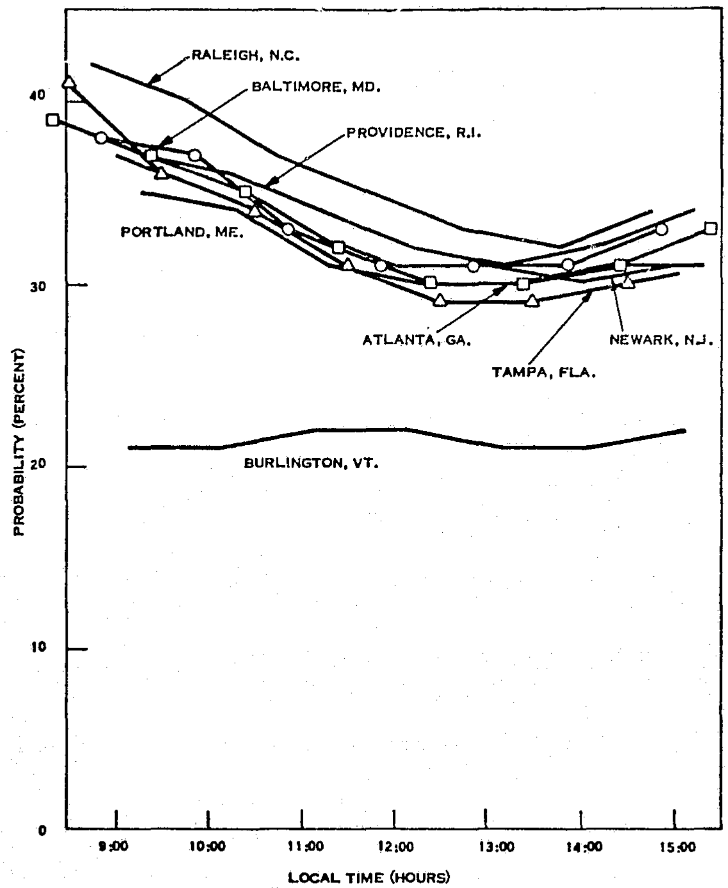


Figure 8.2-4. Probability of <30% Cloud Cover - Eastern Seaboard

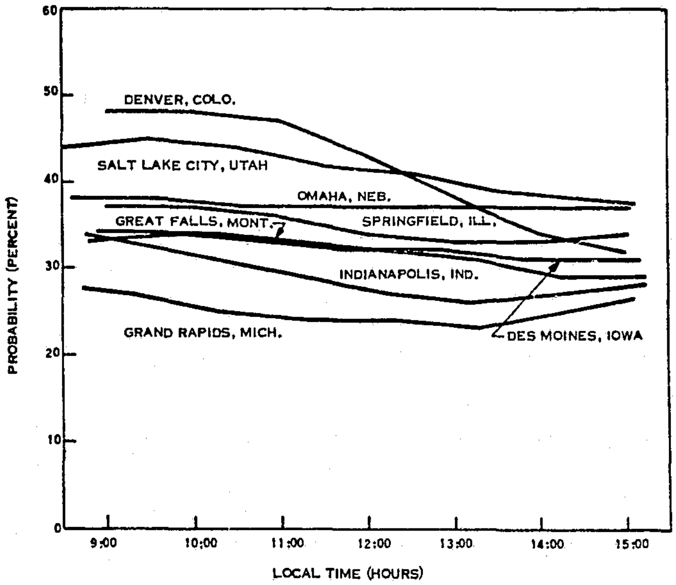


Figure 8.2-5. Probability of 30% Cloud Cover - North Central

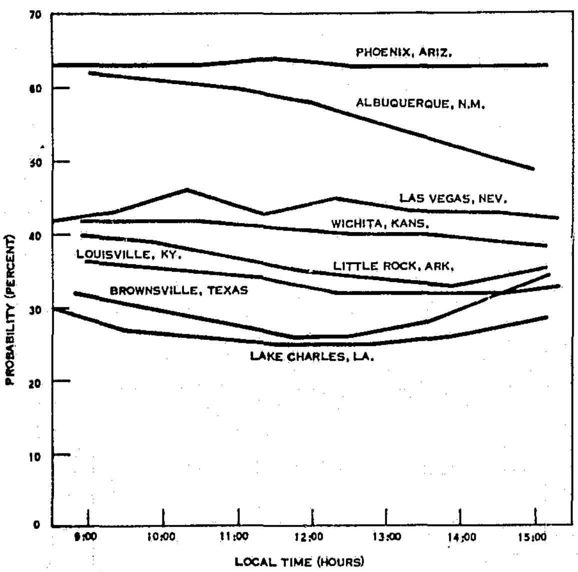


Figure 8.2-6. Probability of 30% Cloud Cover - South Central

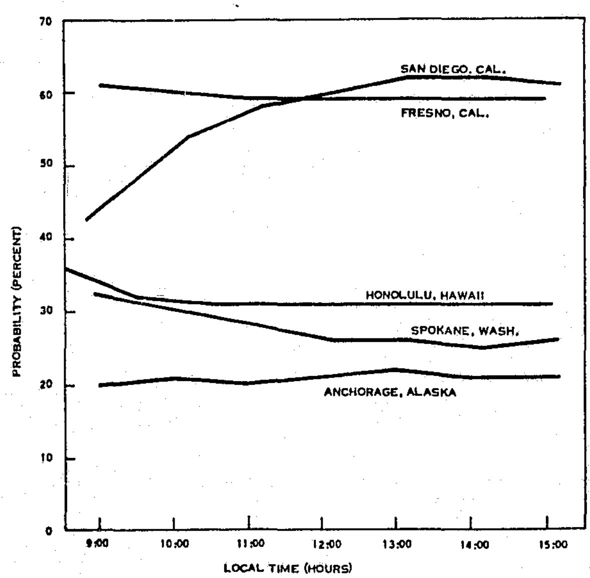


Figure 8.2-7. Probability of 30% Cloud Cover - Western Seaboard

time-of-day. On the United States curves the overall average experienced by ERTS for a shorter time interval (approximately one year) and different (0900 hours) local time-of-day is indicated for comparison. The variation of cloud cover with time-of-day can be seen in Figures 8.2-4 through 8.2-7, which represent long time (5-10 years) averages for 29 locations throughout the U.S.

When viewing this cloud cover data it must be borne in mind that this represents the mean fraction (in eights) of cloud cover for an area and is not necessarily equivalent to the mean fraction of cloud free (or totally cloudy) days. This relationship involves a more detailed investigation of the actual distribution of cloud cover. One clear day and one totally cloudy day are not the same as two days each with 50% cloud cover.

8.3 RESOLUTION

The question of spatial resolution and sensor instantaneous field-of-view, IFOV, is a constantly recurring one for remote sensing in general and remote sensing for ERS in particular. This section contains a brief discussion of some of the general trends as appropriate for TERSSE.

The usefulness or utility of better spatial resolution is generically depicted in Figure 8.3-1.

This figure indicates that there are quantum levels of utility corresponding to better resolution (smaller pixel size). The utility (benefit) function is not a smoothly increasing one but rather is a function of the parameter being viewed. For example, when considering housing there is a utility associated with being able to identify/distinguish suburbs, one with particular developments within a suburb, and one with particular houses within a development. There is no significant utility associated with intermediate levels of identification. Similarly, agriculture has a set of utility quantums; those being agriculture areas, individual fields, and individual plants/trees/rows. Each discipline may have its own set of quantum levels corresponding to different resolutions; but these will be discrete levels or "knees" in the utility curve.

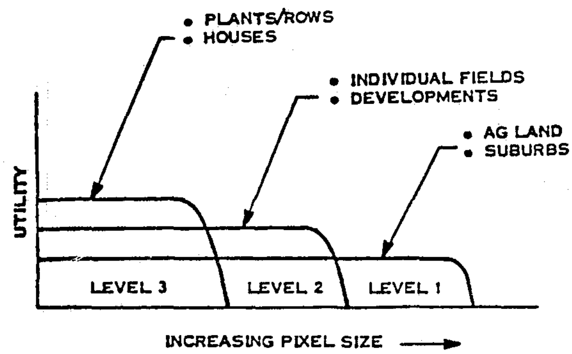


Figure 8.3-1. Utility of Spatial Resolution

Now to consider the cost of obtaining increases in spatial resolution, refer to Figure 8.3-2.

Although the actual real world curve is not a smooth one as shown in the figure, it has discontinuities corresponding to different sensor types, the point is still valid. Better resolution is not free, there is a definite higher cost associated with achieving higher spatial resolution.

When the previous two trends are combined to yield a utility per cost curve, as shown in Figure 8.3-3, some interesting conclusions become evident. The utility per cost function (bang per buck) is not a smooth montonoicly increasing function at all. Rather, there are unique peaks of "efficiency." The exact location, height, and spacing of these peaks varies according to the different disciplines. The point, however, remains, that significant changes in resolution are required to move from one peak to the next. Further, when cost is included as in the previous figure, it may not be desirable to move to the next peak. In the case illustrated, higher resolution did have higher utility (and a higher cost) but the "efficiency" curve of utility/cost had all three peaks of equal height. Significant work remains for the ERS community to better define the various utility quantums and the resultant efficiency curves.

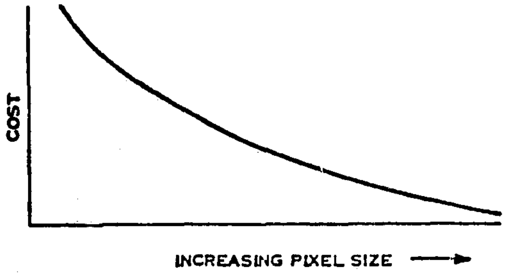
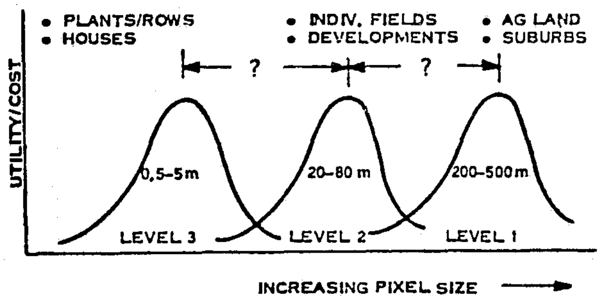


Figure 8.3-2. Generic Cost of Resolution

For example, consider the situation where remote sensing is used to determine the size of agricultural fields. (Refer to Figure 8.3-4.) The spectral signature of each pixel is classified and a decision as to whether or not that pixel is part of the field is made. The area of the field is then computed as the sum of the individual identified pixels.



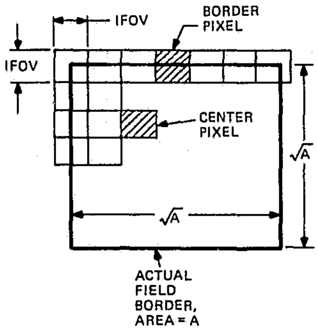
• PEAK LOCATIONS VARY BY DISCIPLINE, BY REGION
• SIGNIFICANT UTILITY ACHIEVED ONLY NEAR PEAKS
• MAJOR INCREASE/DECREASE IN RESOLUTION REQUIRED TO REACH ADJACENT PEAK

Figure 8.3-3. Utility/Cost Versus Resolution

Assuming that the center pixels, those wholly within the field, are correctly identified, the source of field size error is then attributable to the border pixels. The figure, (Figure 8.3-4,) contains the relationships of estimated field size to actual, for square fields, depending on the treatment of border pixels.

If the errors in estimated field sizes for individual fields are independent and have a zero mean, then the expected error of the aggregate is relatively small. Referring to Figure 8.3-5, the sum of four smaller areas is used to determine the single larger area. If each of the small fields has an error (random) of 1σ then when these are combined the error of the total will be 2σ (random independent errors add as the sum of the variances - not as the sum of the individual errors). The implication is significant - the total acreage error is not primarily a function of field size but of the total acreage measured.

This issue of resolution (pixel size) as related to agricultural acreage determination is summed up by Figure 8.3-6. These curves express the error (measured area/actual area) as a function of the number of pixels in the area for the three border pixel treatments discussed earlier. For example, if 80 meter pixels (IFOV) are used to



- MAX. HIGH ERROR (ALL BORDER PIXELS CLASSIFIED "YES"):

$$\frac{\text{MEASURED AREA}}{\text{ACTUAL AREA}} = 1 + \frac{IFOV^2}{A} + \frac{2 IFOV}{\sqrt{A}}$$

- MAX. LOW ERROR (ALL BORDER PIXELS CLASSIFIED "NO"):

$$\frac{\text{MEASURED AREA}}{\text{ACTUAL AREA}} = 1 + \frac{IFOV^2}{A} - \frac{2 IFOV}{\sqrt{A}}$$

- NOMINAL ERROR (HALF BORDER PIXELS CLASSIFIED "YES"):

$$\frac{\text{MEASURED AREA}}{\text{ACTUAL AREA}} = 1 + \frac{IFOV^2}{A}$$

$$\text{ABSOLUTE ERROR} = IFOV^2 + \begin{cases} +2\, IFOV \sqrt{A} & \text{(MAX HIGH ERROR)} \\ +0 & \text{(NOMINAL ERROR)} \\ -2\, IFOV \sqrt{A} & \text{(MAX LOW ERROR)} \end{cases}$$

THEREFORE ERROR IS PROPORTIONAL TO $\sqrt{A}$

Figure 8.3-4. Measurement Error and Border Pixels

ERROR PER FIELD = σ_A

TOTAL ERROR = $\sqrt{4\sigma_A^2} = 2\sigma_A$

ERROR = σ_B

AREA B = 4 AREA A

ASSUME MAX HIGH ERROR

EACH $\sigma_A = IFOV^2 + 2\,(IFOV)\sqrt{A}$

TOTAL ERROR $= 2\,(IFOV^2 + 2\,(IFOV)\sqrt{A})$

$= 2\, IFOV^2 + 4(IFOV)\sqrt{A}$

$\sigma_B = IFOV^2 + 2(IFOV)\sqrt{B}$

AND $\sqrt{B} = 2\sqrt{A}$

$\sigma_B = IFOV^2 + 2(IFOV)\,(2\sqrt{A})$

$= IFOV^2 + 4(IFOV)\sqrt{A}$

$\sigma_B = \text{TOTAL}\,\sigma_A + IFOV^2$

$\sigma_B = \text{TOTAL}\,\sigma_A$ (FOR ALL PRACTICAL PURPOSES)

- (MEASURED AREA) – (ACTUAL AREA) $\propto \sqrt{A}$

THE TOTAL ACREAGE ERROR IS NOT A FUNCTION OF FIELD SIZE BUT OF THE TOTAL ACREAGE MEASURED

Figure 8.3-5. Large Area Measurements

measure an 8 hectare (20 acres) field, the field estimate could be as high as 175% or as low as 48% of the actual field size. On the other hand, if the 80 meter pixels are used to estimate a 256 hectare area (either all at once or as the sum of many small fields), the estimate will be between 106% and 97% of actual. Thus, the resolution required is a function of the total area of concern for the problem.

8.4 AIRCRAFT VS. SATELLITES AS ERS PLATFORMS

8.4.1 BASIC COMPARISON OF AIRCRAFT AND SATELLITE

The general usefulness of both aircraft and satellites for performing remote sensing has been demonstrated by years of experience. Aircraft have been employed heavily in many types of mapping surveys and are responsible for the vast majority of the raw data which produces the maps in use throughout the world today. Satellites have been in

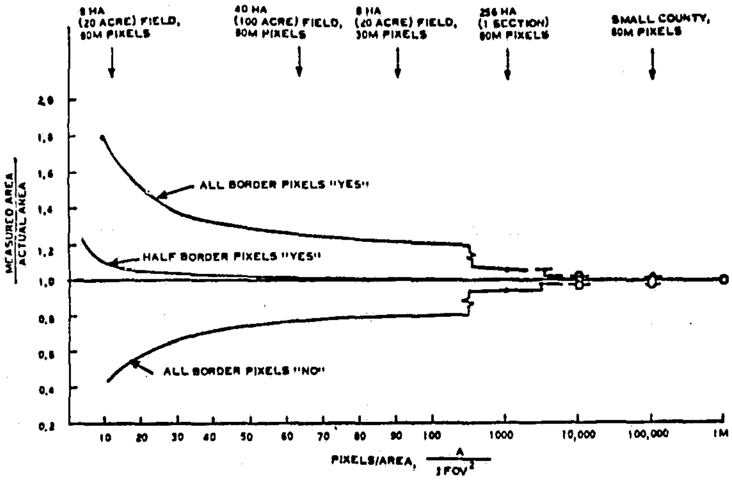


Figure 8.3-6. Area Measurement Error

operational use for several years performing meteorological remote sensing in the form of cloud cover images, both from low altitude and geostationary orbits. Both of these uses have created prototype platforms and techniques useful for the present requirements of global earth surveys; however, the specific requirements of the global system make thorough examination of the inherent and the controllable characteristics of both platforms necessary.

The literature provides an animated, if incomplete, debate on the relative merit of aircraft and satellites in the role of earth resource survey. Katz* claims for aircraft a superior product obtained more economically and with more flexibility and political safety. Doyle and Moeckel** claim for spacecraft a superior product obtained more economically, and identify the global reach of the satellite as dominating. What is lacking in the literature is a comparison of the two platforms on any sort of common basis which includes the total extent of the range of information requirements which will exist for future operational systems. A basic comparison of the two carriers follows as the first step in such a process.

*Katz, Amrom H., "Let Aircraft Make Earth Resource Surveys," Astronautics and Aeronautics, Vol. 7 No. 6, p. 60, June 1969.

**Moeckel, Wolfgang, and Katz, Amrom, "A Mild Confrontation Over, 'Let Aircraft Make Earth Resource Surveys,' "Astronautics and Aeronautics, Vol. 7, No. 8, p. 89, August 1969.

**Doyle, Fred J., and Katz, Amrom, "Further Confrontation over 'Let Aircraft Make Earth Resource Surveys,' "Astronautics and Aeronautics, Vol. 7, No. 10, p. 78, October 1969.

Carrier Vehicle Function

The function to be performed by the carrier vehicle is that of

- transporting and positioning the sensor package;
- at the proper points in 3-D space above the surface of the glove which are dictated by target and sensor requirements;
- at the proper times;
- while providing the housekeeping and communications functions necessary for sensor package operation.

The aircraft and satellites as carrier vehicles will be compared in their ability to perform the above transportation function.

8.4.2 COMMON OR NORMALIZED TRANSPORTATION CHARACTERISTICS

Both satellite and aircraft are non-stationary platforms which can carry sensors from place to place at constant or variable altitudes in a controlled or predictable fashion. Both can be equipped to provide the electrical power, attitude control, thermal control, and data processing capability required to support sensor payloads of a few hundred to a few thousand pounds. Although the sensor configurations may not be identical (e.g., longer focal length optics for satellites), both can be considered as sensor carrying platforms which produce equivalent data meeting the requirements of the target variables.*

8.4.3 TRANSPORTATION CHARACTERISTICS OF THE SATELLITE

The satellite, as a result of its altitude of hundreds of km and its orbital velocity of many km/sec., has an extremely high area coverage rate per vehicle (e.g., for an altitude of 500 km, and a field of view of $\pm 45^{\circ}$, the area coverage rate is on the order of 10^4 km^2/sec.).

High coverage rate is useful in several ways: it permits imaging of large areas with a small number of satellites and it permits obtaining images of target areas separated by great distance (in the direction of flight) within a short time.

*This is not to say that current data from aircraft and satellites is equivalent or even similar; what is intended is that a meaningful comparison can be made of the two carriers only if their outputs can be compared in terms of system requirements.

The high altitude of the satellite is advantageous in a second way - it permits the capture of a large area in a single image, preserving tonal and textural correlation across the entire area. A mosaic of the same area made up of smaller images would possess tonal and textural decorrelation of varying degrees, sometimes debilitating. ** The satellite is inherently on station continuously; its duty cycle is interrupted only by the overflight of uninteresting terrain, the limitations of data storage or transmission capacity, or the mechanics of its orbit.

The satellite is often considered to be capable of only modest spatial resolutions, on the order of 10 to 50 meters. If the additional costs of large optics, image-motion compensation, and attitude control complexity are borne, however, the low orbit satellite is, on paper, capable of considerably better spatial resolution performance.

A limitation of the satellite, because of its extreme distance from the target, is that of pointing accuracy. For high resolution targets ($\sim$2m) the sensor field-of-view will be only a few to 10 km wide; total pointing vector errors on the order of 0.001 radian are thus required to insure that the target area is enclosed in the sensor field-of-view. Nominal satellite attitude control systems are not this good, but closed-loop control of the sensor line of sight (LOS) via several means can provide the capability at the expense of additional complexity. Three means of closing the loop are: (1) a human observer in the satellite controlling the sensor LOS; (2) an automatic map-matcher in the satellite; and (3) a human observer on the ground using a TV display of the sensor image and controlling the sensor LOS.

Another limitation of the satellite which is inherent in its altitude is the obscuration of desired data by clouds. This limitation may be attacked, with partial success, by (1) using active and passive microwave sensors which are not affected markedly by cloud cover; (2) using a manned observer in the satellite to point the sensors between the clouds, thus capturing some of the desired data under some types of cloud conditions (e.g., sub-tropical scattered cumulus). The only general solution to the cloud cover problem, however, is repeated overflights which image the unobscured portions of the target and finally accumulate the total amount of desired data. It is worth noting that significant resource target areas require upwards of ten overflights to achieve 80% coverage (with P = .95) during some seasons of the year. *

*Cooley, J. L., "Sensor Lighting Considerations for Earth Observatory Satellite Missions," NASA TM X-551-72-202, June 1972.

**Jaffe, Leonard and Summers, Robert A., "The Earth Resources Survey Program Jells," Astronautics and Aeronautics, Vol. 9, No. 4, p. 24, April 1971.

A final characteristic of the satellite, inherent to its being in orbit about the earth, is the fixed nature of its flight path once launched. Small in-plane adjustments to the orbit may be made without excessive fuel weight penalty, and indeed, any long-lived low altitude satellite will need a small amount of thrust applied along its velocity vector to offset the energy lost to atmospheric drag and other perturbations. But large changes to the flight path, particularly out-of-plane, consume major portions of the satellite's total weight* and are out of the question in a practical system. Access to areas on the earth's surface is, instead, pre-programmed by careful selection of the orbital parameters of the satellite.

8.4.4 TRANSPORTATION CHARACTERISTICS OF THE AIRCRAFT

The aircraft, as a result of its human crew and controllability, possesses the ability to vary its path with ease and almost unlimited flexibility. Its position in 3-dimensional space and time is limited only by its range, maximum altitude capability, and speed envelope. And crew vision, either aided or unaided, may be employed in a search for an uncertainly located target, guiding the aircraft over the target after it is identified.

Its area coverage rate, limited practically to a subsonic speed (over land) and an altitude of 20 km, is relatively low - on the order of 40 km^2/sec. And target areas larger than a few tens of km in width will require the use of multiple images prepared in mosaics for full coverage.

High altitude jet aircraft (as opposed to low altitude, piston powered aircraft) are necessary to achieve the economies of higher area coverage rate and the usefulness of high altitude. But these aircraft are impeded by the obscuration caused by clouds almost as much as the satellite, as nearly all cloud cover of significance lies below an altitude of 20 km.

The techniques for attacking the cloud cover problem are (1) to fly repeated passes, using real-time cloud information to maximize the amount of data obtained per pass**; (2) to fly under the clouds and accept the inefficiencies of low altitude; (3) to point the sensors at open areas between the clouds when such opportunities exist (as with the satellite); and (4) to use active and passive microwave sensors.

Another characteristic of the aircraft is that it requires the consumption of fuel and human energy to remain airborne and thus its mission time will be limited to periods of hours, instead of days or years. This characteristic manifests itself in the constraining of the single aircraft to a more regional, as opposed to a global, operation as it cannot (as can the satellite) "follow the sun" indefinitely, and the flexibility which characterizes the aircraft is dimished as it ranges further from a suitable base.

*One 90^o plane change would require a fuel weight on the order of 50% of the total vehicle weight.

**This is an important advantage over the satellite if a staging base is located near to the area to be imaged, as the response time of the aircraft to a clearing of the skies would be short. On the other hand, NASA Earth Resources aircraft spend a signficant amount of time at forward bases waiting for good weather.

8.5 COVERAGE CYCLE

The determination of the proper coverage cycle (orbit repeat interval) involves the consideration and simultaneous juggling of several factors. If a user required updated information once a month, and if all the required information could be assuredly obtained with a single observation, then the coverage cycle would also be one month. In practice this represents the outside limit on the coverage cycle and the actual cycle required is more frequent. Figure 8.5-1 is a representation of the four factors which must be considered simultaneously in order to arrive at a proper coverage cycle. The four factors are (1) phenomenological rhythms; (2) bureaucratic rhythms; (3) Keplerian rhythms; and (4) cloud cover.

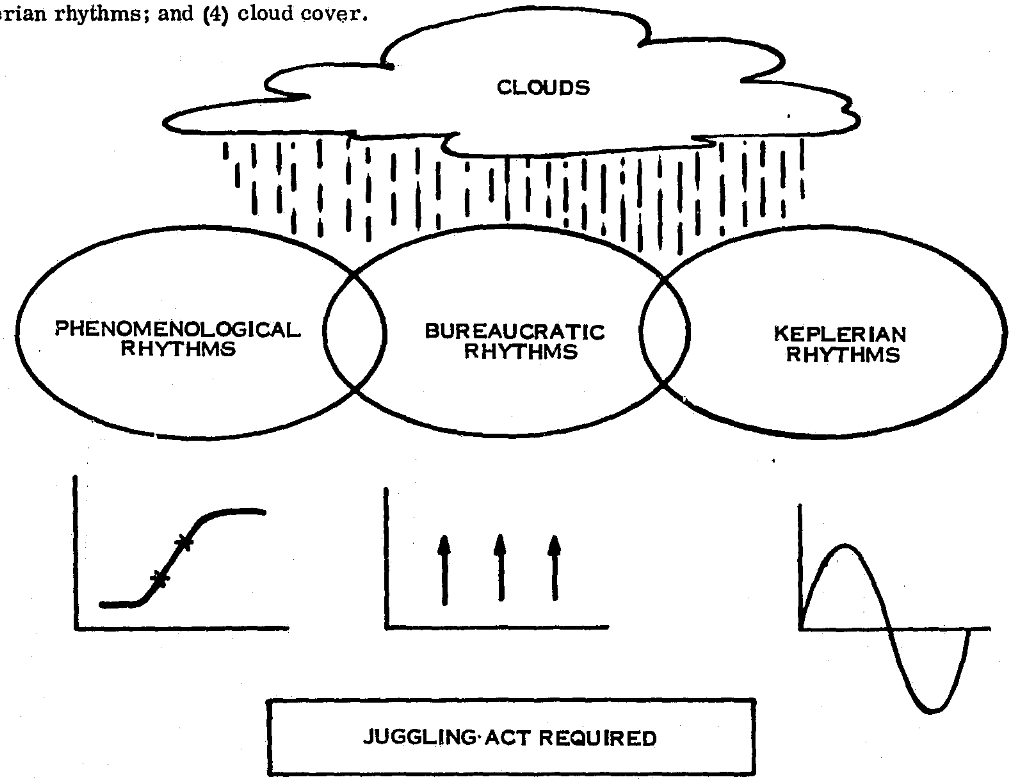


Figure 8.5-1. Coverage Cycle-Rhythm Method

The "phenomenological rhythms" refers to the basic timing and time patterns of the subject about which information is to be obtained. For instance, with agriculture, it is the growth and development characteristics of plants as a function of time that are useful in the identification of individual crops, their vigor and the nature of the various stresses to which they are subjected. It is through the observation of the rate and nature of these biological changes that it appears to be possible to provide useful crop surveys via remote sensing. It is the timing or sampling rate dictated by these fundamental characteristics of the basic phenomena that are referred to as phenomenological rhythms.

For example, Figure 8.5-2 shows how theoretically the green leaf area index for wheat might vary as a function of the productivity of two different wheat fields. Measurement of the slopes of these curves through multiple, time spaced samples, could be used to estimate the expected yield of these fields. It is clear that several measurements a week or two apart will be necessary.

