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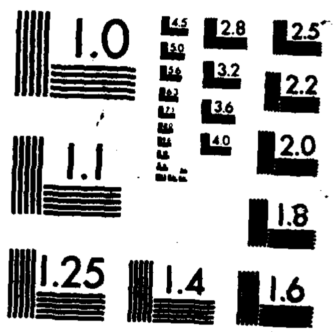
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ENVIROSAT-2000 Report

Federal Agency Satellite Requirements

July 1985

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

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Environmental satellites operated by the National Oceanic and Atmospheric Administration (NOAA) benefit many agencies of the Federal Government. This report summarizes the requirements of Federal agencies, ~~other than NOAA,~~ for the data and services of NOAA's civil operational environmental satellites--both polar-orbiting and geostationary. NOAA's satellite needs are expressed in the companion ENVIROSAT-2000 Report, NOAA Satellite Requirements Forecast, May 1985.

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This report focuses on the direct requirements served by the National Environmental Satellite, Data, and Information Service (NESDIS). Described here are the satellite needs of the Department of Agriculture, the Army Corps of Engineers, the Department of Transportation (which includes the Federal Aviation Administration and the Coast Guard), the Agency for International Development, the Department of Defense, the Department of the Interior, and the National Aeronautics and Space Adminstration. Current data uses and future requirements are addressed, as they have been identified by each agency. These requirements are an important element for guiding NOAA's long-range planning for future environmental satellite services.

ENVIROSAT–2000 Report

Federal Agency Satellite Requirements

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FEDERAL AGENCY SATELLITE REQUIREMENTS

ABSTRACT

Environmental satellites operated by the National Oceanic and Atmospheric Administration (NOAA) benefit many agencies of the Federal Government. This report summarizes the requirements of Federal agencies, other than NOAA, for the data and services of NOAA's civil operational environmental satellites--both polar-orbiting and geostationary. NOAA's satellite needs are expressed in the companion ENVIROSAT-2000 Report, NOAA Satellite Requirements Forecast, May 1985.

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I. INTRODUCTION

NOAA, on behalf of the Department of Commerce, manages the civil operational Earth remote-sensing satellite activities of the United States. This responsibility includes operating Earth remote-sensing space systems that provide data and services in support of national programs. It also includes aggregating Federal requirements for operational remote-sensing data and services that can be satisfied by systems operated by others, or that may be capable of satisfaction by future operational systems. In many instances where the data or service source is other than a NOAA space system, NOAA coordinates the support arrangements and, if appropriate, may act as the agent of the requesting Federal agency in the matter.

NOAA's environmental satellites provide an essential national service, which contributes directly to the accomplishment of many agencies' missions. Most agencies make use of meteorological data and information services from the National Weather Service (NWS). In addition, many agencies also utilize satellite data directly in a variety of ways, and depend on both the polar-orbiting and geostationary satellites as important data sources. (A description of NOAA's current and planned satellites is found in Appendix A.) These requirements for environmental satellite data are a significant consideration in NOAA long-range planning for future satellite programs. This report summarizes the current uses and projected future needs of the U.S. Department of Agriculture (USDA), the Army Corps of Engineers (CE), the Department of Transportation's (DOT) Federal Aviation Administration (FAA) and Coast Guard (CG), the Agency for International Development (AID), the Department of Defense (DOD), the Department of the Interior (DOI), and the National Aeronautics and Space Administration (NASA).

Knowledge about historic, present, and forecast environmental conditions is an integral part of understanding agricultural and forest resources, planning and managing civil works, ensuring the safety of aviation activities, providing assistance in economic development and environmental protection in developing countries, ensuring national defense, and preserving and managing U.S. public lands. For these reasons, Federal agencies have come to depend on continuing observations from space in their operational programs. The non-NOAA agencies generally require derived products and information, but do use raw sensor data in some applications. The availability of daily global, objective satellite observations of Earth and its environment has enhanced the understanding of environmental conditions held by all agencies and allowed them to introduce programs to help mitigate the consequences of environmental conditions.

The charters of many agencies include responsibilities for international activities, such as developing global agricultural production forecasts, ensuring the safety of transoceanic aviation, and protecting national security. However, environmental observations and archives are limited, or cumbersome to access, for some regions of the globe. Because of this, satellites constitute a critical source of reliable global data that helps to satisfy the information needs of agencies with international and domestic obligations.

Many agencies acquire NOAA/National Environmental Satellite, Data, and Information Service (NESDIS) satellite data directly by subscribing to GOES-Tap, a product distribution system that transmits Geostationary Operational Environmental Satellite (GOES) imagery regularly via telephone communications systems. For example, DOD receives GOES-Tap at its weather-support units around the Nation, and the FAA receives GOES-Tap at about 64 locations throughout the United States.

Beyond providing space sensor data, the NOAA satellites also provide communications systems for environmental data relay that are widely used by the Federal agencies. The GOES Data Collection System (DCS) is a major tool of the Corps of Engineers for monitoring water levels in critical flood areas and coastal zones. AID's Office of Foreign Disaster Assistance uses the GOES DCS in a tsunami warning system in Latin America to speed disaster warnings to coastal inhabitants.

Data from the Landsat Earth resources satellites are used extensively within the Federal government as well. However, as awareness of environmental satellite data availability and improved capabilities has expanded, many applications thought to be useful only with Landsat data have been demonstrated to be useful with data from the Advanced Very High Resolution Radiometer (AVHRR), which flies on the NOAA Polar-orbiting Operational Environmental Satellites (POES). This sensor operates at coarser spatial resolutions than the Landsat instruments, but is carried by satellites that each provide daily global coverage, compared to Landsat's 16-day repeat cycle. In many cases, AVHRR data can be used to monitor large-scale developments, reserving Landsat data for use in more detailed analyses of smaller geographic areas. Increased resolution of AVHRR data will be provided in the future, significantly enhancing their utility in land applications and benefiting many Federal users.

Federal agencies that use NOAA's space system services monitor changing satellite capabilities to determine the advantages they may offer to agency operations. Generally, these agencies do not specify requirements in terms of satellite performance characteristics. Rather, they usually request environmental support services that contribute to long-term, stable agency goals, leaving the choice and design of appropriate support systems to NOAA. The missions of the agencies do not change as new technologies become available; the requirements for public service remain constant. Agencies do incorporate new capabilities to meet their responsibilities, but prefer to rely on proven, demonstrated technology that is planned to continue for a long time. They have mandates to provide services that affect the economic health and personal safety of citizens, and cannot be expected to establish a dependence upon unproven systems. Nevertheless, there are agency information needs that should influence the design of future NOAA environmental satellite systems. The purpose of this paper is to identify those information needs now, so that NOAA's future satellite systems can accommodate them.

The critical system requirements expressed by all the agencies are continuity and consistency; long-term planning and budgeting are difficult, and Federal agencies must know that their data sources are reliable. Improvements in sensor performance, information extraction, and data processing and dissemination, along with reductions in communication costs, are specific satellite-related areas that the agencies identify for future attention. The Federal agencies represented in this document generally have requirements for information about standard physical phenomena, such as sea surface temperature and global cloud cover. In most instances, satellites are the observation tool of choice, because they are the only efficient means for reliably gathering worldwide information on a regular basis, while providing rapid data delivery. Not all the agencies' requirements for satellite support are being satisfied now, and some will remain unanswered well into the future. For example, the FAA has special needs for wind speed aloft (presently only derivable in areas with cloud cover) and the prediction, detection, and mapping of lightning. Research is underway in both of these areas that could lead to operational capabilities. As new technologies emerge that offer opportunities to satisfy remaining requirements, the list of unanswered needs will be reduced.

The following chapters address each agency's requirements as the agencies have identified them.

II. SATELLITE REQUIREMENTS

OF THE

DEPARTMENT OF AGRICULTURE

II. SATELLITE REQUIREMENTS OF THE DEPARTMENT OF AGRICULTURE*

A. INTRODUCTION

The U.S. Department of Agriculture (USDA) is responsible for monitoring the production of food and fiber in the United States. Inherent in this activity is the need to track and assess international agricultural production. The relationship between global agricultural production and meteorological conditions is such that wide interannual variations in regional production arise, in large part, from major fluctuations in weather patterns. Agencies of the USDA involved in the evaluation of environmental fluctuations and their impact on agriculture and renewable resources are the Agricultural Research Service, the Economic Research Service, the Foreign Agricultural Service, the Forest Service, the Soil Conservation Service, and the World Food and Agricultural Outlook and Situation Board.

B. SATELLITE REQUIREMENTS

In 1977, a USDA task force identified USDA's requirements for weather data, information, and services. A formal report was developed in 1978 that serves as the basis for this assessment of USDA's needs for environmental support, including satellite data. The requirements stated in the 1978 report, for the most part, are still valid. USDA requirements are stated in terms of data and information services, some of which involve direct NESDIS products and some of which are indirect requirements for satellite data, as when the National Weather Service (NWS) uses satellite data to generate products that support USDA needs. Because of the operational nature of USDA activities, and the important economic impact of its work, USDA relies on proven operational data and information sources. It does not define requirements that rely on research and development activities and experimental systems. Rather, it states requirements for the information that it needs to do its job, even though reliable systems to produce some of this information may not yet exist. The task is for supporting agencies, such as NOAA, to develop appropriate systems and to bring them to the level of maturity at which USDA can confidently transfer operational dependence to the new information source.

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* This statement is focused on the continuing needs of the Department of Agriculture for data and information from NOAA's operational environmental satellites.

Environmental data and services from NOAA needed to support USDA activities, and dependent on satellite data to various degrees, fall into the following categories:

- Climatological services to define and understand characteristic weather and climatic conditions for various geographical areas and time periods, including areas outside the United States

- Current measurements and observational services to define the present state of the atmosphere on a national and global basis

- Forecasting services to predict future weather and climatic conditions and their associated probabilities on as precise a geographic and temporal basis as possible

The highest priority meteorological data elements for both current measurements and climatological services are values for precipitation, air temperature, snow, wind, soil moisture, and data on special weather phenomena such as thunderstorms, lightning, and extremes of temperature and precipitation. These information elements are needed by USDA on anywhere from an hourly to an annual basis. Table II-1 outlines USDA requirements for current measurements and observational services. These data are used in ongoing agricultural, forest, and soil assessments, and for analyses that usually include other inputs, such as crop calendars, ground-based crop observations, and cultural factors.

USDA's Forest Service is a user of NOAA'S Geostationary Operational Environmental Satellite (GOES) Data Collection System (DCS). USDA data collection platforms (DCPs), which are located in remote areas, collect environmental data and relay the data in near-real time through the GOES system for delivery to appropriate USDA offices. The Forest Service and the Department of the Interior's Bureau of Land Management (BLM) are cooperating in a joint wildfire warning network that employs remote automated weather stations (RAWS) and lightning detectors. This instrumentation provides warning of high fire danger by allowing the constant monitoring of the RAWS data, which are telemetered through the GOES relay and collected at BLM's Boise, Idaho, direct readout ground station. Lightning strike data, which are superimposed on the fire danger data base, can be used to manage firefighting resources.

Approximately 400 DCPs (about 250 Forest Service, 150 BLM) are deployed, with the goal of 750 by 1990 and 800 by 1995. Data being collected include wind speed and direction, precipitation, temperature, and relative humidity. The data also are relayed to the NWS, which produces weather forecasts that are sent to Forest Service users. Currently, RAWS operates during the fire season, normally May until December. The program is moving toward a nearly continuous operation, however, to enable the Forest Service to perform prescribed burning operations with reduced risk.

In addition to meteorological data, USDA has interests in Earth resources satellite data. It has used Landsat data in experimental programs to examine their applicability to large-area agricultural assessments and the routine monitoring of crop development. Earth resources satellite data have been proven applicable to the measurement of crop acreage and agricultural production, the differentiation of crop types, and the assessment of vegetation vigor. Landsat data are one source of information relevant to production estimation, but alone are not sufficient to determine final yields.

USDA has incorporated the use of Advanced Very High Resolution Radiometer (AVHRR) data from NOAA's polar-orbiting satellites into programs for the routine monitoring of foreign crop production through the analysis of vegetation "greenness." AVHRR provides daily, large-scale views of the entire globe, and is being used as a base for more refined assessments using other data sources. For example, USDA applies AVHRR data to qualitative assessments of crop conditions and to the delineation of areas where significant change has taken place in the condition of surface vegetation. Where changes of interest are identified, other data sources are used to determine the nature and impact of the changes. The Soil Conservation Service is in the initial stages of using AVHRR for soil mapping and determining land use changes.

USDA is now using AVHRR data for the quantitative assessment of crop conditions. A product known as the Vegetation Index, derived from AVHRR data, is used to detect the greening of vegetation as the seasons advance and growing conditions, including crop disease and pests, change. The daily revisits of each Polar-orbiting Operational Environmental Satellite (POES) permit frequent crop assessments, even for locales that are very often under cloud cover. Although the subpoint resolution of AVHRR is 1,100 m, compared to 80 m and 30 m for Landsat instruments, the reduced data volume of AVHRR is a benefit in global crop monitoring programs and provides a means for tracking gross trends and detecting them early. Refined small-area surveys of regions showing stress in AVHRR products can be carried out with Landsat data, at the Landsat revisit frequency of 16 days.

Improvements on behalf of USDA agricultural applications are planned for the next revision of AVHRR, which will be flown in the late 1980's. Spectral sharpness will be increased in the channels used to produce the Vegetation Index. USDA has requested that spatial resolution of the AVHRR channels of interest be improved to at least 600 m. To accommodate this request and others, NOAA plans to modify the AVHRR capability to provide 500 m resolution at all viewing angles.

The primary concern of USDA is that the data NOAA provides remain at the level of quality they now exhibit, whatever the means of data collection. As satellite data use becomes ever more prevalent, the expressed USDA need is for the continuous calibration of satellites, their data systems, and their sensors. The objective of this requirement is to assure the maintenance of the present level of data accuracy and to guarantee the accurate comparison of data from the several sensors of a given series with sensors of other kinds.

C. SUMMARY

USDA has operational requirements for NOAA environmental services, which have been stated to NOAA in generic terms (data elements, frequencies, accuracies, volumes, etc.) without reference to the systems NOAA may use to satisfy them. USDA's position is that new or changed NOAA support systems must be proven reliable before USDA alters its operations to become dependent on them.

NOAA support to USDA operations is delivered chiefly through the resources of NWS, but large parts are delivered by NESDIS, including direct satellite support, archive services, and specialized products. USDA's satellite requirements are met by the POES, GOES, and Landsat systems. The Landsat service that is provided to USDA is direct, in that Landsat data are collected and preprocessed on behalf of USDA, then provided to the agency for internal use in applications. In the POES and GOES cases, satellite support to USDA is both direct and indirect. Direct POES support includes Vegetation Index products and AVHRR temperature products; direct GOES support includes DCS services and direct readout broadcasts. Indirect environmental satellite support to USDA is in the form of NWS products derived from satellite and other data. USDA's requirements are for worldwide coverage and, therefore, depend in large measure upon satellite data for satisfaction.

The projection of USDA requirements for the next 10 to 15 years includes needs for additional data and services from the POES and GOES systems. USDA plans to increase its use of the GOES DCS service, both in terms of the number of remote platforms in use and the length of the observation season of fire-watch platforms. USDA has requested AVHRR improvements that would be useful in Vegetation Index applications. The addition of the Advanced Microwave Sounding Unit (AMSU) on the next series of POES spacecraft (circa 1990-2000) will help provide the precipitation, temperature, soil moisture, cloud cover, and other measurement needs reflected in Table II-1. The separation

Table II-1
Current USDA Requirements for
Measurement and Observational Services

Data Element (Variable)	Frequency					
	Hour	6-Hour	Day	7-10 Day	Month	Season
Precipitation						
Total	X	X	X	X	X	X
Intensity	X	X				
Duration		X	X			
Temperature, air, max-min, and average	X	X	X	X	X	X
Snow						
Depth			X	X	X	
Water content			X	X	X	
Aerial coverage			X	X		
Wind						
Velocity		X	X	X		
Direction		X	X	X		
Soil moisture			X	X		
Soil temperature			X	X	X	
Cloud cover		X	X	X	X	
Special phenomena			As required			
Solar radiation			X	X	X	
Dewpoint temperature (humidity)			X	X	X	
Evaporation						
Pan			X	X		
Evapotranspiration			X	X	X	
Radiation, net			X	X	X	
Visibility			X	X		
Pressure						
Surface		X	X		X	
Upper air		X	X		X	

of the imaging and sounding sensors on GOES-Next (circa 1989 and beyond) also will help provide some of these measurements, in finer detail, over the Western Hemisphere. Measuring the phenomena shown in Table II-1, worldwide and with the skill and frequency needed by USDA, is the challenge facing the designers of NOAA's future observation system. That system will be a mix of satellite- and ground-based observation components that also will integrate data received from non-NOAA sources.

III. SATELLITE REQUIREMENTS

OF THE

AGENCY FOR INTERNATIONAL DEVELOPMENT

III. SATELLITE REQUIREMENTS OF THE AGENCY FOR INTERNATIONAL DEVELOPMENT

A. INTRODUCTION

The mission of the Agency for International Development (AID) is to foster the growth of developing countries by providing a wide range of assistance programs aimed at enhancing basic capabilities in such areas as food security, infrastructure and institutional development, and environmental protection. AID needs environmental and Earth resources data bases to better understand the environmental impacts of its development activities and the interactions of complex ecological systems. Among other purposes, these data bases are used to assess the likely secondary consequences of AID programs on the natural resources of an area. As a foreign assistance agency, AID must be able to delineate environmental trends and support remedial steps as early as possible, before a natural resource base is seriously degraded.

There are many applications of satellite data in the developing world, especially in the areas of agriculture, forestry, geology, geography, hydrology, and atmospheric sciences. Food and agriculture in developing countries are critically sensitive to climate and weather, and most developing countries are dependent on local agriculture for their overall well-being. Also, many parts of the developing world are climatically hostile areas (such as flood- and drought-prone areas and deserts) or are vulnerable to climatic disasters such as cyclones and typhoons. In remote and less developed areas, environmental satellites often provide the only access to weather data, such as through direct readout of Polar-orbiting Operational Environmental Satellite (POES) data broadcasts.

The natural resources of less developed areas, such as mineral, forest, and water resources, represent an economic potential, but they must be identified and mapped before plans can be designed for their balanced exploitation. The identification and mapping processes, at least for gross details, are often first accomplished through satellite data. As nations progress, new industrial and renewable resource developments may have environmental impacts that must be understood and managed appropriately. Environmental satellites are powerful tools for the collection of regional environmental data--data that hold significant potential for assessing the impact of the development process. AID will continue to require a large amount of satellite data to fulfill its mission, because satellites offer the most efficient, and often the only, means of gathering routine observations of the environmental state of developing nations.

B. CURRENT APPLICATIONS OF SATELLITE DATA

AID has programs underway that depend on NOAA satellite data for their effectiveness. The more prominent of these, and their satellite data requirements, are discussed below.

1. Climatic Impact Assessment for Developing Countries

AID's Office of Foreign Disaster Assistance (OFDA) needs a reliable and cost-effective program to provide early warnings of natural disasters such as crop failure, drought, and flooding. To meet this need, AID supported and has implemented the Early Warning Program, which was developed and is operated by the NOAA/NESDIS Assessment and Information Services Center (AISC). The Early Warning Program combines scattered rainfall observations from rain gauge stations with cloud data obtained from NOAA meteorological satellites to improve the accuracy of regional rainfall estimates. Also, daily satellite data are used to monitor crop conditions for evidence of moisture stress and to search for standing water reserves as potential irrigation sources. Weather data are combined with climatic impact assessment models to help predict crop production.

Biweekly assessments are provided to countries of the Caribbean Basin, Africa, South and Southeast Asia, the South Pacific Islands, Central America, and the Andes countries of South America. Under this same OFDA activity, NOAA/NESDIS is assisting 25 developing countries in the operational implementation of national climatic impact assessment systems. These implementations are based primarily on operational weather data reports. In Southeast Asia, pilot projects to incorporate analyzed data from the POES Advanced Very High Resolution Radiometer (AVHRR) instrument have been established with Thailand and Malaysia.

AID's Early Warning Program relies on satellite imagery and digital data, as well as information from conventional sources, for its crop production assessments. Imagery from POES and geostationary satellites, such as the European Meteosat, are combined with ground observations to infer rainfall distributions and general meteorological conditions, to detect sizable areas of standing water, and to recognize drought conditions and their onset.

In the Sahel, for example, observations from about 50 ground weather stations help refine the environmental assessments that are derivable from satellite imagery. Satellite imagery substitutes for ground observations in regions where they are unavailable or unreliable. Digital AVHRR data from POES are used to produce the Vegetation Index product. The visible band (channel 1) and the near-infrared band (channel 2) of the

AVHRR differ sharply in their responsiveness to reflectance from the chlorophyll in green leaves. This condition allows sensitive indicators (vegetation indices) of the presence of green vegetation to be obtained from simple mathematical manipulations of data from these two channels.

Satellite data are acquired and processed daily in support of the Early Warning Program. The AVHRR-derived Vegetation Index product is a time composite covering 7 days of observations. Weekly composites meet the analysis needs and also allow cloud cover to be filtered from the daily observations. On the one hand, detecting clouds permits rain and other weather conditions to be interpreted from satellite data; on the other, clouds block the satellite viewing of stands of vegetation.

The use of satellite data significantly improves the reliability and quantification of the Early Warning Program. Drought conditions can be identified with nearly 100 percent accuracy for areas as small as 100 to 250 km on a side. Because this program now considers only weather-related variables, insect and disease problems that impact on crops are not part of current routine assessments. In the future, Landsat data may be used to detect crop disease and insect problems, or to evaluate other conditions in finer detail. Landsats 4 and 5 each provide multispectral data from instruments with 80 m and 30 m spatial resolutions, compared to the 1.1 km resolution of AVHRR.

2. <u>Agro-Climatic/Environmental Monitoring Project (Bangladesh)</u>

The purpose of the Agro-Climatic/Environmental Project is to improve the planning and management of resources in Bangladesh, particularly those related to agriculture and water development. To this end, a meteorological satellite ground receiving station has been installed in Bangladesh. It enables the Space Research and Remote Sensing Organization (SPARRSO) of Bangladesh to collect satellite data on a 24-hour basis. The station acquires data from POES spacecraft and the Japanese geostationary satellite (GMS).