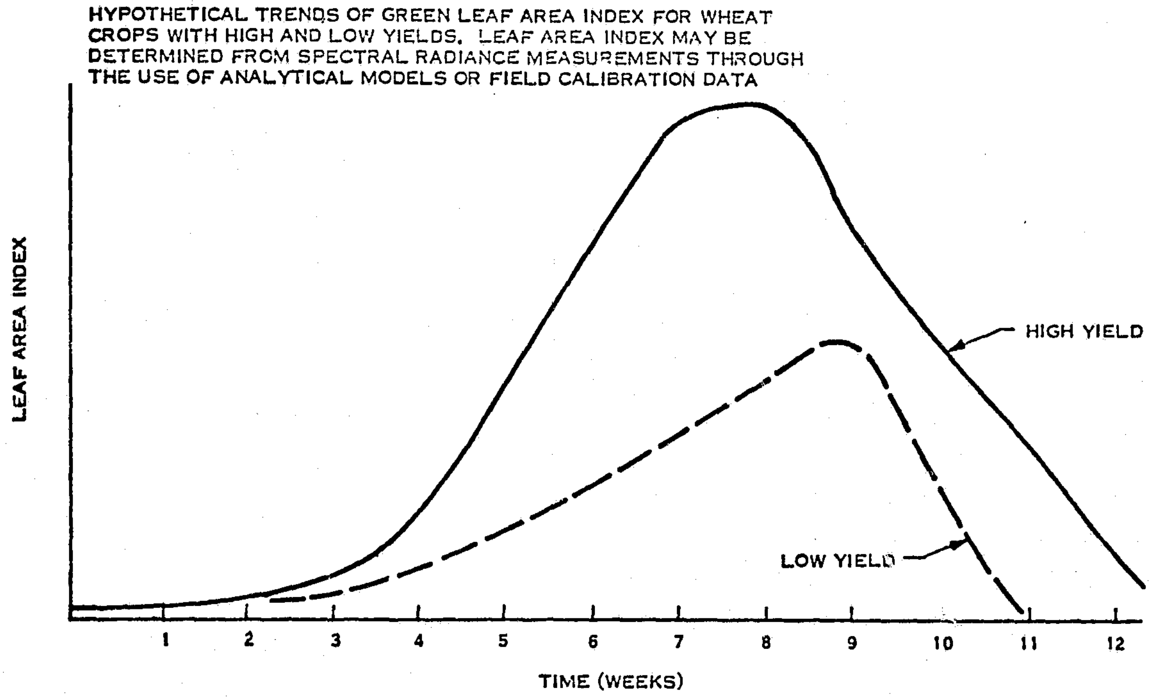


Figure 8.5-2. Phenomenological Rhythms

The "bureaucratic rhythms" refers to the timing of the information requirements, the information update cycle. Many users of Earth Resources information (especially government agencies) are required to produce reports (resource management information) on a regular repeated calendar basis (e.g., weekly, monthly, quarterly, etc.). This is demonstrated by Figure 8.5-3 which shows a histogram of the update cycle requirements of the major federal agencies. Note the large peaks at the monthly, quarterly, and yearly intervals.

The "Keplerian rhythms" refers to the basic orbital period of a satellite (or similar parameter for other platforms).

The orbital period of a satellite is related to its mean distance from the center of the earth. Furthermore, the width of the ground swath beneath the satellite that can be viewed with minimum degradation in resolution due to the curvature of the earth increases with increased altitude, although larger and larger optics are required with increasing altitude to maintain the desired resolution. Thus, there is a series of trade-offs that must be made

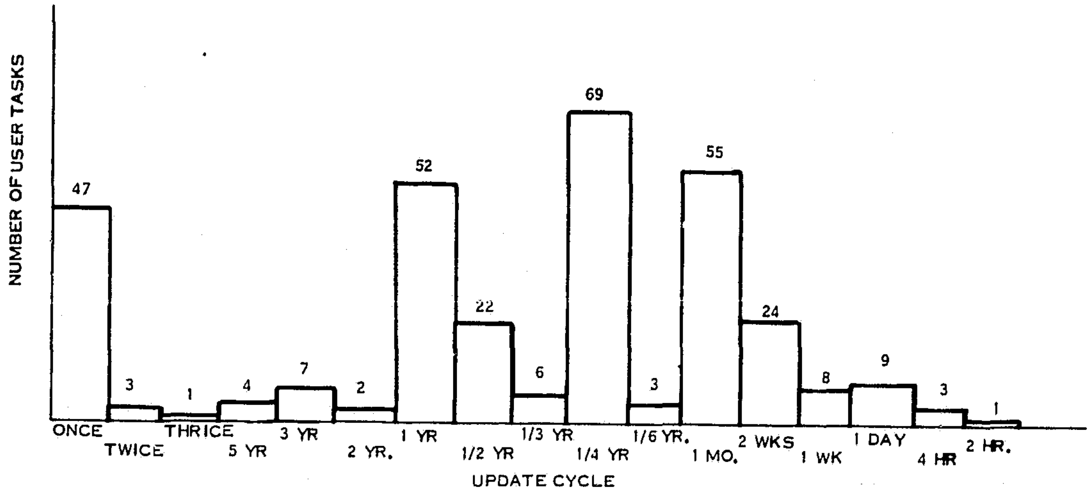


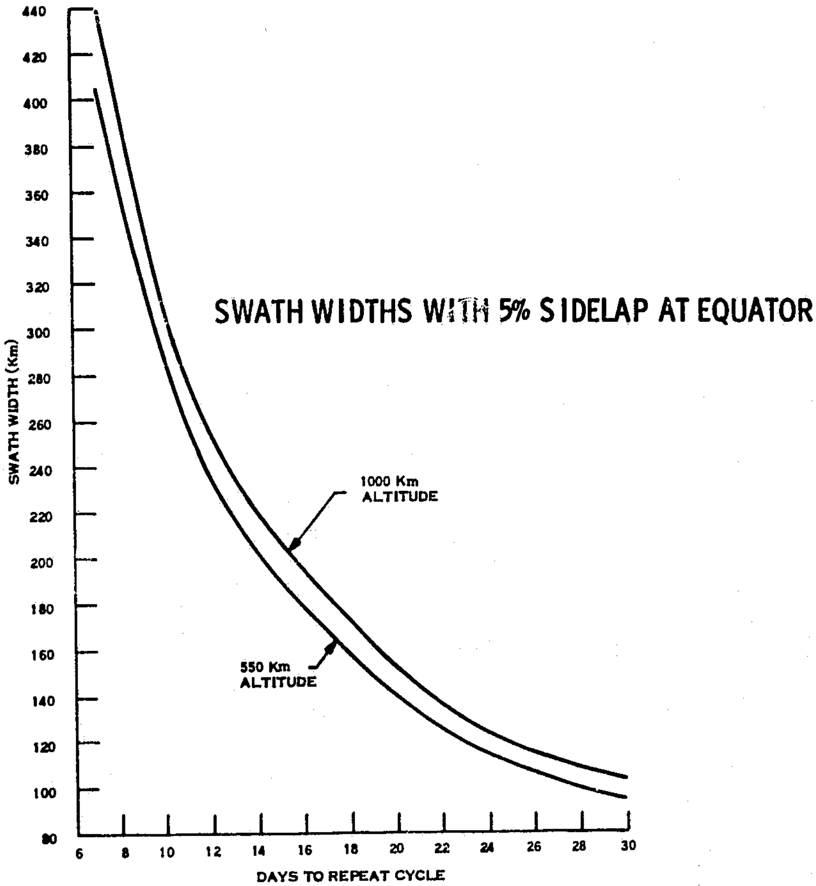
Figure 8.5-3. Update Cycle Bureaucratic Rhythms

between the width of the coverage swath used, spacecraft orbital altitude, size of the optics required for the sensors, the resulting size and weight of the sensors, and the frequency with which the same ground areas can be viewed from any given spacecraft. Figure 8.5-4 illustrates one of many trade-off curves needed, showing the relationship between swath width and coverage repetition period for satellites at 550 km or 1000 km. The point to be made here is that for specific values of coverage repetition frequency, there are very definite orbit mechanical constraints (refer to Section 8.1 for a brief discussion of orbital mechanics) that must be met.

Superimposed over all the other constraints for obtaining the desired coverage frequency is the problem of the earth's cloud cover. From the point of view of quoting the probability of seeing some point on the earth's surface during any season of the year, conventional cloud cover climatological data that have been collected for decades are somewhat misleading. First of all, as satellite imagery has shown, the earth's cloud cover is usually quite discontinuous; samples of sky cover as seen by an observer on the ground cannot be readily interpolated to areas between ground observation points. Furthermore, reports of certain fractions of the sky covered by clouds, usually quoted in octas, tell nothing of the spatial distribution of the clouds. For example, a sky cover of 3 octas could mean a few clouds are scattered over the entire field of view of the observer, or a solid bank of clouds is covering one "corner" of the sky.

Recently, development of a global cloud cover atlas* has been initiated jointly by NOAA and the USAF Air Weather Service based on four years of weather satellite. Full global data on average monthly, seasonal, semiannual and

*Global Atlas of Relative Cloud Cover, 1967-70, NOAA Dept. of Commerce and USAF Air Weather Service, Washington, D. C., Sept. 1971.



Relationship between coverage repetition period and swath width for satellites at 550 Km altitude or at 1000 Km altitude.

Figure 8.5-4. Swath Widths Vs. Repeat Cycle

annual cloud cover have been compiled for each approximately 40 x 40 km segment of the earth's surface. The major shortcomings of these initial compilations is the relatively short period of time so far compiled and the fact that the data are all for a local sun time of 1400-1600 hours. In areas of important diurnal cloud cover phenomena, e.g., equatorial Brazil or Southern California, this could place a noticeable bias in the data. Refer to Section 8.2 for a brief discussion of cloud cover.

APPENDIX A

USER'S MISSION AND SYSTEM REQUIREMENTS DATA

Due to the physical size of this appendix (300 pages) it has been seperately bound as:

Volume 8, User's Mission and System Requirements Data

APPENDIX B

RESULTS OF PLATFORM ASSIGNMENT (CASE 2)

The computer output contained in this appendix is that used for the assignment of missions to remote sensing platforms as discussed in Section 4.2 of this TERSSE report Volume.

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	NON-MICROWAVE ACC	MICROWAVE BNDS	ACC (K)	POL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 10 M COV CYCLE: ONE DAY DUR: 4-7 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4)	* E/M 5.5	1.0E+03	6	0	1	1	.40-.50 .50-.60 .60-.70 .70-.80 .80-.90 .90-1.0 8.0-14.	--- --- --- .5 K	X(P)	---	ANY	50	THERM RAD THERM RAD (MW) SPECTRAL SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 20 M COV CYCLE: ONE DAY DUR: 5,7,12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.SHUTTLE	* FOR 1.1 * FOR 1.2 * FOR 1.3 * FOR 1.4 * FOR 1.9	5.3E+04 5.3E+04 8.1E+04 3.0E+05 3.0E+05	4 4 4 4 4	2 2 2 2 2	1 1 1 1 1	2 2 2 2 2	.53-.58 .64-.69 .72-.76 .80-1.1 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- ---	X(A) L(A)	--- ---	30 30	50 50	SPECTRAL SIG SPATIAL SIG SCAT CROSS SEC
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M COV CYCLE: ONE DAY DUR: 5,7,12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.SHUTTLE	* FOR 1.1 * FOR 1.2 * FOR 1.3 * FOR 1.4 * FOR 1.9	1.0E+02 1.0E+02 1.0E+02 5.0E+02 5.0E+02	4 4 4 4 4	2 2 2 2 2	1 1 1 1 1	2 2 2 2 2	.53-.58 .64-.69 .72-.76 .80-1.1 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- ---	X(A) L(A)	--- ---	30 30	50 50	SPECTRAL SIG SPATIAL SIG SCAT CROSS SEC
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 20 M COV CYCLE: ONE DAY DUR: 5,7,12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4)	* FOR 1.5 * FOR 1.6 * FOR 1.7 * FOR 1.8 * FOR 1.10	1.0E+03 1.0E+03 3.0E+06 3.0E+06 1.0E+06	4 4 4 4 4	2 2 2 2 2	1 1 1 1 1	2 2 2 2 2	.53-.58 .64-.69 .72-.76 .80-1.1 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- ---	X(A) L(A)	--- ---	30 30	50 50	SPECTRAL SIG SPATIAL SIG SCAT CROSS SEC
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 5 M COV CYCLE: ONE DAY DUR: 5,7,12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.SHUTTLE (POLAR)	* FOR 1.5 * FOR 1.6 * FOR 1.7 * FOR 1.8 * FOR 1.10	1.0E+03 1.0E+03 3.0E+03 3.0E+03 1.0E+03	4 4 4 4 4	2 2 2 2 2	1 1 1 1 1	2 2 2 2 2	.53-.58 .64-.69 .72-.76 .80-1.1 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- ---	X(A) L(A)	--- ---	30 30	50 50	SPECTRAL SIG SPATIAL SIG SCAT CROSS SEC

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M COV CYCLE: ONE DAY DUR: 3/6 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.SHUTTLE	*LAND 1.1 *LAND 1.2 *LAND 2.5	7.3E+05 7.3E+05 1.0E+03	5 5 6	1 1 2	1 1 1	0 0 0	.40-.50 .40-.52 .50-.60 .52-.64 .60-.70 .64-.76 .70-.80 .76-.88 .80-.90 .88-1.0 .90-1.0 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- --- --- --- --- ---					THERM RAD SPECTRAL SIG TEMP SPEC SIG TEMP SPC/SPA SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 50 M COV CYCLE: ONE DAY DUR: 3/6 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE 2.POLAR SATELLITE (4)	*LAND 1.3 *LAND 2.1 *LAND 2.2 *LAND 2.3 *LAND 2.4 *LAND 2.5	4.8E+06 1.0E+04 1.0E+04 3.4E+06 6.1E+04 2.6E+04	5 6 6 6 6 6	1 2 2 0 2 2	1 1 1 1 1 1	0 0 0 0 0 0	.40-.50 .40-.52 .50-.60 .52-.64 .60-.70 .64-.76 .70-.80 .76-.88 .80-.90 .88-1.0 .90-1.0 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- --- --- --- --- ---					THERM RAD SPECTRAL SIG TEMP SPEC SIG TEMP SPC/SPA SIG
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 50 M COV CYCLE: ONE DAY DUR: 3/6 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4)	*LAND 1.4 *LAND 1.5 *LAND 1.7 *LAND 1.12 *LAND 2.16	6.1E+04 2.7E+06 3.0E+05 9.1E+06 9.1E+06	5 5 5 5 6	1 1 1 1 2	1 1 1 1 1	0 0 0 0 0	.40-.50 .40-.52 .50-.60 .52-.64 .60-.70 .64-.76 .70-.80 .76-.88 .80-.90 .88-1.0 .90-1.0 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- --- --- --- --- ---					THERM RAD SPECTRAL SIG TEMP SPEC SIG TEMP SPC/SPA SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 10 M COV CYCLE: ONE DAY DUR: 3/6 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4) 2.SHUTTLE	*LAND 1.6 *LAND 1.9 *LAND 1.10 *LAND 1.11 *LAND 2.6 *LAND 2.7 *LAND 2.14	7.9E+02 5.0E+04 2.0E+05 2.0E+05 5.4E+03 7.9E+02 5.0E+04	5 5 5 5 6 4 4	1 1 1 1 2 1 1	1 1 1 1 1 1 1	0 0 0 0 0 0 0	.40-.50 .40-.52 .40-.55 .50-.60 .52-.64 .55-.70 .60-.70 .64-.76 .70-.80 .70-.85 .76-.88 .80-.90 .85-1.0 .88-1.0 .90-1.0 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- --- --- --- --- --- --- ---					THERM RAD SPECTRAL SIG TEMP SPEC SIG TEMP SPC/SPA SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 20 M COV CYCLE: ONE DAY DUR: 3/6 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4) 2.SHUTTLE	*LAND 1.8 *LAND 2.10	1.0E+05 1.0E+05	5 4	1 1	1 1	0 0	.40-.55 .40-.52 .52-.64 .55-.70 .64-.76 .70-.85 .76-.88 .85-1.0 .88-1.0 2.0-2.6 8.0-14.	--- --- --- --- --- ---					THERM RAD SPECTRAL SIG TEMP SPEC SIG TEMP SPC/SPA SIG

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 2 M COV CYCLE: ONE DAY DUR: 3/6 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	*LAND 3.1	2.6E+05	4	0	1	0	.40-.55 .55-.70 .70-.85 .85-1.0 8.0-14.	--- --- ---					TEMP SPEC SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 1 M COV CYCLE: ONE DAY DUR: 3/6 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	*LAND 3.2 *LAND 3.3 *LAND 3.4 *LAND 3.5 *LAND 3.6	2.6E+05 2.6E+05 2.6E+05 2.6E+05 3.1E+04	4 4 4 4 4	0 0 0 0 0	1 2 2 2 1	0 0 0 0 0	.40-.55 .55-.70 .70-.85 .85-1.0 8.0-14. 8.0-11. 11.-14.	--- --- --- ---					TEMP SPEC SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M COV CYCLE: ONE DAY DUR: 3/10 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.SHUTTLE	* WAT 5.14	8.0E+02	3	1	2	0	.50-.60 .60-.70 .80-.90 1.5-1.8 4.5-5.5 9.5-11.	--- --- ---					THERM RAD SPECTRAL SIG TEMP SPEC SIG SPATIAL SIG
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 50 M COV CYCLE: ONE DAY DUR: 3/10 SUN ANGLE: 0600/1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (2 AND 4)	E/M 1.1 E/M 1.3 E/M 1.6 E/M 1.7 E/M 1.8 E/M 1.9	8.8E+06 8.8E+06 5.8E+04 8.8E+06 2.5E+04 2.5E+04	3 3 3 3 3 3	1 1 1 1 1 1	2 2 2 2 2 2	2 2 2 2 2 2	.50-.55 .60-.65 .80-.90 2.0-2.6 8.0-11. 11.-14.	--- --- .5 K	X(A) L(A)	--- ---	30 30	50 50	THERM RAD SPECTRAL SIG SPEC SIG (TH IR) SCAT CROSS SEC
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 50 M COV CYCLE: ONE DAY DUR: 3/10 SUN ANGLE: 0600/1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE	E/M 1.4 LAND 2.12	3.3E+06 8.0E+04	3 4	1 2	2 2	2 0	.50-.60 .50-.55 .60-.70 .60-.65 .70-.80 .80-.90 1.5-1.8 2.0-2.6 8.0-11. 11.-14.	--- --- --- --- .5 K	X(A) L(A)	--- ---	30 30	50 50	THERM RAD SPECTRAL SIG SPEC SIG (TH IR) TEMP SPEC SIG TEMP SPC/SPA SIG SCAT CROSS SEC

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	NON-MICROWAVE ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M COV CYCLE: ONE DAY DUR: 3,10 SUN ANGLE: 0600,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	E/M 1.5	2.0E+03	3	1	2	2	.50-.55 .60-.65 .80-.90 2.0-2.6 8.0-11. 11.-14.	--- --- .5 K	X(A) L(A)	--- ---	30 30	30 30	THERM RAD SPECTRA. SIG SPEC SIG (TH IR) SCAT CROSS SEC
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 100 M COV CYCLE: ONE DAY DUR: 3,6,10 SUN ANGLE: 0600,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE	E/M 2.1 E/M 2.2 E/M 2.3 E/M 2.4 E/M 2.5	9.1E+06 9.1E+06 1.1E+06 9.1E+06 1.0E+03	3 3 3 3 3	0 0 0 0 0	2 2 2 2 2	0 0 0 0 0	.50-.60 .60-.70 .80-.90 8.0-11. 11.-14.	--- --- .2 K					THERM RAD SPECTRA. SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 10 M COV CYCLE: ONE DAY DUR: 4-7 SUN ANGLE: 0600,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (2 AND 4)	FOR 2.1 FOR 2.3 FOR 2.4 FOR 2.7	5.3E+04 3.0E+05 7.7E+05 3.4E+05	4 4 4 4	2 2 2 2	1 1 1 1	2 2 2 2	.53-.58 .64-.69 .72-.76 .80-1.1 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- .5 K	X(A) L(A)	--- ---	30 30	30 30	THERM RAD SPECTRA. SIG
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 10 M COV CYCLE: ONE DAY DUR: 4-7 SUN ANGLE: 0600,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (2 AND 4)	FOR 2.2 FOR 2.6	6.1E+04 3.0E+06	4 4	2 2	1 1	2 2	.53-.58 .64-.69 .72-.76 .80-1.1 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- .5 K	X(A) L(A)	--- ---	30 30	30 30	THERM RAD SPECTRA. SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M COV CYCLE: ONE DAY DUR: 4-7 SUN ANGLE: 0600,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	FOR 2.5	1.0E+03	4	2	1	2	.53-.58 .64-.69 .72-.76 .80-1.1 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- .5 K	X(A) L(A)	--- ---	30 30	30 30	THERM RAD SPECTRAL SIG

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 5 M COV CYCLE: ONE DAY DUR: 4-7 SUN ANGLE: 0600/1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	FOR 2.8	1.0E+06	4	2	1	2	.53-.58 .64-.69 .72-.76 .80-1.1 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- .5 K	X(A) L(A)	--- ---	30 30	30 30	THERM RAD SPECTRAL SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 20 M COV CYCLE: ONE DAY DUR: AS REQUIRED SUN ANGLE: ANY OBLIQ: ANY DISASTERS POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (ANY-DISASTERS) 2.SHUTTLE 3.AIRCRAFT	FOR 3.1	5.0E+03	2	0	2	0	.60-.70 .80-1.0 4.5-5.5 8.0-14.	--- ---					THERM RAD SPECTRAL SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 20 M COV CYCLE: 5 DAYS DUR: 3-11 SUN ANGLE: 0600/0900/ OBLIQ: ANY 1200/1500 POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (2/3/4/AND 5)	* MAR 4.6	2.5E+05	4	1	1	1	.40-.50 .50-.54 .54-.64 .64-.70 1.5-1.8 9.5-11.	2.0 P 2.0 P 2.0 P .5 K	L(P)	.05	ANY	300	SPECTRAL SIG TEMP SPEC SIG
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 5 M COV CYCLE: 12 TIMES A DAY DUR: AS REQUIRED SUN ANGLE: ANY OBLIQ: ANY DISASTERS POSSIBLE PLATFORM(S): 1.AIRCRAFT	FOR 3.8 FOR 3.9	7.7E+03 1.0E+03	4 4	0 0	2 2	0 0	.50-.63 .63-.75 .75-.88 .88-1.0 4.5-5.5 8.0-14.	--- --- ---					THERM RAD SPECTRAL SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M COV CYCLE: 6 TIMES A DAY DUR: AS REQUIRED SUN ANGLE: ANY OBLIQ: ANY DISASTERS POSSIBLE PLATFORM(S): 1.AIRCRAFT	FOR 3.2 * FOR 3.6 FOR 3.7 * FOR 3.11	5.0E+03 3.0E+04 3.0E+04 3.0E+03	2 2 2 2	0 0 0 0	2 2 2 2	0 0 0 0	.60-.70 .80-1.0 4.5-5.5 8.0-14.	--- ---					THERM RAD SPECTRAL SIG

B-7

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	NON-MICROWAVE ACC	MICROWAVE BNDS	ACC (K)	DBL	RES (M)	DISTING. CHARACT.
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 5 M COV CYCLE: 6 TIMES A DAY DUR: AS REQUIRED SUN ANGLE: ANY OBLIQ: ANY DISASTERS POSSIBLE PLATFORM(S): 1.AIRCRAFT	* FOR 3.4 * FOR 3.10 * FOR 3.12	6.0E+03 7.7E+03 1.0E+04	4 2 4	3 0 0	2 2 2	0 0 0	.50-.63 .60-.70 .63-.75 .75-.88 .80-1.0 .88-1.0 1.0-1.4 1.5-1.8 2.0-2.6 4.5-5.5 8.0-14.	--- --- --- --- --- ---					THERM RAD SPECTRAL SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 20 M COV CYCLE: 6 TIMES A DAY DUR: AS REQUIRED SUN ANGLE: ANY OBLIQ: ANY DISASTERS POSSIBLE PLATFORM(S): 1.AIRCRAFT	* FOR 3.5	3.0E+04	4	3	2	0	.50-.63 .63-.75 .75-.88 .88-1.0 1.0-1.4 1.5-1.8 2.0-2.6 4.5-5.5 8.0-14.	--- --- --- --- ---					THERM RAD SPECTRAL SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 50 M COV CYCLE: EVERY DAY DUR: 1-12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE	* MAR 4.8 * WAT 5.8 * WAT 5.10	1.6E+03 1.6E+05 1.3E+05	4 4 4	1 1 1	1 1 1	1 0 0	.40-.50 .50-.54 .54-.64 .64-.70 1.5-1.8 9.5-11.	2.0 P 2.0 P 2.0 P .5 K	L(P)	.05	ANY	300	THERM RAD SPECTRAL SIG TEMP SPEC SIG SPATIAL SIG
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 5 M COV CYCLE: EVERY DAY DUR: AS REQUIRED SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	* WAT 5.18	5.0E+04	5	1	1	1	.40-.50 .50-.54 .54-.64 .60-.70 .64-.70 1.5-1.8 9.5-11.	2.0 P 2.0 P 2.0 P .5 K	X(P)	.50	ANY	50	THERM RAD SPECTRAL SIG TEMP SPEC SIG SPATIAL SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 2 M COV CYCLE: EVERY DAY DUR: FOR 1 WEEK SUN ANGLE: 0900,1200 OBLIQ: TWO OBSERVATIONS DIFFERING BY 45 (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	AGRI 4.4	1.0E+03	3	2	1	2	.51-.55 .62-.66 .80-1.0 1.5-1.8 1.8-2.6 9.5-11.	2.0 P 2.0 P 2.0 P .5 K	X(A) L(A)	--- ---	30 30	30 30	SPECTRAL SIG TEMP SPEC SIG SCAT CROSS SEC

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V I T M	NON-MICROWAVE BANDS (MICRONS)	NON-MICROWAVE ACC	MICROWAVE BNDS	MICROWAVE ACC (K)	MICROWAVE OBL	MICROWAVE RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 50 M COV CYCLE: EVERY DAY DUR: 1-12 SUN ANGLE: 0900,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE	* MAR 5.4	3.1E+04	1 1 1 2	.40-1.0 1.5-1.8 9.5-11.	--- .5 K	X(P) L(P)	1.00 .05	ANY ANY	300 300	SPECTRAL SIG TEMP SPEC SIG
LAT/LOC: 57-72 DEGREES VIS/IR RES: 50 M COV CYCLE: EVERY DAY DUR: 3,6,9,12 SUN ANGLE: 0600,0900, OBLIQ: ANY 1200,1500 POSSIBLE PLATFORM(S): (NONE) (CAN BE PARTIALLY PERFORMED BY POLAR SATELLITE,SHUTTLE (POLAR) AND AIRCRAFT)	* MAR 4.4	9.3E+03	4 1 1 1	.40-.50 .50-.54 .54-.60 .60-.70 1.5-1.8 9.5-11.	2.0 P 2.0 P 2.0 P .5 K	L(P)	.05	ANY	300	SPECTRAL SIG TEMP SPEC SIG
LAT/LOC: N ATLANTIC VIS/IR RES: 10 M COV CYCLE: EVERY DAY DUR: 5,6 SUN ANGLE: 0600,0900, OBLIQ: ANY 1200,1500 POSSIBLE PLATFORM(S): 1.AIRCRAFT (MULTIPLE) 2.POLAR SATELLITE 3.SHUTTLE (POLAR)	* MAR 5.1	3.6E+07	1 1 1 0	.40-1.0 1.5-1.8 9.5-11.	--- .5 K					SPECTRAL SIG TEMP SPEC SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 50 M COV CYCLE: EVERY DAY DUR: 1-12 SUN ANGLE: 0300,0900, OBLIQ: ANY 1500,2100 POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE	WAT 3.1 * MAR 5.3 * MAR 5.2 WAT 3.2 WAT 3.3 WAT 3.4 WAT 3.5	2.5E+05 2.5E+05 2.5E+05 2.5E+05 2.5E+05 2.5E+05 2.5E+05	1 0 1 1 1 1 1 0 1 1 1 0 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1	.40-1.0 .70-1.1 1.5-1.8 9.5-11.	--- --- .5 K	X(P)	---	ANY	100	THERM RAD SPECTRAL SIG TEMP SPEC SIG

B-8

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-72 DEGREES VIS,IR RES: 10 M	* MAR 5.5	3.1E+04	1	1	1	0	.40-1.0 1.5-1.8	---					SPECTRAL SIG
							9.5-11.	.5 K					TEMP SPEC SIG
COV CYCLE: EVERY DAY DUR: 6-10													
SUN ANGLE: 0600,0900, 1200,1500 OBLIQ: ANY													
POSSIBLE PLATFORM(S): 1.AIRCRAFT													
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 50 M	* WAT 5.1	1.0E+04	4	1	1	0	.40-.50 .50-.54	2.0 P					THERM RAD
							.54-.64 .64-.70	2.0 P					SPECTRAL SIG
COV CYCLE: 1 DAY EVERY 3 DUR: 3,4							1.5-1.8	2.0 P					TEMP SPEC SIG
							9.5-11.	.5 K					SPATIAL SIG
SUN ANGLE: 1200 (* >30DEG) OBLIQ: ANY													
POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE													
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 50 M	* MAR 4.9	3.5E+04	4	1	1	1	.40-.50 .50-.54	2.0 P	L(P)	.05	ANY	300	SPECTRAL SIG
							.54-.64 .64-.70	2.0 P					TEMP SPEC SIG
COV CYCLE: 6 HR/DY FOR 6 DYS DUR: 3,6,9,12							1.5-1.8	2.0 P					
							9.5-11.	.5 K					
SUN ANGLE: ANY DAYLIGHT OBLIQ: ANY													
POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE													
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 50 M	WAT 1.12	1.1E+06	4	2	1	2	.40-.50 .50-.60	2.0 P	X(A)	---	30	50	THERM RAD
	*AGRI 6.2	1.9E+05	3	2	1	0	.50-.58 .50-.54	2.0 P	L(A)	---	30	50	SPECTRAL SIG
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12	*AGRI 6.3	1.4E+05	3	2	1	0	.50-.63 .51-.55	2.0 P	L(P)	.05	ANY	300	SPEC/SPAT SIG
	*AGRI 6.4	1.4E+06	3	2	1	0	.54-.64 .56-.59	2.0 P					TEMP SPEC SIG
SUN ANGLE: 1200 OBLIQ: ANY	*AGRI 6.5	2.0E+03	3	2	1	0	.60-.70 .62-.66	2.0 P					SPATIAL SIG
(* >30DEG)	* MAR 1.1	3.4E+06	5	1	1	0	.63-.75 .64-.70	2.0 P					SCAT CROSS SEC
	* MAR 4.10	3.1E+04	4	1	1	1	.75-.88 .80-.90	2.0 P					
POSSIBLE PLATFORM(S):	* MAR 4.11	2.5E+05	4	1	1	1	.80-1.0 .88-1.0	2.0 P					
1.GEOSYNCHRONOUS SATELLITE	*AGRI 6.1	1.2E+05	4	2	1	0	1.5-1.8 2.0-2.6	2.0 P					
2.POLAR SATELLITE (4)	WAT 1.14	5.0E+04	4	2	1	2	4.5-5.5 8.0-14.	.5 K					
	* WAT 5.2	9.1E+06	4	1	1	0	9.5-11.	.5 K					
	* WAT 5.4	1.0E+04	4	1	1	0							
	* WAT 5.5	1.2E+05	4	1	1	0							
	* WAT 5.6	1.1E+05	4	1	1	0							
	* WAT 5.7	1.0E+03	4	1	1	0							
	* WAT 5.9	1.1E+05	4	1	1	0							
	* WAT 5.11	3.9E+05	4	1	1	0							
	* WAT 5.12	3.4E+04	4	1	1	0							
	* WAT 5.13	5.2E+04	3	1	1	0							
	* WAT 5.14	8.0E+02	3	1	2	0							

B-9

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	NON-MICROWAVE ACC	MICROWAVE BNDS	MICROWAVE ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 10 M	* E/M 4.5	3.1E+04	4	0	1	2	.40-.55 .55-.70	---	X(P)	---	ANY	30	THERM RAD
	*LAND 4.7	6.7E+04	1	0	1	2	.70-.85 .80-1.0	---	L(P)	---	ANY	50	THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12	*LAND 4.8	4.9E+06	1	0	1	2	.85-1.0	---	X(P)	.50	ANY	100	SPECTRAL SIG
	*LAND 4.9	4.7E+06	1	0	1	2	8.0-14. 9.5-11.	.5 K	K(P)	.50	ANY	100	SPEC SIG (TH IR)
SUN ANGLE: 1200 OBLIQ: ANY													SPEC/SPAT SIG
(* >30DEG)													SPATIAL SIG
													SCAT CROSS SEC
POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4)													
LAT/LOC: 57-72 DEGREES VIS/IR RES: 10 M	E/M 5.2	5.2E+04	6	0	1	1	.40-.50 .50-.60	---	X(P)	---	ANY	50	THERM RAD
							.60-.70 .70-.80	---					THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12							.80-.90 .90-1.0	---					SPECTRAL SIG
							8.0-14.	.5 K					
SUN ANGLE: 1200 OBLIQ: ANY													
(* >30DEG)													
POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4)													
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 10 M	LAND 4.6	2.0E+02	1	0	1	2	.50-.63 .63-.75	---	X(P)	.50	ANY	100	THERM RAD
	*LAND 4.10	3.0E+04	1	0	1	2	.75-.88 .80-1.0	---	K(P)	.50	ANY	100	THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12	WAT 1.13	2.5E+04	4	2	1	2	.88-1.0 1.5-1.8	---	X(A)	---	30	50	SPECTRAL SIG
							2.0-2.6	---	L(A)	---	30	50	SPEC/SPAT SIG
SUN ANGLE: 1200 OBLIQ: ANY							8.0-14. 9.5-11.	.5 K					TEMP SPEC SIG
(* >30DEG)													SPATIAL SIG
													SCAT CROSS SEC
POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4)													
LAT/LOC: GLOBAL OCEANS VIS/IR RES: 50 M	* MAR 4.7	3.6E+08	4	1	1	1	.40-.50 .50-.54	2.0 P	L(P)	.05	ANY	300	SPECTRAL SIG
							.54-.64 .64-.70	2.0 P					TEMP SPEC SIG
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12							1.5-1.8	2.0 P					
							9.5-11.	.5 K					
SUN ANGLE: 1200 OBLIQ: ANY													
(* >30DEG)													
POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4)													
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M	WAT 3.1	1.0E+03	1	0	1	1	.70-1.1	---	X(P)	---	ANY	100	THERM RAD
	WAT 3.2	1.0E+03	1	0	1	1	9.5-11.	---					SPECTRAL SIG
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12	WAT 3.3	1.0E+03	1	0	1	1							
	WAT 3.4	1.0E+03	1	0	1	1							
SUN ANGLE: 1200 OBLIQ: ANY	WAT 3.5	1.0E+03	1	0	1	1							
(* >30DEG)													
POSSIBLE PLATFORM(S): 1.AIRCRAFT													

B-10

PLATFORM REQUIREMENTS	MTS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	NON-MICROWAVE ACC	MICROWAVE BNDS	MICROWAVE ACC (K)	MICROWAVE OBL	MICROWAVE RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-72 DEGREES VIS,IR RES: 50 M	* WAT 5.18	9.1E+06	5	1	1	1	.40-.50 .50-.54	2.0 P	X(P)	.50	ANY	30	THERM RAD
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12							.54-.64 .60-.70	2.0 P					SPECTRAL SIG
SUN ANGLE: 1200 OBLIQ: ANY							.64-.70 1.5-1.8	2.0 P					TEMP SPEC SIG
(* >30DEG)							9.5-11.	.5 K					SPATIAL SIG
POSSIBLE PLATFORM(S):													
1.POLAR SATELLITE (4)													
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 5 M	*AGRI 2.1	2.0E+03	3	2	1	0	.51-.55 .62-.66	2.0 P					MULTI SPEC SIG
	*AGRI 2.1	8.0E+03	3	2	1	0	.80-1.0 1.5-1.8	2.0 P					TEMP SPEC SIG
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12	*AGRI 2.2	5.0E+04	3	2	1	0	2.0-2.6	2.0 P					
	*AGRI 2.2	2.0E+05	3	2	1	0	9.5-11.	.5 K					
SUN ANGLE: 0900,1200 OBLIQ: TWO OBSERVATIONS	*AGRI 2.3	5.0E+02	3	2	1	0							
(* >30DEG) DIFFERING BY 45	*AGRI 2.3	1.4E+03	3	2	1	0							
	*AGRI 2.6	2.3E+04	3	2	1	0							
POSSIBLE PLATFORM(S):	*AGRI 2.7	6.1E+04	3	2	1	0							
1.AIRCRAFT	*AGRI 2.8	5.0E+04	3	2	1	0							
	*AGRI 2.8	2.0E+05	3	2	1	0							
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 50 M	AGRI 4.1	4.8E+04	3	2	1	2	.51-.55 .62-.66	2.0 P	X(A)	---	30	100	SPECTRAL SIG
	AGRI 4.2	1.5E+06	3	2	1	2	.80-1.0 1.5-1.8	2.0 P	L(A)	---	30	100	TEMP SPEC SIG
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12	AGRI 4.3	4.8E+04	3	2	1	2	1.8-2.6	2.0 P					SCAT CROSS SEC
	AGRI 4.5	5.4E+05	3	2	1	2	9.5-11.	.5 K					
SUN ANGLE: 0900,1200 OBLIQ: TWO OBSERVATIONS													
(* >30DEG) DIFFERING BY 45													
POSSIBLE PLATFORM(S):													
1.POLAR SATELLITE (3 AND 4)													
LAT/LOC: 28.5-72 DEGREES VIS,IR RES: 50 M	E/M 4.1	1.2E+07	6	0	1	2	.40-.50 .40-.45	---	X(P)	---	ANY	100	THERM RAD
	E/M 4.12	1.2E+07	6	0	1	2	.45-.50 .50-.60	---	K(P)	---	ANY	100	THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12							.50-.55 .55-.60	---	X(P)	---	ANY	30	SPECTRAL SIG
							.60-.70 .60-.65	---	K(P)	---	ANY	30	SPEC SIG (TH IR)
SUN ANGLE: 0900,1200 OBLIQ: ANY							.65-.70 .70-.80	---					SPEC/SPAT SIG
(* >30DEG)							.80-.90 .90-1.0	---					SCAT CROSS SEC
							8.0-14.	.5 K					
POSSIBLE PLATFORM(S):													
1.POLAR SATELLITE (3 AND 4)													
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 50 M	E/M 4.2	2.3E+05	6	0	1	2	.40-.45 .45-.50	---	X(P)	---	ANY	100	THERM RAD
	E/M 4.3	3.1E+06	6	0	1	2	.50-.55 .55-.60	---	K(P)	---	ANY	100	THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12	E/M 4.4	3.4E+06	6	0	1	2	.60-.65 .65-.70	---	X(P)	---	ANY	30	SPECTRAL SIG
	E/M 4.9	3.4E+06	6	0	1	2	8.0-14.	.5 K	K(P)	---	ANY	30	SPEC SIG (TH IR)
SUN ANGLE: 0900,1200 OBLIQ: ANY													SPEC/SPAT SIG
(* >30DEG)													SCAT CROSS SEC
POSSIBLE PLATFORM(S):													
1.GEOSYNCHRONOUS SATELLITE													

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	NON-MICROWAVE ACC	MICROWAVE BNDS	ACC (<)	DBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 10 M COV CYCLE: 1 DAY EVERY 7 DUR: 1-12 SUN ANGLE: 0900,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (3 AND 4)	E/M 4.10 E/M 4.11	8.0E+03 1.0E+04	6 6	0 0	1 1	2 2	.40-.50 .50-.60 .60-.70 .70-.80 .80-.90 .90-1.0 8.0-14.	--- --- --- .5 K	X(P) K(P)	--- ---	ANY ANY	50 50	THERM RAD THERM RAD (MW) SPECTRAL SIG SPEC SIG (TH IR) SPEC/SPAT SIG SCAT CROSS SEC
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 10 M COV CYCLE: 1 DAY EVERY 7 DUR: 1-12 SUN ANGLE: 0900,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (3 AND 4)	E/M 5.1 E/M 5.3 E/M 5.4 E/M 5.6 E/M 5.7	1.9E+04 3.4E+06 1.9E+04 1.9E+04 1.9E+04	6 6 6 6 6	0 0 0 0 0	1 1 1 1 1	1 1 1 1 1	.40-.50 .50-.60 .60-.70 .70-.80 .80-.90 .90-1.0 8.0-14.	--- --- --- .5 K	X(P)	---	ANY	30	THERM RAD THERM RAD (MW) SPECTRAL SIG
LAT/LOC: GLOBAL OCEANS VIS/IR RES: 80 M COV CYCLE: 1 DAY EVERY 7 DUR: 1-12 SUN ANGLE: 0900,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (3 AND 4)	* MAR 3.2 * MAR 3.4 * MAR 3.5	4.0E+07 4.0E+07 3.6E+08	3 3 3	1 1 1	1 1 1	1 1 1	.40-.50 .50-.54 .54-.64 1.5-1.8 9.5-11.	2.0 P 2.0 P .5 K	L(P)	.05	ANY	300	SPECTRAL SIG TEMP SPEC SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 10 M COV CYCLE: 1 DAY EVERY 7 DUR: 1-12 SUN ANGLE: 0600,0900, OBLIQ: ANY 1200,1500 POSSIBLE PLATFORM(S): 1.AIRCRAFT	* E/M 4.7 * E/M 4.8	8.0E+02 1.9E+04	6 6	0 0	1 1	2 2	.40-.45 .45-.50 .50-.55 .55-.60 .60-.65 .65-.70 8.0-14.	--- --- --- .5 K	X(P) L(P)	--- ---	ANY ANY	50 50	THERM RAD THERM RAD (MW) SPECTRAL SIG SPEC SIG (TH IR) SPEC/SPAT SIG SCAT CROSS SEC
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M COV CYCLE: 1 DAY EVERY 7 DUR: 1-12 SUN ANGLE: 0300,0900, OBLIQ: ANY 1200,1500 POSSIBLE PLATFORM(S): 1.AIRCRAFT	E/M 6.1 E/M 6.2 E/M 6.3 E/M 6.4 E/M 6.5	3.1E+04 3.1E+04 3.1E+04 3.1E+04 3.1E+04	7 7 7 7 7	0 0 0 0 0	1 1 1 1 1	0 0 0 0 0	.32-.38 .40-.50 .50-.60 .60-.70 .70-.80 .80-.90 .90-1.0 8.0-14.	--- --- --- --- .5 K					THERM RAD SPECTRAL SIG

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 50 M	* MAR 3.1	3.1E+04	3	1	1	1	.35-.43 .40-.50	2.0 P	L(P)	.05	ANY	300	THERM RAD
	* MAR 3.6	3.1E+04	3	1	1	1	.43-.52 .50-.54	2.0 P	X(P)	---	ANY	50	THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 7 DUR: 1-12	* MAR 3.7	3.1E+04	3	1	1	1	.52-.59 .54-.64	2.0 P					SPECTRAL SIG
	* MAR 3.8	2.5E+05	3	1	1	1	.59-.68 .68-.75	2.0 P					TEMP SPEC SIG
SUN ANGLE: 0300,0600, OBLIQ: ANY	* MAR 3.9	2.5E+05	3	1	1	1	.75-.83 .83-.92	2.0 P					SPATIAL SIG
1200,1500	* WAT 6.7	2.6E+05	8	3	2	1	.92-1.0 1.0-1.4	2.0 P					
	* WAT 6.8	5.7E+04	8	3	2	1	1.5-1.8 2.0-2.6	2.0 P					
POSSIBLE PLATFORM(S):							8.0-11. 9.5-11.	.5 K					
1.GEOSYNCHRONOUS SATELLITE							11.-14.	.5 K					
//////////////////////////	//////////	//////////	////	////	////	////	//////////////	//////	//////	//////	//////	//////	//////////////
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 2 M	AGRI 4.6	8.0E+04	3	2	1	2	.51-.55 .62-.66	2.0 P	X(A)	---	30	100	SPECTRAL SIG
							.80-1.0 1.5-1.8	2.0 P	L(A)	---	30	100	TEMP SPEC SIG
COV CYCLE: 2 DAYS EVERY 7 DUR: 1-12							1.8-2.6	2.0 P					SCAT CROSS SEC
							9.5-11.	.5 K					
SUN ANGLE: 0900,1200 OBLIQ: TWO OBSERVATIONS													
(* >30DEG) DIFFERING BY 45													
POSSIBLE PLATFORM(S):													
1.AIRCRAFT													
//////////////////////////	//////////	//////////	////	////	////	////	//////////////	//////	//////	//////	//////	//////	//////////////
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 10 M	*AGRI 1.1	5.0E+05	2	3	1	2	.51-.55 .62-.66	---	X(A)	---	30	100	SPECTRAL SIG
	*AGRI 1.1	1.4E+06	2	3	1	2	.80-1.1 1.0-1.4	---	L(A)	---	30	100	TEMP SPEC SIG
COV CYCLE: 1 DAY EVERY 14 DUR: 1-12	*AGRI 1.4	1.4E+06	2	3	1	2	1.5-1.8 2.0-2.6	---	X(P)	---	ANY	50	SCAT CROSS SEC
	*AGRI 1.4	5.0E+05	2	3	1	2	9.5-11.	---					
SUN ANGLE: 1200 OBLIQ: ANY	* WAT 2.1	5.0E+04	1	1	1	1							
(* >30DEG)	* WAT 2.2	5.0E+04	1	1	1	1							
	* WAT 2.3	1.2E+04	1	1	1	1							
POSSIBLE PLATFORM(S):	* WAT 2.6	3.0E+04	1	1	1	1							
1.POLAR SATELLITE (4)													
//////////////////////////	//////////	//////////	////	////	////	////	//////////////	//////	//////	//////	//////	//////	//////////////
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 50 M	*AGRI 1.2	5.0E+05	2	3	1	2	.32-.38 .35-.43	2.0 P	X(A)	---	30	100	THERM RAD
	*AGRI 1.2	1.4E+06	2	3	1	2	.40-.48 .40-.50	2.0 P	L(A)	---	30	100	THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 14 DUR: 1-12	*AGRI 1.2	3.7E+03	2	3	1	2	.43-.52 .48-.53	2.0 P	L(P)	.05	ANY	300	SPECTRAL SIG
	*AGRI 1.3	5.0E+05	2	3	1	2	.50-.54 .51-.55	2.0 P	X(P)	---	ANY	50	TEMP SPEC SIG
SUN ANGLE: 1200 OBLIQ: ANY	*AGRI 1.3	1.4E+06	2	3	1	2	.52-.59 .53-.58	2.0 P					SPATIAL SIG
(* >30DEG)	*AGRI 1.3	7.5E+03	2	3	1	2	.54-.60 .58-.65	2.0 P					SCAT CROSS SEC
	* MAR 4.5	3.1E+04	4	1	1	1	.59-.68 .60-.70	2.0 P					
POSSIBLE PLATFORM(S):	* WAT 4.15	2.5E+05	8	0	1	0	.62-.66 .65-.72	2.0 P					
1.GEOSYNCHRONOUS SATELLITE	* WAT 6.11	5.4E+05	8	3	2	1	.68-.75 .72-.80	2.0 P					
2.POLAR SATELLITE (4)	* WAT 6.12	8.0E+03	8	3	2	1	.75-.83 .80-1.0	2.0 P					
							.83-.92 .92-1.0	2.0 P					
							1.0-1.4 1.5-1.8	2.0 P					
							2.0-2.6	2.0 P					
							8.0-14. 8.0-11.	.5 K					
							9.5-11. 11.-14.	.5 K					

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 5 M	LAND 4.15	1.7E+06	3	0	2	0	.50-.60 .51-.55	---	X(A)	---	30	100	THERM RAD
COV CYCLE: 1 DAY EVERY 14 DUR: 1-12	*AGRI 1.3	2.5E+03	2	3	1	2	.60-.70 .62-.66	---	L(A)	---	30	100	SPECTRAL SIG
SUN ANGLE: 1200 OBLIQ: ANY	*LAND 4.14	1.7E+06	3	0	2	0	.80-1.0 1.0-1.4	---					SPEC/SPAT SIG
(* >30DEG)	*AGRI 1.2	1.3E+03	2	3	1	2	1.5-1.8 2.0-2.6	---					TEMP SPEC SIG
POSSIBLE PLATFORM(S):	LAND 4.16	1.7E+06	3	0	2	0	8.0-11. 9.5-11.	.5 K					SPATIAL SIG
1.AIRCRAFT	LAND 4.17	2.0E+03	3	0	2	0	11.-14.	.5 K					SCAT CROSS SEC
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 10 M	*AGRI 3.1	1.4E+06	2	0	2	2	.62-.66 .80-1.0	---	X(A)	---	30	50	SPECTRAL SIG
COV CYCLE: 1 DAY EVERY 14 DUR: 1-12	*AGRI 3.1	5.0E+05	2	0	2	2	9.5-10. 10.-11.	---	L(A)	---	30	50	SCAT CROSS SEC
SUN ANGLE: 1200 OBLIQ: 10,20,30 DEGREES	*AGRI 3.2	1.4E+06	2	0	2	2							SCAT CR SEC (MW)
(* >30DEG) OFF NADIR	*AGRI 3.2	5.0E+05	2	0	2	2							POLARIZA SIG
	*AGRI 3.3	1.4E+06	2	0	2	2							
	*AGRI 3.3	5.0E+05	2	0	2	2							
POSSIBLE PLATFORM(S):	*AGRI 3.4	1.4E+06	2	0	2	2							
1.POLAR SATELLITE (4)	*AGRI 3.4	5.0E+05	2	0	2	2							
	*AGRI 3.5	1.4E+06	2	0	2	2							
	*AGRI 3.5	5.0E+05	2	0	2	2							
LAT/LOC: WORLD AG AREAS VIS,IR RES: 20 M	*AGRI 5.1	1.5E+06	3	2	1	2	.51-.55 .62-.66	5.0 P	X(A)	---	30	100	TEMP SPEC SIG
COV CYCLE: 1 DAY EVERY 14 DUR: 1-12	*AGRI 5.2	1.5E+06	3	2	1	2	.80-1.0 1.5-1.8	5.0 P	L(A)	---	30	100	
SUN ANGLE: 1200 OBLIQ: ANY	*AGRI 5.3	1.5E+06	3	2	1	2	1.8-2.6	5.0 P					
(* >30DEG)	*AGRI 5.4	1.5E+06	3	2	1	2	9.5-11.	1.0 K					
POSSIBLE PLATFORM(S):													
1.POLAR SATELLITE (4)													
LAT/LOC: WORLD AG AREAS VIS,IR RES: 5 M	*AGRI 5.1	1.5E+03	3	2	1	2	.51-.55 .62-.66	5.0 P	X(A)	---	30	100	TEMP SPEC SIG
COV CYCLE: 1 DAY EVERY 14 DUR: 1-12	*AGRI 5.2	1.5E+03	3	2	1	2	.80-1.0 1.5-1.8	5.0 P	L(A)	---	30	100	
SUN ANGLE: 1200 OBLIQ: ANY	*AGRI 5.3	1.5E+03	3	2	1	2	1.8-2.6	5.0 P					
(* >30DEG)	*AGRI 5.4	1.5E+03	3	2	1	2	9.5-11.	1.0 K					
POSSIBLE PLATFORM(S):													
1.AIRCRAFT													
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 2 M	*LAND 2.15	1.5E+03	6	0	0	0	.40-.50 .50-.60	---					THERM RAD
COV CYCLE: 1 DAY EVERY 14 DUR: 1-12							.60-.70 .70-.80	---					SPECTRAL SIG
SUN ANGLE: 1200 OBLIQ: ANY							.80-.90 .90-1.0	---					TEMP SPEC SIG
(* >30DEG)													TEMP SPC/SPA SIG
POSSIBLE PLATFORM(S):													
1.AIRCRAFT													

B-14

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	NON-MICROWAVE ACC	MICROWAVE BNDS	ACC (<)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-72 DEGREES VIS,IR RES: 10 M COV CYCLE: 1 DAY EVERY 14 DUR: 1-12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4)	* WAT 2.4 * WAT 2.5	7.7E+04 7.7E+04	1 1	1 1	1 1	1 1	.80-1.1 1.5-1.8 9.5-11.	--- ---	X(P)	---	ANY	50	TEMP SPEC SIG
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 50 M COV CYCLE: 1 DAY EVERY 14 DUR: 1-12 SUN ANGLE: 0900,1200 OBLIQ: TWO OBSERVATIONS DIFFERING BY 45 (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (3 AND 4)	*AGRI 2.1 *AGRI 2.1 *AGRI 2.2 *AGRI 2.2 *AGRI 2.3 *AGRI 2.3 *AGRI 2.4 *AGRI 2.5 *AGRI 2.6 *AGRI 2.7 *AGRI 2.8 *AGRI 2.8	2.0E+03 8.0E+03 5.0E+05 1.4E+06 5.0E+05 1.4E+06 1.5E+04 2.4E+06 2.3E+04 6.1E+04 5.0E+05 1.4E+06	3 3 3 3 3 3 3 3 3 3 3 3	2 2 2 2 2 2 2 2 2 2 2 2	1 1 1 1 1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0 0 0 0 0	.51-.55 .62-.66 .80-1.0 1.5-1.8 2.0-2.6 9.5-11.	2.0 P 2.0 P 2.0 P .5 K					MULTI SPEC SIG TEMP SPEC SIG
LAT/LOC: 57-72 DEGREES VIS,IR RES: 50 M COV CYCLE: 1 DAY EVERY 14 DUR: 6-10 SUN ANGLE: 0900,1200 OBLIQ: TWO OBSERVATIONS DIFFERING BY 45 (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (3 AND 4)	*AGRI 2.5	6.6E+03	3	2	1	0	.51-.55 .62-.66 .80-1.0 1.5-1.8 2.0-2.6 9.5-11.	2.0 P 2.0 P 2.0 P .5 K					MULTI SPEC SIG TEMP SPEC SIG
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 5 M COV CYCLE: 1 DAY EVERY 14 DUR: 1-12 SUN ANGLE: 0900,1200 OBLIQ: TWO OBSERVATIONS DIFFERING BY 45 (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	*AGRI 2.9 *AGRI 2.10	3.7E+06 7.3E+04	3 3	2 2	1 1	0 0	.51-.55 .62-.66 .80-1.0 1.5-1.8 2.0-2.6 9.5-11.	2.0 P 2.0 P 2.0 P .5 K					MULTI SPEC SIG TEMP SPEC SIG
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 5 M COV CYCLE: 1 DAY EVERY 14 DUR: 1-12 SUN ANGLE: 0600,1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	* WAT 1.3	1.2E+03	1	1	1	2	.80-1.0 1.5-1.8 9.5-11.	--- .5 K	X(A) L(A)	--- ---	30 30	50 50	THERM RAD SPECTRAL SIG SPEC/SPAT SIG TEMP SPEC SIG SCAT CROSS SEC