The project uses all POES direct readout services: High Resolution Picture Transmission (HRPT), which broadcasts data from the AVHRR instrument at 1.1 km resolution; Automatic Picture Transmission (APT), which transmits AVHRR data at 4 km resolution; and Direct Sounder Broadcast (DSB), which provides data from the TIROS Operational Vertical Sounder (TOVS) instrument. The POES HRPT transmission provides all spacecraft system and sensor data, including Argos data, to the ground receiving station. (The Argos data collection and platform location system is provided by France and is flown on POES.) The Bangladesh station is able to extract from the received HRPT signal the environmental data that are transmitted from remote Data Collection Platforms (DCPs), which are located within the country and in the Bay of Bengal. There are now about 30 of these DCPs in operation. More accurate estimates of rainfall can be obtained by combining satellite imagery and DCP data.

Data provided by meteorological and land satellites are complementary in nature, with meteorological satellites providing synoptic views over much larger areas and repeat coverage by more frequent passes. The primary sources of early warning data are the NOAA POES and the Japanese GMS. SPARRSO provides the Bangladesh Meteorological Department and the Water Development Board with satellite imagery and data from DCPs within 20 minutes of ground station reception.

3. Weather Modification Project (Morocco)

The goal of this project is to assist the Government of Morocco in establishing a scientifically based weather modification program, especially for long-term precipitation enhancement. A Secondary Data Utilization Station receives, displays, and prints imagery from both POES and Meteosat. Environmental data, acquired by aircraft and ground-based radars and augmented by synoptic satellite coverage, are required to initiate, monitor, and control cloud-seeding missions.

C. FUTURE APPLICATIONS OF SATELLITE DATA

Some AID programs that are under consideration, and would involve the use of NOAA satellite data, are discussed in this section.

1. El Niño and the Southern Oscillation: Scientific Plan of the Climate Research Committee, National Research Council

The meteorological and ecological effects of the El Niño/ Southern Oscillation (ENSO) are of particular interest to AID because ENSO affects the lives of millions of people, particularly those in developing countries of the Pacific region and the equatorial belt. Within the past several years, El Niño has been recognized as a chain of related meteorological and oceanographic events rather than a number of unrelated occurrences. The 1982-83 El Niño event caused widespread coastal flooding in Ecuador and Peru, and severe droughts in Australia, Indonesia, India, southern Africa, and Central America.

The general objective of an ENSO investigation program would be to develop an improved understanding of the ENSO system, with the goal of developing an ability to predict the short- and long-term climatic impacts of these events. AID will continue to consider funding research to investigate the global effects of the ENSO phenomenon, while watching for the links between this complex ocean-atmosphere process and economic development problems to become clearer.

To study the cyclical variations of ENSO, data must be collected over a period of 10 years or more. Many different types of data would need to be integrated into the coupled atmospheric and oceanic models that must be used to study the workings of ENSO events. Current data from atmospheric and oceanic observing systems would be needed for this effort, as would relevant historic data.

El Niño events signal their onset and development in ocean surface temperature changes that take place far out to sea in areas not frequented by shipping. The only routine surveillance of these ocean areas is conducted by satellites. Continuous coverage by U.S., Japanese, and Indian geostationary satellites is essential to the success of the ENSO research project. At least one polar-orbiting satellite must supplement data collected by the geostationary satellites at all times. Specific satellite data requirements are shown in Table III-1.

2. Disaster Management

Satellite technology, using both geostationary and polar-orbiting satellites, plays an ever-increasing role in disaster preparedness, prevention, and recovery.

The data sets required for this program are generally the same as those required for the ENSO project, such as surface wind data and quantitative estimates of precipitation. Other data sets required include high-resolution data (such as Landsat Thematic Mapper), cloud penetration (microwave) data, data on seismically active plate boundaries, and archives of historic data. Another requirement is for soil moisture measurements. New capabilities for measuring soil moisture will be available from the Advanced Microwave Sounding Unit (AMSU), which will be flown on the next series of POES, beginning about 1990.

3. Building the Meteorological Capacities of Developing Countries

Environmental satellites are an important source of data for regular weather forecasts, and play a principal role in the early identification and tracking of storms. In addition, the early detection of seasonal floods, droughts, and storm damage can lead to active measures that lessen the damaging consequences of these events. For these reasons, AID may consider programs aimed at creating new, and improving existing, meteorological capabilities in developing nations. A simple, inexpensive ground receiving station for environmental

Table III-1
ENSO Satellite Data Requirements

Data	Source
• Surface wind data	Satellite borne scatterometers
• Cloud motion vectors	Geostationary satellite data
• Sea surface temperature	Satellite data (derived from POES AVHRR data) augmented by surface ship observations
• Quantitative estimates of precipitation	Satellite sensors; combinations of satellite and ground sensor data
• Cloud cover (type and extent)	Satellite imagery (visible and infrared)
• Surface energy fluxes between the atmosphere and ocean	Satellite measurements (monthly averages)
• Historic satellite data	Archive (histograms of the frequency distribution of satellite-observed radiances) and other data analysis products

satellite data can provide a core capability for the emerging environmental service organization of a developing nation.

Data must be supplied and received continuously from the POES satellites and appropriately positioned geostationary satellites to support in-country meteorological services. These synoptic environmental data could, in the future, complement Landsat or other land remote-sensing data, which already are in general use, for example, in small-area damage assessment studies. As in the case of the Agro-Climatic/Environmental Monitoring Project in Bangladesh, these satellite data would be supplemented with transmissions from ground-based DCPs through a satellite data collection system.

4. Three-Tiered Early Warning and Crop Reporting System

A major initiative that AID is exploring is a collaborative effort among the Economic Summit states to develop an early warning and crop reporting system for the continent of Africa. This initiative probably would involve other U.S. Government agencies that have interests in satellite remote sensing.

Continuous daily coverage of affected areas would be required. The three-tiered monitoring and alerting system would first use meteorological satellites to scan and identify problem areas. When severe vegetation changes are detected, higher resolution remote sensing would be used to define sample fields. The third level would be composed of field surveys to collect the refined observations needed to quantify food deficits. The same three-tiered system could be used to monitor and protect fragile ecological zones.

5. Verification of Crop Statistics

Satellite imagery can be used as a tool for verifying crop types. However, crop patterns in developing countries do not provide sufficiently large, homogeneous crop areas for the accurate discrimination of crop varieties by coarse-resolution (hundreds of meters) environmental satellites. Satellite systems providing resolution in the 10 to 30 m range (such as Landsat and SPOT) will lead to increased usage of satellite imagery for the verification of crop types and crop production figures. However, the concomitant increase in data employed in such analyses will require increased levels of computer capacity and information management systems designed to reduce data sets to manageable proportions.

D. FUTURE PROGRAM AND DATA REQUIREMENTS

AID will require access to satellite data through the forseeable future for bilateral and regional programs. The emphasis is on the monitoring of food and fiber production, environmental profiling, renewable resources assessment, and environmental monitoring. AID's future requirements for satellite system support appear in Tables III-2, III-3, and III-4.

More research is needed to further AID's goal of being able to anticipate the impact of development activities on complex ecological systems. Higher spatial and spectral resolutions than today's civil satellite sensors make available are being considered, and the practical benefits of these improvements need to be explored. AID's intent is to experiment with data from new and refined sources, and to determine if they can be used to delineate dangerous environmental trends and the depletion of natural resources.

The following are some of AID's requirements for future programs.

Table III-2
AID's Future Requirements for Satellite Data
(Resource Mapping, Agricultural Statistics, and Landscape Monitoring)

Wavelength (μm)	Band Width (μm)	IFOV (m) Desired	IFOV (m) Minimum	Priority (1 highest)
0.49	0.03	10	30	4
0.56	0.03	10	30	6
0.66	0.02	10	10	2
0.92	0.02	10	30	1
1.65	0.05	10	30	3
2.20	0.05	10	30	5

Remarks:
1. 14-day acquisition cycle
2. 185 km x 185 km scenes
3. Delivery delay: 3-5 days
4. Product formats: digital and imagery
5. Frequency of reanalysis of areas: 2-4 times per year

Table III-3
AID's Future Requirements for Satellite Data
(Vegetation Monitoring for Production and Conditions)

Wavelength (μm)	Band Width (μm)	IFOV (m) Desired	IFOV (m) Minimum	Priority (1 highest)
0.66	0.02	250	500	2
0.92	0.02	250	500	1
1.65	0.05	250	500	3

Remarks:
1. 12-hour acquisition cycle
2. 500 x 500 km scenes
3. Delivery delay: 2 days
4. Product formats: digital and imagery
5. Frequency of reanalysis of areas: 30 times per year

Table III-4
AID's Future Requirements for Satellite Data
(Vegetation Monitoring and Global Targeting)

Wavelength (μm)	Band Width (μm)	IFOV (m) Desired	IFOV (m) Minimum	Priority (1 highest)
0.66	0.02	4	4	2
0.92	0.02	4	4	1
1.65	0.05	4	4	3
11.50	0.50	4	4	4

Remarks:
1. 12-hour acquisition cycle
2. 2,500 x 2,500 km scenes
3. Delivery delay: 1 day
4. Product formats: digital and imagery
5. Frequency of reanalysis of areas: 150 times per year

1. Country Environmental Profiles and National Conservation Strategies

AID's goal is to enhance its capability to develop environmental policies and natural resources management strategies by founding them on improved applications of a more diverse data base. In the case of AID's Country Environmental Profiles and National Conservation Strategies programs, attempts will be made to include satellite remotely sensed data to increase the sharpness of their assessments. Both programs are major AID data collection efforts, but the information tends to be qualitative and leads to qualitative results that limit planning options. The Profiles program, which deals with regional descriptions of land capabilities and the like, provides the baseline information for planning. Adding a satellite remote-sensing capability would expand and help quantify the set of baseline information, and would give a new perspective to the work of developing effective policies for coping with issues like loss of fragile topsoil, depletion of potable and irrigation waters, and other habitability and resources problems.

2. Regional Environmental Problems

AID believes that far more can be done to estimate agricultural production in threatened regional areas such as the Sahel. Polar-orbiting satellites can provide data on changes in vegetation that indicate vigor or stress, drought or flooding.

Higher resolution Landsat and SPOT data can zero in on areas identified as experiencing stress. The three-tiered system can be used to monitor and protect fragile ecological zones.

3. Geographic Information Systems

Significant progress is being made in the construction of geographic information systems (GIS). These systems integrate digital data from many sources, including satellites and resource surveys, in programs designed to provide decision makers with the necessary insights to make meaningful resource management choices. The global scope of AID's mission and its requirements for current, accurate environmental data mean that satellite data will be a primary component of AID's GIS.

4. Collaborative Efforts

NOAA's Geostationary Operational Environmental Satellite (GOES), POES, and Landsat systems contribute to AID's ongoing programs, and they will continue to be needed as data sources for AID's future work. Foreign and non-NOAA satellites, such as SPOT, GMS, and GEOSAT, have contributions to make in furthering AID's efforts, as will the other satellite systems that will come on line in the years ahead. AID looks to NOAA, in its role as manager of the Nation's civil operational Earth remote-sensing satellite activities, to continue to provide useful data from U.S. satellite systems.

E. SUMMARY

AID's global mission is concentrated in regions that are undeveloped and likely to be remote. AID provides and advises on programs that often impact on ecological and resources systems that are in delicate balance with each other. AID's success depends on careful decision-making processes that consider and correctly interpret the best available data representing the conditions of the region under review.

Satellite data are an increasingly important component of AID's data base. In part, this is due to the flexibility and convenience that have become associated with satellite data applications over the past few years. Additionally, new satellites, U.S. and foreign, are entering operation and broadening the supply of useful data. Principally, however, the use of environmental satellite data in the programs of AID and others has come about because of more than two decades of reliable data delivery by NOAA satellites; this reliability has given users the confidence to establish operations that depend upon satellites as data sources.

AID's outlook on the continued use of NOAA satellite data is that its mission will require the steady acquisition and use of global data through the foreseeable future. All the current products and services of Landsat, POES, and GOES will be needed, probably in larger volumes, as new programs are initiated and existing programs are modified to take advantage of satellite resources. Some new kinds of satellite data products are needed, such as soil moisture estimates and precipitation measurements. AMSU on POES will help with this need, as will GOES improvements.

IV. SATELLITE REQUIREMENTS
OF THE
DEPARTMENT OF TRANSPORTATION

IV. SATELLITE REQUIREMENTS OF THE DEPARTMENT OF TRANSPORTATION

A. INTRODUCTION

The Department of Transportation has two operational components with major interests in NOAA's environmental satellites. The Coast Guard, which is responsible for search and rescue in the offshore areas of the United States, is an active participant in the Search and Rescue Satellite-Aided Tracking (SARSAT) program. NOAA Polar-orbiting Operational Environmental Satellites (POES) are the platforms for SARSAT instruments. Advice about the weather and ocean conditions influencing rescue operations, including advice derived from NOAA's satellite data, is also required by the Coast Guard. The other component of the Department of Transportation with satellite requirements is the Federal Aviation Administration (FAA), which is responsible for ensuring the safety of U.S. aviation activities.

B. FEDERAL AVIATION ADMINISTRATION SATELLITE REQUIREMENTS

The provision of aviation weather information in the United States is a joint venture directly involving the Federal Aviation Administration, NOAA, the Department of Defense, and the civil aviation community. The current aviation weather system is limited in its ability to rapidly acquire measured or observed data, and to process and disseminate operationally significant information to various categories of users. Capabilities to detect real-time weather situations that could adversely affect flight safety also are limited. The FAA has assumed a leadership role in a concerted effort to define the activities needed to improve the accuracy, availability, and timeliness of aviation weather information. This effort is documented in the annual FAA Aviation Weather System Plan, which is the basis of much of this chapter.

In general, improving weather data services to meet the FAA requirements involves increasing the frequency of observations (particularly ground-based), reducing communications delays and expanding the communication capability at reduced cost, and increasing the data processing capability to provide weather products pertaining to real-time air traffic control operations.

Aviation weather information requirements are based on domestic flight needs for current and forecast weather, as well as severe storm information. Among the parameters relevant to environmental satellites are:

- Area synopsis/outlook
- Clouds/sky cover
- Visibility; present weather
- Winds and temperatures aloft
- Pilot reports
- Convective activity (embedded thunderstorms, heavy precipitation)
- Presence of lightning; thunderstorms

While en route, the fixed-wing aircraft pilots need winds aloft updates for cruise altitudes, and information about changes in winds and weather at intermediate and destination airports. In addition, the International Civil Aviation Organization (ICAO) needs the following information, which satellites can help provide, for oceanic flights:

- Active thunderstorms
- Revolving tropical storms
- Severe squall lines
- Cumulonimbus clouds (at transonic levels)

For sea-based naval operations, the following satellite-related information is required in addition to the requirements for domestic flights:

- Wave height, period, and direction
- Sea ice accretion
- Synoptic and mesoscale wind forecasts, essential for aircraft carrier operations and flight planning

Support to aviation depends, in part, on the timely availability of the following weather products:

- Surface weather analysis and prognosis charts
- Radar summary charts
- Satellite imagery
- Severe weather outlook charts
- Winds aloft depiction charts and wind messages
- Weather depiction charts
- Freezing level charts
- Constant pressure charts
- Surface temperature forecast charts

The input data from which these products are derived come from all sources, including weather radars, satellites, and pilot reports. The FAA operates about 64 GOES-Tap locations to provide near-real time access to satellite information, in addition to having on-site support from National Weather Service (NWS) meteorologists at major locations.

The FAA has been using the GOES Data Collection System (DCS) experimently for the Aircraft to Satellite Data Relay System

(ASDAR), which permits data to be collected from commercial aircraft and relayed to ground-based users via geostationary meteorological satellites. The ASDAR system is being developed to provide better and more frequent aviation wind and temperature observations over data-sparse land and ocean areas. An important use of these data is in updating global weather and fine-mesh prediction models. Initial deployment of ASDAR production units is expected in 1986, with 80 ASDAR-equipped aircraft expected to be operational by 1990. The planned improvements in NOAA's GOES DCS capability will be essential to the expansion and operational development of the ASDAR network.

Several areas have been identified for future research to support FAA weather requirements. Those areas that relate to improved satellite capabilities include:

- Accurate descriptions of storm systems. There is a need to describe mesoscale storm systems accurately (location, vertical and horizontal extent, intensity, growth, motion, etc.), to allow operational decisions to be made about the safety of conducting flight operations in and around the storm systems.

- Improved winds aloft observations and forecasts. There is a need to improve the number and accuracy of upper air observations, to provide an expanded data base capable of providing more accurate wind and temperature information, both observed and forecast, with much greater resolution.

The FAA is working with NASA in developing techniques to measure upper atmospheric winds from satellites. These techniques would supplement the current capability for deriving winds from the cloud motions appearing in sequences of Geostationary Operational Environmental Satellite (GOES) images. The technique under study involves deriving wind velocity by using satellite-borne pulsed carbon dioxide lasers to detect and measure the velocity components of aerosols embedded in atmospheric layers.

In response to another FAA requirement, NASA is studying the feasibility of a sensor placed on a satellite in geosynchronous orbit, which would map any lightning stroke within its field of view.

C. SUMMARY

Satellite data are an essential input to virtually all derived weather products of interest to the FAA. The FAA is actively pursuing improvements in satellite sensors, communications, and data collection systems that offer gains in aviation safety and efficiency. Wind and lightning information are areas for potential satellite sensor improvements; the ASDAR program will contribute directly to improved data availability by facilitating the reporting and redistribution of flight-level environmental information that is collected automatically and broadcast by the aircraft segments of the ASDAR system. Improved processing of all data bearing on the safety of flight is an urgent requirement, as is the rapid distribution of weather products to the FAA's operations facilities. The National Weather Service is the primary NOAA interface with the FAA on weather requirements. NWS's future satellite requirements, based in part on the need to support FAA operations, are addressed in detail in the ENVIROSAT-2000 Report, <u>NOAA Satellite Requirements Forecast</u>, May 1985. The FAA needs the meteorological and communications services provided by NOAA environmental satellites, both polar-orbiting and geostationary, and will benefit from improvements made in the future.

V. SATELLITE REQUIREMENTS OF THE ARMY CORPS OF ENGINEERS

V. SATELLITE REQUIREMENTS OF THE ARMY CORPS OF ENGINEERS

A. INTRODUCTION

The Army Corps of Engineers (CE), through its Civil Works Program, carries out a nationwide water resources planning, construction, and operations effort in cooperation with a wide range of public and private organizations. Specific CE project areas include navigation improvements related to the Nation's rivers and harbors; flood damage reduction through structural and/or nonstructural measures and participation in flood plain management; hydropower generation through development, construction, and maintenance of projects that provide salable power; beach erosion control through restoration and preservation of coastal and lake shores to mitigate damage from storm tides and wave action; water supply and conservation through the development of water storage space for municipal and industrial purposes in multipurpose projects; natural resource management designed to provide a quality outdoor recreational experience while maintaining or enhancing the quality of the natural environment; fish and wildlife management; and environmental enhancement.

Effective management of CE projects calls for collection of a wide variety of environmental, hydrological, and meteorological data. Satellite systems provide the only feasible means for repetitive, large aerial extent, and up-to-date collections of terrestrial, oceanographic, and atmospheric data.

This chapter describes the Corps' use of NOAA satellite data and systems to fulfill its mission.

B. OPERATIONAL SATELLITE DATA PROGRAMS

1. GOES Data Collection System

Until the mid-1970's, land-line communication was the most common means of real-time water control data collection within the Corps. Despite general cost effectiveness, land-line communications are vulnerable to failure under severe weather conditions, when the need for real-time data is the greatest. The development of satellite technology for use in hydrometeorological data collection allowed the Corps, in 1972, to begin using data transmitted from on-site Data Collection Platforms (DCPs) via the Landsat satellite. The drawback of the Landsat data collection system was that the satellite, in polar orbit, could not provide continuous data relay for a given area. Satellites in appropriate geosynchronous locations do provide the round-the-clock coverage needed. In view of this, the

Corps switched, in 1976, to NOAA's Geostationary Operational Environmental Satellite (GOES) Data Collection System (DCS) to transmit real-time river runoff data to the streamflow models used to regulate lake and reservoir levels for flood control, navigation, hydropower, fish and wildlife management, and recreation. The primary types of data collected through DCS are lake stage, lake/reservoir elevation, volume of discharge, precipitation, temperature, snow depth, evaporation, and water quality.

The GOES DCS provides the Corps with 24-hour-a-day coverage of its DCPs. The data from GOES are accessed at the NOAA receiving station at Wallops Island, Virginia, and are transferred via dedicated high-speed links to a central National Weather Service (NWS) data distribution facility in Maryland for relay to Corps offices.

The CE further reduced its reliance on land-line communications (microwave and wire) by establishing six operational GOES direct readout ground stations to receive DCP data. These are located in Vicksburg, Mississippi; Cincinnati, Ohio; Fort Worth, Texas; Waltham, Massachusetts; Omaha, Nebraska; and Rock Island, Illinois.

There were approximately 200 CE DCPs being serviced by the GOES DCS in 1977. Now there are more than 1,500, with more than 1,200 in an active status. The Corps is the largest user of the GOES DCS system today. Eventually, all divisions in the Corps will automate their data systems for compatability with GOES DCS satellite telemetry. The CE plans on increasing its DCP number to 2,650 by 1990 and to 3,350 by 1995.

2. Landsat Emergency Access and Products

Landsat Emergency Access and Products (LEAP) is a cooperative program between NOAA and the Federal Emergency Management Agency (FEMA) that was initiated and codeveloped with NOAA by the CE. LEAP is designed to provide Landsat Multi-Spectral Scanner (MSS) data quickly to Federal, state, and local government agencies. LEAP delivers disaster-area coverage information to Corps and other users within 12 hours of its receipt by NOAA. LEAP coverage of the disaster scene is continued in the postevent period, as an aid in conducting postdisaster recovery activities. Without CE's codevelopment and implementation of LEAP, Landsat data would not be available for disaster recovery operations until the days or weeks of normal processing and delivery methods had passed. The MSS data are ideal for studying river and coastal flooding and other disasters affecting large geographic areas. The Corps has been using LEAP since the service became operational in 1984.