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 10 M	* E/M 7.1	2.8E+04	6	0	1	0	.32-.38 .40-.50	---					THERM RAD
	* E/M 7.2	2.8E+04	6	0	1	0	.40-.48 .48-.53	---					SPECTRAL SIG
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12	* E/M 7.3	2.8E+04	6	0	1	0	.50-.60 .50-.54	---					SPEC/SPAT SIG
	* E/M 7.4	2.8E+04	6	0	1	0	.53-.58 .54-.64	---					TEMP SPEC SIG
SUN ANGLE: 1200 OBLIQ: ANY	* E/M 7.5	2.8E+04	6	0	1	0	.58-.65 .60-.70	---					SCAT CROSS SEC
(* >30DEG)	* E/M 7.6	2.8E+04	6	0	1	0	.64-.70 .65-.72	---					
	* E/M 7.7	2.8E+04	6	0	1	0	.70-.80 .72-.80	---					
POSSIBLE PLATFORM(S):	* WAT 1.7	8.0E+03	4	1	2	0	.80-.90 .80-1.0	---					
1.POLAR SATELLITE (4)	* WAT 1.8	8.0E+03	4	1	2	0	.90-1.0 1.5-1.8	---					
	* WAT 4.3	7.3E+04	8	0	1	0	8.0-14. 8.0-11.	.5 K					
	* WAT 4.6	1.0E+03	8	0	1	0	11.-14.	.5 K					
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 20 M	* FOR 3.5	3.0E+06	4	3	2	0	.32-.38 .35-.43	2.0 P	X(P)	---	ANY	50	THERM RAD
	* MAR 1.2	3.0E+05	5	1	0	0	.40-.48 .40-.50	2.0 P					THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12	* WAT 4.5	2.5E+05	8	0	1	0	.43-.52 .48-.53	2.0 P					SPECTRAL SIG
	* WAT 4.8	1.0E+04	8	0	1	0	.50-.63 .50-.54	2.0 P					TEMP SPEC SIG
SUN ANGLE: 1200 OBLIQ: ANY	* WAT 6.1	1.0E+04	8	3	2	1	.50-.58 .52-.59	2.0 P					SPATIAL SIG
(* >30DEG)							.53-.58 .54-.64	2.0 P					
							.58-.65 .59-.68	2.0 P					
POSSIBLE PLATFORM(S):							.63-.75 .64-.70	2.0 P					
1.POLAR SATELLITE (4)							.65-.72 .68-.75	2.0 P					
							.72-.80 .75-.83	2.0 P					
							.75-.88 .80-1.0	2.0 P					
							.83-.92 .88-1.0	2.0 P					
							.92-1.0 1.0-1.4	2.0 P					
							1.5-1.8 2.0-2.6	2.0 P					
							4.5-5.5 8.0-11.	.5 K					
							8.0-14. 11.-14.	.5 K					
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 5 M	* FOR 3.10	7.7E+05	2	0	2	0	.50-.63 .60-.70	---					THERM RAD
	* FOR 3.12	1.0E+06	4	0	2	0	.63-.75 .75-.88	---					SPECTRAL SIG
COV CYCLE: 1 DAY EVERY 30 DUR: 3-10							.80-1.0 .88-1.0	---					
							4.5-5.5 8.0-14.	---					
SUN ANGLE: 1200 OBLIQ: ANY													
(* >30DEG)													
POSSIBLE PLATFORM(S):													
1.AIRCRAFT													
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M	LAND 4.18	2.7E+06	3	1	2	0	.40-.50 .50-.60	2.0 P					THERM RAD
	* FOR 3.11	3.0E+05	2	0	2	0	.50-.54 .50-.58	2.0 P					SPECTRAL SIG
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12	* MAR 1.2	3.0E+03	5	1	0	0	.54-.64 .60-.70	2.0 P					SPEC/SPAT SIG
	* WAT 1.2	2.3E+05	1	1	1	0	.64-.70 .80-1.0	2.0 P					TEMP SPEC SIG
SUN ANGLE: 1200 OBLIQ: ANY							1.5-1.8 2.0-2.6	2.0 P					SPATIAL SIG
(* >30DEG)							4.5-5.5 8.0-11.	.5 K					SCAT CROSS SEC
							8.0-14. 9.5-11.	.5 K					
POSSIBLE PLATFORM(S):							11.-14.	.5 K					
1.AIRCRAFT													

B-16

B-17

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 10 M	*LAND 4.11	1.7E+06	2	0	1	3	.32-.38 .40-.50	2.0 P	X(A)	.50	30	100	THERM RAD
	*LAND 4.12	1.7E+06	2	0	1	3	.40-.48 .48-.53	2.0 P	X(P)	.50	30	100	THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12	*LAND 4.13	1.7E+06	2	0	1	3	.50-.58 .50-.54	2.0 P	K(P)	.50	30	100	SPECTRAL SIG
	* MAR 1.6	3.1E+04	5	1	1	1	.53-.58 .54-.64	2.0 P	L(P)	---	ANY	300	SPEC/SPAT SIG
SUN ANGLE: 1200 OBLIQ: ANY	* WAT 4.16	2.0E+05	8	0	1	0	.58-.65 .60-.70	2.0 P					TEMP SPEC SIG
(* >30DEG)	* WAT 4.17	2.0E+05	8	0	1	0	.64-.70 .65-.72	2.0 P					SPATIAL SIG
							.72-.80 .80-1.0	2.0 P					SCAT CROSS SEC
POSSIBLE PLATFORM(S):							1.5-1.8	2.0 P					
1.POLAR SATELLITE (4)							8.0-14. 9.5-11.	.5 K					
LAT/LOC: GLOBAL OCEANS VIS/IR RES: 1000 M	* MAR 1.3	3.6E+08	5	1	1	1	.40-.50 .50-.58	2.0 P	L(P)	.50	ANY	300	THERM RAD
							.50-.54 .54-.64	2.0 P					TEMP SPEC SIG
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12							.64-.70 1.5-1.8	2.0 P					SPATIAL SIG
							9.5-11.	.5 K					
SUN ANGLE: 1200 OBLIQ: ANY													
(* >30DEG)													
POSSIBLE PLATFORM(S):													
1.POLAR SATELLITE (4)													
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 100 M	* MAR 1.3	3.4E+06	5	1	1	1	.40-.50 .50-.58	2.0 P	L(P)	.50	ANY	300	THERM RAD
							.50-.54 .54-.64	2.0 P					TEMP SPEC SIG
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12							.64-.70 1.5-1.8	2.0 P					SPATIAL SIG
							9.5-11.	.5 K					
SUN ANGLE: 1200 OBLIQ: ANY													
(* >30DEG)													
POSSIBLE PLATFORM(S):													
1.POLAR SATELLITE (4)													
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 50 M	WAT 1.12	1.1E+06	4	2	1	2	.32-.38 .35-.43	2.0 P	X(A)	---	30	50	THERM RAD
	* WAT 1.6	2.0E+05	4	1	2	0	.40-.50 .40-.48	2.0 P	L(A)	---	30	50	THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12	* WAT 4.4	2.0E+05	8	0	1	0	.43-.52 .48-.53	2.0 P	X(P)	---	ANY	50	SPECTRAL SIG
	* WAT 4.7	2.0E+04	8	0	1	0	.50-.60 .50-.54	2.0 P					SPEC/SPAT SIG
SUN ANGLE: 1200 OBLIQ: ANY	* WAT 4.9	2.0E+05	8	0	1	0	.50-.63 .52-.59	2.0 P					TEMP SPEC SIG
(* >30DEG)	* WAT 4.10	2.0E+05	8	0	1	0	.53-.58 .54-.64	2.0 P					SPATIAL SIG
	* WAT 4.12	1.8E+06	7	0	1	0	.56-.65 .59-.68	2.0 P					SCAT CROSS SEC
POSSIBLE PLATFORM(S):	* WAT 4.14	5.0E+05	8	0	1	0	.60-.70 .63-.75	2.0 P					
1.GEOSYNCHRONOUS SATELLITE	* WAT 5.3	9.1E+06	4	1	1	0	.64-.70 .65-.72	2.0 P					
2.POLAR SATELLITE (4)	* WAT 5.15	6.9E+06	3	1	2	0	.68-.75 .72-.80	2.0 P					
	* WAT 5.16	6.9E+06	3	1	2	0	.75-.88 .75-.83	2.0 P					
	* WAT 5.17	3.5E+04	3	1	2	0	.80-.90 .80-1.0	2.0 P					
	* WAT 6.3	1.0E+04	8	3	2	1	.83-.92 .88-1.0	2.0 P					
	* WAT 6.4	2.8E+05	8	3	2	1	.92-1.0 1.0-1.4	2.0 P					
	* WAT 6.5	2.0E+05	8	3	2	1	1.5-1.8 2.0-2.6	2.0 P					
	* WAT 6.6	1.8E+06	8	3	2	1	4.5-5.5 8.0-11.	.5 K					
	* WAT 6.13	9.1E+06	8	3	2	1	8.0-14. 9.5-11.	.5 K					
	* WAT 6.14	9.1E+06	8	3	2	1	11.-14.	.5 K					

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 50 M	* WAT 4.1	6.1E+04	8	0	1	0	.32-.38 .35-.43	2.0 P	X(P)	.50	ANY	30	THERM RAD
	* WAT 4.2	8.0E+03	8	0	1	0	.40-.48 .40-.50	2.0 P					THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12	* WAT 5.18	9.1E+06	5	1	1	1	.43-.52 .48-.53	2.0 P					SPECTRAL SIG
	* WAT 6.10	5.2E+04	8	3	2	1	.50-.54 .52-.59	2.0 P					TEMP SPEC SIG
SUN ANGLE: 1200 OBLIQ: ANY							.53-.58 .54-.64	2.0 P					SPATIAL SIG
(* >30DEG)							.58-.65 .59-.68	2.0 P					
							.60-.70 .64-.70	2.0 F					
POSSIBLE PLATFORM(S):							.65-.72 .68-.75	2.0 P					
1.POLAR SATELLITE (4)							.72-.80 .75-.83	2.0 P					
							.80-1.0 .83-.92	2.0 P					
							.92-1.0 1.0-1.4	2.0 P					
							1.5-1.8 2.0-2.6	2.0 P					
							8.0-11. 8.0-14.	.5 K					
							9.5-11. 11.-14.	.5 K					
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 100 M	* WAT 6.2	1.1E+05	8	3	2	1	.35-.43 .43-.52	2.0 P	X(P)	---	ANY	100	THERM RAD
	* WAT 6.9	3.1E+06	8	3	2	1	.52-.59 .59-.68	2.0 P					THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12							.68-.75 .75-.83	2.0 P					SPECTRAL SIG
							.83-.92 .92-1.0	2.0 P					SPATIAL SIG
SUN ANGLE: 1200 OBLIQ: ANY							1.0-1.4 1.5-1.8	2.0 P					
(* >30DEG)							2.0-2.6	2.0 P					
							8.0-11. 11.-14.	.5 K					
POSSIBLE PLATFORM(S):													
1.GEOSYNCHRONOUS SATELLITE													
2.POLAR SATELLITE (4)													
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 50 M	E/M 1.?	3.4E+06	6	0	1	2	.40-.45 .45-.50	---	X(P)	---	ANY	100	THERM RAD
	F/M 3.1	3.4E+06	6	0	1	2	.50-.55 .55-.60	---	K(P)	---	ANY	100	THERM RAD (MW)
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12	E/M 3.2	3.4E+06	6	0	1	2	.60-.65 .65-.70	---	X(P)	---	30	100	SPECTRAL SIG
	E/M 3.3	3.4E+06	6	0	1	2	.80-1.0 1.5-1.8	---	K(P)	---	30	100	SPEC SIG (TH IR)
SUN ANGLE: 0900,1200 OBLIQ: ANY	E/M 3.4	3.4E+06	6	0	1	2	8.0-14. 9.5-11.	.5 K	X(A)	---	30	50	SPEC/SPAT SIG
(* >30DEG)	* WAT 1.5	1.8E+06	1	1	1	2			L(A)	---	30	50	TEMP SPEC SIG
													SCAT CROSS SEC
POSSIBLE PLATFORM(S):													
1.GEOSYNCHRONOUS SATELLITE													
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 5 M	LAND 4.20	3.3E+06	3	2	2	0	.50-.60 .60-.70	---					THERM RAD
	*LAND 4.19	3.3E+06	3	2	2	0	.80-1.0 1.5-1.8	---					SPECTRAL SIG
COV CYCLE: 1 DAY EVERY 30 DUR: 1-12	LAND 4.21	4.0E+05	3	2	2	0	2.0-2.6	---					SPEC/SPAT SIG
	LAND 4.22	3.8E+04	3	2	2	0	8.0-14. 8.0-11.	.5 K					TEMP SPEC SIG
SUN ANGLE: 0600,1200 OBLIQ: ANY	WAT 1.25	4.0E+03	3	2	1	0	11.-14.	.5 K					SPATIAL SIG
(* >30DEG)													SCAT CROSS SEC
POSSIBLE PLATFORM(S):													
1.AIRCRAFT													

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V	I	T	M	NON-MICROWAVE BANDS (MICRONS)	ACC	MICROWAVE BNDS	ACC (K)	OBL	RES (M)	DISTING. CHARACT
LAT/LOC: GLOBAL OCEANS VIS/IR RES: 50 M COV CYCLE: 1 DAY EVERY 30 DJR: 1-12 SUN ANGLE: 0900/1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (3 AND 4)	* MAR 3.3	4.0E+07	3	1	1	1	.40-.50 .50-.54 .54-.64 1.5-1.8 9.5-11.	2.0 P 2.0 P .5 K	L(P)	.05	ANY	300	SPECTRAL SIG TEMP SPEC SIG
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 10 M COV CYCLE: 1 DAY EVERY 30 DJR: 1-12 SUN ANGLE: 0600/1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (2 AND 4)	WAT 1.9 * WAT 1.4	7.3E+04 2.5E+04	4 1	2 1	1 1	0 2	.50-.63 .63-.75 .75-.88 .80-1.0 .88-1.0 1.5-1.8 2.0-2.6 8.0-14. 9.5-11.	--- --- --- --- .5 K	X(A) L(A)	--- ---	30 30	50 50	THERM RAD SPECTRAL SIG SPEC/SPAT SIG TEMP SPEC SIG SCAT CROSS SEC
LAT/LOC: 28.5-72 DEGREES VIS/IR RES: 50 M COV CYCLE: 1 DAY EVERY 30 DJR: 1-12 SUN ANGLE: 0600/1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (2 AND 4)	WAT 1.10 WAT 1.24	6.1E+04 9.1E+06	4 3	2 2	1 1	0 0	.50-.60 .50-.63 .60-.70 .63-.75 .75-.88 .80-1.0 .88-1.0 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- --- --- .5 K					THERM RAD SPECTRAL SIG SPEC/SPAT SIG TEMP SPEC SIG SCAT CROSS SEC
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 50 M COV CYCLE: 1 DAY EVERY 30 DJR: 1-12 SUN ANGLE: 0600/1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE	WAT 1.15 WAT 1.16 WAT 1.17 WAT 1.18 WAT 1.19 WAT 1.21 WAT 1.22 WAT 1.23	5.0E+04 5.0E+04 2.0E+05 2.0E+05 1.5E+04 2.0E+05 2.0E+05 1.8E+06	3 3 3 3 3 3 3 3	2 2 2 2 2 2 2 2	1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0	.50-.60 .60-.70 .80-1.0 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- .5 K					THERM RAD SPECTRAL SIG SPEC/SPAT SIG TEMP SPEC SIG SCAT CROSS SEC
LAT/LOC: 28.5-57 DEGREES VIS/IR RES: 20 M COV CYCLE: 1 DAY EVERY 30 DJR: 1-12 SUN ANGLE: 0600/1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (2 AND 4)	WAT 1.20	1.0E+04	3	2	1	0	.50-.60 .60-.70 .80-1.0 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- .5 K					THERM RAD SPECTRAL SIG SPEC/SPAT SIG TEMP SPEC SIG SCAT CROSS SEC

PLATFORM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NO. OF BANDS V I T M	NON-MICROWAVE BANDS (MICRONS)	NON-MICROWAVE ACC	MICROWAVE BNDS	MICROWAVE ACC (K)	MICROWAVE DBL	MICROWAVE RES (M)	DISTING. CHARACT
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 100 M COV CYCLE: 1 DAY EVERY 30 DUR: 1-12 SUN ANGLE: 0300,0900, 1500 OBLIQ: ANY POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE	* MAR 1.4 * MAR 1.5	2.6E+04 2.6E+04	5 1 1 1 5 1 1 1	.40-.50 .50-.54 .50-.58 .54-.64 .64-.70 1.5-1.8 9.5-11.	2.0 P 2.0 P 2.0 P .5 K	L(P)	---	ANY	300	THERM RAD TEMP SPEC SIG SPATIAL SIG
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 5 M COV CYCLE: 1 DAY EVERY 90 DUR: 3,6,9,12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	* FOR 3.3	5.0E+03	4 3 0 0	.50-.63 .63-.75 .75-.88 .88-1.0 1.0-1.4 1.5-1.8 2.0-2.6	--- --- --- ---					THERM RAD SPECTRAL SIG
LAT/LOC: 28.5-72 DEGREES VIS,IR RES: 5 M COV CYCLE: 1 DAY EVERY 90 DUR: 3,6,9,12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.AIRCRAFT	* FOR 3.4	6.0E+03	4 3 2 0	.50-.63 .63-.75 .75-.88 .88-1.0 1.0-1.4 1.5-1.8 2.0-2.6 4.5-5.5 8.0-14.	--- --- --- --- ---					THERM RAD SPECTRAL SIG
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 100 M COV CYCLE: 1 DAY EVERY 90 DUR: 3,6,9,12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.GEOSYNCHRONOUS SATELLITE 2.POLAR SATELLITE (4)	*LAND 2.8	2.6E+06	6 2 1 0	.40-.50 .50-.60 .60-.70 .70-.80 .80-.90 .90-1.0 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- --- ---					THERM RAD SPECTRAL SIG TEMP SPEC SIG TEMP SPC/SPA SIG
LAT/LOC: 28.5-57 DEGREES VIS,IR RES: 20 M COV CYCLE: 1 DAY EVERY 90 DUR: 3,6,9,12 SUN ANGLE: 1200 OBLIQ: ANY (* >30DEG) POSSIBLE PLATFORM(S): 1.POLAR SATELLITE (4)	*LAND 2.9 *LAND 2.11	3.0E+05 3.0E+05	6 2 1 0 6 2 1 0	.40-.50 .50-.60 .60-.70 .70-.80 .80-.90 .90-1.0 1.5-1.8 2.0-2.6 8.0-14.	--- --- --- --- ---					THERM RAD SPECTRAL SIG TEMP SPEC SIG TEMP SPC/SPA SIG

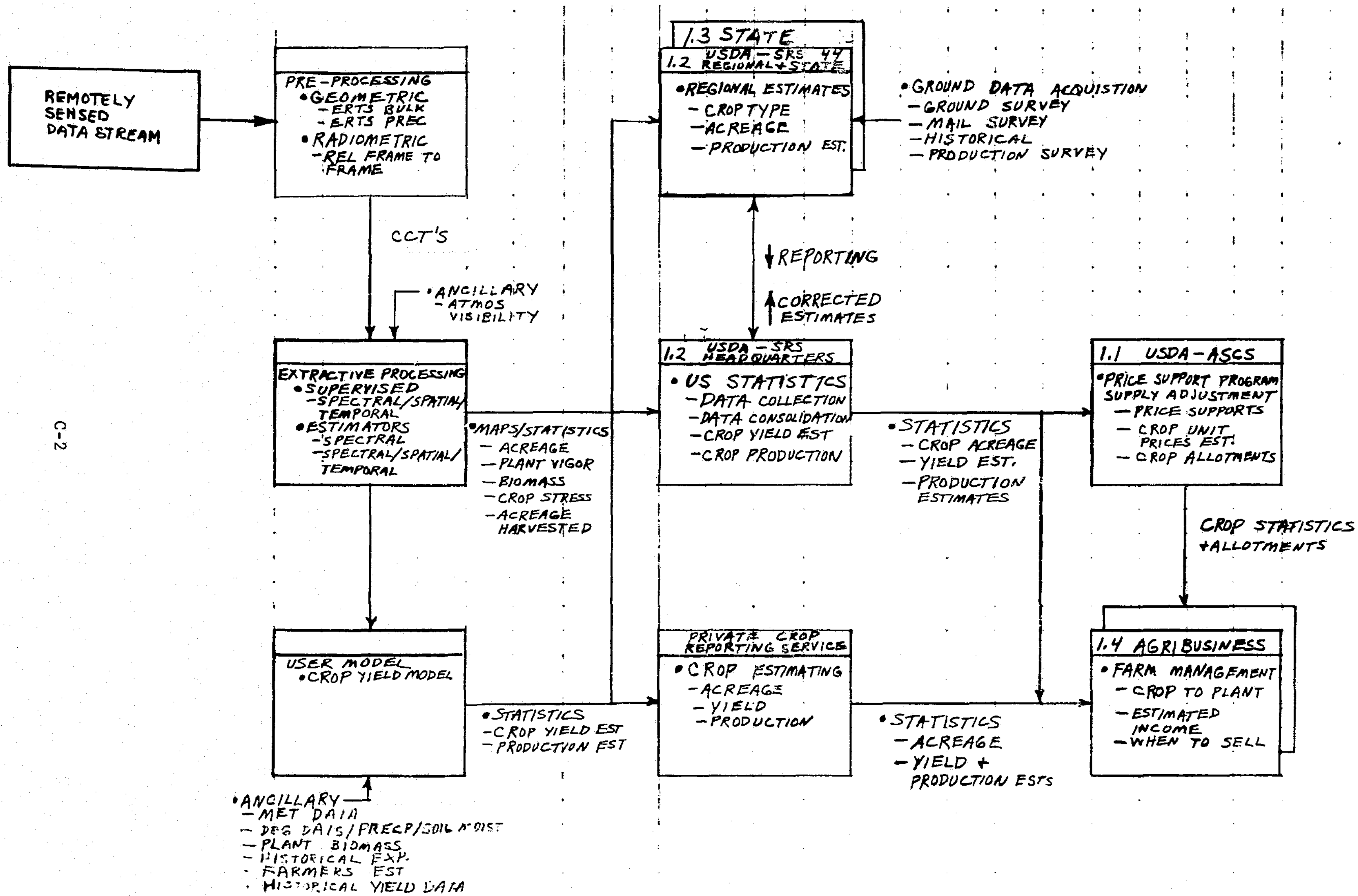
PLATFØRM REQUIREMENTS	MIS/USERS	AREA (KM**2)	NØ. ØF BANDS V	I	T	M	NØN-MICRØWAVE BANDS (MICRØNS)	ACC	MICRØWAVE BNDS	ACC (K)	ØBL	RES (M)	DISTING. CHARACT
LAT/LØC: 28.5-57 DEGREES VIS,IR RES: 50 M CØV CYCLE: 1 DAY EVERY 90 DUR: 1-12 SUN ANGLE: 1200 ØBLIQ: ANY (* >30DEG) PØSSIBLE PLATFØRM(S): 1.GEØSYNCHRØNØUS SATELLITE 2.PØLAR SATELLITE (4)	WAT 1.11 * WAT 1.1 *LAND 2.13	2.0E+05 9.1E+06 5.0E+05	4 1 6	2 1 2	1 1 1	0 0 0	.40-.50 .50-.60 .50-.63 .60-.70 .63-.75 .70-.80 .75-.88 .80-.90 .80-1.0 .88-1.0 .90-1.0 1.5-1.8 2.0-2.6 8.0-14. 9.5-11.	--- --- --- --- --- --- --- .5 K					THERM RAD SPECTRAL SIG SPEC/SPAT SIG TEMP SPEC SIG TEMP SPC/SPA SIG SCAT CRØSS SEC
LAT/LØC: 28.5-57 DEGREES VIS,IR RES: 10 M CØV CYCLE: 1 DAY EVERY 90 DUR: 1-12 SUN ANGLE: 1200 ØBLIQ: ANY (* >30DEG) PØSSIBLE PLATFØRM(S): 1.PØLAR SATELLITE (4)	* WAT 4.11 * WAT 4.13	6.0E+04 5.4E+04	7 8	0 0	1 1	0 0	.32-.38 .40-.48 .48-.53 .53-.58 .58-.65 .65-.72 .72-.80 .80-1.0 8.0-14.	--- --- --- --- .5 K					THERM RAD SPECTRAL SIG
LAT/LØC: 28.5-72 DEGREES VIS,IR RES: 5 M CØV CYCLE: 1 DAY EVERY 90 DUR: 3,6,9,12 SUN ANGLE: 0600,0900, ØBLIQ: ANY 1200 PØSSIBLE PLATFØRM(S): 1.AIRCRAFT	LAND 4.1 LAND 4.2 LAND 4.3 LAND 4.4 LAND 4.5	2.8E+06 2.8E+06 2.8E+06 2.8E+06 2.8E+06	4 4 4 4 4	0 0 0 0 0	2 2 2 2 2	2 2 2 2 2	.51-.55 .62-.66 .80-.90 .90-1.1 8.0-11. 11.-14.	--- --- .5 K	X(A) L(A)	--- ---	30 30	30 30	THERM RAD THERM RAD (MW) SPECTRAL SIG SPEC/SPAT SIG SPATIAL SIG SCAT CRØSS SEC
LAT/LØC: 28.5-57 DEGREES VIS,IR RES: 10 M CØV CYCLE: 1 DAY EVERY 90 DUR: 1-12 SUN ANGLE: 0600,0900, ØBLIQ: ANY 1200,1500 PØSSIBLE PLATFØRM(S): 1.PØLAR SATELLITE (2,3,4,AND 5) 2.AIRCRAFT	* F/M 4.6	5.0E+02	4	0	1	2	.40-.55 .55-.70 .70-.85 .85-1.0 8.0-14.	--- --- .5 K	X(P) L(P)	--- ---	AN ANY	30 30	THERM RAD THERM RAD (MW) SPECTRAL SIG SPEC SIG (TH IR) SPEC/SPAT SIG SCAT CRØSS SEC
LAT/LØC: 28.5-57 DEGREES VIS,IR RES: 50 M CØV CYCLE: 1 DAY EVERY 90 DUR: 3,6,9,12 SUN ANGLE: 0600,0900, ØBLIQ: ANY 1200,1500 PØSSIBLE PLATFØRM(S): 1.GEØSYNCHRØNØUS SATELLITE	* MAR 4.1 * MAR 4.2 * MAR 4.3	2.6E+04 8.3E+03 2.3E+03	4 4 4	1 1 1	1 1 1	1 1 1	.40-.50 .50-.54 .54-.60 .60-.70 1.5-1.8 9.5-11.	2.0 P 2.0 P 2.0 P .5 K	L(P)	.05	ANY	300	SPECTRAL SIG TEMP SPEC SIG

B-21

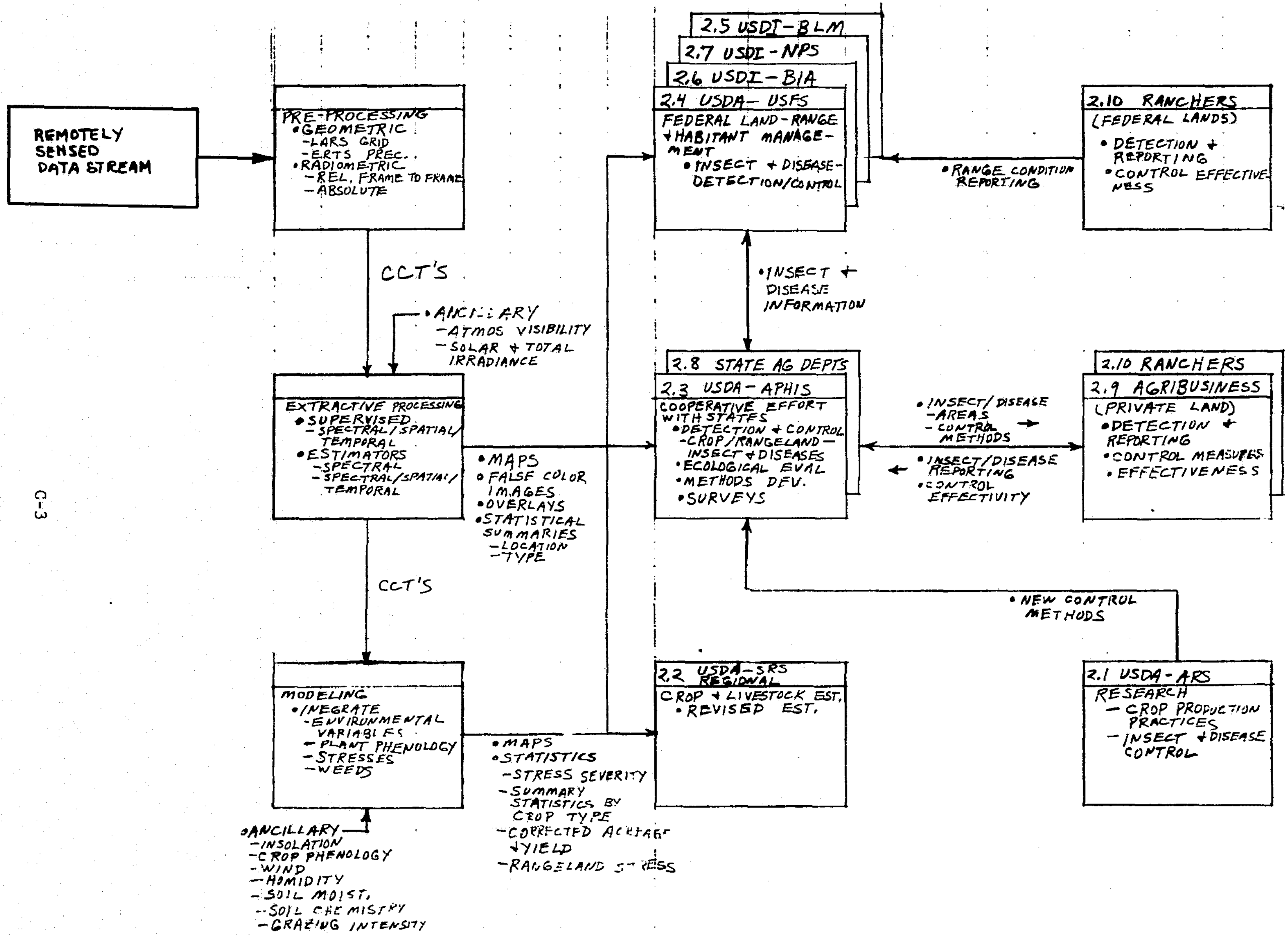
APPENDIX C

TERSSE MISSION INFORMATION FLOWS

The figures contained in this appendix represent the information flows for each of the 30 TERSSE missions as discussed in Section 3.4 of this TERSSE report Volume.