C. REMOTE-SENSING RESEARCH AND DEVELOPMENT ACTIVITIES

In 1983, the Cold Regions Research and Engineering Laboratory (CRREL) was assigned the responsibilty of managing the CE's Civil Works Remote Sensing Research and Development Program. CE's program includes laboratory research and development efforts, demonstration projects, and user assistance. The research is designed to feed directly into demonstration projects, which are carried out in cooperation with Corps field offices. Feedback from the demonstration projects (and ultimately from operations) prompts changes in the research and development program to meet field requirements.

The CE document in Appendix B, Civil Land Processes Research from Space, January 1985, describes in depth CE's Remote-Sensing Research and Development Program in support of civil works. It also describes the CE's remote-sensing research, demonstration, and technology transfer programs. From this source and others, the following capsules offer a view of CE's present and future satellite requirements.

The main objectives of the CE's remote-sensing program are:

- To understand the capabilities of remote sensors (satellite, aircraft, in situ)
- To demonstrate the use of sensor data
- To establish cooperative programs with CE districts and other agencies

1. Understanding the Capabilities of Remote Sensors

The sensors aboard NOAA's Landsat and meteorological satellites, and on foreign satellites, are being evaluated by CE's laboratories to determine how their data can be used in accomplishing CE's mission.

a. Environmental and Hydrological Data. High-resolution digital satellite data have great potential for supplying hydrologic and environmental information for the Corps' planning process. CE presently is evaluating the use of Landsat-5 MSS and Thematic Mapper (TM) data, as well as simulated data for the French SPOT satellite, due for launch in 1985, in flood forecasting, habitat evaluation, water quality, and flood damage models.

b. Wildlife Habitat Data. The Fish and Wildlife Coordination Act calls for a comprehensive study of the impact of each Corps project on natural species. Large areas are affected by Corps projects, so guidelines are needed for finding out how remotesensing technology can help develop wildlife data at reasonable expense. The Corps is comparing the information content, reliability, and cost of acquiring and analyzing TM, MSS, and SPOT data for wildlife identification and mapping.

c. GOES Data Collection System. Various hydrologic and meteorologic sensors, such as for measuring wind speed and direction, winter river flow, precipitation, and snow water equivalent, are required for flood forecasting by CE district offices. Reliable data, transmitted and received even during severe weather conditions at the observation site, are needed in near-real time. The Corps is evaluating ways to interface state-of-the-art hydrometeorological and environmental sensors (for deployment on data collection platforms) to the GOES DCS and other data relay systems.

2. Demonstrating the Use of Sensor Data

a. Land Use Data. The Corps is developing procedures for using satellite digital data in CE planning, engineering, and operational activities. Currently, the Corps is using Landsat TM data to prepare land cover maps for sites in the Ohio River Main Stem study area. The satellite maps will be used to detect areas of urban change and assign priorities to areas where more detailed surveys are required to update the Corps' structure inventories (dams, construction, etc.). Landsat TM and MSS data will be evaluated for recreation resource management of Berlin Lake, Pennsylvania, by the Pittsburgh District. Landsat TM land cover information also will be placed into a geographic data base for use in hydrologic runoff modeling, and for mapping crop types for use in agricultural flood damage assessments.

b. Flood Location Data. The Corps is developing a capability to obtain rapid, repetitive coverage of flood water extent over the total Lower Mississippi Valley District region. The area is subject to large Mississippi River floods, and the information would be used in flood water control and emergency operations. During floods, the Corps must gather information both for itself and for other Federal, state, and local agencies. The information must be gathered faster and be more accurate than is now possible by conventional data collection methods. Environmental satellites can provide synoptic views of flood progress over large areas at intervals of 1/2 (GOES) to 12 (POES) hours. The Landsat revisit period is 16 days. Flood location maps must be readily available during emergency operations; the frequent views provided by NOAA's environmental satellites can contribute to this availability.

The primary source of data for this effort will be NOAA's Polar-orbiting Operational Environmental Satellites (POES), each of which provides twice-a-day coverage of the whole Earth through a five-channel multispectral scanner with a 1.1 km spatial resolution. Secondary sources of data will be NOAA's GOES and the spacecraft of the Defense Meteorological Satellite Program (DMSP). GOES visible data are available at 1.0 km spatial resolution every 30 minutes during daylight, and 7 and 14 km infrared during daylight and darkness. Data collection platforms that transmit flood stage data through the GOES DCS also will be used. The goal of the program is to produce a set of initial flood interpretation maps within 24 hours of the first satellite image of flooding and to repeat this operation once every 2 hours over the flood's duration. The planned improvement of POES imager spatial resolution to 500 m by the end of the 1980's will aid Corps programs in determining flood extent.

c. Soil Moisture Data. The Corps is developing methodology and analytical techniques for using remotely sensed soil moisture data in hydrologic modeling. Some soil moisture information can now be inferred by using infrared channels 4 and 5 of the Advanced Very High Resolution Radiometer (AVHRR) instrument on POES. The next POES series will include the Advanced Microwave Sounding Unit (AMSU), which will add new capabilities for gathering direct information about soil moisture by using microwave capabilities.

3. Establishing Cooperative Programs

The CE plans to develop and demonstrate the capability to quickly delineate flooded areas. In parallel, the CE will attempt to develop fast and cheap ways to establish and update land use profiles based on Landsat data, and to incorporate into this data base historical information on flooding. A system called Flood Analysis Simulation Technology (FAST) has been developed and applied to eight major flood control planning studies for areas in the Vicksburg District, and to two additional areas in the Mobile District. FAST is designed to use Landsat as a source for its land use data. Techniques for rectifying an entire Landsat scene to the Universal Transverse Mercator standard coordinate system are being developed. A prototype procedure will be developed for mapping historical flood areas in the same coordinate system.

D. SUMMARY

The CE requires improved satellite remote-sensing data for applications in topographic mapping, geographic positioning, land use analyses, soil moisture delineations, coastal wave and current assessments, and other areas under the Corps' purview. These requirements are referenced in more detail in Appendix B.

In the area of satellite sensor development, the CE sees the need for improvements in visible and infrared imaging systems that would result in increased resolution, higher radiometric quality, and simplified analysis procedures. The development of both active and passive operational microwave sensors, with all-weather capabilities, would be of great advantage to the Corps. Microwave remote sensing, among other advantages, would allow surface observations in the presence of the clouds associated with disaster-causing storms, measurements of soil moisture, and new data sources for land use and coastal processes assessments.

The CE has plans to expand greatly its use of GOES DCS services. CE will continue to access data from its remote observation platforms both by intercepting GOES direct readout broadcasts at CE ground stations and receiving NOAA messages containing platform information.

VI. SATELLITE REQUIREMENTS OF THE DEPARTMENT OF DEFENSE

VI. SATELLITE REQUIREMENTS OF THE DEPARTMENT OF DEFENSE

The Department of Defense (DOD) works closely with other Federal agencies to ensure that all national capabilities are used efficiently in national security activities. The DOD mission requires global capabilities. Satellites, the most important source of data on global environmental conditions, contribute to the accomplishment of this mission. NOAA, as operator of U.S. civil environmental satellites, has capabilities that complement the data and service capabilities provided by DOD's Defense Meteorological Satellite Program (DMSP). Major areas of cooperation between NOAA and DOD include the exchange of meteorological, oceanographic, and space environmental observations, operation of the Joint Ice Center, and the sharing of data processing responsibilities to enhance the efficiency of satellite data handling and exchange among the Navy, Air Force, and NOAA.

DOD's DMSP operations diverge from NOAA's Polar-orbiting Operational Environmental Satellite (POES) operations in significant aspects, such as orbit requirements, sensor payloads, and the provision of direct readout services. The two programs do share the same spacecraft design, and all POES data ingested at NOAA's Command and Data Acquisition ground stations also are acquired at DOD locations. A detailed analysis of the two programs, and outlooks on their immediate futures, are given in the ENVIROSAT-2000 Report, <u>Comparison of the Defense Meteorological Satellite Program (DMSP) and NOAA Polar-orbiting Operational Environmental Satellite (POES) Program</u>, August 1985.

The report that follows has been provided by DOD for use in this volume. Together with Appendix C, it establishes DOD's requirements for environmental satellite support.

A. INTRODUCTION

Department of Defense missions require capabilities to conduct operations anywhere in the world. Support of global operations requires a full spectrum of meteorological, oceanographic, topographic, and space environmental observations, provided by systems that are secure, survivable, and responsive to changing needs. Satellite-based data collection and dissemination systems are key sources of the needed information. Combat-critical environmental data are normally provided by dedicated military satellite systems (including platforms, sensors, communications, processing, and dissemination subsystems), which can be tailored to meet unique requirements. These requirements and the dedicated military capabilities designed to meet them are described fully in the associated ENVIROSAT-

2000 Report, Comparison of the Defense Meteorological Satellite Program (DMSP) and NOAA Polar-orbiting Operational Environmental Satellite (POES) Program, August 1985, and in the Joint Chiefs of Staff memorandum MJCS 251-76, "REVALIDATION OF MILITARY REQUIREMENTS FOR METEOROLOGICAL SATELLITE DATA," Appendix C, which will be superseded by MJCS XXX-85, "MILITARY REQUIREMENTS FOR DEFENSE ENVIRONMENTAL SATELLITES," now being coordinated for publication later this year.

The Department of Defense relies on the elements of the Defense Meteorological Satellite Program and, in the future, will depend on the Navy Remote Ocean Sensing System (N-ROSS) to satisfy critical combat-related requirements. Neither of these systems can meet the full range of environmental sensing needs of DOD; therefore, some elements of the DOD environmental support system rely upon data or services from NOAA. Specifically, DOD will use NOAA data or services in all cases where the limitations of security, survivability, and responsiveness can or must be accepted.

B. SATELLITE REQUIREMENTS

DOD activities to which satellite-sensed data are applied cover virtually the full range of military functions. They include communications; concealment; construction; electronic countermeasures; geolocation/navigation; intelligence evaluation; maintenance; maneuver (ground, sea, air, and space); mission planning; reconnaissance/surveillance; research, development, design, testing, and evaluation; resource protection; search and rescue; training; weapon development; weapon guidance; weapon selection; target planning, selection, evaluation, acquisition, identification, lock-on, tracking, and kill.

Nearly every environmental element that can be sensed from a satellite platform has relevance and utility to DOD. Sensors with DOD relevance include topographic, oceanic, and atmospheric imagers (visual, infrared, microwave, etc.); atmospheric sounders (multispectral, microwave, laser, etc.); altimeters, scatterometers, radiometers, particle spectrometers, magnetometers, plasma probes, ultraviolet and X-ray spectrometers, ultraviolet and X-ray imagers; and radiation dosimeters.

DOD applications of satellite-sensed environmental data can be conveniently divided into four categories: land, ocean, atmosphere, and space. In each area, environmental information is used to increase the effectiveness of a weapon system, provide intelligence for tactical and strategic command decisions, protect life and property, support military research and development projects, and contribute to other military activities. Examples of requirements and applications follow.

Land-related data are used to improve and produce geoid, geodetic, and topographic models and maps of the Earth. Information is applied to analyses of snow and ice location and characteristics; soil moisture; vegetation; and surface, subsurface, and ocean bottom features. Data from the U.S. Landsat program are now used by DOD to meet some of these requirements.

Ocean-related data are used to support maritime military operations. Sea ice, sea state, sea surface temperature and topography, surface winds, and other information may be measured directly or derived from satellite data. Remotely sensed ocean data are used to improve analyses and forecasts of ocean fronts and eddies, internal waves, subsurface characteristics, and other physical variables in the open ocean. Research and development projects to measure and understand the air-sea interaction are heavily dependent on both ocean and atmospheric data, as are research programs aimed at improving predictions of birth, growth, and movement of typhoons and hurricanes. A specific example of the DOD application of NOAA data and services exists in the NOAA/Navy Joint Ice Center, Suitland, Maryland, which relies on the NOAA polar-orbiting satellite system for its basic observational data.

Atmospheric data provide operational meteorological information for military weapon systems, tactical and strategic commanders, and safety. Cloud images and soundings of temperature and moisture are used in analyzing and forecasting weather parameters affecting military operations. Engineering and development projects use climatic-atmospheric data for military system design. Research and development projects use atmospheric data to improve point and area forecasting capabilities, to improve models, and to simulate the battlefield environments of tactical areas over the globe. Of particular importance is the DOD use of NOAA satellite data for resource protection (equipment, facilities, and people) in the continental United States; access to the GOES-Tap system is important to the resource protection mission of DOD weather support units throughout the United States.

Additionally, NOAA data and services related to atmospheric soundings provide significant support to the global analysis and forecasting responsibilities of both the Navy and the Air Force under a formal "Memorandum of Agreement on the Shared Processing of Satellite Data" among three major computer centers: the National Environmental Satellite, Data, and Information Service (NESDIS), the Fleet Numerical Oceanography Center (FNOC), and the Air Force Global Weather Central (AFGWC). Shared processing of data will be for the sensors on DMSP, N-ROSS, and POES. Each computer center will be a "center of expertise" for an area of primary interest. NESDIS is the center of expertise for atmospheric soundings, FNOC for sea surface measurements, and AFGWC for cloud imagery. Wide band satellite communications will be used for data exchange between the three centers of expertise. The processing of satellite data by sensors is as follows:

NESDIS.

- TOVS (NOAA)
- SSM/T (DMSP)
- SSM/I (DMSP)

FNOC.

- SSM/I (DMSP, N-ROSS)
- Altimeter (N-ROSS)
- Scatterometer (N-ROSS)
- Low Frequency Microwave Radiometer (N-ROSS)

AFGWC.

- OLS (DMSP)
- AVHRR (NOAA)

Space-related data are used by DOD to support surveillance and reconnaissance systems, communications sytems, and on-orbit operations of military satellite systems. Impacts include degradation in the performance of communications and surveillance systems (related primarily to changes in the ionosphere), changes in orbital elements of satellites caused by atmospheric heating and subsequent neutral-density changes, and deterioration or physical damage to satellites caused by enhanced radiation levels in near-Earth space (i.e., inside the magnetosphere). Direct observations of the near-Earth space environment acquired by polar-orbiting and geostationary satellites provide the primary source of intelligence on characteristics of that environment. NOAA and the U.S. Air Force jointly operate the Space Environment Services Center (SESC) in Boulder, Colorado. The function of SESC is analogous to the NOAA/Navy Joint Ice Center. The SESC relies heavily on space environment data from DMSP, POES, and Geostationary Operational Environmental Satellites (GOES).

C. SERVICES REQUIREMENTS

DOD use of services provided by NOAA is not limited to direct environmental observation and data processing. NOAA provides a vital interface with international data sources for important peacetime applications, especially those related to cost reduction efforts for aircraft and ship routing, and worldwide resource protection functions.

DOD does not have a requirement to provide an archive for environmental data collected by military systems. Such data can be of high value for research, climatic, and postanalysis projects. DOD provides unclassified environmental data from military satellites to NOAA for the national archive, and relies on NOAA to store and retrieve data as required.

Currently, copies of DMSP imagery and DMSP space environmental data are sent to the NOAA archives in Boulder, Colorado, within 30 to 60 days after observation. Selected digital data tapes are maintained by DOD, for DOD operational purposes, beyond 60 days. NOAA retrieves data (i.e., data no longer retained by DOD in its operational data bases or on selected digital tapes) from the national archive for DOD as needed.

VII. SATELLITE REQUIREMENTS
OF THE
DEPARTMENT OF THE INTERIOR

VII. SATELLITE REQUIREMENTS OF THE DEPARTMENT OF THE INTERIOR

A. INTRODUCTION

The Department of the Interior (*DOI*), through its various bureaus and offices, has direct administrative responsibilities for more than 500 million acres, or roughly 40 percent, of the total land and continental shelf areas of the United States. In addition, the Department is responsible for mapping and resource appraisal for the entire country, has responsibilities in the Trust Territories of the United States and Antarctica, and conducts studies in other countries in cooperation with foreign governments. The vastness of the territories involved in the inventory, monitoring, mapping, and management activities of the Department requires efficient and effective means for acquiring many different types of information. Satellite remotely sensed data represent one such source of information that has been applied and will continue to be applied with increasing frequency by DOI bureaus and offices.

B. SATELLITE DATA AND SYSTEM REQUIREMENTS

1. Satellite Remote-Sensing Data Applications and System Requirements

DOI uses satellite remote-sensing data for geologic and hydrologic investigations, cartographic mapping, land management, wildlife management and inventory, and environmental monitoring. The spatial resolution needs of most of these activities are in the range of 10 to 80 m and, therefore, rule out current environmental satellite sensors. However, lower resolution data may be necessary to supplement or substitute for land remote-sensing data to fulfill requirements for more frequent and complete data coverage than is possible from NOAA's Landsat or the French SPOT satellites. Once detailed base maps are completed, Advanced Very High Resolution Radiometer (AVHRR) data from NOAA's Polar-orbiting Operational Environmental Satellites (POES) can be used by DOI for operational monitoring of large-scale changes in surface conditions.

Many of the bureaus and offices within DOI use satellite data to collect and disseminate information to assess the Nation's energy and mineral resources, evaluate geologic hazards, and conduct basic geologic investigations that support administrative responsibilities. The satellite data are unique in that they provide continuous information over large areas, from which interpretations relating to the composition, form, distribution, and structural relationships of geologic materials exposed at the Earth's surface can be made. Such information is used to compile regional geologic maps, delineate structural features, determine rock composition, facilitate prediction of geologic hazards, and conduct geobotanical investigations.

Satellite data are used in combination with other types of ground-based data to determine the occurrence, extent, quantity, quality, and use of the Nation's water resources. Because of the increase in the frequency and severity of water problems, satellite data will likely play a more important role in the future, being used to monitor mountain snowpack and surface water, measure irrigation usage, interpret shallow aquifers, and detect pollution in lakes, streams, and coastal areas.

Satellite remotely sensed data are being used to create image maps that are merged with thematic data such as terrain, land cover, and other base cartographic data to support specific management needs in several DOI bureaus. Satellite image maps fitted to other thematic data can be used to inventory and update land and cultural resources; the periodic coverage, spectral sensitivity, sensor resolution, and geometric accuracy of satellite data are important parameters for these applications.

Vegetative land cover mapping represents one of the major operational uses of satellite data by the bureaus with land management responsibilities. Monitoring public rangelands, detecting change such as conversion of agricultural land to urban or new mining activities, observing natural disasters, and detecting vegetation changes induced by variations in climatic conditions, crop disease, and insects are important factors in making timely and prudent land management decisions. The vast area of public lands in the western United States and Alaska, the diversity of terrain and land cover, the demands for timely information, the requirement for repetitive coverage, and the urgent need to conserve manpower and budget resources all point to the important role satellite remote sensing plays in DOI land management activities.

Bureaus and offices within DOI are responsible for the management and preservation of the Nation's wildlife resources. Satellite remote sensing is used to collect some of the information required for wildlife-related activities, especially in vast, inaccessible remote areas, such as in Alaska, that require initial data collection and frequent updating. Applications of satellite data include habitat inventory, analysis and monitoring, and wetlands inventory and evaluation.

Research and development activities in geographic information systems (GIS) within DOI will include the integration of remotely sensed satellite data with other types of disparate data. The ability to integrate various data sources into the decision-making process enhances the execution of responsibilities of all DOI agencies. Vertical integration of multiple layers of data that are spatially registered permits a variety of information on a specific area to be analyzed simultaneously. Horizontal integration of data sources permits analyses of large areas with consistent and coherent results. Remotely sensed data provide spectral and spatial information from which geologic, hydrologic, vegetative, cultural, and geographic information can be interpreted. The geometric registration of digital remotely sensed data allows a convenient and efficient incorporation of the data into geographic information systems, which are amenable to the application of a multitude of extraction techniques.

Appendix D is a detailed report submitted by DOI listing and describing representative examples of existing or potential applications of remote-sensing satellite data. It identifies corresponding satellite system characteristics required to meet the information needs of those applications.

2. <u>GOES Data Collection System</u>

DOI is the second largest user of the Geostationary Operational Environmental Satellite (GOES) Data Collection System (DCS), currently employing more than 660 active Data Collection Platforms (DCPs) and using 29 percent of the total system. Within DOI, the major users are the Bureau of Reclamation (BOR), the Bureau of Land Management (BLM), and the U.S. Geological Survey's (USGS) Water Resources and Geological Divisions.

a. <u>Bureau of Reclamation</u>. The Bureau of Reclamation uses more than 260 active DCPs and operates two GOES DCS direct readout stations (Idaho and Colorado) to collect hydrometeorological data for a variety of operational and research purposes. The Pacific Northwest Region maintains an operational hydromet system that gathers near-real time data from several river basins. Data collected at the Boise, Idaho, direct readout station are fed into the Columbia River Operational Hydromet System for the use of several agencies in the Pacific Northwest; some data are fed into the National Weather Service's Automatic Hydrologic Observing System (AHOS).

The Division of Atmospheric Resources in Denver, Colorado, operates a GOES DCS direct readout station mainly for research programs involving weather modification, solar energy, and dam safety, while providing some operational data to other BOR offices. BOR intends to implement the Standard Hydrometeorologic Exchange Format on the Denver direct readout station so that data can be exchanged automatically with other environmental data networks.

The types of data collected through the GOES DCS for BOR are: river stage, reservoir elevation, water temperature, precipitation, air temperature, soil moisture, solar radiation, wind speed and direction, water quality, relative humidity, snow water content, discharge, pan evaporation, air pressure, and wind run.

b. Bureau of Land Management. The Bureau of Land Management is cooperating with the Department of Agriculture's Forest Service in a joint wildfire warning network using about 400 DCPs (150 BLM, 250 Forest Service), with a goal of more than 800 (about 400 DCPs for each agency). (For details, see Chapter II).

c. U.S. Geological Survey. The U.S. Geological Survey (USGS) uses the GOES DCS for cost- and time-effective automated remote acquisition of data in response to the needs of cooperating agencies that rely on USGS for the collection and analysis of hydrologic data. USGS has primary responsibility for collecting hydrologic data for Federal agencies, and provides major support to state and local agencies in the collection and interpretation of hydrologic data.