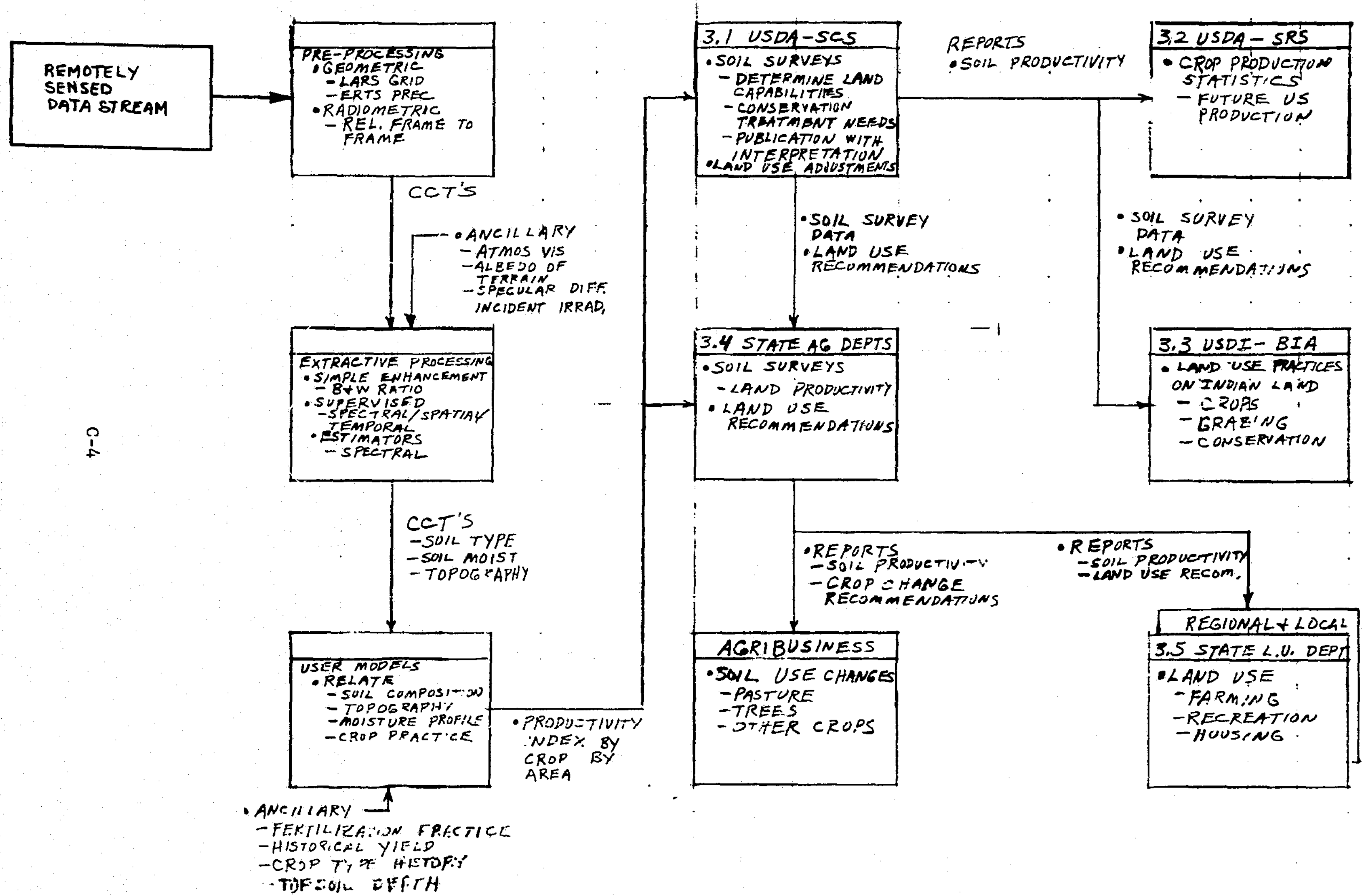


DATA FLOW/USER CHAIN
CROP FORECASTING (AGRICULTURE-1)

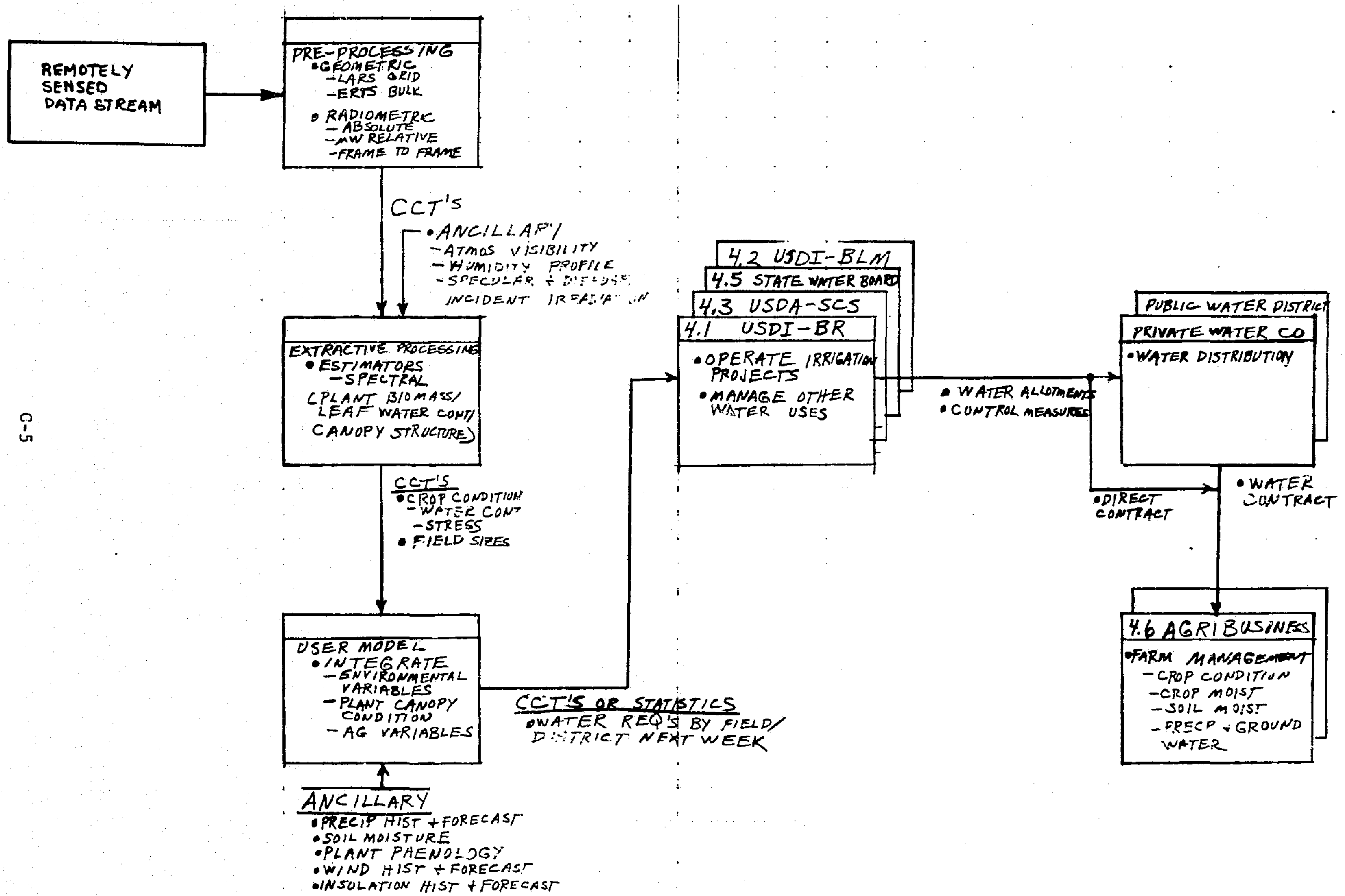


C-3

DATA FLOW/USER CHAIN
RANGE & CROP - INSECT/DISEASE & STRESS (AGRICULTURE-2)

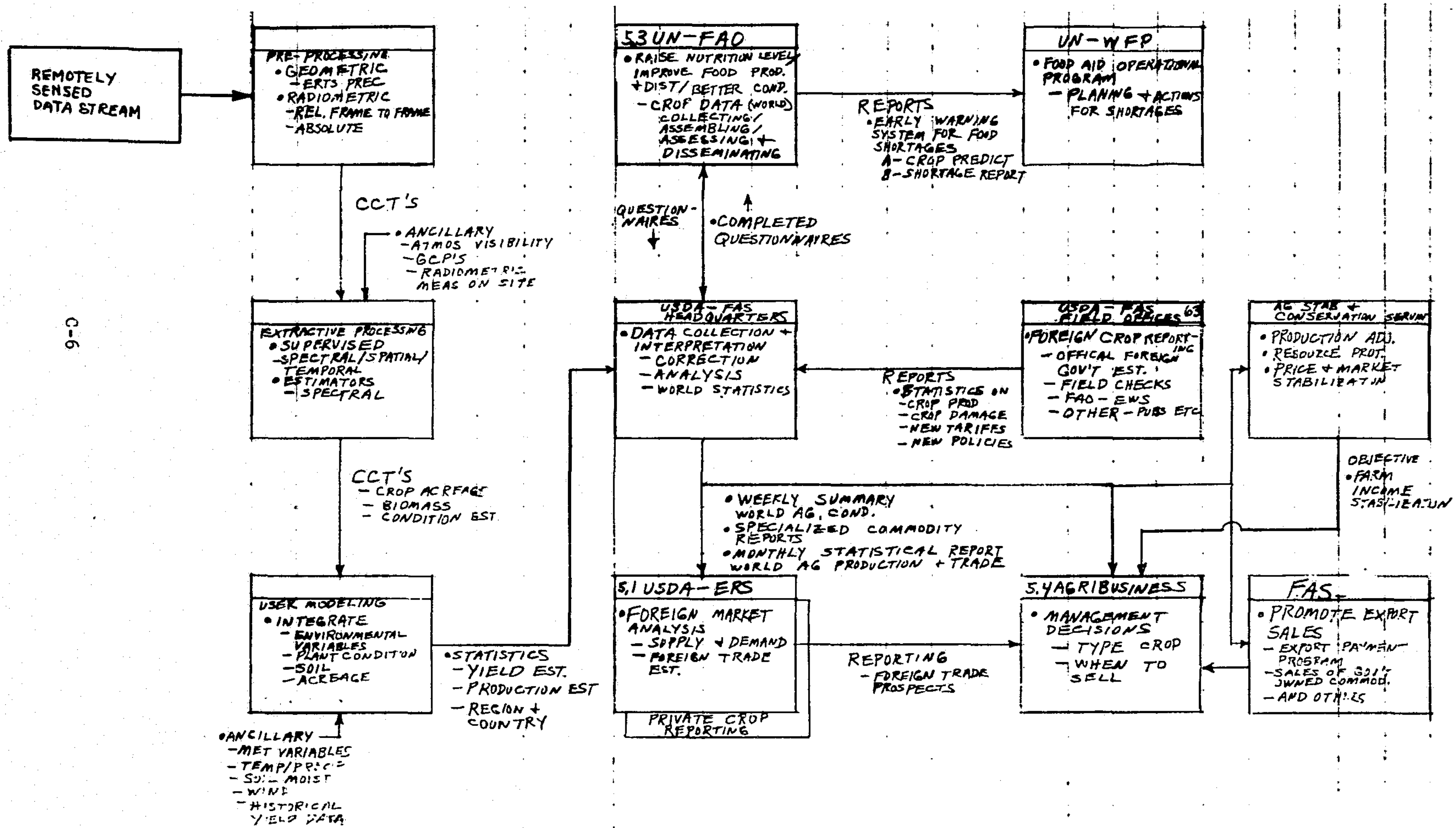


DATA FLOW/USER CHAIN
EVALUATE CURRENT FARMING PRACTICES & CLASS SOIL PRODUCTIVITY (AGRICULTURE-3)

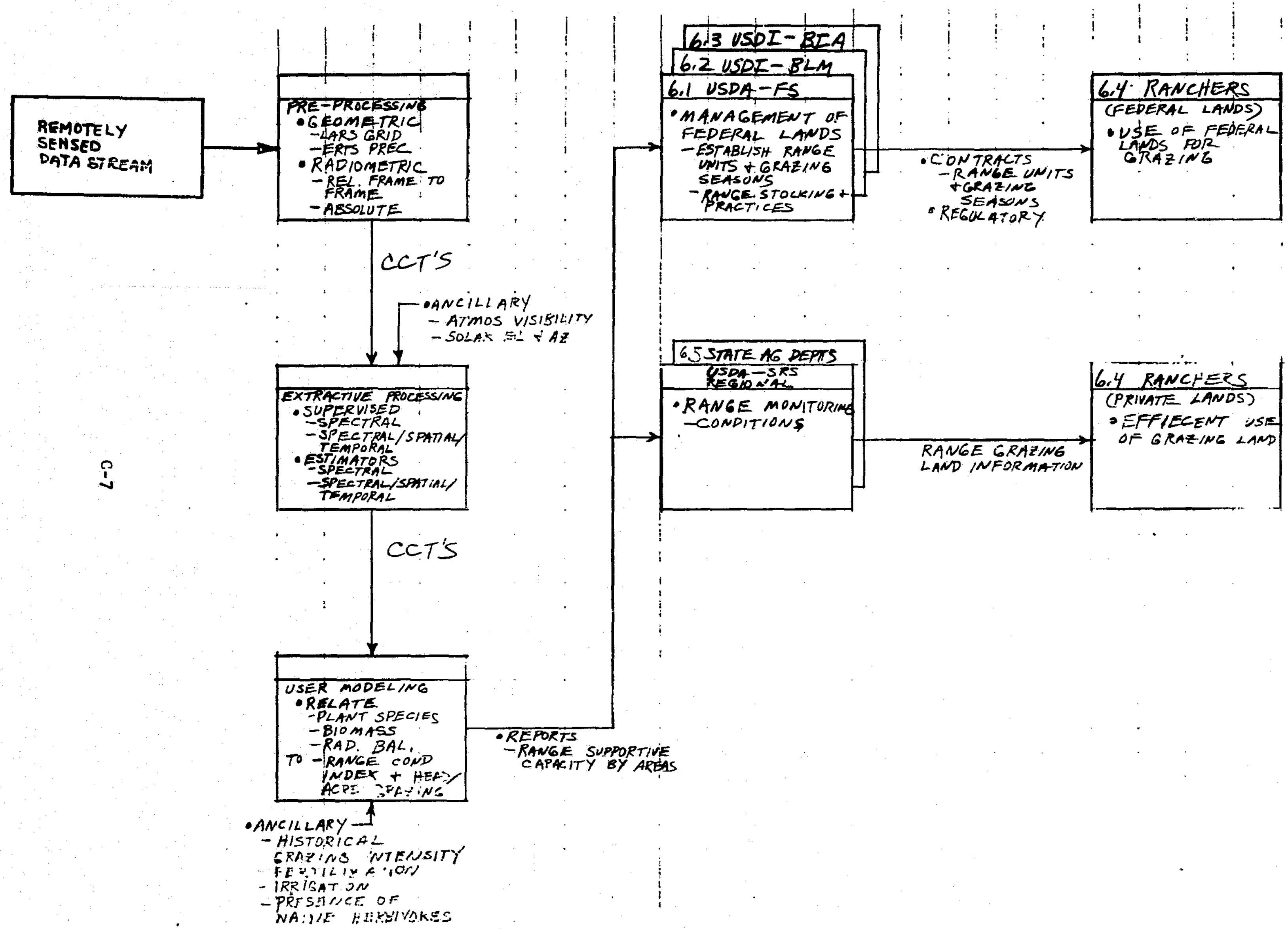


C-5

DATA FLOW/USER CHAIN
IRRIGATION WATER DEMAND FORECASTING (AGRICULTURE–4)

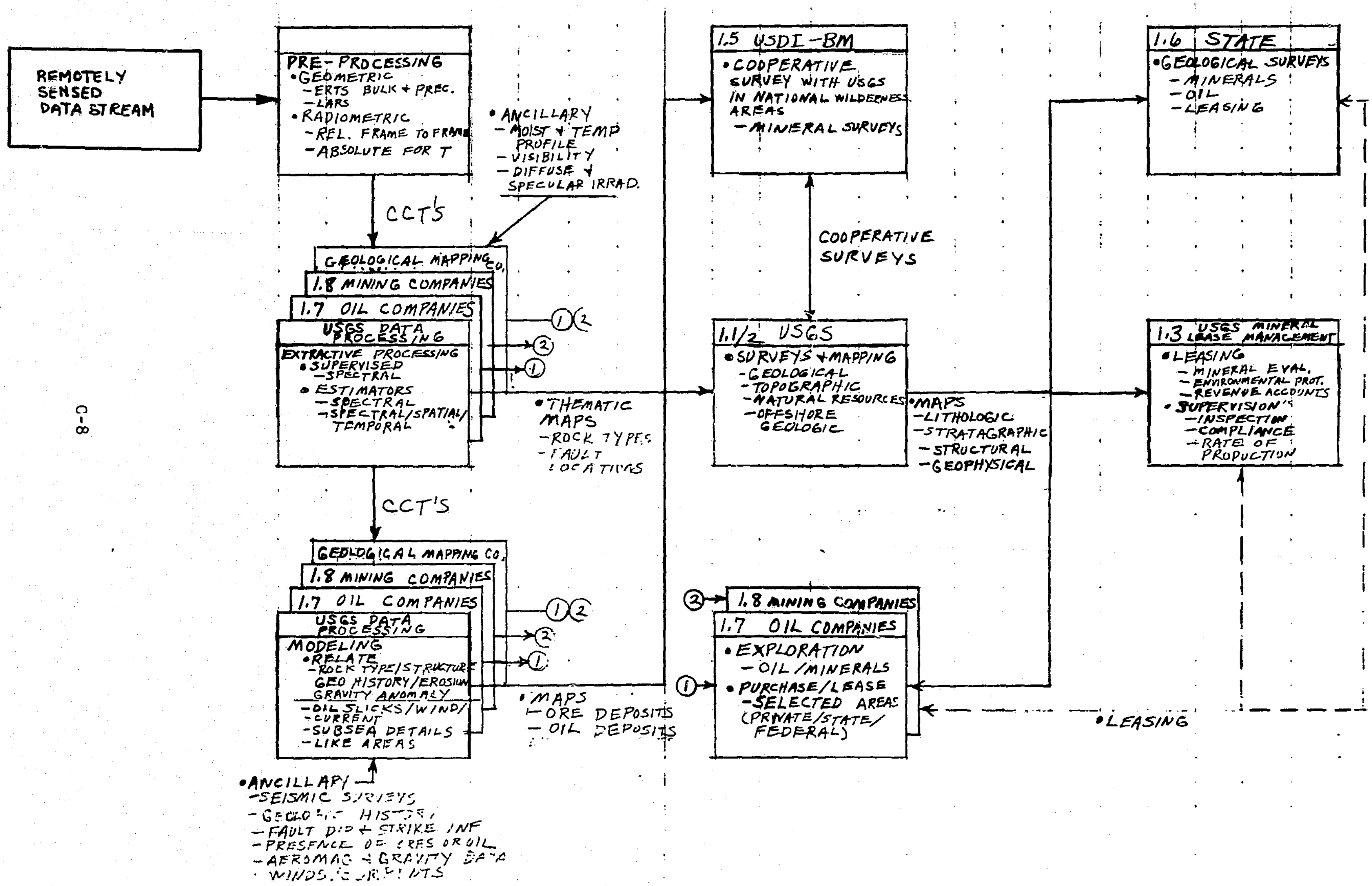


DATA FLOW/USER CHAIN
GLOBAL CROP INVENTORY & FORECAST (AGRICULTURE-5)

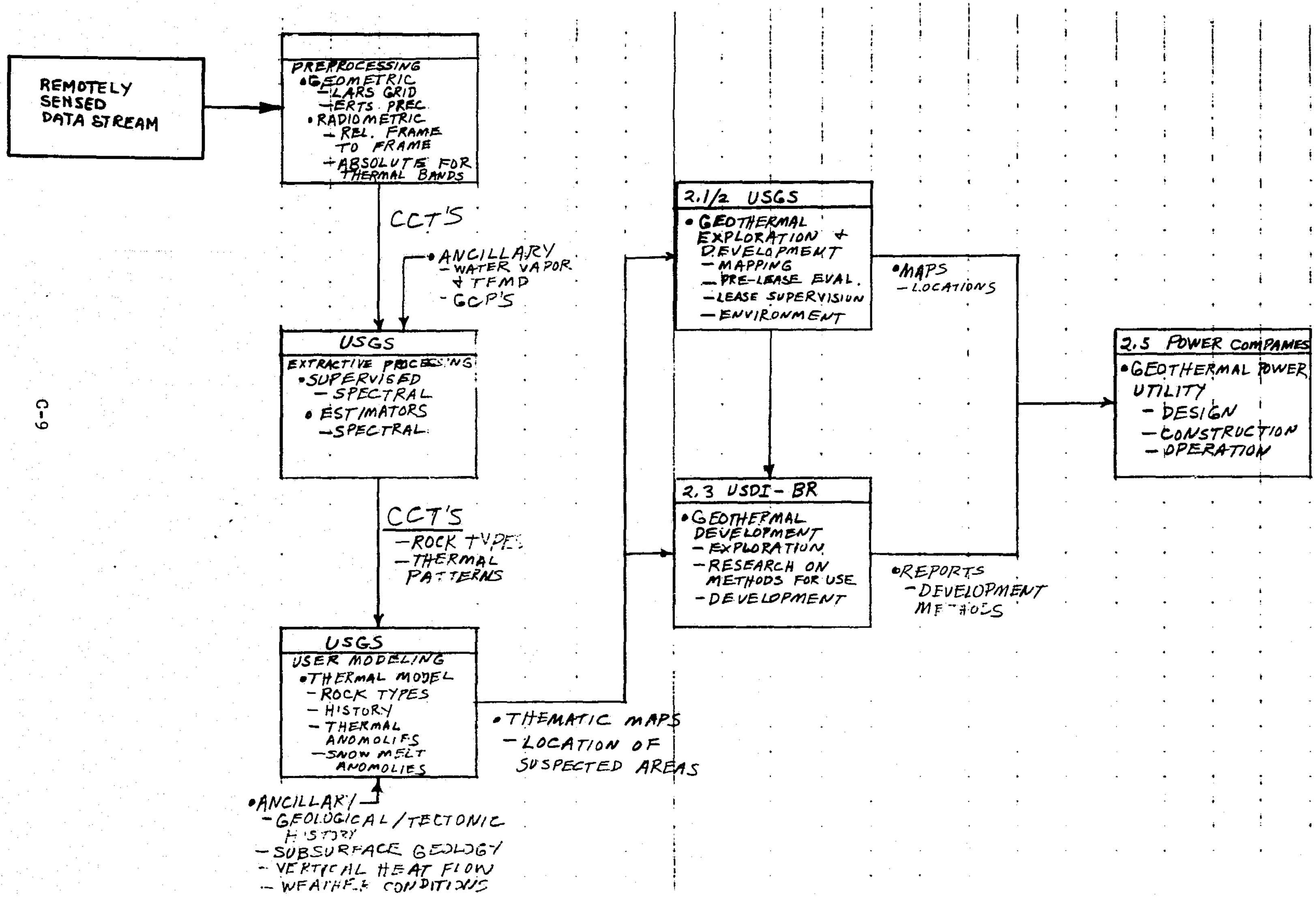


DATA FLOW/USER CHAIN

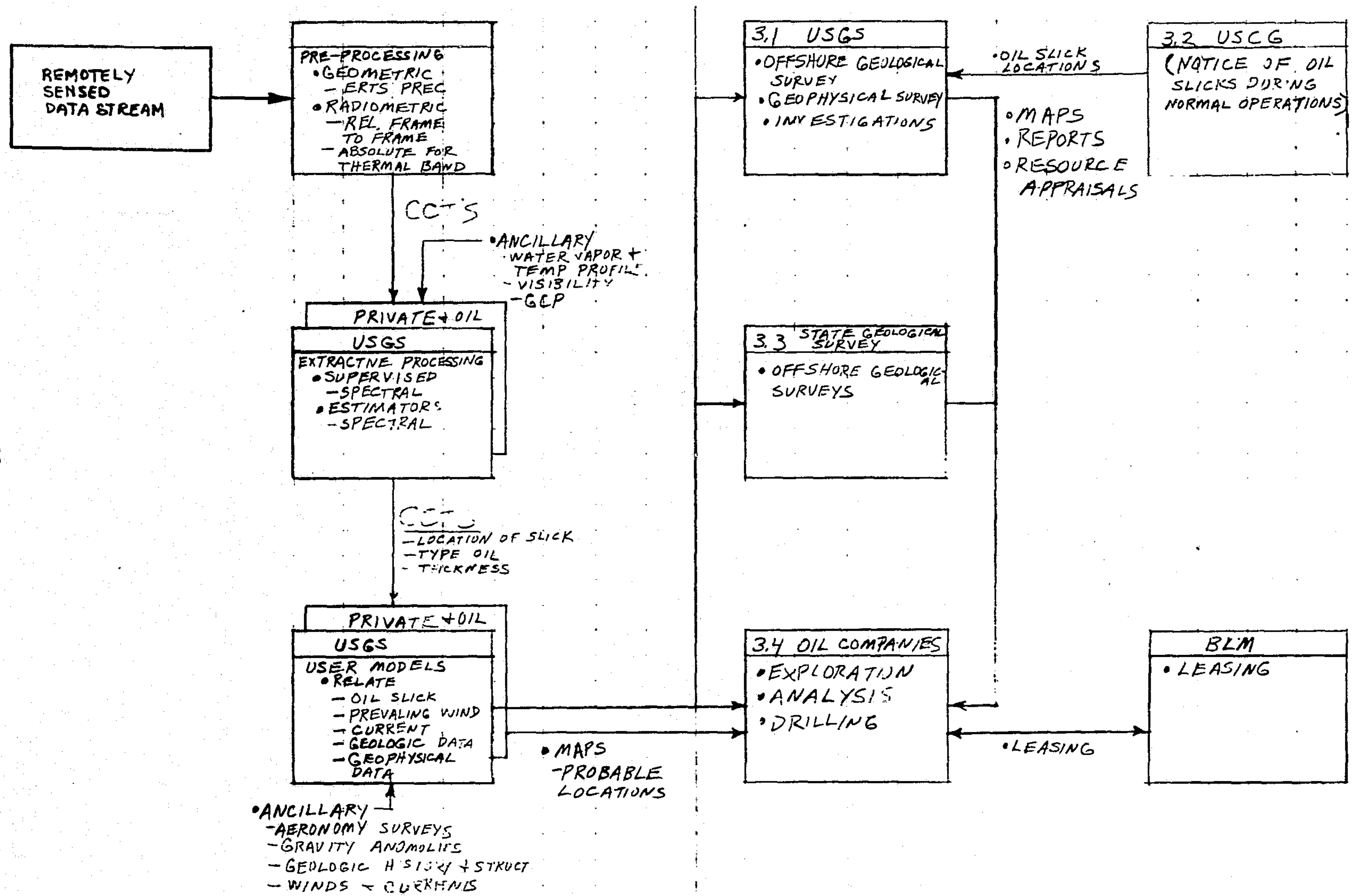
RANGE FORAGE ACREAGE/LIVESTOCK SUPPORTIVE CAPACITY & ASSESSMENT OF CURRENT PRACTICES (AGRICULTURE-6)