Data collected using the DCS includes precipitation, river stage, temperature, water quality, reservoir levels, and selected meteorological parameters. Cooperating agencies, including the Corps of Engineers, Bureau of Reclamation, National Weather Service, Soil Conservation Service, and state and local governments, use the data for river forecasting, flood warning, reservoir management, irrigation control, and water quality monitoring. USGS uses the telemetry to enhance station operations, including instrumentation monitoring and sampling, and measurement activities in response to hydrologic events.

There are 1,400 GOES DCPs operating at USGS's stream-gauging stations, located in every state. They monitor hydrologic data from every major river basin in the country. Approximately 1,000 of these units are operated for, or by, Federal cooperating agencies. The remaining units are operated for state and local agencies by USGS. It is anticipated that USGS will operate 3,000 DCPs (2,000 for other Federal agencies) by 1990 and 7,000 by 1995.

The U.S. Geological Survey's Water Resources Division (WRD) collects stream flow data from DCPs located throughout the United States. USGS is engaged in developing a network that will tie together approximately nine direct readout ground stations operated by WRD itself or by other users. WRD is working to transmit data received at these direct readout stations over a private telecommunication network that operates throughout the continental United States, Alaska, Hawaii, and Puerto Rico.

USGS's Geological Division plans to install 10 DCPs at Mammoth Lake to monitor the seismic activity in that area. The Geological Division also is engaged in earthquake monitoring along the San Andreas Fault in California and operates its own direct readout station to support that program.

C. FUTURE SATELLITE REQUIREMENTS

The GOES DCS is a vital element in the collection of hydrometeorological data for water resources and land management programs. DOI plans to increase its number of DCPs in the future. The Bureau of Reclamation anticipates approximately a doubling of DCP usage during the next 5 years. For the next 10 years, enhancements of BOR's data collection network will include emphasis on sharing data, improving instrumentation, and optimizing the use of the satellite transponder. BOR will be participating with NESDIS in an effort to improve the efficiency of data transmissions. USGS and the Bureau of Land Management also plan on increasing their DCP usage.

In order for NOAA's data collection system to expand, the ground system must be upgraded. A proposed budget initiative for FY86 would expand total DCP capacity to at least 12,500 per spacecraft (a 20 percent increase). Provisions also will be made for increased DCP data rates and a wider band width on the random reporting channel, although other funding may be needed to implement these last two improvements.

In the areas of geologic and hydrologic investigations, cartographic mapping, land management, wildlife management and inventory, and environmental monitoring, DOI has requirements for land remote-sensing satellites, such as NOAA's Landsat and the French SPOT satellites, with spatial resolutions in the range of 10 to 80 m (see tables in Appendix D). These resolutions exceed the capabilities of GOES and POES. However, GOES and POES data can fulfill requirements for more frequent and complete data coverage than is possible from Landsat or SPOT. In addition, once detailed base maps are completed, AVHRR data from POES can be used by DOI for operational monitoring of large-scale changes in surface conditions. Higher resolution AVHRR data also would be an extremely useful source of information for DOI's programs; the improvement of AVHRR spatial resolution from 1,100 m to 500 m, planned for a 1990 implementation, should increase the advantage of POES data to DOI programs.

D. SUMMARY

The Department of the Interior's responsibilities include administration of vast areas of public lands; assessment, inventory, and management of the Nation's energy and mineral resources, water resources, land cover resources, and wildlife resources; preparation of cartographic maps; and monitoring environmental changes and impacts. These responsibilities require the use of satellite data in combination with ground-based and other sources of data to effectively serve the information needs of the public. DOI bureaus currently are making extensive use of Landsat image data and data from environmental satellites, and the requirements for these data will increase in the future. DOI plans to increase the number of DCPs to collect site-specific data on hydrologic, geologic, and climatologic variables. The use of AVHRR data to monitor large areas in the western U.S. and Alaska, to detect changes in biomass and predict the potential for wildfires, is operational.

Satisfying DOI's information requirements in the future will depend heavily upon the availability of a combination of satellite data with varying resolutions, spectral sensitivities, geometric characteristics, and frequency of coverage. Data with 500 to 1,000 m resolution, acquired frequently, will be used for regional mapping, monitoring, and change detection; 10 to 80 m data acquired less frequently will be needed for site-specific mapping, inventory, and resource assessment. Stereoscopic data will be used for topographic mapping, geologic investigations, and other studies that require three-dimensional observation of the Earth's surface. Increased spectral sensitivity in the visible, near-infrared, and short wavelength infrared bands will be needed to support geoscience, bioscience, and natural science investigations. Microwave data will be used for snow and ice investigations and for cloud penetration to support disaster assessment.

To effectively process, manipulate, analyze, and display the varied combinations of satellite data collected at point locations and over large geographic areas, DOI is conducting research and development of geographic information systems to integrate remotely sensed data with other sources of information. For DOI to carry out its mission responsibilities and meet information demands in the future, the use of GIS technologies is required. The GIS approach will allow DOI to extract needed information efficiently from data originating at a wide variety of sources and appearing in varied formats, scales, and structures. NOAA satellite data will play an integral role in meeting DOI's mission responsibilities.

VIII. SATELLITE REQUIREMENTS
OF THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

VIII. SATELLITE REQUIREMENTS OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

A. INTRODUCTION

The National Aeronautics and Space Act of 1958, as amended, vests in the National Aeronautics and Space Administration (NASA) the responsibility for conducting space-based research and development aimed at increasing humanity's understanding of the Earth and its environment, and for providing the widest possible dissemination of the results of that research. The role of the Earth Science and Applications program in NASA's Office of Space Science and Applications is to conduct the space-based research necessary to carry out the Earth science responsibilities assigned to NASA by the Space Act. This research is directed toward increasing human understanding of the physical, chemical, and biological processes of the solid Earth, as well as the terrestrial environment, and includes space-based, in situ, and laboratory measurements.

B. CURRENT SATELLITE REQUIREMENTS

NASA has two basic requirements for operational environmental satellite data. The first is to support research in Earth science disciplines, providing observations of relevance to studies of biogeochemical cycles. The second use is to support space launch operations. NOAA provides special meteorological satellite data products to NASA for use in launch activities.

NASA and NOAA have a formal Memorandum of Understanding establishing their respective roles in the development, procurement, launch, and operation of operational environmental satellites. This agreement is under revision, and annexes are being developed covering data management, advanced sensor development, research, and operational satellite activities. These documents will lay out the framework within which the two agencies provide support to each other~~. In the~~ data area, NASA and NOAA use data generated by each other's programs for both operational and research purposes. Without a consistent baseline of time-series data sets, future research missions would not have a foundation upon which to evaluate their results. NASA has a major program of global, interdisciplinary studies that is built upon existing satellite observations. It will lead to improved understanding of our environment and may contribute to future operational capabilities.

In launch operations, NASA relies on NOAA-provided observations to forecast weather conditions at its launch and landing sites. At 48 to 24 hours before launch, NOAA provides a briefing to NASA's Launch Management Team. Data provided include temperature, precipitation and precipitation forecasts, wind and wind forecasts, cloud ceilings, and visibility. Weather reports and forecasts are provided until launch time. After launch, meteorological data from Geostationary Operational Environmental Satellites (GOES), Meteorological Satellites (Meteosat), and the Geostationary Meteorological Satellite (GMS) are provided to Mission Control at Johnson Space Flight Center.

C. FUTURE SATELLITE REQUIREMENTS

NASA's Earth Observation System Science and Mission Requirements Working Group issued a technical memorandum in August 1984, Earth Observing System, Volume I, examining important Earth science questions for the 1990's and defining the requirements for low Earth-orbit observations needed to answer these questions on a comprehensive, multidisciplinary basis. The following information is extracted from that report.

NASA views Earth science research as ready for a unified approach based on the view that the physical, chemical, and biological processes at work on the Earth comprise a coupled global system. NASA plans to establish an Earth Observing System (EOS) consisting of an advanced information system, including a data system and new observing facilities, to pursue a comprehensive multidisciplinary approach to understanding the Earth as a system.

To address the multidisciplinary problems confronting Earth science research, NASA will require observational capabilities ranging in scale from detailed in situ and laboratory measurements to the global perspective offered by satellite-based remote sensing. Parameters that need to be measured include the composition and dynamics of the atmosphere, the dynamics and biological activity of the ocean and inland waters, the distribution of sea and land ice, the distribution of both biological and geological regimes over the land surface, and the underlying structure of the planet. Since many of the important changes at work in the Earth system have time scales of seasons to years, persistent observations of dynamic phenomena are needed to build data records that stretch over a decade or more.

Part of NASA's strategy for EOS is to make use of the observational satellite systems already or soon to be available that can provide long-term data records. These include the Polar-orbiting Operational Environmental Satellite (POES), GOES, the land satellite (Landsat), non-U.S. geostationary meteorological satellites, the Navy Remote Ocean Sensing System (N-ROSS), the European Space Agency's (ESA) Remote-Sensing Satellite (ERS-1), Japan's Marine Observation Satellites (MOS-1), and other ocean-observing satellites. POES, GOES, and Landsat have provided years of observations, many of which are crucial to NASA's research efforts. The continuation of NOAA's environmental satellites is an essential basis for and complement to EOS.

In general, NASA requires that acquisition of data sets for a given environmental parameter of the Earth system should continue until new techniques for obtaining these data have been developed and implemented, and the new data records have been overlapped with the old ones for intercalibration. NOAA's operational satellites will provide significant contemporary data to EOS science investigations and will greatly reduce the need for EOS to carry certain types of instruments. POES and GOES will provide cloud coverage, temperature soundings, and limited-resolution moisture soundings for understanding the atmospheric condition, the global distribution of precipitation, energy inputs, moisture, sea surface temperature, and the circulation patterns of the atmosphere. Landsat could provide morning, high-spatial-resolution viewing of sites that EOS would view at another time of day with enhanced spectral resolution at both moderate and high spatial resolution.

Table VIII-1 lists NASA's future observational needs. The table provides not only the observations needed, but also some of the driving requirements for these observations, periodicity of observation and, in some cases, the level of resolution or sensitivity. Many of these observations will be provided by NASA's planned Earth science research missions.

Table VIII-1
National Aeronautics and Space Administration
Observational Needs

PARAMETER	APPLICATION	ACCURACY DESIRED	ACCURACY REQUIRED	APPROACH	SPATIAL RES.	OBSERVATION FREQUENCY	SPECTRAL RES
Soil Features							
• Moisture	Hydrologic and geochemical cycles	5 moisture levels	5 moisture levels				
• Surface		5%	10%	Microwave Radiometer	1-10 km	2 day	20 cm ± 1 cm
• Root Zone		5%	10%	Model	30-1000 m	1 week	20 cm ± 1 cm
• Types-Areal Extent (peat, wet lands)	Geochemical cycles Agricultural & Forestry	10%	10%	Visible/SAR	30 m	annual	20 nm/50 nm
• Texture-Color	Agriculture & Forestry	10%	10%	Visible/SAR	30 m	annual	20 nm/50 nm
• Erosion	Geochemical cycles	10%	10%	Visible/SAR	30 m	annual	20 nm/50 nm
• Elemental storage	Geochemical cycles						
• Carbon		10%	10%	Visible/SAR	30 m	monthly	20 nm/50 nm
• Nitrogen		10%	10%	Visible/SAR	30 m	monthly	20 nm/50 nm
• Permafrost	Geochemical	10%	10%	Visible/SAR	30 m	annual	20 nm/50 nm
Surface Temperature							
• Land	Primary production, soil moisture and respiration	0.5°C	±1°C	Thermal IR	1 km ± 0.5 km	12 hours	50 nm
• Inland Waters	Mass/Energy Flux	0.1°C	0.5°C	Thermal IR	30 m	12 hours	50 nm
• Ocean	Mass/Energy Flux	0.1°C	0.5°C	Thermal IR, Microwave	4 km (open ocean) 1 km (coastal ocean)	12 hours 12 hours	
• Ice	Mass/Energy Flux	0.5°C	1°C	Microwave, Thermal IR	1 km	1 day	
Vegetation							
• Identification	Hydrologic cycle, biomass distributions and change,	1%	5%	Visible, Near IR, Thermal IR	1 km	7 day	10-20 nm
• Areal Extent	primary production, plant productivity, respiration,	1%	10%	Visible, Near IR, Thermal IR	30 m	30 day	30 nm
• Condition (stress, morphology, phytomass)	nutrient cycling, trace gas, source sinks, vegetation-climate interaction, microclimate	10%	15%	Visible, Near IR Thermal IR, SAR	30 m	3 day	10-20 nm
• Leaf area index canopy structure and density		10%	20%	Visible, Near IR, Thermal IR, SAR	30 m	3 days	50 nm
Clouds							
• Cover	Radiation balance, weather forecasting, hydrologic cycle, climatologic processes, tropospheric chemistry	2%	5%	Visible, Thermal IR	1 × 1 km	6 hours	
• Top height		± .25 km	± .5 km	Lidar	1 km	6 hours	
• Emission temp.		± .5°C	± 1°C	Thermal IR	1 × 1 km	6 hours	
• Albedo		± 0.01	± .02	Visible	50 × 50 km	6 hours	
• Water Content		.05 kgm/m^2	.1 kgm/m^2	Microwave	50 × 50 km	6 hours	
Water Vapor	Weather forecasting, hydrologic cycle, climatologic processes	.001 ppm	.002 ppm	Microwave, Thermal IR, Lidar	100 × 100 km × 100 mbar (vertical)	12 hours	

Table VIII-1
National Aeronautics and Space Administration
Observational Needs
(continued)

PARAMETER	APPLICATION	ACCURACY DESIRED	ACCURACY REQUIRED	APPROACH	SPATIAL RES.	OBSERVATION FREQUENCY	SPECTRAL RES.
Snow							
• Areal Extent	Hydrologic cycle	5%	10%	Visible/Microwave	1 km	7 days	0.6-0.7 μm/1 cm
• Thickness	Water equivalent	5%	10%	Microwave	1 km	7 days	3 bands, 0.8-3.0 cm
Radiation							
• Shortwave	Surface energy budget	2%	5%	Visible	1 × 1 km	1 day	
• Longwave	Surface energy budget	2%	5%	Thermal IR	1 × 1 km	1 day	
• Short & Long wave	Hydrologic cycle	2%	5%	Visible, Thermal IR	100 × 100 km	6 hours	broadband
Precipitation	Hydrologic cycle	5%	10%	Microwave or in situ	1 km	daily	several bands, 0.1-10 cm
	Climatologic cycle	5%	10%	in situ	1 km	daily	
Evapotranspiration	Hydrologic cycle	5%	10%	Thermal IR, Visible, Microwave combination (model)	1 km	daily	multiple sensors
Runoff	Hydrologic cycle	10%	10%	Thermal IR, Visible, Microwave combination (model)	—	daily	multiple sensors
Wetland Areal Extent	Hydrologic cycle	2%	5%	Visible, Thermal IR	30-100 m	monthly	multiple bands
	Biogeochemical cycle	10%	30%	Visible, Near IR/SAR	30 m	3 days	20 nm/2 radar bands
Phytoplankton	Biogeochemical cycles						
• Chlorophyll Open Ocean/Coastal Ocean/Inland waters		10%	20%	Visible, Near IR	4 km/1 km/30 m	2 days	10-30 nm
• Fluorescence Open Ocean/Coastal Ocean/Inland waters		10%	20%	Visible, Near IR	4 km/1 km/30 m	2 days	5-15 nm
• Pigment groups Open Ocean/Coastal Ocean/Inland waters		10%	20%	Visible, Near IR	4 km/1 km/30 m	2 days	10-20 nm
Turbidity	Biogeochemical cycles						
• Inland water/coastal ocean	Erosion assessment	10%	20%	Visible, Near IR	30 m/1 km	2 days	10-30 nm
Bioluminescence	Ecological processes	presence/absence		Visible	4 km	monthly	10-20 nm
Wetland areal extent	Biogeochemical cycle	10%	30%	Visible, Near IR, SAR	30 m	3 days	three bands/20 nm
Surface Elevation							
• Land	Continental techtonics and surface processes	1 m	5 m	Laser or radar altimetry or stereo-	100 m IFOV	10 years	
	Interpretation and modeling of gravity and magnetic field data		±3 m (from averaging within 3 km blocks)	photogrammetry, SAR altimeter, 1 meter, laser altimeter	300 m × 300 m for averaging into 3 km blocks	10 years	
• Ocean	Circulation	1 cm		Microwave altimeter	25 km	2 days	
• Inland Ice	Hydrologic cycle	0.1 m	1.0 m	Altimetry	30 m	5 years	

Table VIII-1
National Aeronautics and Space Administration
Observational Needs
(continued)

PARAMETER	APPLICATION	ACCURACY DESIRED	ACCURACY REQUIRED	APPROACH	SPATIAL RES.	OBSERVATION FREQUENCY	SPECTRAL RES.
Wave							
• Height	Air-Sea interactions	10%	10%	Scanning altimeter, SAR	50 km	3 days	
• Spectrum		± 10 degrees	± 20 degrees	Scanning altimeter, SAR	50 km	3 days	
Inland Ice							
• Thickness	Ice dynamics	1%	2%	Radar Sounding (probably airborne)	1 km	50 years	
• Velocity Field	Ice dynamics	5%	5%	SAR, ADCLS	one per 100 × 100 km	10 years	
• Mass Balance	Ice dynamics,	5%	10%	Thermal IR, Microwave,	one per 100 × 100 km	annual total	
Temperature	Hydrologic cycle, Climate	1.0°C	1.0°C	ADCLS		annual mean	
Sea Ice							
• Areal Extent	Hydrologic cycle	10 km	100 km	Microwave radiometer	5-20 km	weekly	
• Concentration	Oceanic processes	1%	10%	Microwave radiometer	1 km	bi-weekly	
• Sea Ice Dynamics	Climatological processes	10 m	100 m	SAR, ADCLS	100 m	daily	
Atmospheric Constituents (Ozone & Compounds of Carbon, Nitrogen, Hydrogen, Chlorine, Sulfur, etc.)	Tropospheric chem.	5%	20%	Dial/Correlation Spectrum	10 × 10 × 1 km	1 day	
	Middle atmosphere	5%	10%	Thermal IR, UV, etc.	500 × 500 × 3.5 km	1 day	
	Upper atmosphere	10%	25%	Thermal IR, UV, etc.	500 × 500 × 3.5 km	1 day	
Aerosols	Tropospheric chem.	5%	20%	Lidar	10 × 10 × 1 km	1 day	
	Stratospheric chem.	25%	50%	Lidar/Occultation	200 × 500 × 1 km	1 day	
Temperature	Troposphere	.5° K	1° K	Thermal IR, Microwave, Lidar	100 × 100 × 5 km	1 day	
	Middle atmosphere	1° K	2° K	Thermal IR, Microwave	500 × 500 × 3.5 km	1 day	
	Upper atmosphere	5° K	10° K	Thermal IR, Microwave	500 × 500 × 3.5 km	1 day	
Winds	Troposphere		2 m/s	Doppler Lidar	100 × 100 × 3.5 km	12 hours	
	Middle atmosphere		3 m/s	Visible, IR (Interferometer)	500 × 500 × 3.5 km	1 day	
	Upper atmosphere		10 m/s	Visible, IR (Interferometer)	500 × 500 × 3.5 km	1 day	
	Surface	0.5 m/s	1 m/s	Scatterometry	50 km^2	1 day	
Lightning (number of flashes, cloud to cloud, cloud to ground)	Tropospheric chem., Atmospheric elect.	stroke count	same	Visible to near IR	10 × 10 km	continuously	
				Electromagnetic spectrum from ground	1 × 1 km	continuously	
Emission Features	Upper Atmosphere	10%	25%	Near IR	10 × 10 × 3.5 km	10 minutes	
Electric Fields	Global electric circuit		10%	In situ electric field probe			
Rock Unit Minerology	Continental rock types	1% absolute	1% relative	Visible, Near IR-spectral reflectance	30 m pixel	10 years	10 nm; ~200 channels
	Continental soil and rock types and distribution	.1° K (NEΔT)	.3° K (NEΔT)	Thermal IR-spectral emissivity	30 m pixel	Seasonal coverage once every 10 years	6 channels, 8 to 14 μm, 500 nm; 2 channels, 3 to 5 μm, 500 nm

Table VIII-1
National Aeronautics and Space Administration
Observational Needs
(concluded)

PARAMETER	APPLICATION	ACCURACY DESIRED	ACCURACY REQUIRED	APPROACH	SPATIAL RES.	OBSERVATION FREQUENCY	SPECTRAL RES.
Surface Structure	Tectonic history	7dB SNR in image	5 db SNR in image	SAR	30 m radar cell width (4 looks)	yearly	variable incidence; variable frequency; variable polarization
Gravity Field	Mantle convection, oceanic lithosphere, continental lithosphere, sedimentary basins, passive margins, etc.	0.5 mgal	1 mgal	gravity gradiometer tethered system, satellite tracking	<30 × 30 km	10 years	
Surface Stress	Weather forecasting, climate processes, oceanography	$u_* = 2.5$ cm/s	$u_* = 5$ cm/s	Radar scatterometer	50 × 50 km	12 hours	
Oceanic Geoid	Mantle convention oceanic lithosphere	0.5 cm	1 cm	Altimeter	1 km	10 years	
Magnetic Field	Crust & upper mantle, composition and structure, lithospheric thermal structure, secular variation of main field (core problem) upper mantle conductivity	0.5 nT	1.0 nT	Magnetometer, Magnetometer/ gradiometer, tethered systems	<30 × 30 km	10 years	
Plate Motion	Plate tectonic theory, fault motion	0.5 cm in each component	1 cm in each component	Satellite tracking by radar laser, GPS, VLBI, ground transponder arrays in conjunction with satellite	Varies with problem, 1 km 1000 km	0.5 years in most cases, more frequently in areas of very active deformation	

IX. CONCLUSION

Agencies of the Federal Government have wide responsibilities, ranging from providing for national security to managing wildlife habitats. The data and services of NOAA's operational environmental satellites are broadly used by these agencies, but to degrees and purposes that vary according to the business of the particular agency.

The preceding chapters have provided the views of several Federal agencies regarding their current uses of and projected requirements for support and services from NOAA's satellite systems. The Department of State, while not a direct satellite user, plays a role in overseeing the foreign relations aspects of NOAA's arrangements with the operators of foreign systems, the open exchange of satellite data, and NOAA cooperation in international space undertakings. The ENVIROSAT-2000 Report, International Coordination of and Contributions to Environmental Satellite Programs, June 1985, discusses this aspect of NOAA's satellite programs in detail.

NOAA interacts constantly with other Federal agencies to ensure that the current operations and future satellite plans take into account the requirements of this user community. This interaction includes the meetings of formal committees and boards, exchanges of reports, and the working of interagency technical committees, as well as informal, continuing discussions at every level.

The development of this report is a vital step in the process of defining NOAA's future satellite programs; the cooperation of the other Federal agencies in defining these requirements has made realistic planning possible. Combined with the analysis of NOAA's internal requirements, which is presented in the ENVIROSAT-2000 Report, NOAA Satellite Requirements Forecast, May 1985, and the outlooks for science and technology that are presented in companion reports of the ENVIROSAT-2000 series, a basis for NOAA's long-range planning for satellite programs has been established.

APPENDIX A

CURRENT AND PLANNED NOAA SATELLITES

APPENDIX A

CURRENT AND PLANNED NOAA SATELLITES

NOAA's Polar-orbiting Operational Environmental Satellites (POES):

The current POES series has spacecraft in sun-synchronous polar orbits at 833 and 870 km. Imaging, surface temperatures, and cloud mapping are provided by a 5-channel visible and infrared radiometer with 1.1 km resolution. Three instruments provide atmospheric sounding data: a 20-channel high-resolution infrared sounder, a 3-channel selective absorption sensor to determine weighting functions at 15 μm wavelengths, and a 4-channel Dicke microwave radiometer. Additionally, these satellites monitor solar particle flux at the spacecraft and provide for the collection and relay of data from fixed and moving automatic sensor platforms. Satellite sensor data are broadcast continuously for intercept by any ground station within range.

The next POES series will include the Advanced Microwave Sounding Unit (AMSU), which will replace the 3-channel infrared absorption and 4-channel Dicke microwave sounding instruments now in use. The AMSU will provide 15 channels of coverage in the 20-90 GHz range and 5 channels in the 90-184 GHz range. It will add new capabilities for atmospheric humidity measurements, distinguishing sea ice, and gathering information about snow thickness and soil moisture. AMSU will make soundings more accurate and will permit sounding through clouds over areas with active weather patterns. The current imager will be improved by providing a spatial resolution of 500 m at all viewing angles, adding one or two new channels, and sharpening others; some channel changes also are planned for the High-Resolution Infrared Sounder (HIRS). A major planned sensor addition is the Ocean Color Instrument (OCI), which probably will be introduced on an early spacecraft in this series. The other functions and services of the series will remain as they are currently.

NOAA's Geostationary Operational Environmental Satellites (GOES):

The current GOES series provides imaging and sounding data via a single instrument. A visible channel (0.55 to 0.75 μm) and 12 IR channels (from 3.9 to 15.0 μm) are provided. Subpoint resolution is 1 km in the visible and 7 or 14 km in the IR, determined by detector selection. The single optical system of the instrument precludes its simultaneous operation in both the imaging and sounding modes. GOES are equipped to monitor the flux of solar X-rays, alpha particles, protons, and electrons at the spacecraft. They are provided with data collection systems for the relay of information from automatic sensor platforms. Sensor data are broadcast continuously for receipt by ground stations. A GOES service is the retransmission of meteorological charts and other environmental information, including satellite imagery, in facsimile format.

The next GOES series will provide separate imaging and sounding instruments, so that these functions can occur simultaneously. More imaging and sounding channels will be included. The other capabilities and services of the current series will be continued.

NOAA's Land Remote-Sensing Satellites (Landsat):

Current Landsat spacecraft provide Earth imaging through two separate instruments. One, the Multi-Spectral Scanner (MSS), is a 4-channel instrument that provides visible and infrared data at 80 m subpoint resolution. The other, the Thematic Mapper (TM), is a 7-channel visible and infrared spectrometer that provides data at 30 m resolution, except for 120 m resolution in the thermal infrared band. Two spacecraft of the current series are in orbit, Landsat-4 and -5. The orbit is sun-synchronous at 705 km, providing a 16-day repeat cycle for revisits to the same Earth scene. Direct data broadcasts are provided to non-Federal ground stations, which pay a data access fee and enter into formal agreements covering the receipt and distribution of Landsat data.

The Landsat system is being commercialized. Under the expected conditions of commercialization, the U.S. Government will continue services from Landsat-4 and -5 through their design lifetimes (probably mid-1987) by contracting with a private company for the day-to-day operation of the system. The same company also will be responsible for the marketing of Landsat data. The company will continue service beyond Landsat-5 by launching an improved Landsat-6 in late 1988. Landsat-6 will provide a TM-class instrument and an MSS emulator to convert TM data to MSS format. The new satellite also will provide a panchromatic imager with 15 m subpoint resolution. A 5-year lifetime is projected for Landsat-6. Landsat-7 probably will replace it in orbit in late 1992.

APPENDIX B

ARMY CORPS OF ENGINEERS

CIVIL LAND PROCESSES RESEARCH FROM SPACE

APPENDIX B

U.S. Army Corps of Engineers
Civil Works

CIVIL LAND PROCESSES RESEARCH FROM SPACE
January 1985

I. CURRENT PROGRAM

A. Goals

CIVIL WORKS

PROGRAM OBJECTIVES

Support the defense of the U.S. by maintaining an experienced engineer organization immediately available for defense needs.

Promote the quality of life by reflecting society's preferences for attaining the objectives of:

Enhancing national economic and social development by increasing the value of the nation's output of goods and services and improving national economic efficiency.

Protecting the quality of the environment by the management, conservation, preservation, creation, restoration or improvement of the quality of certain natural and cultural resources and ecological systems.

Determine the appropriate role of water resources in solving current and emerging problems.

B. Missions

PROJECT PURPOSES

Navigation Improvements

Development, improvement, construction and maintenance of the nation's rivers and harbors for safe and efficient conduct of waterborne commerce

Flood Damage Reduction

Control and alleviation of the effects of floods through structural and/or non-structural measures and participation in flood plain management

Hydropower Generation

Development, construction and maintenance of projects which provide saleable power. These projects may also include flood control, navigation, recreation and other purposes. Power costs are fully recovered through sale of electric power.

Beach Erosion Control

Restoration and preservation of coastal and lake shores through such remedial works as beach replenishment, dunes, groins and seawalls designed to prevent damage from storm tides and wave action.

Water Supply and Conservation

Development of water storage space for municipal and industrial purposes in multipurpose projects.

Natural Resource Management

Protection and management of natural resources in such a manner as to provide a quality outdoor recreational experience while maintaining or enhancing the quality of the natural environment, consistent with other project purposes.

Fish and Wildlife Management

Environmental Enhancement

C. Authorities

IMPORTANT STEPS IN THE DEVELOPMENT OF THE CIVIL WORKS PROGRAM

1824	First appropriation for improving navagability of rivers
1850	Comprehensive study of Mississippi River authorized
1899	Regulatory authority over navigable waters established
1917	First flood control authorization (Lower Mississippi and Sacramento Rivers)
1927	First authorization for comprehensive river basin studies
1928	Authorization of the Mississippi River and Tributaries Project
1930	Authorization of Lake Okeechobee levees (precedent for hurricane protection)
1935	First major Corps hydroelectric power facility authorized
1936	First general flood control legislation
1944	Comprehensive coordinated planning and development encouraged, Corps required to prescribe operation of all Federal flood control storage
1946	Beach erosion control program started
1955	Public Law 99 broadened emergency flood authorities
1958	Water supply authorized as project purpose
1960	Flood plain information program authorized
1961	Water quality control authorized as project purpose
1965	Framework river basin planning authorized, recreation authorized as project purpose
1968	National Flood Insurance Program Act
1969	National Environmental Policy Act
1970	Four national planning objectives (Sec 209) and significant project effects (Sec 122)
1972	National dam inspection program
1973	Principles and Standards for water resources planning approved by President
1974	General authority to consider nonstructural alternatives in all flood control planning. First nonstructural flood control projects authorized
1974	Authorized streambank and shoreline erosion control demonstration programs
1975	Court decision expanding jurisdiction of Section 404 permit regulations
1977	Clean Water Act of 1977-changed Federal/state relationships in regulating discharge of dredged or fill material into U.S. waters
1981	Reagan Administration proposal on Navigation Cost Sharing

D. ACTIVITIES

1. CE Research and Development Program in Support of Civil Works

R&D Elements

Cold Regions Research and Engineering Laboratory (CRREL)
Construction Engineering Research Laboratory (CERL)
Engineer Topographic Laboratories (ETL)
Waterways Experiment Station (WES)
Hydrologic Engineering Center (HEC)
Institute for Water Resources (IWR)

Functional Areas

Material
Coastal engineering
Flood control and navigation
Environmental quality
Water resources planning studies
Surveying and satellite applications
Environmental and water quality operational studies
Construction, Operations and Maintenance
Aquatic plant control

2. Corps of Engineers Remote Sensing Research Program

a. Overview: The objective of the Corps of Engineers Satellite Remote Sensing Research Program is to provide cost-effective methods to acquire data to assist in the planning, engineering, design, construction, and maintenance of Corps of Engineers projects. The program is managed by four co-technical monitors from Water Resources Support Center Data Collection & Management Division, (WRSC-C), Department of the Army Engineering Civil Works Planning Division (DAEN-CWP), Civil Works Hydraulics and Hydrology Division (DAEN-CWH), and Engineering and Construction (DAEN-EC). U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), is the Research and Development (DAEN-CWZ-RDZ), laboratory program manager.

The FY 85 budget of $750,000 supports nine research work units being accomplished by Waterways Experiment Station (WES), CRREL, U.S Army Engineer Topographic Laboratories (ETL), and Hydrologic Enineering Center (HEC). The Corps of Engineer functions being addressed by these nine work units are: real-time data for emergency operations and water control, wildlife habitat studies, land use for hydrologic and environmental studies, updating of flood damage data bases, and coastal engineering. The remote sensing technologies being addressed are LANDSAT Thematic Mapper (US civil land satellite with 30 meter resolution), SPOT (a French civil land satellite to be launched in 1985 with 20 and 10 meter resolution), transmission of environmental ground sensor data via satellite communications, and active ground radars. Paragraph I.D.2.b. provides details of funding, objectives and areas of investigation for the remote sensing research work units.

b. Program Summary: Provided is a detailed summary of the individual work units for remote sensing.

RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	CRREL-RE	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	WORK UNIT NO.	TITLE
2	31746	Evaluation of SPOT, Landsat and Future Satellite Sensor Data

FY FUNDING REQUIREMENTS – THOUSAND DOLLARS

PRIOR YEARS	CFY FY 85	BFY FY 86	+1 FY 87	+2 FY 88	+3 FY 89	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED

OBJECTIVE: To evaluate the use of Landsat-5 TM and MSS, SPOT HRV data products and future satellite simulation sensor data for addressing water resources, geology and cold regions phenomena relevant to the Corps of Engineers (CE) mission.

DESCRIPTION OF WORK: Research and development is required to keep abreast of new and emerging remote sensing technology for application to CE problems. The approach used in this work unit is to evaluate simulation data of future satellite sensor systems and then to test the developed algorithms on the actual satellite data. Evaluations are also made of the increased spatial and spectral resolution of the sensor data and the impact on computer processing. Coordination with the French Toulouse Space Center on CE data requirements for the SPOT satellite HRV (High Resolution Visible) sensor data products will be continued. The satellite is scheduled for launch in August, 1985. Acquisition of SPOT HRV 20-m and 10-m digital data over selected Corps project areas will be accomplished. Algorithms developed for the SPOT HRV simulation data will be tested on the actual SPOT HRV data. Cognizance of future satellite sensor systems will be maintained. As required, proposals will be initiated for using data from: the West German MOMS (Modular Opto-electric Multispectral Scanner) system, scheduled for launch in 1985-1986; the ESA/ERS-1 (European Space Agency/Earth Resources Satellite-1), scheduled for launch in 1988 with a C-band (5.7cm) SAR (Synthetic Aperture Radar) sensor; the Japanese ERS-1 (Earth Resources Satellite-1), scheduled for launch in 1990 with an L-band (23.5cm) SAR; and the Canadian satellite, Radarsat, scheduled for launch in 1990, either a C- or L-band SAR.

MILESTONES AND FORM OF OUTPUT

Report on use of Landsat and SPOT HRV data at a Corps site (Sep 85)

Report on analytical procedures for using satellite data in Corps modeling activities (Sep 86)

Report on use of satellite data in Corps Civil Works, revision of Remote Sensing Manual (Sep 88)

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK
62-023-2	Use of Remote Sensing in Planning Studies	High (I)
62-019-1	The Use of Remotely Sensed Data for Calculating Spatial Averages as Input into Hydrologic Models	High (A)
52-029-0	Remote Sensing Determination of Soil Moisture for Flood Forecasting Modeling	High (A)
62-027-2	Use of Satellite Data Coupled with Statistical Sampling of Floodplain Structures for COE Flood Damage Calculations	High (I)
51-023-0	Fielding Sampling Procedure for Estimation of Flood Damage Potential	High (I)
62-026-2	Application of Satellite-Derived Data for Habitat, Fish and Wildlife Evaluation	High (I)
62-012-1	Evaluation of Future Satellite Sensor Systems for Spatial and Multispectral Resolution	High (A)
62-007-1	Wildlife Habitat Identification and Mapping Using Landsat Data	High (A)
62-024-2	Assessment of Snow Pack Water Equivalency and Soil Moisture	High (I)
62-025-2	Snowpack and Soil Moisture Assessment for Forecasting Snow Melt Runoff Potential	High (I)

RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	CRREL-RE	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	WORK UNIT NO.	TITLE
2	31746	Evaluation of SPOT, Landsat and Future Satellite Sensor Data

FY FUNDING REQUIREMENTS – THOUSAND DOLLARS

PRIOR YEARS	CFY FY	BFY FY	+1 FY	+2 FY	+3 FY	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED

WHY R&D IS NEEDED: The satellite sensor evaluations will provide state-of-the-art technology for digital data input compatible with the data base management schemes used in planning, engineering, and operational projects and activities. Presently hydrologic models (SSARR, NWS and others) cannot accept spatially distributed data on soil moisture or snow water content. A modification to the models is required for the interactive use of the satellite digital data.

MILESTONES AND FORM OF OUTPUT

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK
62-022-8	Landsat Data Gridded Geographic Data Bank Applications-Gridded Graphic Data Bank	Med (A)
62-004-8	Programmed Image Interpretation	Med (A)
62-008-1	General Land Use Mapping Using Multispectral Satellite Data	Med (A)

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY

(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE: Surveying and Satellite Applications/Remote Sensing

ORGANIZATIONAL SYMBOL: WRSC-HEC

DATE: 85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY: 1

WORK UNIT NO.: 32298

TITLE: Remote Sensing and Spatial Data Applications

FY FUNDING REQUIREMENTS THOUSAND DOLLARS

PRIOR YEARS	CFY FY	BFY FY	+1 FY	+2 FY	+3 FY	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED	MILESTONES AND FORM OF OUTPUT
OBJECTIVE: Improve spatial data system's use of remotely sensed data. Develop a methodology and analytical techniques for use of remotely sensed soil moisture data in hydrologic modeling. DESCRIPTION OF WORK: SAM will be used to analyze spatial variations in remotely sensed and corresponding ground truth data. Software and procedures for retrieval, geometric registration, error analysis, resampling, and storage of the remotely sensed images in the SAM system will be developed. Existing capabilities for LANDSAT MSS and new techniques for use of other sensors (e.g., Thematic Mapper, thermal IR, gamma, microwave, etc.) will be incorporated in the SAM system. Priority will be given to those sensors most applicable to Corps water resource activities. Soil moisture can be measured by microwave, gamma or thermal IR sensors. The spatially distributed and point measurements of soil moisture and rainfall will be incorporated into a SAM grid cell data bank and spatial averages computed for use in the HEC-1 model. Antecedent moisture conditions will be calculated using observations from several test watersheds. Infiltration parameters in HEC-1 will be estimated and rainfall-runoff simulated. The improvement in hydrologic model performance using spatially distributed soil moisture and rainfall can then be evaluated. WHY R&D IS NEEDED: Hydrologic, environmental and socio-economic applications models cannot readily use remotely sensed data in its existing format. The spatial data management system (SAM) will provide an effective means to link the remotely sensed data to those applications models. Soil moisture is a key but largely unknown parameter in hydrologic models. Remote sensing provides spatially distributed rainfall and soil moisture data which will improve the representation of those critical components in the models.	The primary output will be computer software and applications manuals. Technology transfer will be accomplished through technical reports, applications workshops, and guidance manuals. Draft procedures for use of two types of imagery with SAM (Sep 85) Evaluate remotely sensed soil moisture data and interpolation of point measurements (Sep 86) Interface other imagery with SAM system. Draft procedural manual for access to and interpretation of the recommended sensors (Sep 87) Incorporate spatially distributed soil moisture into existing/modified hydrologic models. Finalize software and guidance for use of remotely sensed data through SAM and by hydrologic models (Sep 88)

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK
62-012-1	Evaluation of Future Satellite Sensor Systems for Spatial and Multispectral Resolution	High (A)
62-018-1	Acquisition of Reliable Real-Time Data for Input into Hydrologic and Environmental Models	High (A)
62-019-1	The Use of Remotely Sensed Data for Calculating Spatial Averages as Input into Hydrologic Models	High (A)
62-023-2	Use of Remote Sensing in Planning Studies	High (I)
62-024-2	Assessment of Snowpack Water Equivalency and Soil Moisture	High (I)
62-017-1	Use of Real-Time Airborne Microwave and Gamma Data in Hydrologic Forecasting	Med (A)
62-022-8	LANDSAT Data Gridded Geographic Data Bank Applications - Gridded Graphic Data Bank	Med (A)

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(Proponent: DAEN-RD) SHEET 1 of 1

RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	WESEN-B	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	WORK UNIT NO.	TITLE
3	32237	Regional Flood Location Data Update for Emergency Operations

FY FUNDING REQUIREMENTS — THOUSAND DOLLARS

PRIOR YEARS	CFY FY85	BFY FY 86	+1 FY 87	+2 FY88	+3 FY89	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED	MILESTONES AND FORM OF OUTPUT
OBJECTIVE: To develop and demonstrate a capability to provide rapid repetitive coverage of the flood waters over the total LMVD region involved in large Mississippi River floods for use in flood water control and emergency operations. DESCRIPTION OF WORK: The primary source of data will be the NOAA satellites and the secondary source the GOES and Defense Meteorological Satellites Program (DMSP). The NOAA satellites provide twice-a-day coverage of the whole earth through a five-channel multispectral scanner with a 1.1 kilometer spatial resolution. Visible data is available at 0.8 kilometer and infrared at 8.0 kilometer spatial resolution every 30 minutes during daylight from GOES spacecraft. Visible and infrared data at 0.6 kilometer spatial resolution are available from DMSP every 6 hours. The interpretation of the flood locations from satellite data will be registered to topographic maps at varying scales so the flood location maps will be readily usable for emergency operations. In addition to producing transparent map overlays on a plotter the capability will be tested to combine the flood location graphics with a video disk image of the topographic map for large video image display in a briefing room. The primary project goal will be to produce one set of flood interpretation maps within 24 hours of satellite image formation and to repeat this operation once every 24 hours. This will be done through use of available satellite data receiving stations and will not require the purchase of special direct-reception equipment. For example, NORDA in Slidell, LA, is scheduled to receive data directly from GOES and NOAA satellites. WHY R&D IS NEEDED: During floods, the Corps must gather information both for its own use in flood fighting operations and for other Federal agencies and state and local governments. Extensive floods occur with	Develop Procedures to Rectify NOAA Satellite Data to Earth Coordinate System (Sep 84) Create Flood Maps from Satellite Data (Feb 85) Verify Accuracy of Flood Maps (Sep 86) First Generation Flood Mapping Capability (Apr 86) Report on Satellite Data Rectification Procedures and Flood Mapping Capability (Sep 87) Transfer of Emergency Flood Mapping Procedures to LMVD (Sep 88) Evaluation of Operational System (Sep 89) Final Report on Operational System (Sep 90)

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK
33-040-8	Emergency Flood Fighting Techniques	High (I)
62-009-1	Regional Flood Location Data Update for Emergency Operations Using Satellite Data	Med (A)

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	WESEN-B	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	TITLE
3	Regional Flood Location Data Update for Emergency Operations
WORK UNIT NO 32237	

FY FUNDING REQUIREMENTS THOUSAND DOLLARS

PRIOR YEARS	CFY FY	BFY FY	+1 FY	+2 FY	+3 FY	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED	MILESTONES AND FORM OF OUTPUT	MISSION PROBLEMS ADDRESSED: NO.	TITLE	FIELD RANK
frequency in the Lower Mississippi Valley, and the daily extent of flooding and floodwater movement are determined from measurements taken from hydrographic survey boats and the scattered permanent gage locations throughout the Valley. The required data must be collected and manually interpreted from these measurements. Attempts are being made to install very expensive remote gaging apparatus capable of telemetering flood stage data. It is incumbent on the Corps to advance its capability to gather information on flood development more rapidly and accurately. Satellites offer the potential of providing synoptic views of flood progress over large areas at intervals of 1 to 12 hours. The developed system will be useful not only in the Mississippi Valley but also in Corps' flood control work involving any large river system such as the Red River of the North or river systems in the Republic of China. LMVD schedules flood fight exercises annually to test emergency operations procedures in anticipation of possible high water stages in the period March-June. The scenarios include the use of existing capability to predict flooded areas from river stage forecasts. This is evidence of the importance of accurate and rapid assessments of flooded area and protected area evaluations in emergency floodways. This research is aimed directly at improving the Corps' operational capability in emergency flood situations for the benefit of reducing flood damages to public and private property. This technology also will have immediate application potential to display the area subjected to surge flooding before (predicted) and after (actual) hurricane landfall disaster emergency operations.				