DATA FLOW/USER CHAIN
LOCATION OF MINERAL DEPOSITS (ENERGY/MINERALS-1)

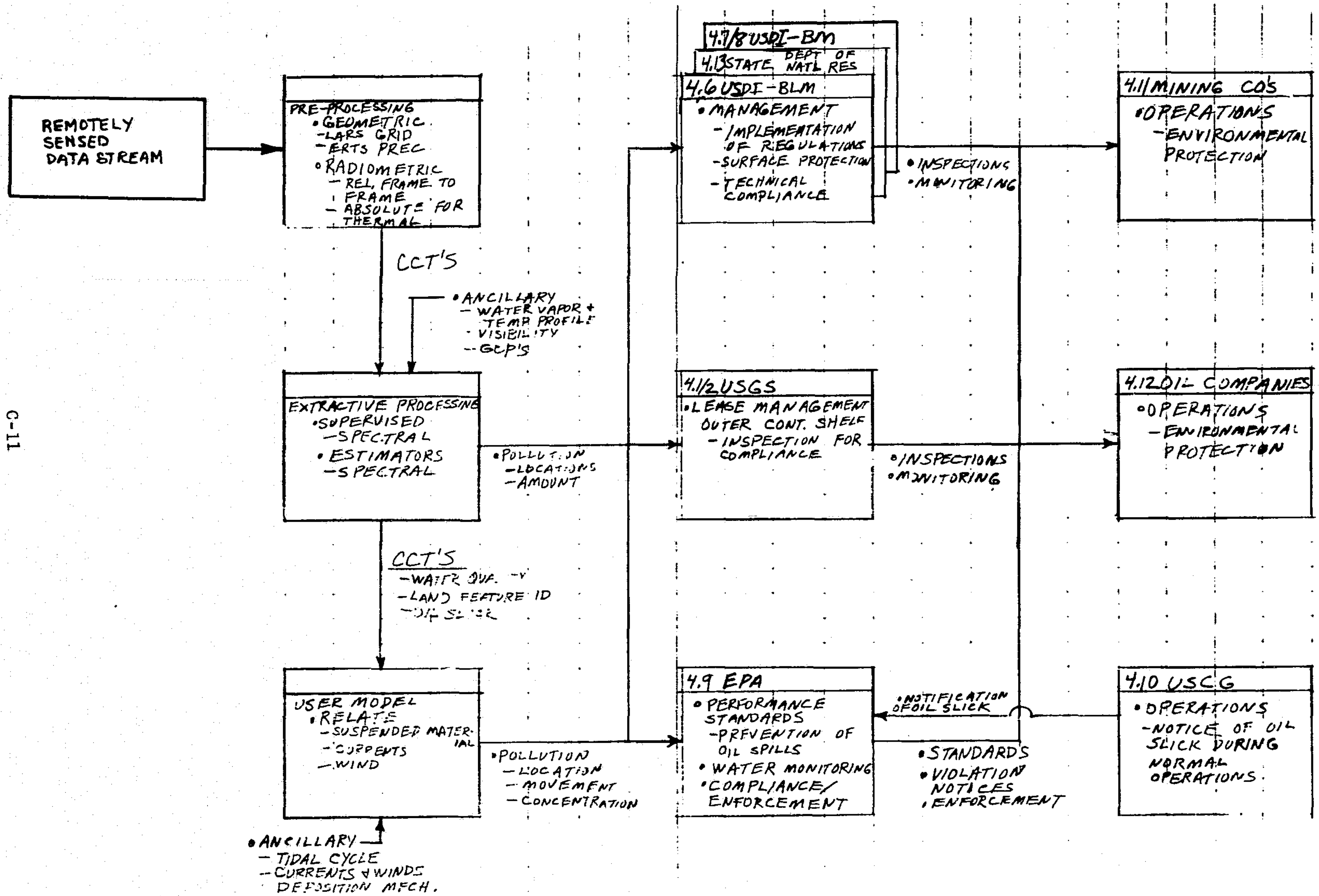


DATA FLOW/USER CHAIN
SURVEY SURFICIAL THERMAL PATTERNS TO DETECT POTENTIAL GEOTHERMAL SOURCES (ENERGY/MINERALS-2)



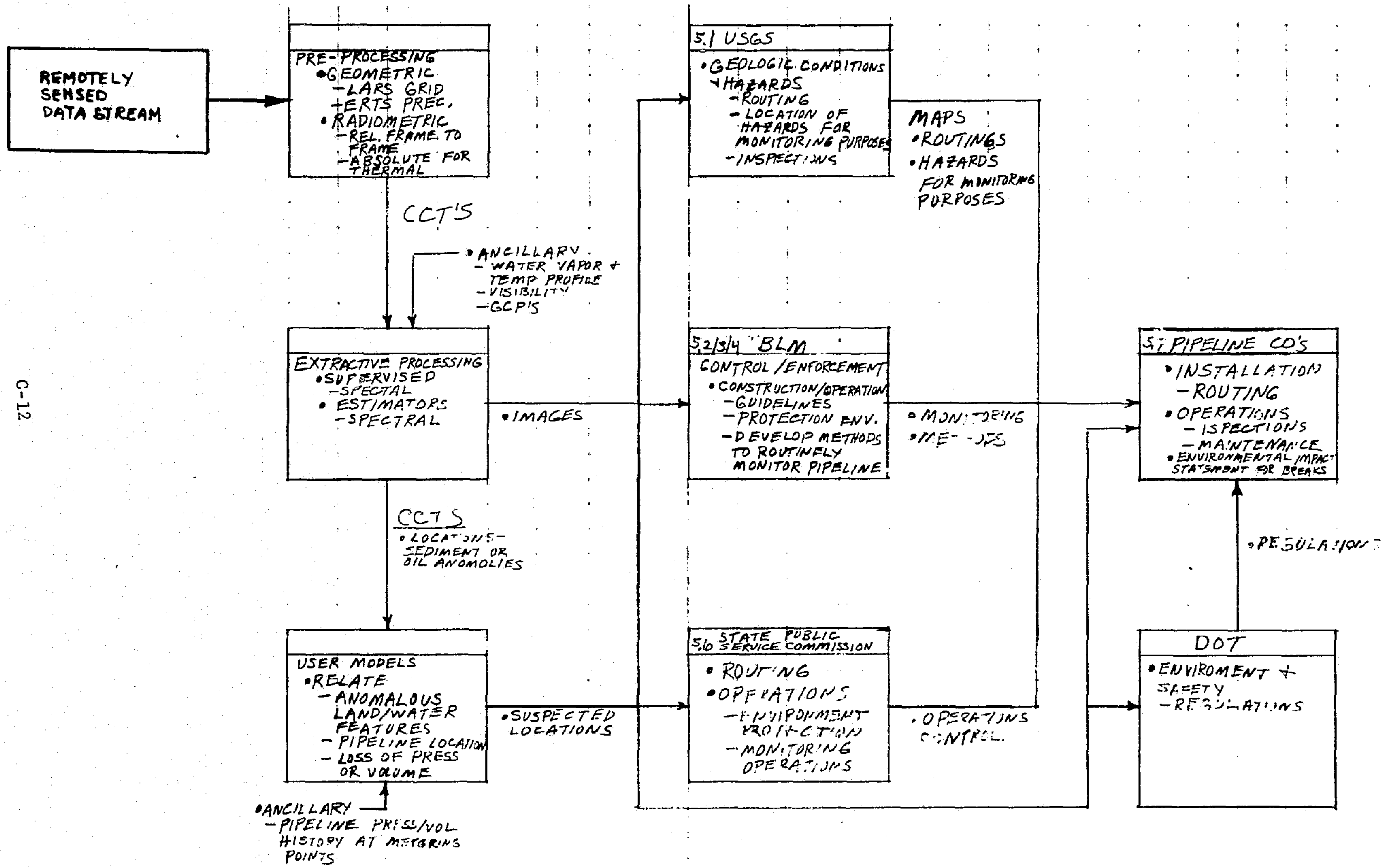
DATA FLOW/USER CHAIN

SURVEY WATERS OF OUTER CONTINENTAL SHELF AREAS TO DETECT OIL FILM POSSIBLY INDICATIVE OF SUBMARINE OIL DEPOSITS (ENERGY/MINERALS-3)



DATA FLOW/USER CHAIN

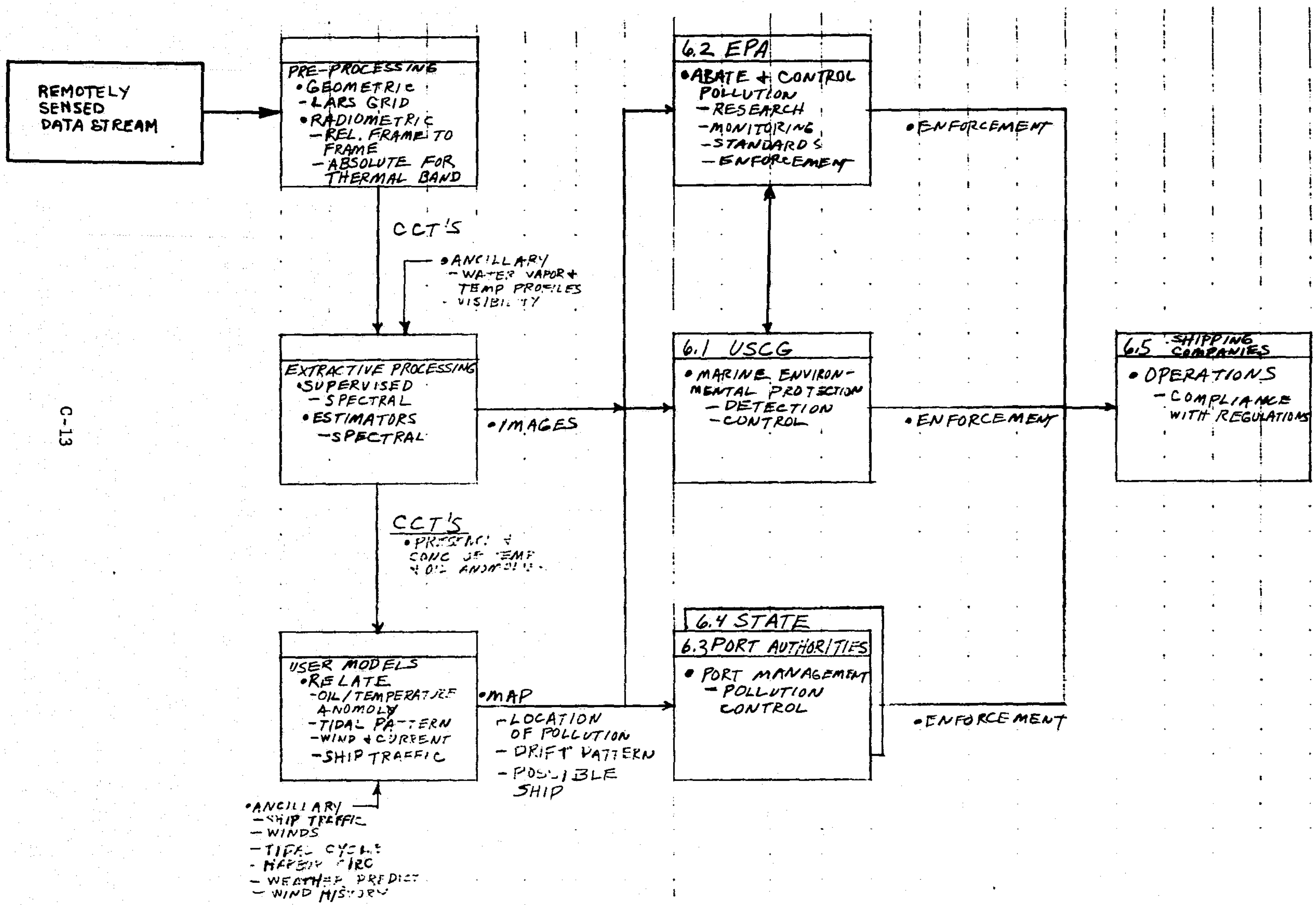
MONITOR SURFACE MINING & OIL DRILLING OPERATIONS TO DETECT RESULTANT ENVIRONMENTAL POLLUTION (ENERGY/MINERALS-4)



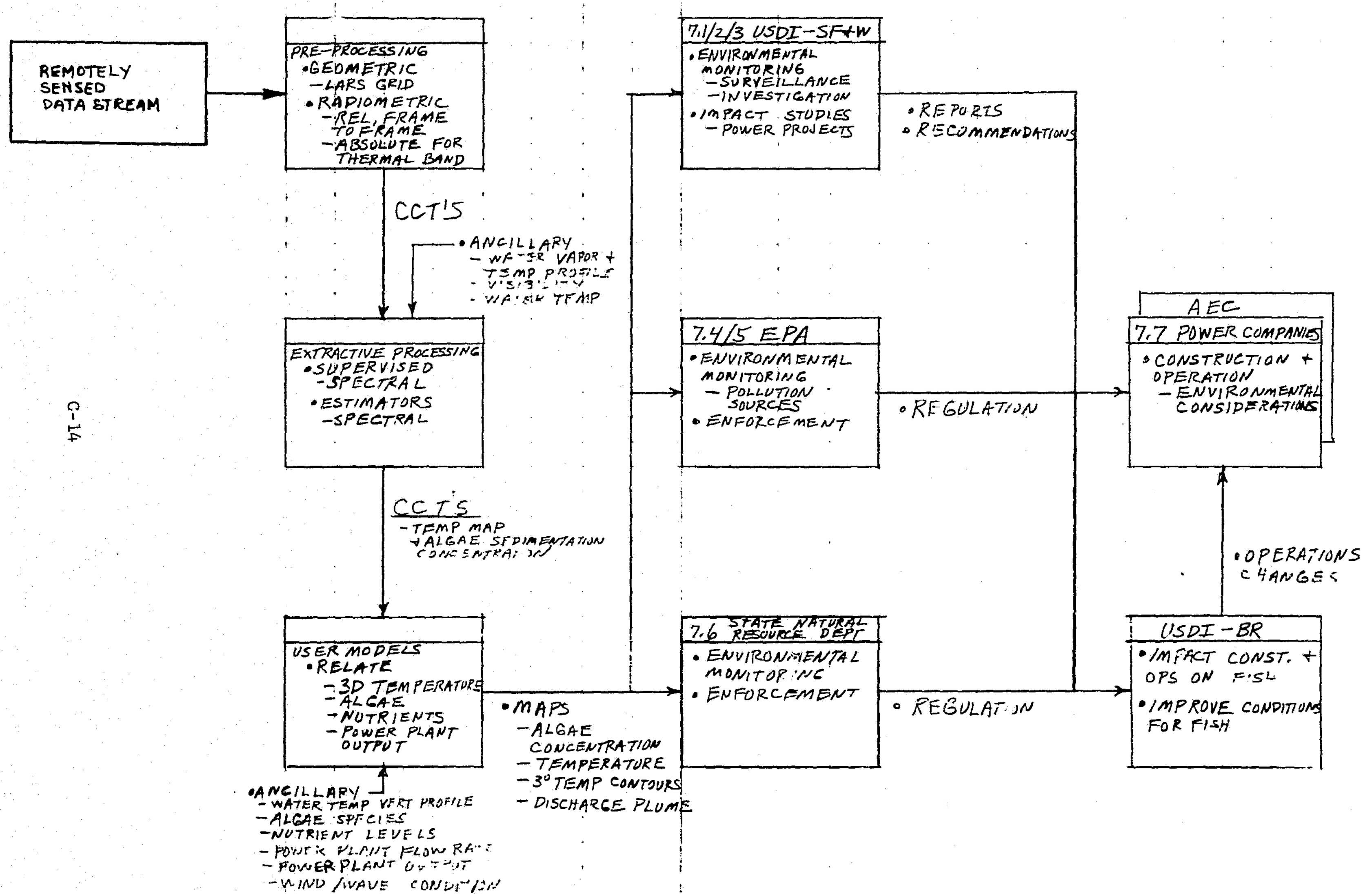
C-12

DATA FLOW/USER CHAIN

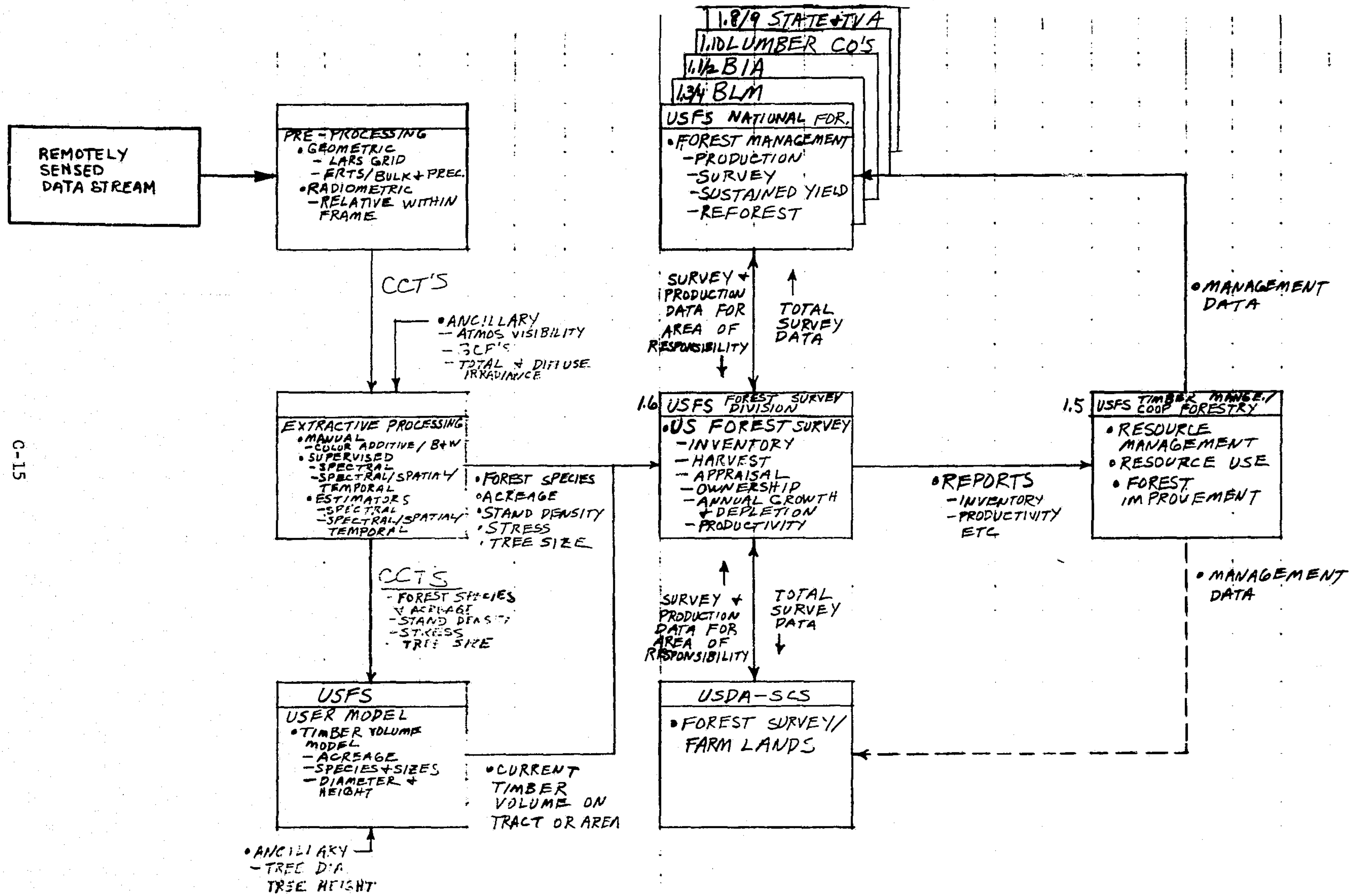
MONITOR OIL & GAS PIPELINES TO DETECT BREAKS OR OTHER ENVIRONMENTAL DYNAMICS (ENERGY/MINERALS-5)



DATA FLOW/USER CHAIN
MONITOR DEEP WATER PORTS TO DETECT & ASSESS OIL POLLUTION (ENERGY/MINERALS-6)

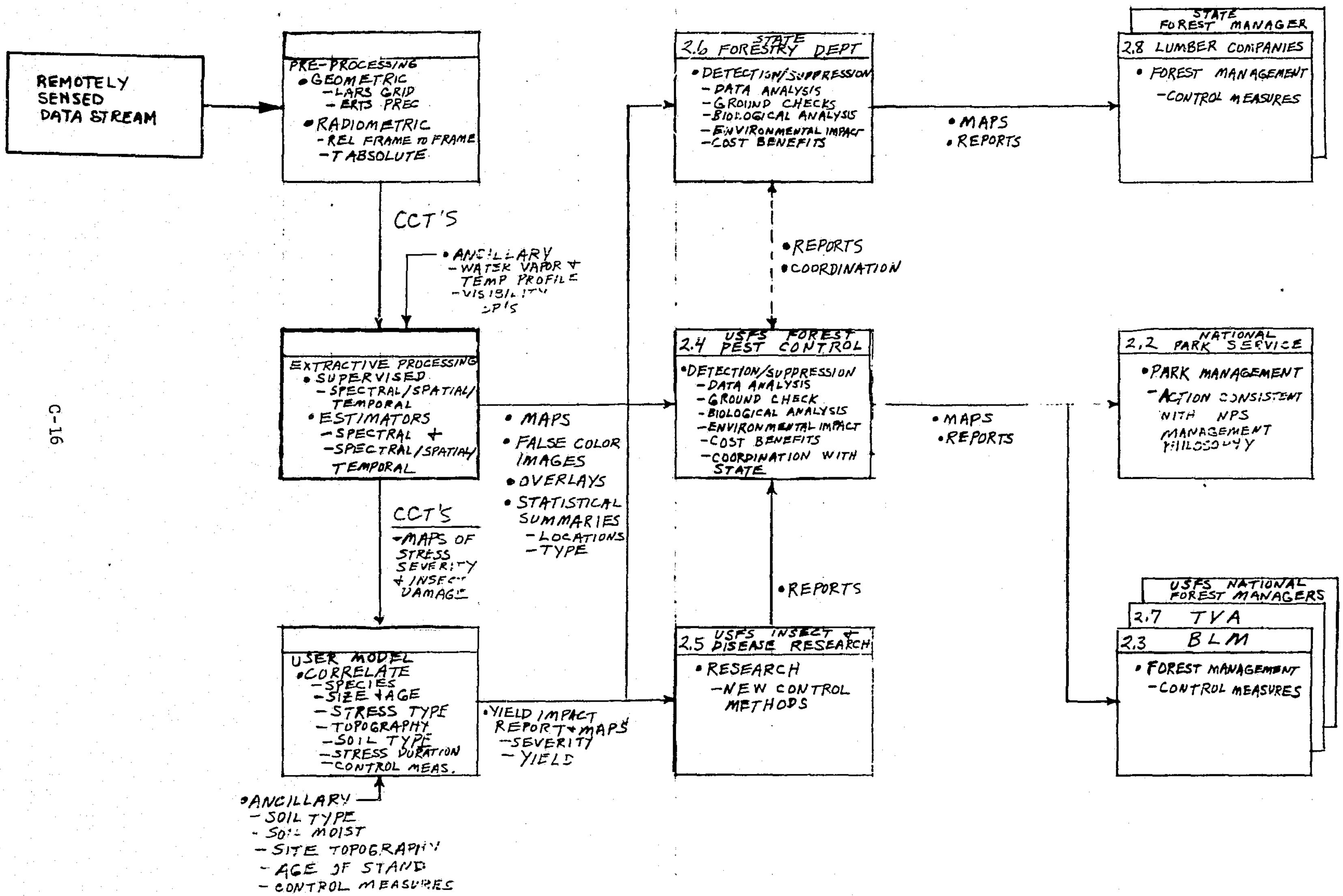


DATA FLOW/USER CHAIN
MONITOR POWER PLANT OPERATIONS TO DETECT & ASSESS THERMAL POLLUTION IN ADJACENT WATERS (ENERGY/MINERALS-7)

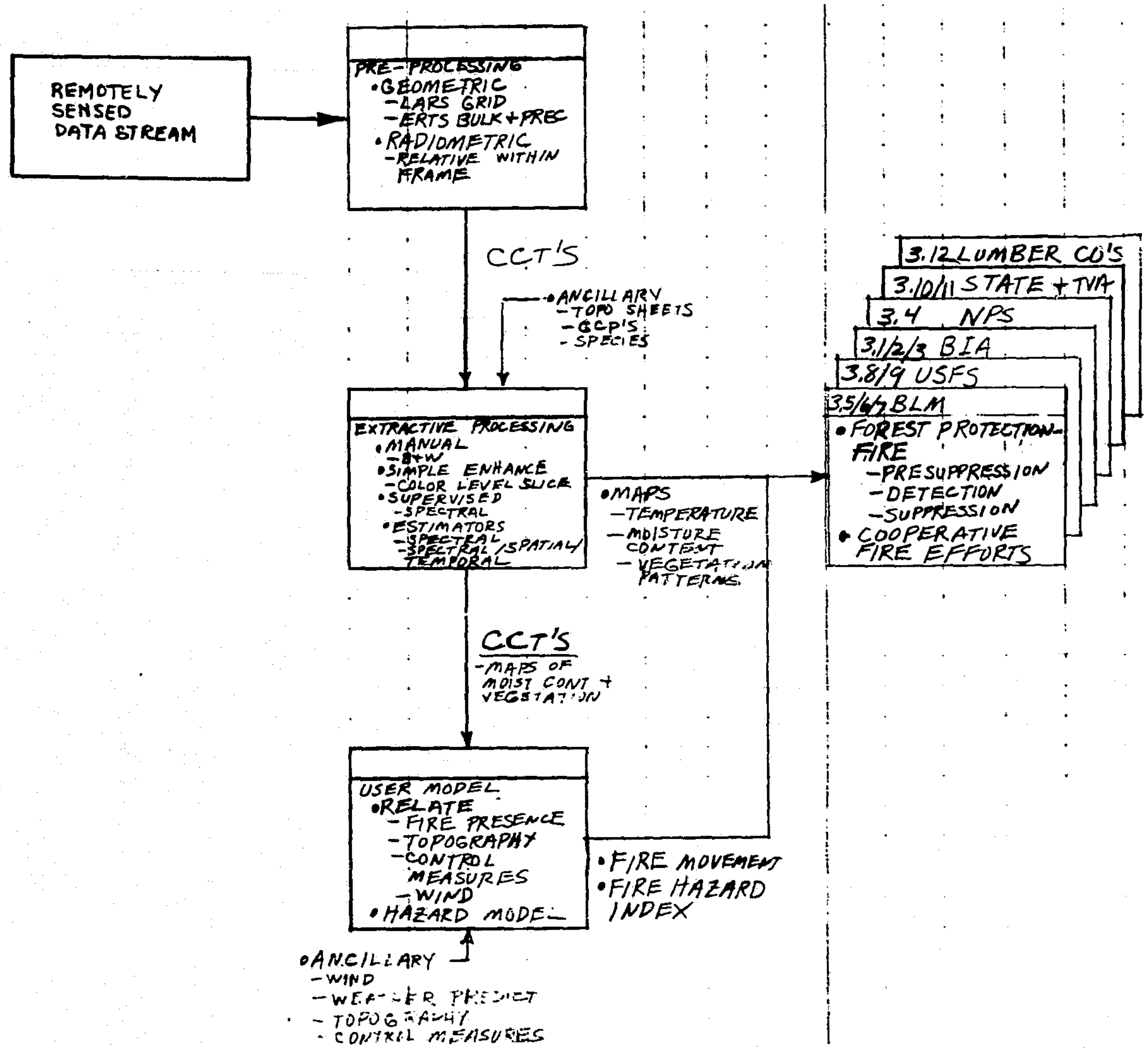


C-15

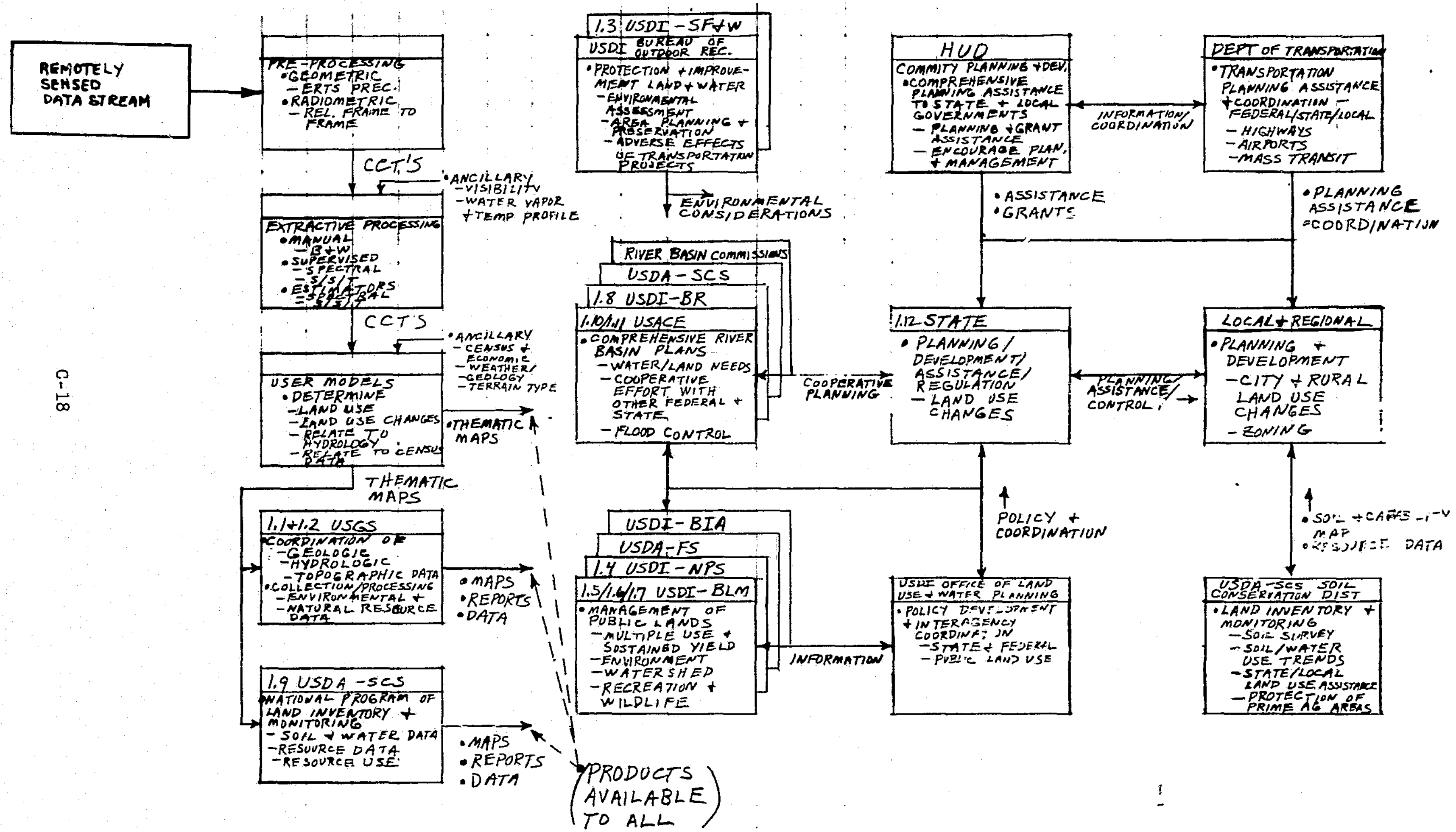
DATA FLOW/USER CHAIN
SURVEY FOREST LAND FOR PRODUCTIVITY/PRODUCTIVITY CLASSIFICATION/ EFFICIENCY & ECOLOGICAL ASPECTS OF PRODUCTION (FORESTRY-1)