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN-RD-6

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	CRREL-RE	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	TITLE
4	Demonstration of Satellite Digital Data in Corps Planning, Engineering and Operational Activities
WORK UNIT NO. 32297	

FY FUNDING REQUIREMENTS – THOUSAND DOLLARS

PRIOR YEARS	CFY FY 85	BFY FY 86	+1 FY 87	+2 FY 88	+3 FY 89	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED

<u>OBJECTIVE</u>: To develop and document procedures for the use of satellite digital data in Corps planning, engineering and operational activities.

<u>DESCRIPTION OF WORK</u>: The approach used in this work unit is to obtain remote sensing data for use in Corps demonstration projects. The analyses are performed in cooperation with the Corps Districts. The remote sensing data are formatted for the District's data base management system that is being used for their particular project. The Corps Districts work closely with the research laboratory to ensure that the analyzed data sets meet with their own needs. The data are run through the Corps models to see how cost-effective and accurate the remote sensing data are in comparison to their own conventionally-gathered data. New demonstration sites are selected as required. Reports are prepared documenting the procedures used and the usefulness of the remote sensing data.

The procedures required for using remotely sensed data for parameters such as soil type, slope, future land use, etc., that are used in Corps modeling activities will be continued. The 30-m TM resolution will be evaluated and documented for use in the Corps emergency operations and water resources management responsibilities. A major emphasis will be placed on the transfer of information to the public and private sectors. This will ensure that the Corps will have a group of contractors capable of performing according to the Corps' responsibilities.

<u>WHY R&D IS NEEDED</u>: Presently conventional data collection for Corps hydrologic, environmental and operational data collection activities is costly and time consuming. Remotely sensed data can provide a savings

MILESTONES AND FORM OF OUTPUT

Report on the use of remote sensing in Corps hydrologic, environmental and economic models (Sep 85)

Reports on modification of existing Corps models to accept remotely sensed data (Sep 85, 86, 87)

Update of the applications section of the Corps Remote Sensing Manual (Sep 85, 86, 87)

Publication of the Remote Sensing Information Exchange Bulletin (Sep 85, 86, 87, 88)

Preparation of remote sensing demonstration projects (Sep 85, 86, 87, 88)

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK
62-023-2	Use of Remote Sensing in Planning Studies	High (I)
62-019-1	The Use of Remotely Sensed Data for Calculating Spatial Averages as Input into Hydrologic Models	High (A)
62-027-2	Use of Satellite Data Coupled with Statistical Sampling of Flood-plain Structures for COE Flood Damage Calculations	High (I)
62-026-2	Application of Satellite-Derived Data for Habitat, Fish and Wild-life Evaluation	High (I)
51-023-0	Field Sampling Procedure for Esti-mation of Flood Damage Potential	High (I)
62-012-1	Evaluation of Future Satellite Sensor Systems for Spatial and Multispectral Resolution	High (A)
62-007-1	Wildlife Habitat Identification and Mapping Using Landsat Data	High (A)
62-018-1	Acquisition of Reliable Real Time Data for Input into Hydrologic and Environmental Models	High (A)
62-022-8	Landsat Data Gridded Geographic Data Bank Applications-Gridded Graphic Data Bank	Med (A)
62-004-8	Programmed Image Interpretation	Med (A)
62-008-1	General Land Use Mapping Using Multispectral Satellite Data	Med (A)

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	CRREL-RE	25 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	TITLE
4	Demonstration of Satellite Digital Data in Corps Planning, Engineering and Operational Activities
WORK UNIT NO. 32297	

FY FUNDING REQUIREMENTS - THOUSAND DOLLARS

PRIOR YEARS	CFY	BFY	+1	+2	+3	TO COMPLETE	TOTAL
	FY	FY	FY	FY	FY		
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED	MILESTONES AND FORM OF OUTPUT	MISSION PROBLEMS ADDRESSED: NO.	TITLE	FIELD RANK
both in the amount of time and number of people required for data collection and analysis.				

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN-RD 5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	WESEN-B	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	WORK UNIT NO	TITLE
5	32234	Wildlife Habitat Identification and Mapping Using Airborne Sensors

FY FUNDING REQUIREMENTS THOUSAND DOLLARS

PRIOR YEARS	CFY FY 85	BFY FY 86	+1 FY 87	+2 FY 88	+3 FY 89	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED	MILESTONES AND FORM OF OUTPUT
OBJECTIVE: To compare the information content, reliability, and cost factors associated with acquisition and analysis of aerial photography and satellite data for wildlife habitat identification and mapping. DESCRIPTION OF WORK: Representative wildlife species models will be translated into vegetation cover-type-preference models that are directly and quantitatively related to the original model expressions, but are amenable to definition from airborne sensor data. Species models will be strategically selected based on the degree they represent groups of species (guilds) and potential for discrimination of original model variables with remote sensors. Accuracy and consistency of variable detection and mapping using standard photointerpretation and available satellite data analysis techniques will be evaluated at project study sites in selected Corps Districts. Landsat multispectral scanner data (57 x 79 m resolution), Thematic Mapper data (30 m resolution) and SPOT satellite data (20 m resolution) will be evaluated. Field reconnaissance will be performed to aid in the interpretation of the remotely sensed data and to check the accuracy of the interpreted results. WES has developed computer programs to successively overlay digitized planimetric maps of single environmental factors (single factor maps). The programs automatically perform geometric registration of the individual factor maps and identify the planimetric distributions of unique combinations of single factors to form a factor complex map. These procedures will be used to map single variables in a species model and combine these spatial distributions of single variables into spatially defined variable complexes. The numerical data characterizing the variable complexes will be used to compute Habitat Suitability Indexes (HSI) and the variable complex map converted to map units of HSI. Computation of the HSI's will be done in accordance with the FWS Habitat Evaluation Procedures (HEP).	Prepare report on the potential of airborne sensor applications to the Habitat Evaluation Procedures (HEP) (Dec 83) Construct a white tail deer model for the study site (May 84) Application of automated digital map modeling techniques to the crop and vegetation cover map (Dec 84) Application and evaluation of aerial photography and satellite sensor data to construct crop and natural vegetation cover for a study site (Sep 85) Application and evaluation of Remote Sensor imagery to mapping specific habitat variables for the white tailed deer (Sep 86) Digital mapping of all variables and computation of final HSI map units for white tailed deer (Sep 87)

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK
62-007-1	Wildlife Habitat Identification and Mapping Using Landsat Data	High (A)
62-006-1	Application of the ADAPT (Aerial Design and Planning Tool) System	High (A)
62-026-2	Application of Satellite-Derived Land Cover Data for Habitat, Fish, and Wildlife Evaluation Using Spatial Data Management Techniques	High (I)
62-023-2	Use of Remote Sensing in Planning Studies	High (I)
41-005-8	Techniques for Assessing Mitigation Alternatives	High (A)
62-004-8	Programmed Image Interpretation	Med (A)
62-022-8	Landsat Data Gridded Geographic Data Bank Applications Gridded Graphic Data Bank	Med (A)
41-009-9	Wildlife Habitat Development, Management, and Enhancement	Med (A)

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	WESEN-B	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	TITLE
5	Wildlife Habitat Identification and Mapping Using Airborne Sensors
WORK UNIT NO	
32234	

FY FUNDING REQUIREMENTS THOUSAND DOLLARS

PRIOR YEARS	CFY FY	BFY FY	+1 FY	+2 FY	+3 FY	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED	MILESTONES AND FORM OF OUTPUT
WHY R&D IS NEEDED: The past decade of environmental legislation required a steady growth in CE District monetary and manpower commitments for wildlife habitat impact studies and habitat mitigation plans. A much better balance is needed between the quality of habitat data acquired for analysis and the commitment of manpower and fiscal budget. A need exists for a readily updatable, cost-effective, and more rapid capability for developing wildlife habitat maps and numerical habitat data for Corps projects. Detecting and mapping wildlife habitat by environmental photointerpretation of aerial photography and analysis of Landsat Thematic Mapper and multispectral scanner data should be systematically evaluated. The basic unit of a habitat analysis in the Fish and Wildlife Service's HEP and other procedures in use by the CE Districts is the vegetative cover type. In addition, factors such as distance from forest cover to roads, size of clearings, and other spatial data are required. Present HEP methodology recommends the use of US Geological Survey topographic maps and high altitude color infrared photography for delineation of cover types and subsequent habitat mapping. High quality IR photography at 1:58,000 scale from the National High Altitude Program provides an excellent opportunity for evaluation. In addition, the advantages of low (1:6,000) and intermediate (1:24,000) aerial photography should be evaluated. Recent advancements in information extraction from digital satellite data have demonstrated the feasibility of using Landsat data as a more rapid and comparatively inexpensive source of habitat data. The Thematic Mapper on board Landsat-5 has a resolution element of 30 x 30 m compared to a nominal size of 57 x 79 m for the multispectral scanner Landsat sensors. The SPOT satellite has a 10 m and 20 m resolution. These potential data sources must be developed for HEP analysis.	Field demonstration of total system capability for the deer model at a new study site (Sep 88) Technical Report on the demonstration project (Sep 89) Instruction report on application of remote sensing and digital map modeling techniques to HEP (Sep 90)

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE: Surveying and Satellite Applications/Remote Sensing

ORGANIZATIONAL SYMBOL: CRREL-RE

DATE: 85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY: 6

WORK UNIT NO: 31792

TITLE: In Situ Automated Procedures for Measurement of Hydrologic and Environmental Parameters in Cold Regions

FY FUNDING REQUIREMENTS - THOUSAND DOLLARS

PRIOR YEARS	CFY FY85	BFY FY 86	+1 FY 87	+2 FY 88	+3 FY 89	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED

OBJECTIVE: To test and evaluate techniques for interfacing state-of-the art geophysical, hydrometeorological and environmental sensors to GOES and other data relay systems and demonstrate the utility of data acquisition relay systems on an operational basis.

DESCRIPTION OF WORK: State-of-the-art geophysical, hydrologic and environmental sensors (such as snow and ice gages, temperature sensors, etc) will be tested under cold weather field conditions. Modifications will be made and interfaces for relay systems developed and demonstrated. The spatial distribution for a given sensor will be statistically determined to yield appropriate sample spacing.

WHY R&D IS NEEDED: As new sensors and electronics are developed to measure in situ conditions in time and space, it will be possible to determine spatial average values for the measured parameters. These averages can then be placed into a data base management system and used as required for the Corps planning, engineering and operational monitoring and modeling activities.

MILESTONES AND FORM OF OUTPUT

Install sensor package and document findings (report) (Jun 85)

Report on each sensor system performance (Sep 85, 86, 87)

ETL's on field installation and performance of specific sensor packages (Jan 85, 86, 87)

Report on defining Corps user requirements based on findings from 85-87 (Sep 88)

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK
34-001-8	Optimization of Parameters for Use in Streamflow Simulation Models	High (A)
34-003-8	Continuous Moisture Accounting for Forecasting Flood Events	High (A)
62-018-1	Acquisition of Reliable Real Time Data for Input into Hydrologic and Environmental Models	High (A)
62-019-1	The Use of Remotely Sensed Data for Calculating Spatial Averages as Input into Hydrologic Models	High (A)
52-029-0	Remote Sensing Determination of Soil Moisture for Flood Fore-casting Modeling	High (A)
52-037-0	Water Control Data Management System	High (A)
62-024-2	Assessment of Snow Pack Water Equivalency and Soil Moisture	High (I)
62-025-2	Snow Pack and Soil Moisture Assessment for Forecasting Snow Melt Runoff Potential	High (I)
62-017-1	Use of Real Time Airborne Micro-wave and Gamma Data in Hydrologic Forecasting	Med (A)
62-002-8	Reliable Instrumentation for Measuring Marine, Freshwater and Terrestrial Environmental Para-meters	Low (I)

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY

(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	WESCR-O	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	WORK UNIT NO	TITLE
7	31743	Coastal Engineering Remote Sensing Applications Research Program (CERSARP)

FY FUNDING REQUIREMENTS - THOUSAND DOLLARS

PRIOR YEARS	CFY FY 85	BFY FY 86	+1 FY 87	+2 FY 88	+3 FY 89	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED

OBJECTIVE: To provide accurate coastal engineering data using remote sensing techniques; to test and evaluate remote sensing techniques and systems and demonstrate their cost effective potential for the collection and analysis of data in the coastal zone. Work will be coordinated and accomplished with the cooperation of other federal, private, academic and foreign institutions, wherever feasible.

DESCRIPTION OF WORK: The required accuracy for wave data (height, length and direction) and current vectors will be defined with respect to and matched with remote sensing systems. The relationship of spatial remote sensing data versus temporal in situ data will be established. Coincident field data sets from remote sensing and in situ instruments will be analyzed. The coastal imaging radar, coherent wave radar, high frequency radar (CODAR), and Trifar radar will be the main systems investigated. Satellite remote sensing systems, particularly systems planned for the SPOT and NROSS satellites, and the surface contour radar will also be considered. As remote sensing systems and data are validated, they will be integrated into the coastal engineering research programs.

WHY R&D IS NEEDED: A need exists to develop improved cost-effective techniques for acquiring wave and current data for coastal project design and to be applied to numerical models for validation and calibration. Present in situ techniques are expensive and often unreliable for long-term operation. There is no adequate in situ technique for long-term acquisition of deep water directional wave spectra, a critical gap in technology. Further, in situ techniques sample waves and currents at a point in space which may not be representative of the spatial area over which the physical processes of interest occur. Remote sensing techniques are very promising alternatives to in situ devices.

MILESTONES AND FORM OF OUTPUT

Workshop - Workshop on Capabilities for Radar Detection of Waves (Joint with 31592) (Jan 85)

CETN - High Frequency Radar, Wave Direction (Oct 85)

Report - CODAR - User's Guide for Measurement and Interpretation of Surface Currents and Wave Data (Sep 86)

Report - Wave and Current Measuring Techniques for Calibration of Numerical Models (Jun 87)

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK
62-023-?	Use of Remote Sensing in Planning Studies	High (I)
62-001-8	Remote Sensing of Underwater Topography	High (I)
23-004-9	Estimating Along Shore Sand Movement from Incident Waves	High (A)
21-007-9	Predicting Wave Conditions in Shallow Water	High (A)
21-006-9	Wave Direction	High (A)
21-012-0	Nearshore Current Prediction	High (I)
21-014-0	Wave Current Interaction	High (I)
62-013-1	Wave Transformation	Med (A)
62-015-1	Navigation Hazards Caused by Inlet Wave-Tide Interaction and Ice	Med (I)

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS DAEN-RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	WESEN-B	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	WORK UNIT NO	TITLE
8	31697	Flood Damage Data Base Updating Using Landsat

FY FUNDING REQUIREMENTS THOUSAND DOLLARS

PRIOR YEARS	CFY FY85	BFY FY86	+1 FY87	+2 FY88	+3 FY89	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED

OBJECTIVE: To develop and demonstrate the capability to expedite delineation of flooded areas as a function of river stage and land use classes, and develop timely and economical procedures for establishing and updating land use with Landsat-5 and SPOT satellite data and historical flood data bases with archived Landsat data.

DESCRIPTION OF WORK: The existing LMVD Regional Flood Damage Estimation System will be used as the starting point for this development effort. Parts of the existing system will be replaced, others will be improved and map display capabilities will be added to the system. A major consideration will be to have a working system at all times which will be improved with changes and additions to provide more rapid, economical and accurate calculation capabilities to achieve improved performance and efficiency in system operation. Procedures will be developed to use Landsat digital imagery as a primary source of data for the land use data base. However, the system will retain the capability to accept equivalent data from alternate sources to compensate the situations when land use data cannot be obtained from Landsat or there is a cost or time advantage to using alternate data sources. The system is to be robust--operable on different computer and other hardware equipment--and available for transfer to Corps' FOA's with minimum loss or change of system capabilities. Check point meetings between WES and LMVD and Corps District personnel will be scheduled to periodically review the program, revise methodologies as necessary, and ensure that the products are addressing the user needs.

MILESTONES AND FORM OF OUTPUT

Prepare Report 1 on Geographic Data Base (data formats, data base structure, management programs, retrieval) (Sep 84)

Prepare Report 2 on Data Preparation (Landsat, elevation and polygon map data) (Mar 85)

Prepare Report 3 on Use of FAST System (Include Appendix on color overlays to maps) (Sep 85)

Publish Report 1 (Jun 85)

Publish Report 2 (Oct 86)

Publish Report 3 (Aug 87)

Integrate Use of Thematic Mapper Data into Data Base Updating Procedures (Sep 85)

Develop Procedures for Mapping Flooded Area from Historical Landsat Data (Sep 85)

Integrate Use of SPOT Satellite Data into Data Base Updating Procedures (Sep 86)

MISSION PROBLEMS ADDRESSED

NO.	TITLE	FIELD RANK
62-023-2	Use of Remote Sensing in Planning Studies	High (I)
52-037-0	Water Control Data Management System	High (A)
62-006-1	Application of the ADAPT (Aerial Design and Planning Tool) System	High (A)
62-011-1	Advanced Procedures for Calculating Stage-Area Flooded Relations Using Satellite Data	Med (A)
62-008-1	General Land Use Mapping Using Multispectral Satellite Data	Med (A)
62-022-8	Landsat Data Gridded Geographic Data Bank Applications Gridded Graphic Data Bank	Med (A)
62-004-8	Programmed Image Interpretation	Med (A)

RESEARCH AND DEVELOPMENT PROGRAM SUMMARY
(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Applications/Remote Sensing	WESEN-B	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	TITLE
8	Flood Damage Data Base Updating Using Landsat
WORK UNIT NO. 31697	

FY FUNDING REQUIREMENTS - THOUSAND DOLLARS

PRIOR YEARS	CFY FY	BFY FY	+1 FY	+2 FY	+3 FY	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED	MILESTONES AND FORM OF OUTPUT	MISSION PROBLEMS ADDRESSED: NO	TITLE	FIELD RANK
WHY R&D IS NEEDED: LMVD presently operates a Regional Flood Damage Estimation System used for water management and control, flood control project planning, and regional flood damage estimation. The system presently has data for protected and unprotected areas along the Mississippi River and major tributaries from the Gulf of Mexico to Cairo, Illinois. The system and majority of the data required by the system were developed by WES. There is a need to improve and expand the capabilities of the system and to develop more economical procedures for updating the land use patterns used in regional damage estimates. The rapid updating of the land use information is best accomplished through interpretations of Landsat data, particularly because of the large geographic region on file. A major requirement in system capability improvement involves the use of information on past floods. One of the most useful records of historical flood data is preserved in Landsat data archives from 1972 to the present. The present system must be modified to accept the Landsat data and to output graphic products required by users. LMVD is using the system for water management and control during main stem flood fight exercises and flood control project planning studies. LMVD anticipates further automation of the system and update of the 1975 land use data base with Landsat Thematic Mapper data. Parallel to development of the LMVD Regional Flood Damage Estimation System, the basic techniques have been modified and applied to 7 flood control planning projects in the Vicksburg District and 2 projects in the Mobile District. These modified techniques now constitute the Flood Analysis Simulation Technology (FAST) System for direct-wide application.				

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RESEARCH AND DEVELOPMENT PROGRAM SUMMARY

(ER 70-1-11)

RCS: DAEN-RD-5

PROGRAM TITLE	ORGANIZATIONAL SYMBOL	DATE
Surveying and Satellite Applications/Remote Sensing	ETL-GS-PB	85 01 15

FIVE YEAR RESEARCH PROGRAM WORK UNIT SUMMARY

PRIORITY	WORK UNIT NO.	TITLE
10	New	Integration of Videodisc Technology with Image Analysis Equipment

FY FUNDING REQUIREMENTS – THOUSAND DOLLARS

PRIOR YEARS	CFY FY 85	BFY FY 86	+1 FY 87	+2 FY 88	+3 FY 89	TO COMPLETE	TOTAL
$	$	$	$	$	$	$	$

OBJECTIVE, DESCRIPTION OF WORK AND WHY R&D IS NEEDED	MILESTONES AND FORM OF OUTPUT	MISSION PROBLEMS ADDRESSED NO.	TITLE	FIELD RANK
OBJECTIVE: Develop an integrated unit for low cost image analysis station, the Measuronics VGS-300 system, with a videodisc unit. DESCRIPTION OF WORK: Identify a suitable testing area of the Corps, in conjunction with the technical monitor and Districts. Using equipment at ETL and that purchased develop procedures to (1) integrate a videodisc unit with the image analysis equipment (2) obtain and store the proper imagery and maps on the videodisc unit for use with the Measuronics VGS-300. WHY R&D IS NEEDED: The Corps must keep on hand vast amounts of maps and imagery to monitor changes in project areas. This involves both storage time, filing time and retrieval time. The Measuronics image analysis station offers the capabilities of low cost image digitization and analysis. The videodisc system enables one to store up to 50,000 frames of data. The videodisc system could be used to store archival images and maps of project areas which would supplement recent imagery for change analysis, analysis of different factors, and comparison with topographic maps. The integration of these units would assist in the rapid analysis of areas of concern.	Technical Report (Sep 86)	62-002-8	Reliable Instrumentation for measuring marine, freshwater, and terrestrial environmental parameters	Low (I)

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3. CE Remote Sensing Demonstration Program

a. Overview

The initial demonstration projects began with U.S. Army Engineer Division, Lower Mississippi Valley Division (LMVD), South Atlantic Division (SAD), & WES using the Flood Analysis Simulation Technology (FAST) system in the late 1970's. In 1980 the demonstration program was formalized and expanded to include phase I design studies using Spatial Analysis Methodology (SAM) planning techniques. SAM is comprised of a spatially oriented data bank and a family of data management and data analysis computer programs. Remote Sensing technology can provide various data base elements and being in digital format is compatible to SAM. In March 1981 an Memorandum of Understanding (MOU), was signed with National Aironautics and Space Administration (NASA). The objective is the joint Corps/NASA technology assessment and transfer programs to assess and demonstrate the utility of remotely sensed data and associated technologies in course planning studies and projects. Currently the program consists of six completed and seven ongoing studies, and it is planned to expand the program to include more engineering and operational studies.

b. Completed Demonstration Projects

WES has completed a series of demonstrations of the Flood Analysis Simulation Technology (FAST) system and during FY84 and FY85 WES will complete the documentation. These demonstrations were supported by LMVD and SAD with a funding of $819K.