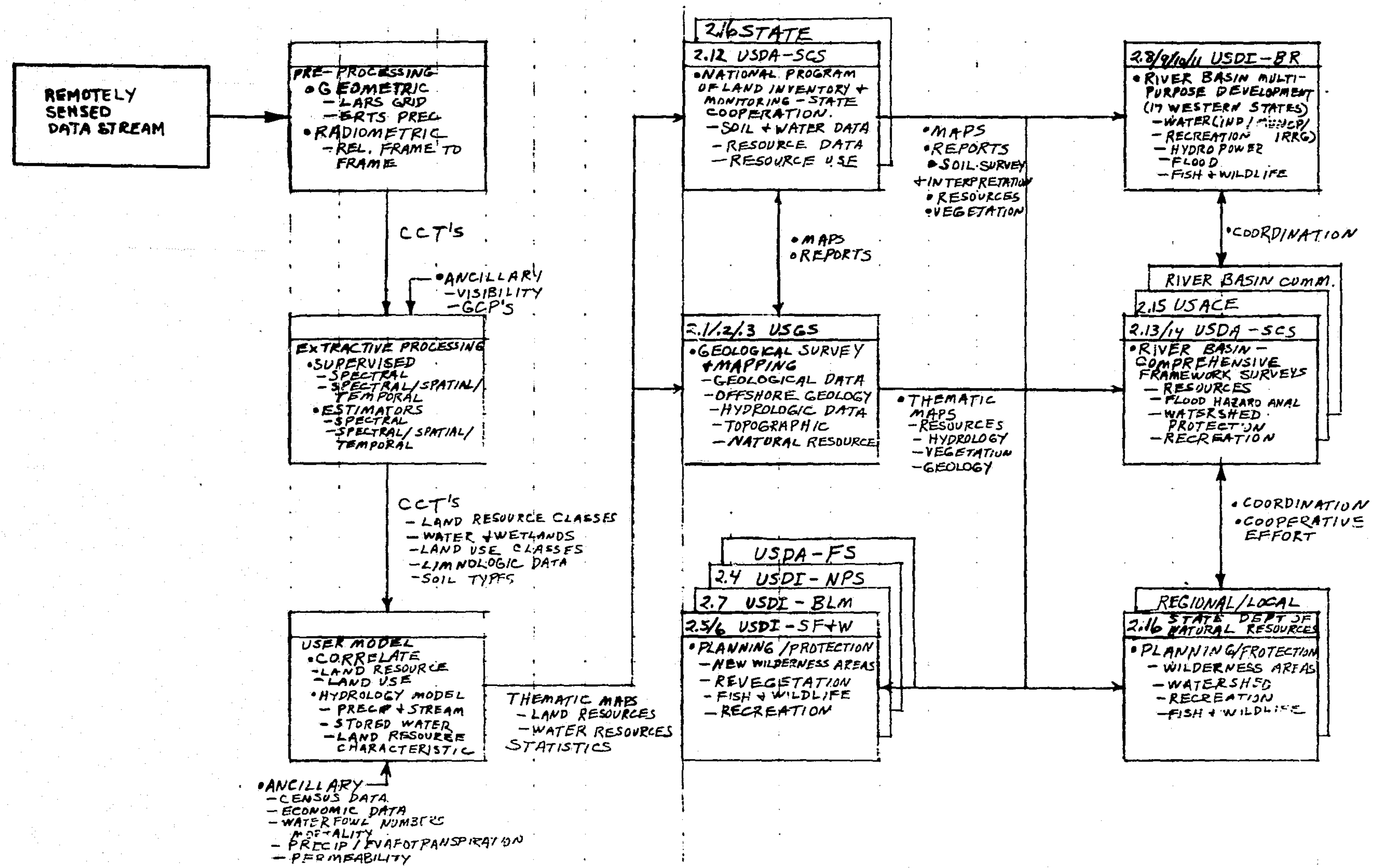
DATA FLOW/USER CHAIN
FOREST INSECT/DISEASE & STRESS (FORESTRY-2)



DATA FLOW/USER CHAIN
SURVEY & MONITOR FOREST & GRASSLANDS/BRUSHLANDS AREAS TO ASSESS FIRE POTENTIAL, DETECT THE OUTBREAK OF FIRE, ASSESS THE DYNAMICS OF FIRE & ASSESS DAMAGE (FORESTRY-3)

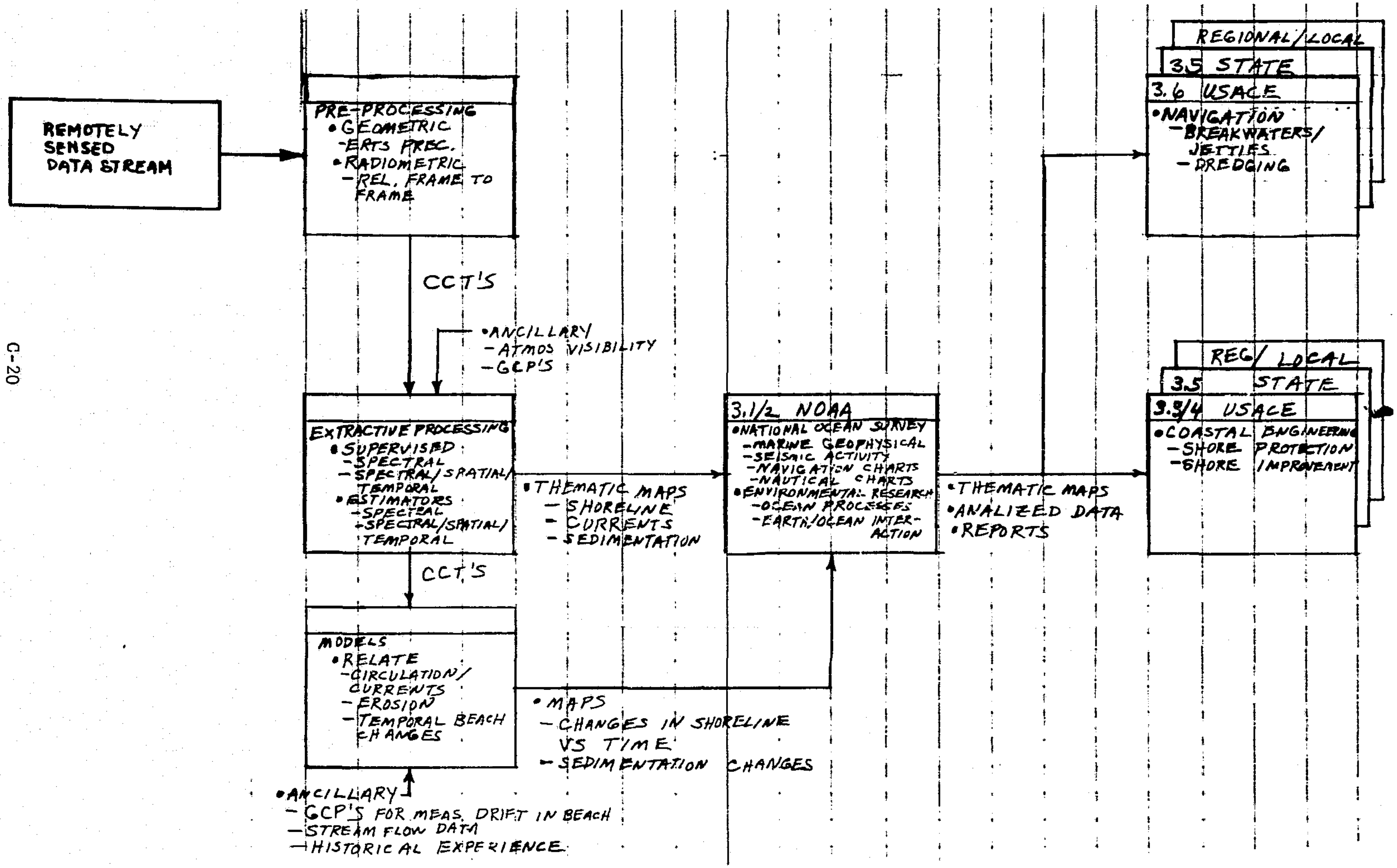


DATA FLOW/USER CHAIN
CURRENT LAND USE MAPPING FOR STATE PLANNING & FEDERAL MANAGEMENT (LAND-1)



DATA FLOW/USER CHAIN
VEGETATION/TOPOGRAPHY/UNDERLYING GEOLOGY & SOIL TYPE (LAND-2)

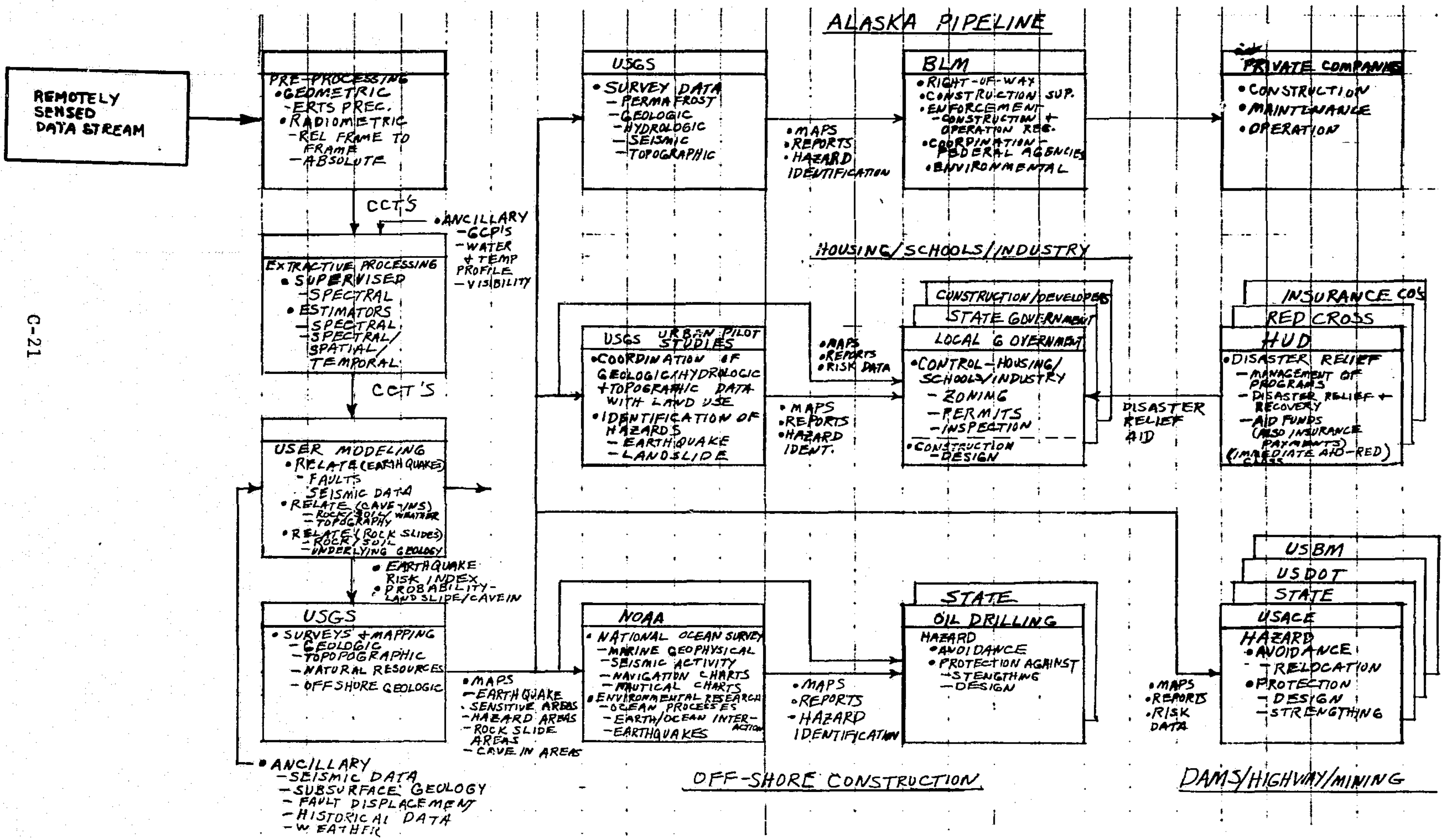
C-20



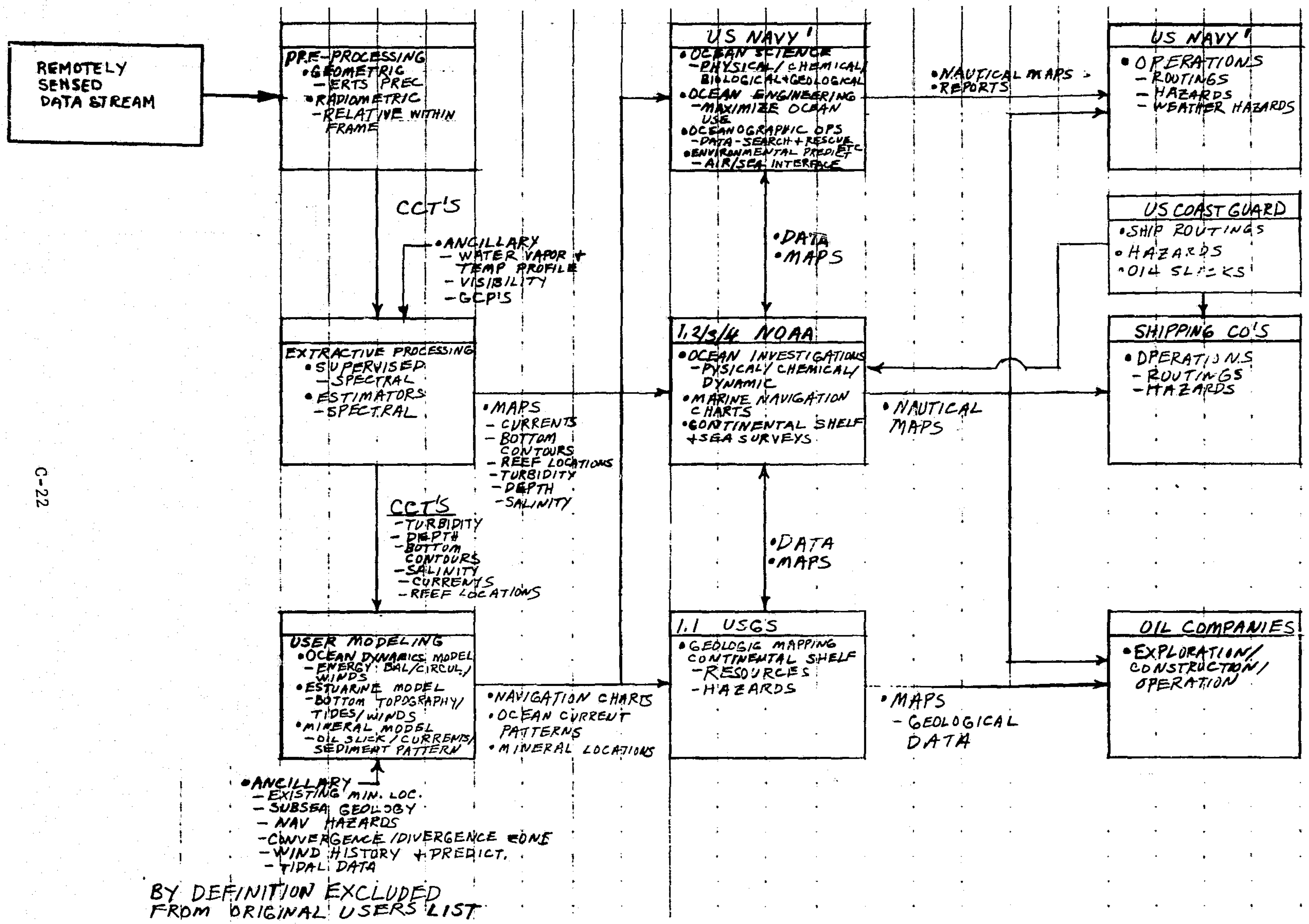
DATA FLOW/USER CHAIN

LAKE & COASTAL SHORELINE MORPHOLOGY & THE NAVIGATION CHANNEL WITHIN THE COASTAL ZONE MONITORING

(LAND-3)

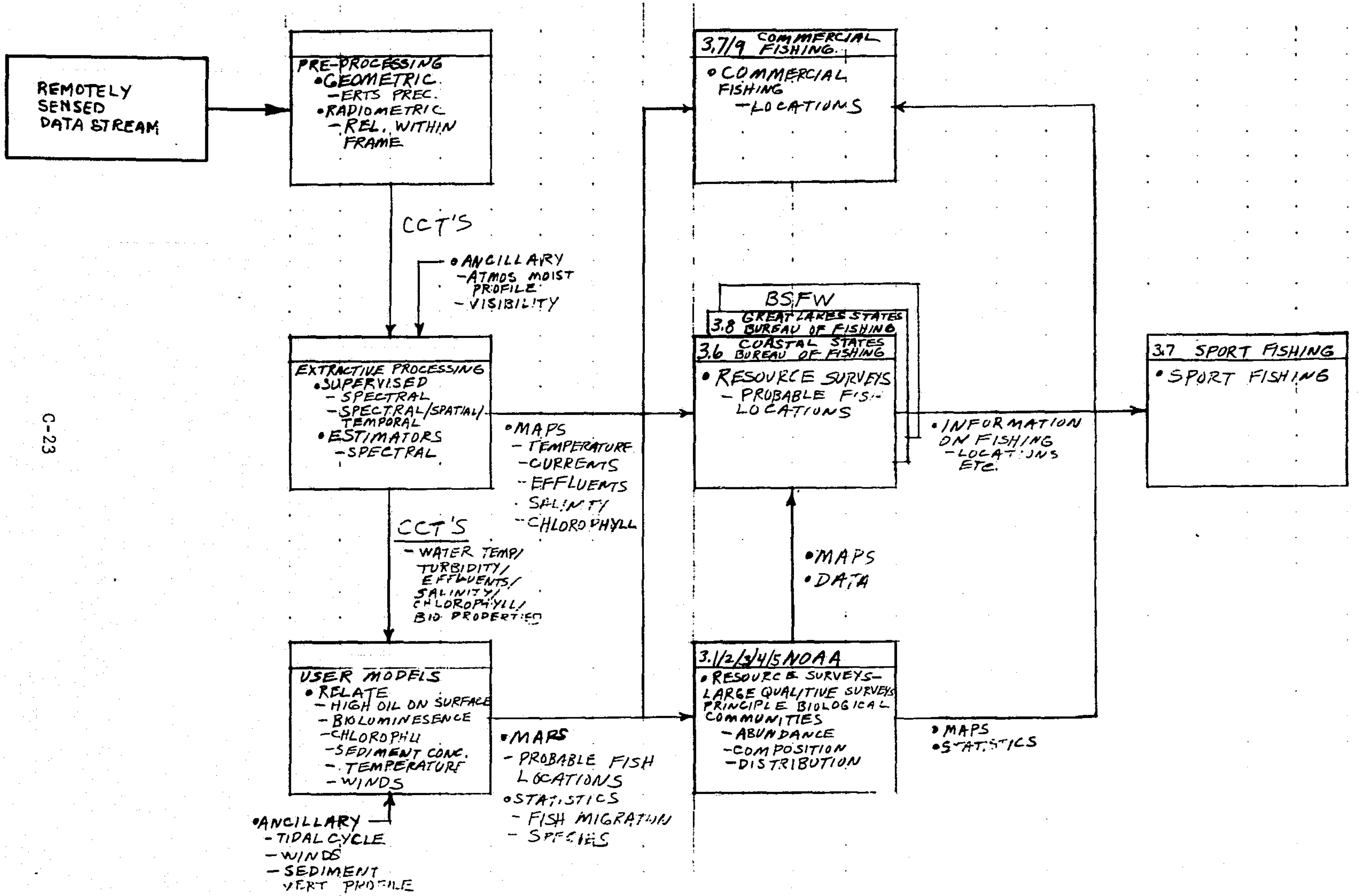


DATA FLOW/USER CHAIN
US GEOLOGICAL HAZARDS (LAND-4)



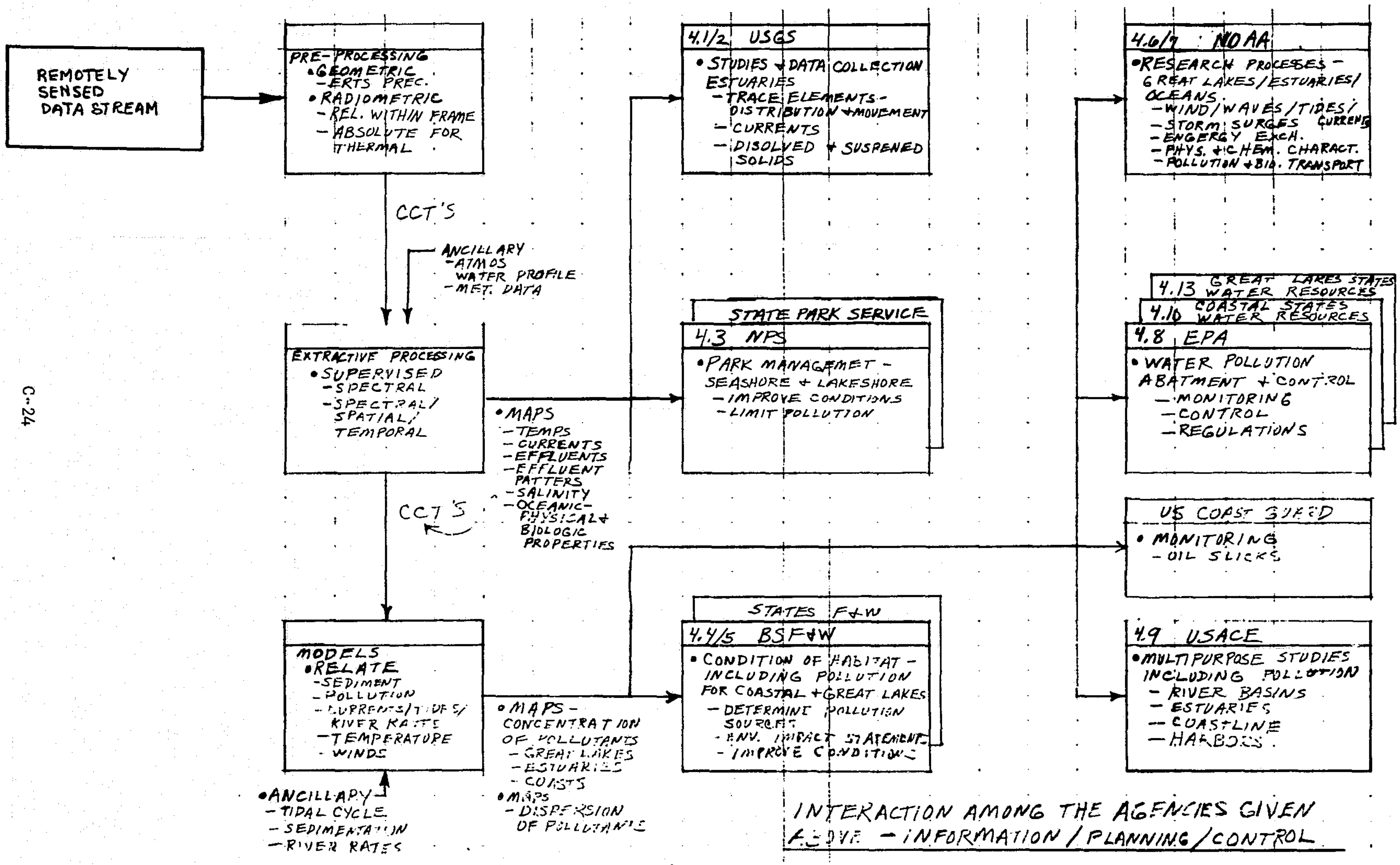
DATA FLOW/USER CHAIN

SURVEY & MAP THE PHYSICAL & CHEMICAL PROPERTIES OF GLOBAL OCEANS RELATIVE TO ENVIRONMENTAL PREDICTION FOR OPTIMUM SHIP TRACK ROUTING, DRILLING OPERATIONS & OTHER OCEAN OPERATION (MARINE-1)



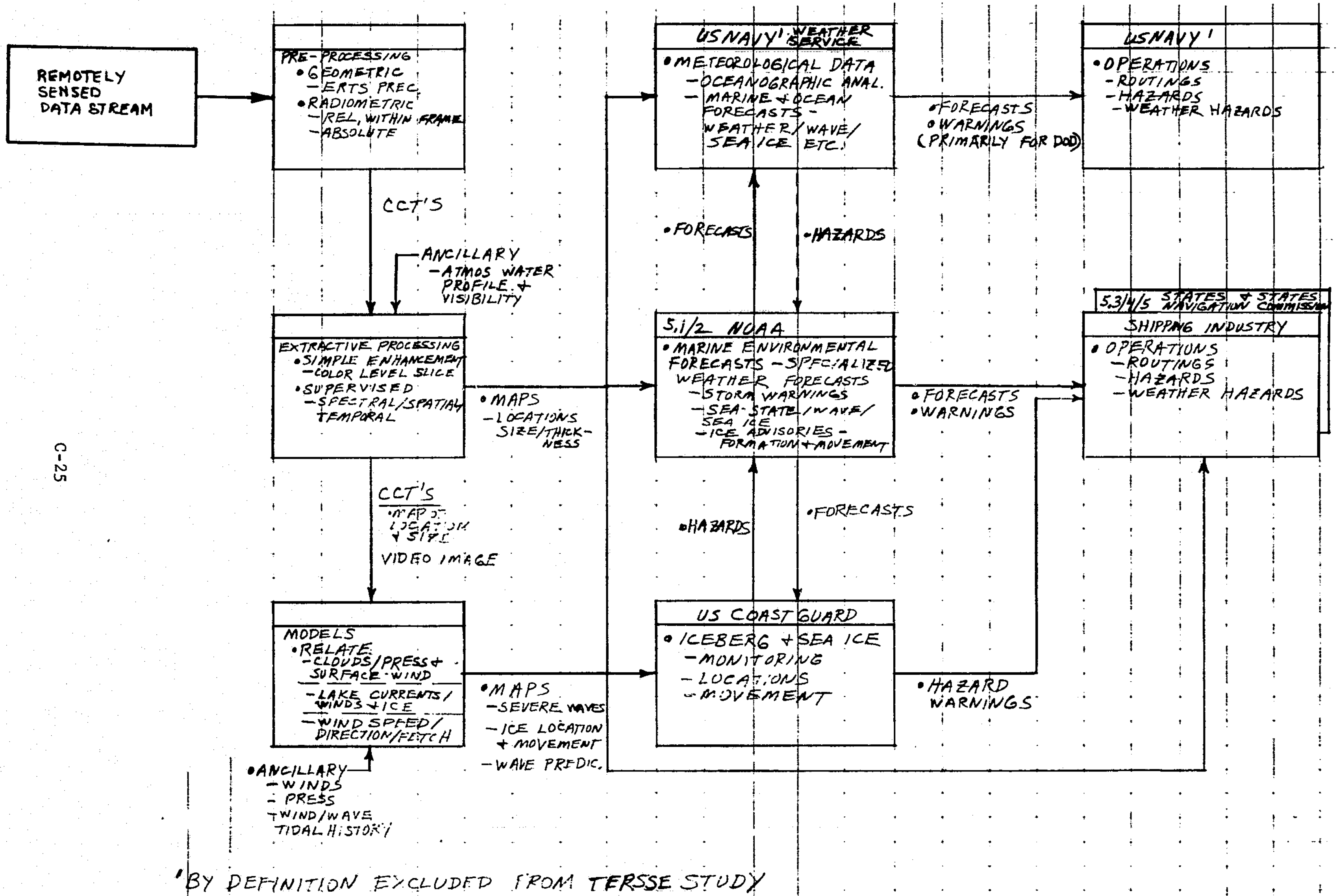
DATA FLOW/USER CHAIN

SURVEY & MAP THE DISTRIBUTION & QUANITY OF COMMERCIAL & SPORT FISH SPECIES IN THE US COASTAL AREA & OFFSHORE WATER, THEIR FOOD SUPPLIES, & THE APPROPRIATE ENVIRONMENTAL FACTORS NECESSARY TO PREDICT FUTURE CATCHES (MARINE-3)

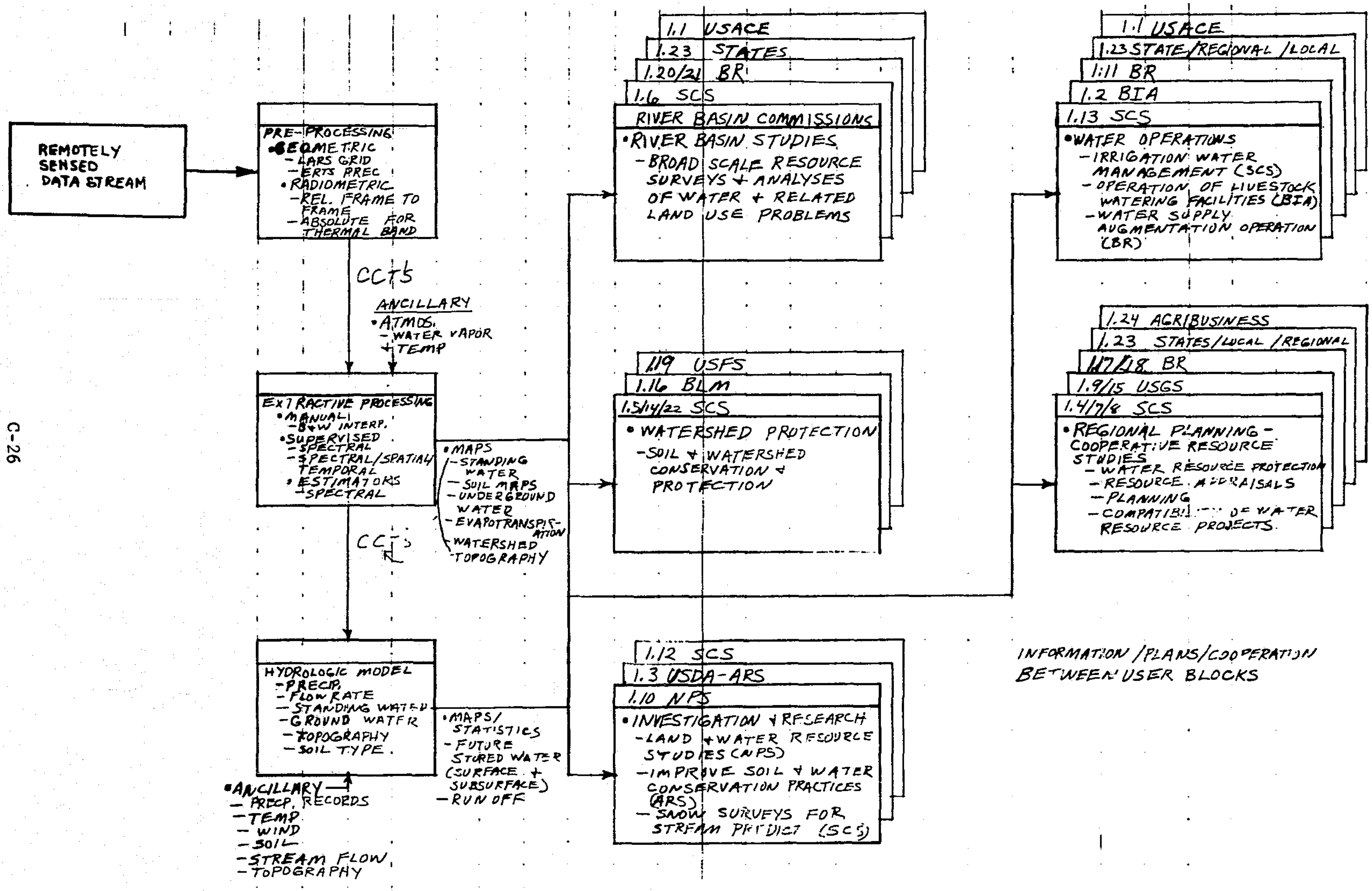


DATA FLOW/USER CHAIN

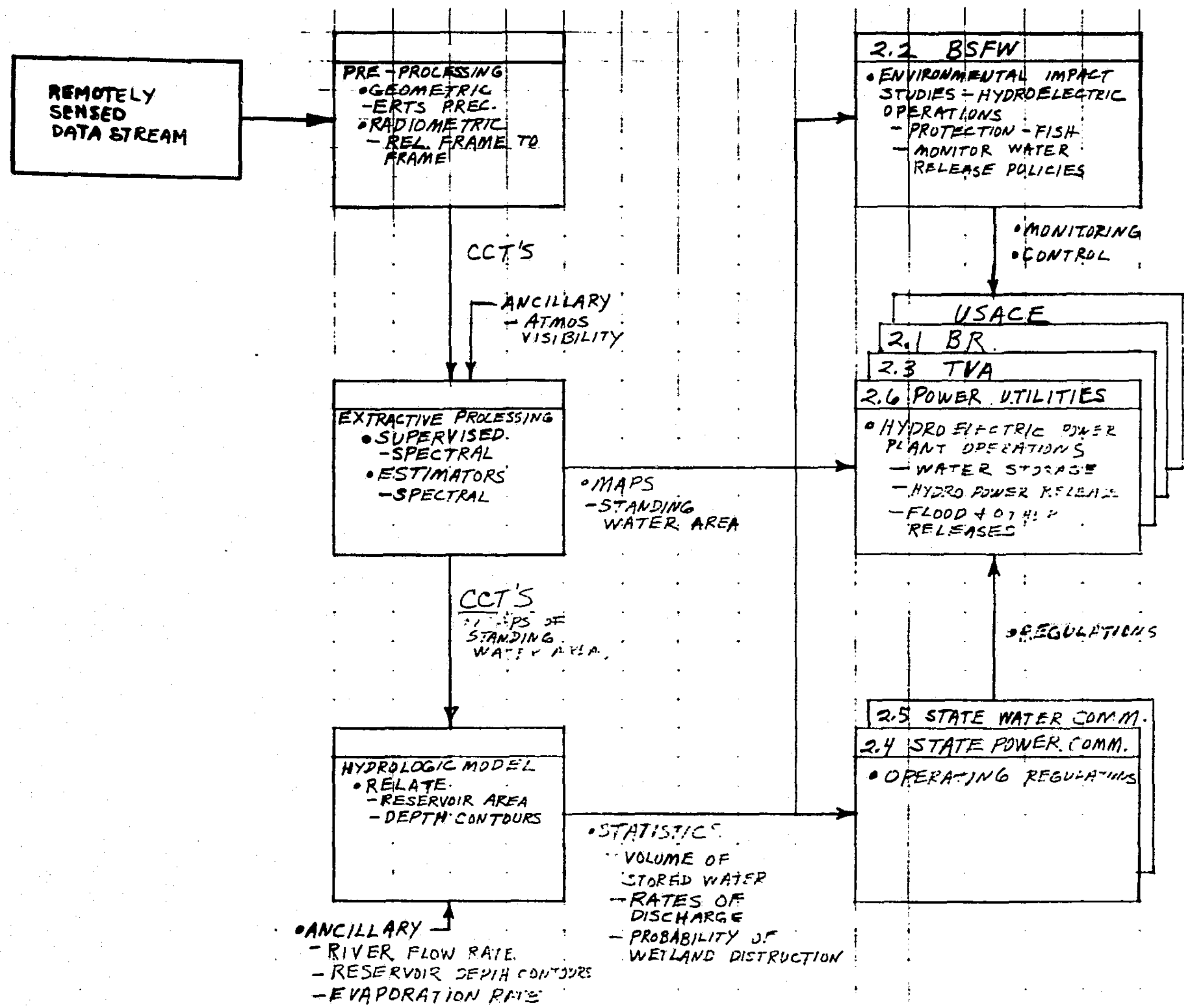
MONITOR THE HEALTH OF GLOBAL OCEANS BY SURVEYING THE SOURCE, DISTRIBUTION & MOVEMENT OF MAIN POLLUTANTS IN THE MARINE ENVIRONMENT & MARINE ORGANISMS (MARINE-4)



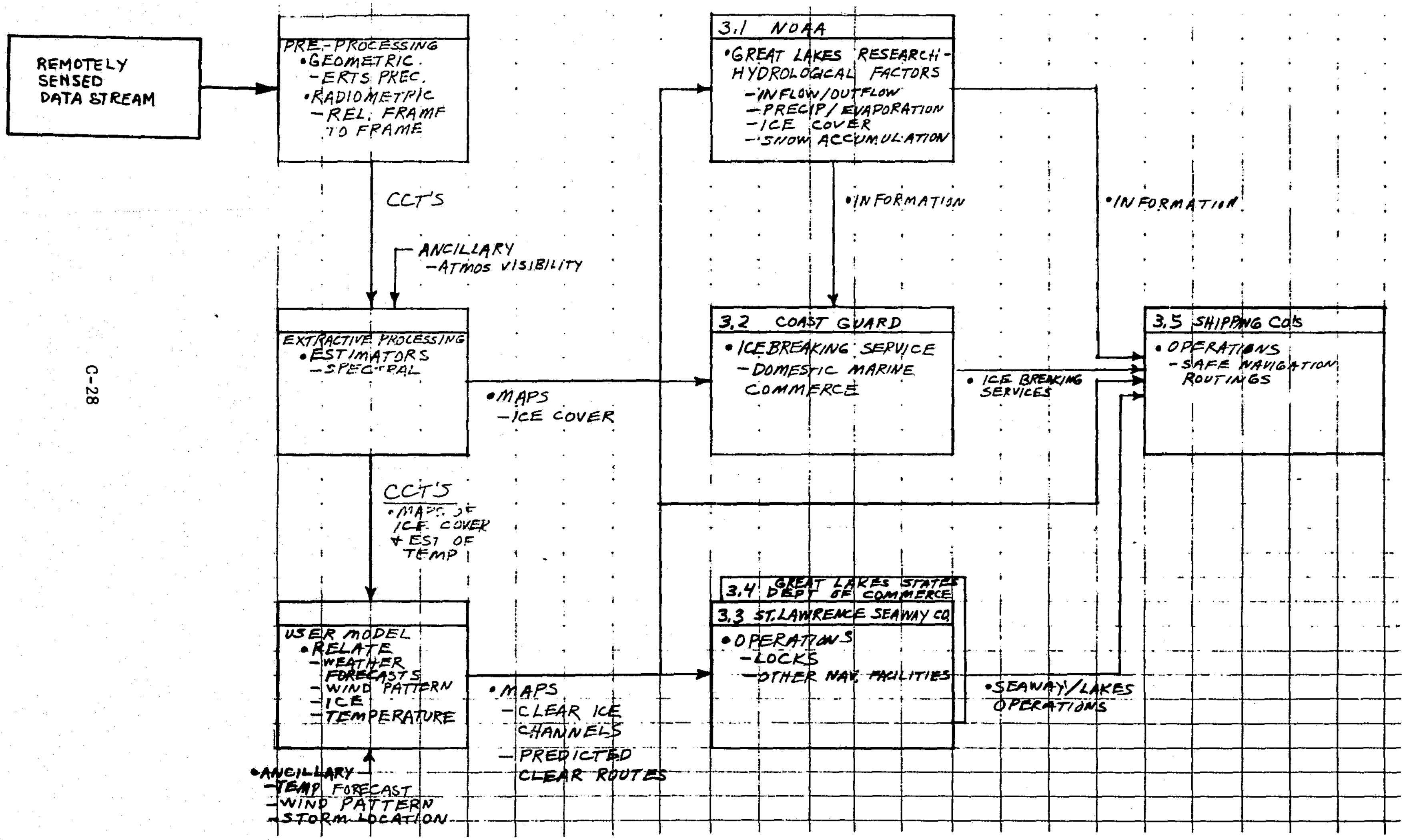
DATA FLOW/USER CHAIN
SURVEY & MONITOR HAZARDS TO NAVIGATION ON THE HIGH SEAS, SUCH AS SEA ICE, ICEBERGS, & SEVERE WAVE CONDITIONS (MARINE-5)



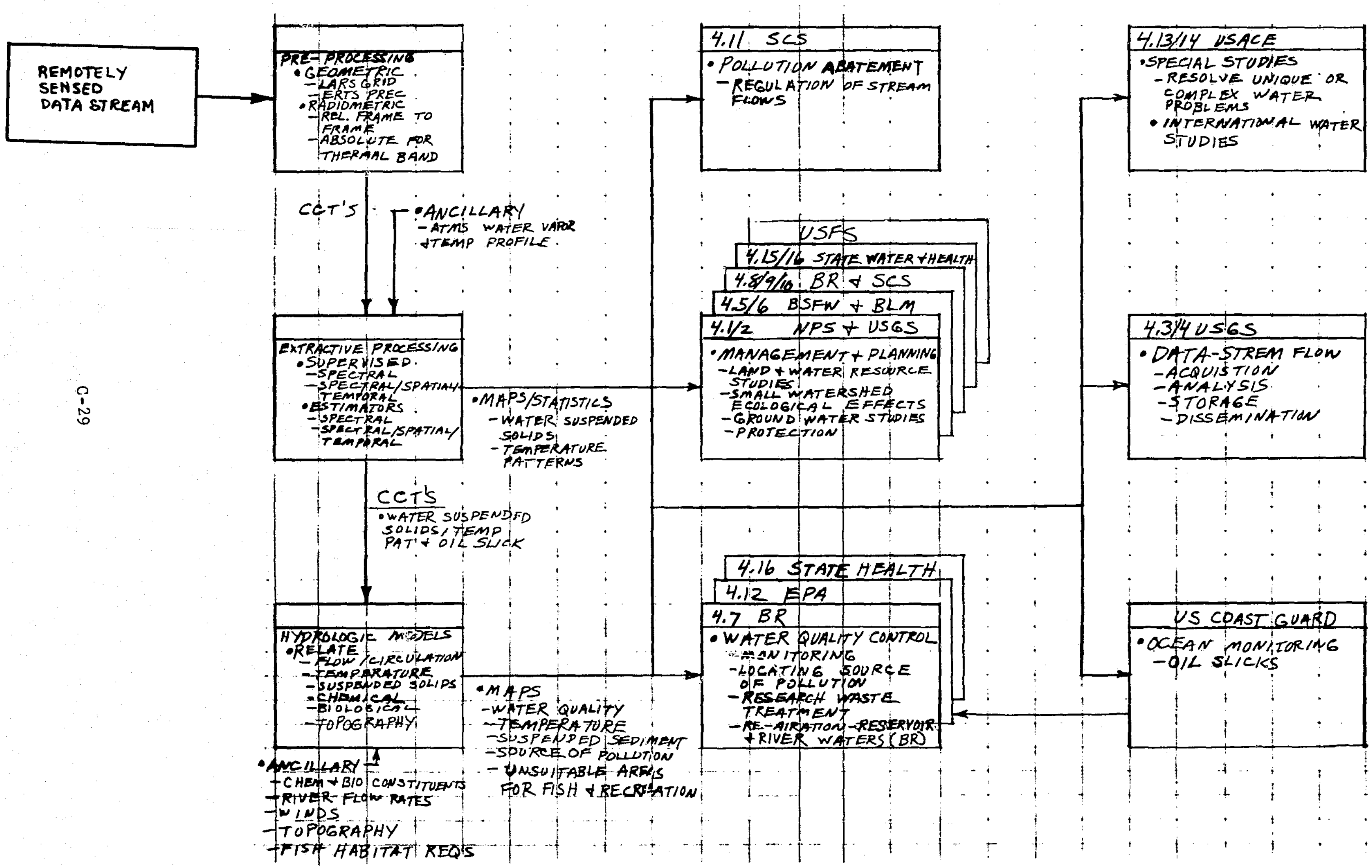
DATA FLOW/USER CHAIN
SURVEY & INVENTORY THE VOLUME & DISTRIBUTION OF SURFACE & GROUND WATER TO ASSESS AVAILABLE SUPPLIED FOR URBAN & AGRICULTURE CONSUMPTION (WATER-1)



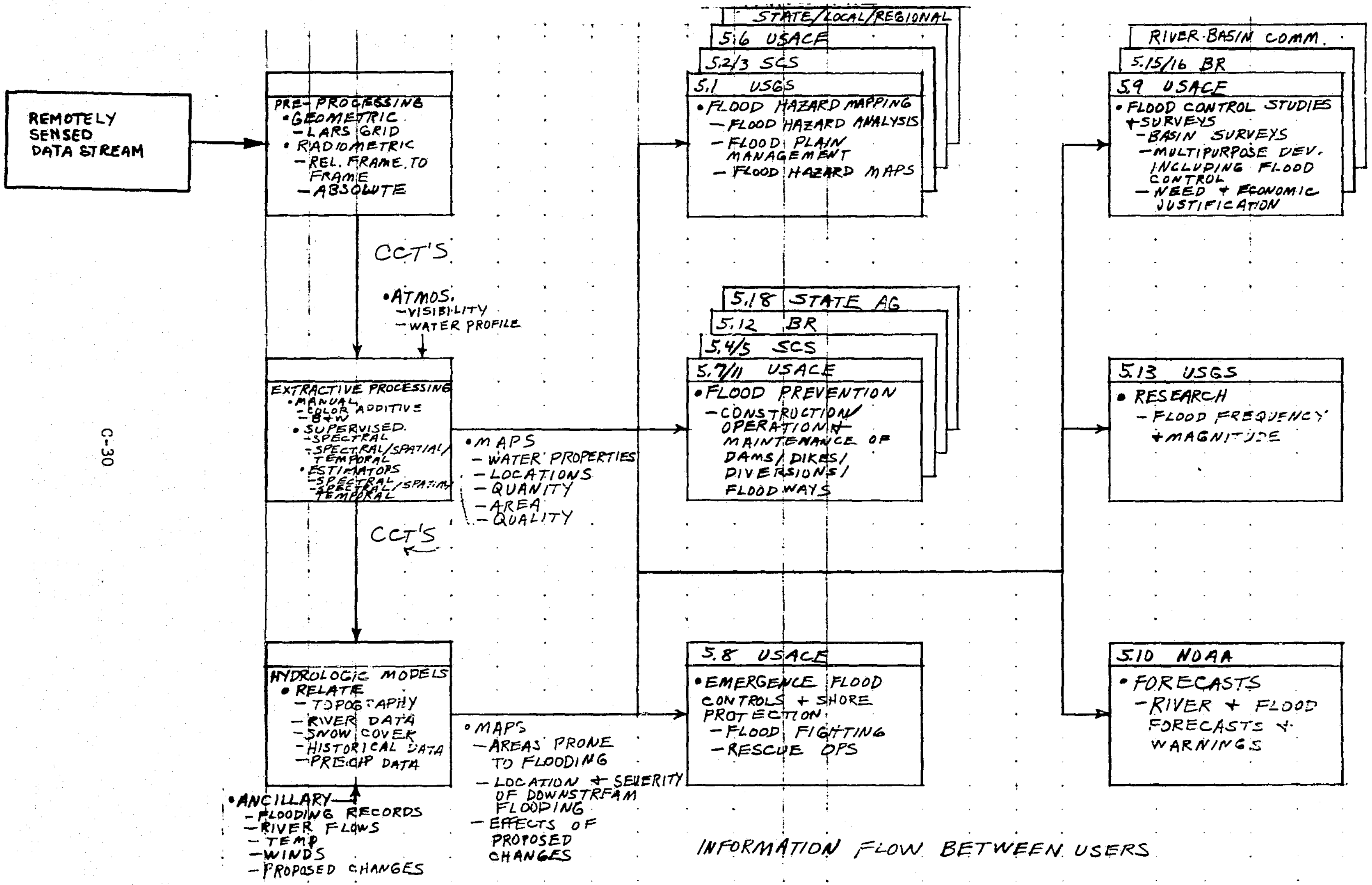
DATA FLOW/USER CHAIN
MONITOR RESERVOIR LEVELS TO MANAGE THE RELEASE OF WATER THROUGH HYDROELECTRIC POWER GENERATION FACILITIES
(WATER-2)



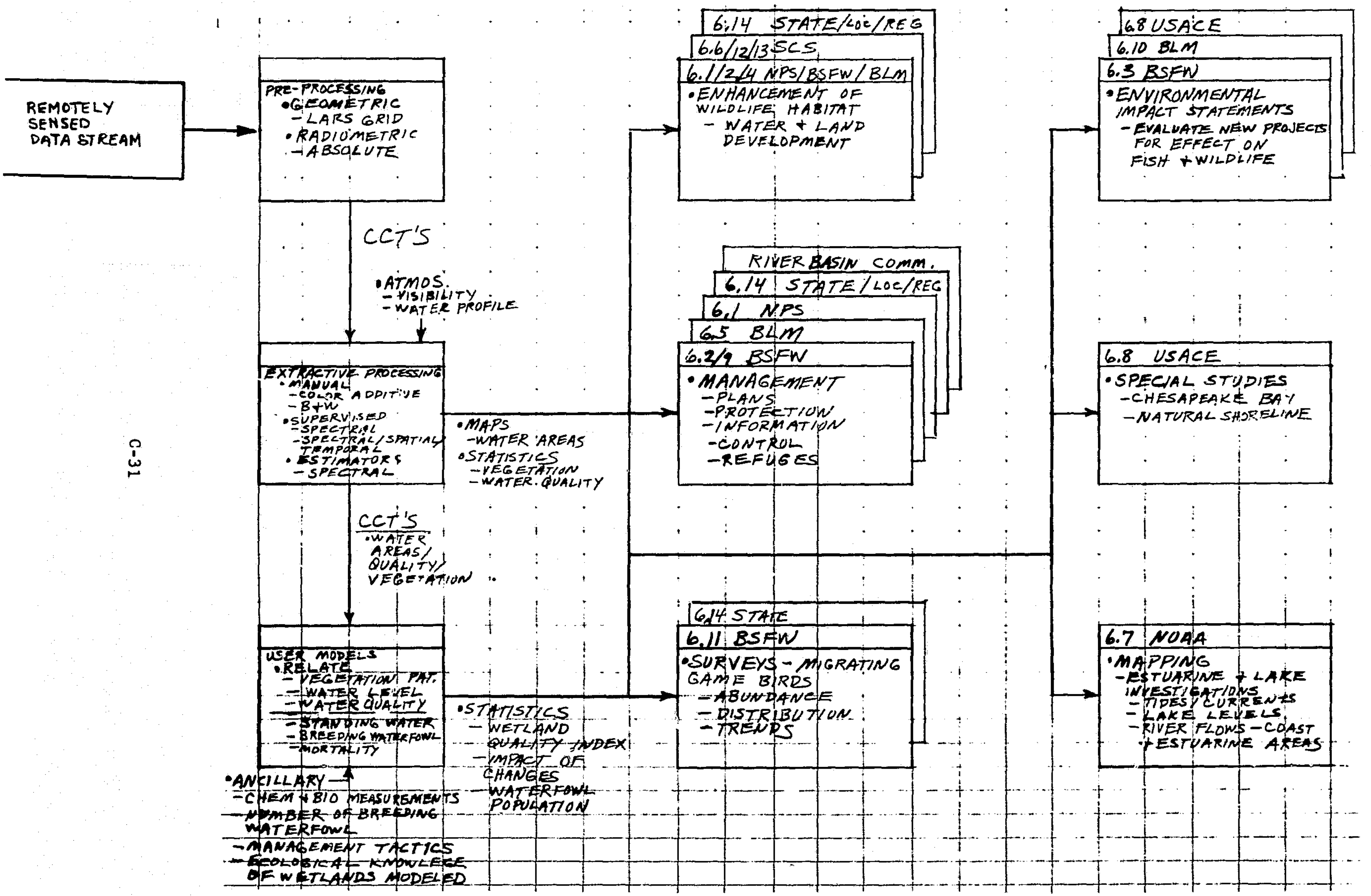
DATA FLOW/USER CHAIN
SURVEY GREAT LAKES ICE COVER TO DETERMINE THE PASSIBILITY OF NAVIGATION CHANNELS (WATER-3)



DATA FLOW/USER CHAIN
SURVEY AND MONITOR THE QUALITY OF SURFACE WATER THROUGHOUT THE US AND SURROUNDING COASTAL AREAS (WATER-4)



DATA FLOW/USER CHAIN
SURVEY AND MONITOR SURFACE WATER, SNOW COVER, GLACIERS, AND GROUND WATER LEVELS AND MOVEMENT TO IDENTIFY POTENTIAL FLOOD CONDITIONS AND TO TRACE THE MOVEMENT OF FLOODWATERS (WATER-5)



DATA FLOW/USER CHAIN

SURVEY & MONITOR THE SURFACE WATER VOLUME & INDICATE SPECIES OF VEGETATION IN WETLANDS & ESTUARIES TO EVALUATE THE ECOLOGICAL PRODUCTIVITY & DEVELOPMENT POTENTIAL OF WETLAND AREAS (WATER-6)