In 1980, the program was initiated with North Central Division (NCD), in conjunction with the Upper Mississippi River and Clinton River Basin Planning Study. In 1982 the program was expanded to include NCD/Saginaw Planning Study, Cottonwood River Basin Engineering Study and the NPD Columbia River Operation Demonstration. Ohio River Division (ORD), in the spring of 1982, began the process of submitting the Ohio Mainstem Study. CRREL has been the lead laboratory providing the technical expertise and coordination for these projects. In FY84, WES initiated a demonstration for Wildlife Habitat Evaluation with NCD on the Saginaw Planning Study. The completed remote sensing demonstration projects are as follows:

1. LMVD/Vicksburg District:	Yazoo River Basin Backwater and Headwater Areas.
	Tensas River Basin
	LaFourche River Basin
	Boeuf River Basin
	Ouachita River/Bayou Desiard
	Bayou Macon
SAD/Mobile District:	Tibber River Basin
	Sawasbee Creek

Objectives:	Flood Control Planning Economic Impact Analysis Land-use Analysis
Data:	Varied with basin 80m LANDSAT MSS Digital Terrain elevation Hydrographic parameter and profiles Urban altitude color IR photography Airborne laser elevation data
Participants:	WES LMVD SAD NASA
Status:	The analysis and products have been completed. Report and documentation of procedures will be completed by FY85. Updating and the integration of LANDSAT-4 Thematic Mapper (TM), data is being considered for FY85.

2. NCD/Upper Mississippi River Basin (Planning)

Objectives:	Natural resources planning Impact assessment Historical land-use change Dredge disposal site selection
Data:	80m-LANDSAT MSS 30m-Simulated Thematic Mapper (STM)
Participants:	NASA NCD
Status:	Data analysis, spatial data base, and field verification completed in FY 1982. Final Report completed in FY 82 and papers were presented at the U.S. Army Corps of Engineers Remote Sensing Symposium (1981) and Fall ASP Convention 1982.

3. NCD/Clinton River Basin Study, (SAM Planning)

Objectives:	Flood assessment Floodplain delineation Economic impact evaluation Environmental quality.
Data:	10m 20m 30m Simulated Thematic Mapper (STM) 80m-LANDSAT (MSS) Low-level Aerial Photography (APPS-IV).
Participants:	CRREL ETL NCD NASA
Status:	LANDSAT MSS Level I land-use classification, APPS-IV structural analysis and LANDSAT STM classification have been completed. Reports on remote sensing data analysis and integration were completed in FY 1983.

4. NPD/Columbia River (Operations)

Objective:	Shoreline change Land-use change Historical data base
Data:	Multi-year low-level aerial photography (APPS-IV)
Participants:	ETL NPD
Status:	Autometrics Inc. contract for data analysis using APPS-IV and AUTOGIS awarded in September 1982. Data analysis and data base development were completed Spring, March 1983 and final report Fall 1983.

5. WRSC/LANDSAT Emergency Access and Products (LEAP): The primary purpose was to develop procedures to acquire LANDSAT products within 12 hours of acquisition for use by emergency operations for natural and national disasters.

Objectives:	Emergency Operations Delineation of Flooding Improve Distribution of LANDSAT data
Data:	80m LANDSAT MSS
Participants:	NOAA FEMA WRSC WES CRREL SWD USDA
Status:	Test and evaluation of producers were completed in March 1984. Operational service will be advertised by National Oceanic and Atmospheric Admisistration NOAA during the spring and summer 1984.

6. WRSC/Remote Sensing for the Corps of Engineers Dredging Program.

Objectives:	Define Remote Sensing Application for Dredging Dredge Site Selection Monitoring Dredge Material Monitoring Water Quality Mapping Vegetation
Data:	LANDSAT, SPOT, CZCS, Airborne Laser
Participants:	WRSC CRREL Jniv. of Deleware
Status:	Report has been completed. A demonstration project has been started with NAB in FY 84.

C. Current Demonstration Projects

1. The primary emphasis is the use of in situ and airborne microwave and gamma systems can obtain soil moisture information over large areas for input to CE hydrologic models.

NCD/Cottonwood River Watershed Study (Engineering)

Objectives:	Run off prediction Soil moisture evaluation Hydrologic forecasting Spatial analysis
Data:	L-band microwave radiometer Gamma ray radiometer In situ soil moisture probe DCP gaging station
Participants:	NOAA (NWS) NASA USDA (SCS, ARS) USGS CE (St. Paul, Detroit, Rock Island Districts) Universities (North Dakota, Minnesota)
Status:	Airborne and ground data collection was completed in FY 1982. Initial evaluation of data quality has been completed, and a spatial data base has been developed and is being tested.

2. NCD/Saginaw River Basin Study (Planning-SAM)

Objectives:	Flood control and run-off prediction Environmental quality Environmental impact evaluation
Data:	80m-LANDSAT MSS 30m-LANDSAT TM 20m & 10m Simulated SPOT
Participants:	CRREL NCD NASA
Status:	LANDSAT MSS Level I land-use classification completed and basin hydrologic run-off model run. Two reports on remote sensing data analysis and data base integration were completed February 1983. SPOT data is being integrated with the spatial data base.

3. ORD/Ohio River Mainstem Study (Planning): Two small test sites have been selected to test and evaluate the feasibility of remote sensing and SAM techniques to be used for the entire study.

Objectives:	Flood assessment Extreme bank erosion Environmental data quality Hydropower potential Water quality
Data:	30m Simulated Thematic Mapper (STM) 80m-LANDSAT MSS 30m-LANDSAT TM 20 and 10m Simulated SPOT
Participants:	CRREL NASA ORD
Status:	Level I LANDSAT STM land-use classification has been completed and provided to the Pittsburgh District for spatial data base integration. The district completed, in FY 84, the correlation of Digital Elevation Model (DEM), land-use classification and tax record maps to develop the land/structural values.

4. NCD/Saginaw River Basin Study

Objectives:	Wildlife Habitat HEP Model
Data:	80m - LANDSAT MSS 30m - LANDSAT TM 20m - Simulated SPOT Low Level Aerial Photography NHAP Aerial Photography
Participants:	WES CRREL NASA NCD
Status:	Aerial photo, LANDSAT TM, and simulated SPOT data has been acquired and is presently being analyzed and incorporated into a spatial data base.

5. In Spring 1984, the Rock Island District completed a comprehensive, six year Remote Sensing Demonstration plan of study to incorporate planning, engineering and operation function.

NCD/Rock Island, Inland Waterways

Objectives:	Flood/drought operations Water quality data collection Emergency management/dam dafety Seepage monitoring Channel Scour moniroting Flood damage assessment Cultural resources monitoring Habitat monitoring Wetland identification/mapping
Data:	80m LANDSAT MSS 30m LANDSAT TM 20 and 10m siumlated SPOT In situ Hydrometerological and environmental sensors Aerial Photography Airborne Laser Mapping CODAR Spectroradiometer
Participants:	NCR NOAA NASA USGS CRREL WES WRSC-HEC USDA SPOT
Status:	The demonstration plan has been forwarded to OCE for approval and funding. Rock Island, in the fall 83, installed A GOES DCP receiving station and 10 DCP.

6. SPD/Coast of California Storm and Tidal Wave Study

Objectives:	Sediment Transport Ocean Wave and Current Shoreline Change Land-use Change
Data:	CODAR CERC Ground Base Radar SAR Surface Contouring Radar Airborne Laser METSAT LANDSAT
Participants:	WES CRREL SPD
Status:	Plan of Study has been completed and Data Collection was initiated in FY 84.

7. NAD/Miller Hart Island Dredge Disposal: The primary purpose is to test and evaluate remote sensing systems capabilities to monitoring dredge disposal sites.

Objectives:	Dredge Disposals Sediment Detection Project Monitoring
Data:	80m LANDSAT MSS 30m LANDSAT TM 20 and 10m Simulated SPOT
Participants:	WRSC CRREL NAD NASA
Status:	Simulated SPOT and LANDSAT TM data have been collected in conjunction with ground sample in Jul 83. Presently, analysis and comparison of ground and remote sensing data is being accomplished.

AD-A165 071 FEDERAL AGENCY SATELLITE REQUIREMENTS(U) NATIONAL ENVIRONMENTAL SATELLITE DATA ANN INFORMATION SERVICE WASHINGTON DC D COTTER ET AL. JUL 85 2/2

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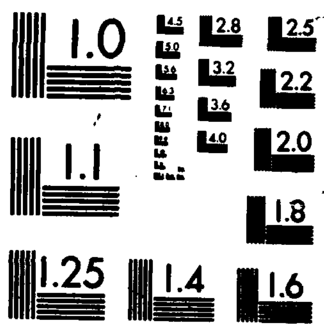

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

4. CE Remote Sensing Technology Transfer

a. Overview: The CE remote sensing technology transfer program objective is to provide forums and promote remote sensing integration with the standard operating procedures of the Corps of Engineers. During the past three years, the district and division participation has increased significantly. The three mechanisms are the Corps of Engineers Remote Sensing Symposium, the CE quarter publication "Remote Sensing Information Exchange Bulletin", and participation in International Symposiums.

b. Discussion: The Corps of Engineers Remote Sensing Symposium attendance has increased from 175 in Reston, Virginia, in 1979, to 225 in Nashville, Tennessee, in 1981, and to 275 in Reston, Virginia in 1983. At the 1979 symposium, the majority of the papers were presented by industry scientists and R&D people from other government agencies. In 1983, the majority of the papers were presented by Corps of Engineer field offices, and there was active participation by OCE Division Chiefs, the Deputy Assistant Secretary of the Army for Civil Works, and district and division engineers. The Fifth CE Remote Sensing Symposium is scheduled for October 1985 in Ann Arbor, Michigan.

The CE Remote Sensing Information Exchange Bulletin is a quarterly CRREL publication, initiated in 1983, which highlights different CE divisions's remote sensing activities. To date, NCD has been featured with planned publication on SPD and SWD. The majority of the articles are written by FOA personnel.

The Corps participation in international symposiums has greatly increased in the past 3 years. Last year at the International Symposium on Remote Sensing of Environment, a paper presented by the Detroit District received Honorable Mention for best scientific paper. This year's Corps of Engineers participation in the International Symposium on Remote Sensing of Environment includes papers from WRSC, ORD, NCD, and CRREL.

E. Coordination Mechanisms

1. Corps of Engineers: The CE has four designated functions for coordination of Remote Sensing activities as follows:

a. Technical Monitors

The technical monitors represent the interests of the FOA's, Directors of Civil Works and EDC; provide technical direction for the Remote Sensing R&D program, determines priorities and funding levels for the individual work units per program funding limits set by the R&D committee. Decisions made by the technical monitors are forwarded by the principal technical monitor to DRD. The technical monitors meet monthly at OCE to coordinate remote sensing activities, review program objectives and discuss future program activities.

The Technical Monitors have amongst themselves delineated areas of major responsibilities as follows:

1) DAEN-CWP (Plott): OCE Coordination and Planning Division Coordination.

2) DAEN-ECE-B (East): Engineering & Construction Coordination, and Military Programs Coordination.

3) DAEN-CWH (Tseng): Hydrology and Hydraulics, Operations and Emergency Operations Coordination.

4) WRSC-C (Lichy): International, Interagency and Training Coordination.

b. Directorate of Research and Development (DRD)

DRD is responsible to provide overall management of the CE Research Program and Laboratories. DRD depends upon the technical monitors to provide programmatic and technical guidance for individual research programs. DRD forwards the technical monitors decisions to the Program Manager (CRREL).

c. Program Manager

It is the program managers responsibilitites to disseminate programmers guidance provided by the technical monitors via DRD to the participating labs and principal investigates. The program manager accumulates the required information for program review, semi-annual progress reports and necessary information required by the technical monitors for programmatic guidance and review.

d. Remote Sensing Coordinators

Each field office has a person designated as the Remote Sensing Coordinator which is responsible to disseminate information, encourage use, determine needs and coordinate their field offices' activities regarding remote sensing.

2. Interagency: The CE is represented on numerous water resources related panels, committees, organizations, MOU's and etc..., which is too numerous to list. Listed are those which are specifically regarding remote sensing.

a. DOD Interservice Board for Commercialization of Civil Land Satellites.

b. DOC. Source of Evaluation Board for Commercialization of Civil Land Satellites.

c. Interagency Board for Civil Observation Earth Satellite Systems.

d. International Symposia on Remote Sensing of Environment, Executive Committee.

e. Satellite Data Collection Systems Interagency Working Group.

f. GOES DCP Technical Working Group.

g. MOU; between CE and NASA, subject: Cooperative Program of Remote Sensing Technology.

h. MOU; between CE and NOAA/NESDIS, subject: GOES DCS.

II. FUTURE PROGRAMS

A. Goals

CHANGING PRIORITIES

Response to changing national priorities and public attitudes

Current Priorities

Completion of hydroelectric energy studies and projects

Improvement and maintenance of navigation facilities critical to movement of energy and food commodities

Completion of projects providing water supply storage needed at an early date

Urban flood control

Water conservation

Dam safety

B. Strategies

Functional Trends

General investigations: Complexity and scope increasing due to emphasis on alternative plans, broader consideration of social and environmental effects of water resource planning and development, public involvement, cost sharing of studies, and increased attention to non-structural alternatives

Construction: Decreasing as a percentage of total program because of stretchout in authorization and planning process, funding constraints, and increasing percentage of operation and maintenance.

Operation and maintenance: Increasing as additional projects are completed and dredging costs increase to provide for environmental considerations mandated by legislation.

General expenses: General administrative and managerial activities have remained relatively constant.

Regulatory program: Increasing scope and complexities of responsibilities.

C. Data Requirements

1. CE Program Data Requirements

The major driver in the design of a system for using LANDSAT-D data for the U.S. Army Corps of Engineers Civil Works Activities is an estimate of the data needed to meet the demands of the Civil Works operations. These estimates are based on the overall CE operations, Division/Districts operations and Corps Civil Works programs. A gross estimate of data loading was established and reviewed in order to have an acceptable data base for use in the trade-off analyses.

A series of CE documents were reviewed, to gather an overview of current activities. CE's experience with CE LANDSAT investigations and NASA Applications Systems Verification and Transfer (ASVT) projects was also integrated into our projection of a reasonable scenario of CE utilization of LANDSAT data in the 1981 time frame. Section II.C.2 provides an update for combined LANDSAT TM and SPOT requirements. The CE Civil Works Activities overall programs were summarized as follows:

a. Studies

Framework and Assessment
Regional River Basins
Implementation

b. Special Continuing Authorities

Small Flood Control Projects
Snagging and Clearing Projects (Floods)
Small Navigation Projects
Small Beach Erosion Control Projects
Mitigation of Shore Damage
Review of Completed Projects
Emergency Bank Protection
Snagging and Clearing Projects (Navigation)
Removal of Wrecks and Obstructions

c. Disaster Assistance, Flood Fighting and Operation Foresight

d. Flood Plain Management Services

e. Urban Studies

f. Environmental Studies

g. Diked Disposal Area Program

h. Recreation, Fish and Wildlife Program

i. National Dam Safety Program

j. Permit Programs Regulatory

k. Ice Survey

l. Corps Information System Program

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The parameter, "Average Coverage Estimate", is divided into eight (8) categories.

These categories are defined as follows:

Fraction of Scene Used: An approximation of the portion of 185km by 185km Thematic Mapper (TM) image required for analysis for the typical project identified.

Basic Number of Scenes per Project: An approximation of the number of TM images required for a typical test site.

Temporal Data: An approximation of the number of temporal data sets required for each project update cycle.

Projects/Year: An estimate of the number of projects conducted by a CE district annually per program.

Repeatability of Project: An estimation of the number of years before updating a project.

Estimation of Data Channel(s) Required: An estimation of TM data channels required for analysis.

Timeliness of Data: The time required by CE user to receive TM data in specified format. Critical turnaround time of two (2) days is associated with two (2) program areas, i.e., Disaster Assistance - Flood Fighting - Operation Foresight and Permit/Regulatory Programs. The first program requires the monitoring of floods and snowpacks. The second program relates to the environmental and regulatory monitoring requirements.

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

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

Environmental Geology: Addresses the evaluation of sites for engineering structures in terms of geologic hazards, earth materials for engineering usage and environmental impact.

Geological Structure Mapping: The mapping includes delineation and analysis of folds (anticlines, synclines, monoclines, structure terraces, etc.) and fractures.

Geomorphic Feature Mapping: The mapping relates to glacial, fluvial, desert, permafrost features and features related to bedrock structures.

Physiographic Mapping: The mapping of watershed basin area and shape, stream network organization, drainage density and pattern.

Snow Mapping: Mapping snowpack areas of watershed for forecasting runoff. Activity is confined to the western, northwestern, north central and northeastern U.S.

Inventory Land Cover: Classification of mapping of land cover, relative to political, watershed, etc. boundaries.

Change Detection Monitoring: Temporal analysis, i.e., flood damage assessment, surface water inventory, periodic watershed land cover updated, etc.

Sediment Transport: Mapping of patterns of suspended solids in lakes, reservoirs, navigable rivers, etc.

Water Quality: Studies relating to water quality of reservoirs and lakes and corresponding surrounding land cover.

Ice Mapping: Ice surveys and monitoring of ice conditions in navigable water bodies.

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

Thematic Maps: Extracted theme data, coded at a specific map scale.

Overlays: Extracted theme data, on registered transparent material, at specific map scales.

Enhancements: Digitally enhanced images, processed using linear and non-linear stretches, ratios, filtering techniques, etc.

Area Measurements: Computer printouts containing thematic area measurements, relative to geopolitical boundaries.

Distance Measurements: Computer printouts of stream lengths, shoreline lengths, lineament lengths, etc.

Project Utilization: Level of product distribution (district, division, external to Corps).

Images (film): Thematic Mapper derived imagery.

TM SCENE REQUIREMENTS

In Table 3-1, the Thematic Mapper requirements are estimated for the Corps of Engineers Civil Works programs. The programs are defined as typical programs, performed by the specified districts with adjustments for district unique activities applied. For instance, certain districts are not involved in snow mapping; some districts have small coastal waterways. Adjustments are made in total equivalent scenes per year, relative to the districts. Likewise, only districts where the CE laboratories are located are allocated TM data for R&D programs. TM scene requirements are shown in Table 302, relative to Corps districts (and divisions) and programs. Corps TM scene requirements sum to 3056 scenes/year.

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

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

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

Table 3-1

REQUIREMENT PARAMETERS / TYPICAL CORPS PROJECTS PER DISTRICT	AVERAGE COVERAGE ESTIMATES								APPLICATIONS TECHNIQUE USED IN PROJECTS										TYPICAL OUTPUT DATA PRODUCTS PER PROJECT												
	FRACTION OF SCENE USED	BASIC NO. OF SCENES	TEMPORAL - DATES	PROJECTS/YEAR	DATA CH. REQUIRED	REPEATABILITY OF PROJ. (YEARS)	TIMELINESS OF DATA DAYS	TOTAL EQUIVAL. SCENES PER YEAR	ENVIRON. GEOLOGY	GEOLOG. STRUC. MAPPING	GEOMORPHOLOGY & FEATURE MAPPING	PHYSIOGRAPHIC MAPPING	SNOW MAPPING	INVENTORY LAND COVER	CHNG. DETEC. MONITORING	SEDIMENT TRANSPORT	WATER QUALITY	ICE MAPPING	THEMATIC MAPS 1	THEMATIC MAPS 2	THEMATIC MAPS 3	OVER-LAYS 1	OVER-LAYS 2	OVER-LAYS 3	ENHANCEMENTS	AREA MEASUREMENTS	DISTANCE MEASUREMENTS	PRODUCT UTILIZATION 4	PRODUCT UTILIZATION 5	PRODUCT UTILIZATION 6	IMAGES (FILM)
1. STUDIES (LARGE RIVER BASINS)	1	3	2	1	all	10	≥30	6	X	X		X		X					X			X			X	X	X	X	X	X	X
2. SPECIAL CONTINUING AUTHORITIES																															
SMALL FLOOD PROJECTS	1/4	1	2	20	all	3	≥30	10	X					X	X						X			X		X		X			X
SMALL NAVIGATION PROJECTS	1/4	1	4	5	?	5	30	5							X			X			X			X				X			
SMALL SHORELINES & OTHERS	1/4	1	4	3	all	3	15	3	X		X			X	X	X	X				X			X	X	X		X			
3. DISASTER ASSISTANCE, FLOOD FIGHTING, AND OPERATION FORESIGHT							*																								
DAMAGE ASSESSMENT	1/2	1	2	5	all	1	2	5						X	X						X			X		X		X	X		X
FLOOD PREDICTIONS	1	2	9	5	3,4 5,6	1	2	90					X		X								X			X					
4. FLOOD PLAIN MGMT. SERVICES	1/2	1	2	5	all	5	7.3	2.5				X		X	X			X			X			X	X	X	X	X			X
6. ENVIRONMENTAL STUDIES	1/2	1	4	5	all	1-3	30	10	X					X	X	X					X	X	X	X	X	X		X	X		X
HABITATS							15																								
WATER QUALITY																															X
EIS																															
8. PERMIT PROGRAM	1/2	2	4	2	4	3	2	4	X						X		X				X			X		X	X	X	X	X	X
REGULATORY					6		*																								
9. R&D	1/2	4	4	2	all	0	≥30	8	X	X	X	X	X	X	X	X	X	X			X				X	X	X	X			X

* 48 HRS. TURNAROUND TIME

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

Projects 5 and 7 have been deleted since this study.

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

LEGEND
4 = DISTRICT
5 = DIVISION
6 = EXTERNAL

Table 3-2

DISTRICTS	DIVISIONS	1	2			3		4	6	8	9
PROGRAMS			SPECIAL CONTINUING AUTHORITIES			DISASTER ASSIST			ENVIRONMENTAL STUDIES*		
		STUDIES	SMALL PROJECTS	NAVIGATION	SHORELINE ETC.	DAMAGE ASSESS.	FLOOD PREDICTIONS (SNOW)	FLOOD PLAIN MGMT. SERVICES	HABITATS WATER QUALITY EIS	REGULATORY PERMIT PROGRAM	R & D
NEW ENGLAND	NEW ENGLAND	6	10	5	3	5	45	2.5	10	4	8
NEW YORK, NY PHILADELPHIA, PA BALTIMORE, MD NORFOLK, VA	NORTH ATLANTIC				2 2 3 3						- - 8 -
WILMINGTON, NC CHARLESTON, SC SAVANNAH, GA JACKSONVILLE, FL MOBILE, AL	SOUTH ATLANTIC				4 4 4 4 4						
NEW ORLEANS, LA VICKSBURG, MS MEMPHIS, TN ST. LOUIS, MO	LOWER MISSISSIPPI VALLEY				4 - - -						- 8 - -
GALVESTON, TX FORT WORTH, TX ALBUQUERQUE, NM LITTLE ROCK, AR TULSA, OK	SOUTHWESTERN			5 - 3 3	4 - - - -	5 2 5 5					
KANSAS CITY, MO OMAHA, NE	MISSOURI RIVER			5 5			90 90				
NASHVILLE, TN LOUISVILLE, KY HUNTINGTON, WV PITTSBURGH, PA	OHIO RIVER										
ST. PAUL, MN ROCK ISLAND, IL CHICAGO, IL DETROIT, MI BUFFALO, NY	NORTH CENTRAL				- - 2 2 2		90 90 45 45 45				8
LOS ANGELES, CA SAN FRANCISCO, CA SACRAMENTO, CA	SOUTH PACIFIC				3 1 1		45 - 90				- - 8
PORTLAND, OR SEATTLE, WA WALLA WALLA, WA ALASKA	NORTH PACIFIC				3 3 - 1		90 90 90 90				
PACIFIC OCEAN		1	10	5	1	5		2.5	10	8	

*Potential large growth areas

NOTE: Projects 5 and 7 have been deleted since this study.

2. CE LANDSAT TM and SPOT Requirements

a. Overview

The CE, in 1980, completed a study which determined the CE requirements for LANDSAT Thematic Mapper (TM) data (Appendix E) which provides a baseline for CE land satellite remote sensing data requirements. The report determined that the three factors which impact CE requirements are: timely data delivery, frequency of coverage and sensor spatial resolution. Table 1 provides a summary of the CE LANDSAT TM requirement by numbers of scences per year versus CE function. Designated are those function which are sensitive to timely data delivery, frequency of coverage and/or resolution. The following paragraphs compare the technical aspects of the LANDSAT TM versus the SPOT system as a function CE requirements.

b. CE Requirement Update

Since the 1980 LANDSAT TM requirement study was completed, two factors have contributed to a decrease in the requirement as presented.

The requirement in Table 1 for the National Dam Safety program of 307 scenes per year has been deleted because at the present the CE is not required to update the National Dam Safety inventory.

The requirement in Table 1 for disaster assistance, flood predictions (snow) of 1035 scenes per year was based on the use of LANDSAT TM as the single source of spatial data. It has been determined that METSAT AVHRR data can sufficiently provide the large area and high repetitive coverage required. The role of LANDSAT type land remote sensing satellites will be for calibration of METSAT data and for areas of steep terrain. The requirement has been adjusted for a 50% reduction.

This update results in a 671 scenes/year reduction in LANDSAT TM requirement as present in TABLE 1. The revised figures are presented in TABLE 2 and anotated are those functions which require multispectral land remote sensing data.

c. Timely Data Delivery

The Corps of Engineers requirement for land remote sensing data has two time requirements for delivery of data. 32% of the CE satellite data requires delivery in less than 48 hours after acquisition to be applicable for emergency operations, disaster assessment, and flood prediction. 68% of the CE requirement is non-time dependant but site spcific and can be acquired from either SPOT or LANDSAT archives. It is anticipated that for non-time dependent data the majority of the CE data will be acquired from the LANDSAT TM archives because SPOT archive will be originally limited. The deciding factor for source of non-time dependent data in the out years will be which system has the best quality data for the specific CE site.

For the timely delivery of data it will be assumed that both LANDSAT and SPOT systems can provide the data within 48 hours, therefore the deciding factor is the frequency and at what time coverage is available for a specific site.

d. Frequency of Coverage

For frequency of coverage technically LANDSAT and SPOT systems have a significant difference. The LANDSAT system has a 16 day repeat cycle where as the SPOT pointable sensor can provide repetitive coverage approximately every 2 days of a specific site, therefore, SPOT has an 8 to 1 improved probability of acquiring data of a specific site and time than LANDSAT. SPOT will provide a significant advantage for the 32% of the CE requirement which is time dependent and site specific.

e. Spatial Resolution

The spatial resolution of SPOT is 20 meter multispectral and 10 meter panchromatic. Since 89% of CE requirement must have multispectral data the comparisons is between LANDSAT TM 30 meter and SPOT 20 meter. The increased resolution of SPOT versus LANDSAT is not enough of a significant impact to require SPOT 20 meter multispectral data instead of LANDSAT TM. Presently, turn-key digital classifications systems for SPOT 20 meter multispectral do not exist. Preliminary results of the CE simulation project shows that new and more complex classification algorithms for SPOT data need to be developed. 11% of the CE requirements is for high resolution data which 10 meter panchromatic SPOT sensor can provide.

f. Spectral Resolution

89% of the CE data requires multispectral data. The LANDSAT TM provides more spectral bands and narrow bandpass than SPOT, therefore, LANDSAT TM will be the required data source. If LANDSAT TM is not available SPOT can be a substitute. 11% of the CE data requirements can be satisfied by the SPOT 10 meter panchromatic data.

g. Stereo

A unique capability of SPOT versus LANDSAT TM is the ability to acquire stereo imagery. SPOT stereo data can be analyzed for slope, aspect and elevation information. It is anticipated that elevation data can be acquired from SPOT data within one pixel or +10 meters. The CE requirement would be for stereo data where digital terrain tapes do not concurr with CE study site which require less than +10 meter elevation or slope and aspect data. This requirement should not exceed 5% of the CE total requirement or 112 scenes per year.

h. Summary

The sensor characteristics of SPOT data can meet and be substituted for the CE LANDSAT TM data requirements. LANDSAT TM data for multispectral classification is preferred over SPOT multispectral data. The minimum CE SPOT requirement provided in Table 3 is based on the high resolution panchromatic SPOT data required for shoreline mapping and regulatory permit program totalling 132 scenes/year and an additional CE requirement which cannnot be satisfied by LANDSAT TM for SPOT stereo coverage of 112 scenes/year. The total minimum CE SPOT requirement is 364 scenes/year. The maximum CE SPOT requirement consists of the CE SPOT minimum requirement plus 10% of the non-time dependent data requirement and an 8 to 1 increase for time dependent data resulting from the increased repetitive coverage capability of SPOT. The total maximum SPOT requirement is 1,189/scenes per year.

D. Coordination and Planning Improvements

1. Program Overview. Spaceborne systems provide the only feasible means for repetitive large aerial extent and up-to-date data collection for terrestrial and oceanographic data. Advances in sensor and computer data processing technology will enhance the application of space technology. For a Federal land processes research from space program to be fully successful, it must encompass technology transfer. If the program addresses only high risk research this still leaves the user in a vulnerable investment position for technology transfer. With NASA's recent shift away for technology transfer and training for the user, future utilization of space technology has been hampered. Without a complete "end to end" program, this program will never provide the full benefit to our nation.

The past space program has designed and developed sensors and collected data very successfully, but the operational use of space collected data must be addressed. The operational use requires analysis and dissemination to be accurate, timely and inexpensive. An area of future potential is development of anlysis algorithms, design "end to end" data handling systems and compact computer data storage hardware. The research program should be a three prong effort of sensor design, data acquisition and analysis.

2. Future Data Needs for Spaceborne Systems. Future improved data needs are positioning, topographic mapping, delineation of urban areas, soil moisture and coastal waves and currents. These five categories can use the repetitive or continuous advantages of spaceborne systems. Improved sensor design and data processing will be required to satisfy these requirements.

It is necessary to know the position on land or water for field personnel and data collection instruments. These field personnel are generally changing location hourly, therefore, the system must allow accurate location determination in less than one hour. The location data must be quickly available to field personnel to be incorporated in their field data bases.

Topographic mapping by spaceborne photographic cameras or scanning lasers could provide up-to-date data with reduced field operations in inaccessible and harsh environments. For emergency operations during national and natural disasters, near real-time damage assessment is necessary, but usually unattainable. For all engineering studies, recent topographic data is needed, but often not obtained due to cost and time delay.

Hydrologic modeling and related economic studies require land use information. Much has been accomplished in the past decade, but accurate determination of urban areas still has a high degree of uncertainty. Reliable sensor techniques and classification schemes to differentiate between various land uses such as single dwelling, multi-family dwelling, commercial, industrial and impervious areas such as asphalt and concrete are needed.

Soil conditions of moisture content and frozen or non-frozen are an elusive parameter for hydrologic and trafficability studies. The need exists to develop a reliable sensor to detect and provide spatial soil conditions information.

Coastal waves and current information are required for marine design, dredging operations and navigation. The oceanographic applications of remote sensing technique are rapidly emerging, and the marine community is expressing interest. Because of the dynamic aspect of a marine environment, repetitive data is required which spaceborne platforms can provide.

3. Sensor Development. Improvements of visible and infrared imaging systems should continue for increased resolution, radiometric quality and analysis procedures. However, the greatest potential is the development of both active and passive microwave sensors. A microwave system provides the capability of all weather, night and day operations, which at least doubles the data acquisition frequency over the visible/infrared systems. Many times the critical data is during severe weather conditions when visible and infrared systems are useless. An added dimension of various microwave frequencies is penetration of vegetation and soil to provide subsurface data.

In summary, the needs through the year 1995 are:

a. Technology transfer, training and cooperative demonstration programs.

b. Improved data processing and computer storage.

c. Improved data collections systems for positioning, topographic mapping, delineation of urban areas, soil moisture and coastal waves and currents.

d. Improved resolution, radiometric quality and analysis for visible and infrared imaging systems.

e. The development of microwave sensors and basic backscatter theory.

TABLE 1: 1980 REQUIREMENTS

CE Program	LANDSAT TM Req. No. Scenes/yr	LANDSAT TM Req. % Req.	Sensitivity Factor Time	Sensitivity Factor Frequency	Sensitivity Factor Resolution
1. Studies	245	8.0	----	----	----
2. Special Continuing Authorities					
a. Small Flood Projects	360	11.7	----	----	----
b. Navigation	182	6.0	----	----	----
c. Shoreline etc.	75	2.5	----	----	X
3. Disaster Assistance					
a. Damage Assessment	194	6.3	X	X	X
b. Flood Prediction (snow)	1035	33.8	X	X	----
4. Floodplain MGMT. Services	98	3.2	----	----	----
5. Urban Studies	23	0.8	----	----	----
6. Environmental Studies	370	12.0	----	----	----
7. National Dam Safety	307	5.7	----	----	----
8. Regulatory Permit Program	177	10.0	----	X	X
T O T A L	3,066	100.0%			

TABLE 2: UPDATED REQUIREMENT

CE Program	LANDSAT TM Req. No. Scenes/yr	% Req.	MSS Req.
1. Studies	245	11.0	X
2. Special Continuing Authorities			
a. Small Flood Projects	360	16.0	X
b. Navigation	182	8.0	X
c. Shoreline etc.	75	3.3	---
3. Disaster Assistance			
a. Damage Assessment	194	8.7	X
b. Flood Prediction (snow)	518	23.0	X
4. Floodplain MGMT. Services	98	4.4	X
5. Urban Studies	23	1.0	X
6. Environmental Studies	370	16.9	X
7. Regulatory Permit Program	177	7.7	---
T O T A L	2,242	100.0%	

TABLE 3: LANDSAT/SPOT REQUIREMENTS

CE Program	MINIMUM No. Scenes/yr. LANDSAT	Spot	MAXIMUM No. Scenes/yr. LANDSAT	Spot
1. Studies	245	---	220	25
2. Special Continuing Authorities				
a. Small Flood Projects	360	---	324	36
b. Navigation	182	---	91	91
c. Shoreline etc.	---	75	---	75
3. Disaster Assistance				
a. Damage Assessment	194	---	24	170
b. Flood Prediction (snow)	518	---	65	453
4. Floodplain MGMT. Services	98	---	88	10
5. Urban Studies	23	---	20	3
6. Environmental Studies	370	---	333	37
7. Regulatory Permit Program	---	177	---	177
8. Stereo Imagery	---	112	---	112
T O T A L	1,990	364	1,165	1,189

APPENDIX C

DEPARTMENT OF DEFENSE REQUIREMENTS

FOR

METEOROLOGICAL SATELLITE DATA

THE JOINT CHIEFS OF STAFF
WASHINGTON, D.C. 20301

MJCS 251-76
31 August 1976

MEMORANDUM FOR THE DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

Subject: Revalidation of Military Requirements for Meteorological Satellite Data

1. Reference your memorandum,* 28 May 1976, subject as above, which requested the Joint Chiefs of Staff to reevaluate the military requirements for meteorological satellite data and to submit a new list of requirements to your office for transmittal to the National Aeronautics and Space Administration and the Department of Commerce for their information.

2. The Services have reviewed and revised the military operational requirements for meteorological satellite data. The new list and accompanying rationale are attached hereto.

3. This memorandum supersedes JCSM-329-70,** 7 July 1970, "Meteorological Satellite Requirements."

For the Joint Chiefs of Staff:

RAY B. SITTON
Lieutenant General, USAF
Director, Joint Staff

* Attached
** Enclosure A to JCS 1910/95

[illegible]

Prepared by:
LTC W. C. Hardwick, [illegible]
Office of [illegible]
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Ext. 77117/30[illegible]76, [illegible]

ENCLOSURE A

MILITARY OPERATIONAL REQUIREMENTS FOR METEOROLOGICAL DATA FROM SATELLITES

DEFINITIONS

1. Horizontal Resolution - The dimension of the smallest object (or horizontal area represented by the parametric value) which can be distinguished by a satellite sensor.

2. Vertical Resolution - The smallest height increment discernible by a satellite sensor.

3. Tactical Station - A military unit with a direct meteorological satellite readout capability that provides direct weather support to tactical operations.

4. Weather Central (MILITARY) - A military unit with a capability of routinely performing, on a realtime basis, the functions of environmental data collection, processing, analysis, prediction, and dissemination of macro, meso and micro scale environmental applications to multiple organizations in support of DOD operations worldwide.

REQUIREMENTS

5. Parameters below are tabulated without division into categories of importance, since the degree of importance of these parameters is dependent upon the particular strategic or tactical operation for which they are needed. However, tactical parameters apply when weather centrals assume the tactical support role for a limited area. These are identified by a double asterisk (**) in the Remarks column.

Parameter	At Tactical Stations	At Weather Centrals	Remarks
1. Cloud Cover			
(Including smoke, haze, smog, type, altitude of base and top)			
Horizontal Resolution	0.25 nm (0.5km)	0.25 nm (0.5km)	
Area Covered	2000x 4000 nm (3500x7500km)	Global	
Frequency	Available on call	30 min.	
Location Accuracy	0.25 nm (0.5 km)	0.25 nm (0.5 km)	
Timeliness	5 min	15 min	
Vertical Resolution	± 100 ft (30 m)	same	Below 10000 ft (3000 m) AGL
	± 1000 ft (300m)	same	Above 10000 ft (3000 m) AGL
Liquid (or solid) water content	0.1 in(0.3mm)	0.1 in (0.3mm)	Equivalent in (mm) of water in a column
2. Vertical Moisture Profile			**
Area covered	2000x4000 nm (3500x7500 km)	Global	
Horizontal Resolution	5 nm (10 km)	50 nm(100km)	
Vertical Resolution	± 100 ft (30 m)	± 100 ft (30 m)	Surface to 10000 ft (3000 m) AGL
	± 1000 ft (300m)	± 1000 ft (300m)	10,000 ft (3000 m) to Stratopause

Parameter	At Tactical Stations	At Weather Centrals	Remarks
Frequency	hourly	3-hourly	
Location Accuracy	1 nm (2km)	10nm (20km)	
Absolute Accuracy	± 1%	± 1%	
Timeliness	1 hour	1 hour	

3. Vertical Temperature Profile

Parameter	At Tactical Stations	At Weather Centrals	Remarks
Area Covered	2000 x 4000 nm (3500x7500 km)	Global	
Horizontal Resolution	5 nm (10km) (10x10 km)	50nm (100km)	
Vertical Resolution	± 100 ft (30 m)	same	Sfc - 10,000 ft (3000 m) AGL
	± 1000 ft (300m)	same	10,000-30,000 ft (3,000-10,000 m)
	± 2000 ft (600m)	same	30,000-200,000 ft (10,000 - 60,000 m)
Frequency	hourly	3 hourly	
Location Accuracy	1 nm (2 km)	10nm (20km)	
Absolute Accuracy	$\pm 1^{o}K$	$\pm 1^{o}K$	
Timeliness	1 hour	1 hour	

4. Albedo

Parameter	At Tactical Stations	At Weather Centrals	Remarks
Area Covered	800x800nm (1500x1500km)	Global	**
Horizontal Resolution	5x5 nm (10x10km)	25 x 25 nm (45x45 km)	
Frequency	hourly	3-hourly	
Location Accuracy	1 nm (2km)	5 nm(10km)	
Absolute Accuracy	± 5%	± 5%	

Parameter	At Tactical Stations	At Weather Centrals	Remarks
Timeliness	1 hour	1 hour	
5. Visibility			
Area Covered	800x800nm (1500x1500km)	2000x4000nm (3500x7500km)	
Horizontal Resolution	5 nm (10km)	5 nm (10km)	Sfc-15000ft (4500m)
Vertical Resolution	500 ft (150m) 1000 ft (300m)	500 ft (150 m) 1000 ft (300 m)	Sfc-15000ft (4500m) 15000-40000 ft (4500-7500m)
Wavelength	0.4-0.7 μm	0.4-0.7 μm	
Frequency	hourly	hourly	
Timeliness	1 hour	1 hour	
Location Accuracy	1 nm (2 km)	1 nm (2 km)	
Absolute Accuracy	± 0.5 nm (1km)	± 0.5 nm (1 km)	
6. Precipitation			
Area Covered	800x800nm (1500x1500km)	Global	**
Frequency	Available on call	3-hourly	
Horizontal Resolution	0.5 nm (1km)	2.5nm (5 km)	
Location Accuracy	1 nm (2 km)	5 nm (10 km)	
Absolute Accuracy	± 0.1 in/hr (0.3 mm/hr)	± 0.1 in/hr (0.3 mm/hr)	
Timeliness	15 min.	15 min.	
7. Winds			**
Area Covered	2000 x 4000 nm (3500x7500 km)	Global	
Frequency	Available on call	3-hourly	

Parameter	At Tactical Stations	At Weather Centrals	Remarks
Horizontal Resolution	5 nm (10 km)	5 nm (10 km)	
Location Accuracy	1 nm (2km)	1 nm (2km)	
Vertical Resolution	± 100 ft (30m)	same	Sfc-10000 ft (3000m) AGL
	± 1000 ft (300m)	Same	10,000-30,000 ft (3000-10000m)
	± 2000 ft (600m)	Same	30,000-200,000 ft (10000-60000 m)
Accuracy Speed:	± 5% not to exceed 2 m/s	± 5% not to exceed 2 m/s	
Direction:	± 5°	± 5°	
Timeliness	Available on call	1 hour	
8. Surface Temperature			
Area Covered	800x800nm (1500x1500km)	Global	Temperature of radiating surface
Frequency	hourly	3-hourly	
Absolute Accuracy	0.5°C	0.5°C	
Timeliness	Available on call	1-1/2 hours	
Location Accuracy	1nm(2km)	5nm (10km)	0.5nm(1km) for sea surface temperature with IR.
Horizontal Resolution	5 nm(10km)	5nm(10km)	
9. Snow and Landlocked Ice Cover			**
Area Covered	tactical areas	Global	
Frequency	3-hourly	6-hourly	
Horizontal Resolution	5 nm (10km)	25 nm (45km)	
Location Accuracy	1 nm (2 km)	5 nm (10km)	

Parameters	At Tactical Stations	At Weather Centrals	Remarks
Timeliness	Available on call	1-1/2 hours	
Thickness Accuracy	± 2 in (5cm)	± 2 in. (5cm)	

10. Sea Ice Cover **

Area covered	Tactical areas	Global	
Frequency	6 hourly	12 hourly	
Horizontal Resolution	0.5nm (1km)	0.5nm (1 km)	15m for ice bergs
Location Accuracy	0.5nm (1km)	0.5nm (1km)	
Timeliness	Available on call	3 hours	
Thickness Accuracy	± 5 in.	± 5 in.	
Age	6 months	6 months	
Concentration	± 10%	± 10%	

11. Soil Moisture

Area Covered	2000x4000 nm (3500x7500 km)	Global	
Horizontal Resolution	1 nm (2 km)	5 nm (10 km)	
Frequency	On request	6-hourly	
Absolute Accuracy	± 10%	± 10%	If frozen, depth to nearest ± 3 in. (8 cm)
Timeliness	On request	1 1/2 hours	
Location Accuracy	1 nm (2 km)	5 nm (10 km)	

12. Sea State

Area covered	Tactical areas	Global	

Parameters	At Tactical Stations	At Weather Centrals	Remarks
Frequency	On call	3 hourly	
Timeliness	3 hours	3 hours	
Horizontal Resolution	1 nm (2km)	1 nm (2km)	
Absolute Accuracy	Amplitude component: 0.3m Wavelength Component: ± 5% Directional Component: ± 10°		
Location Accuracy	1 nm (2 km)	1 nm (2 km)	

13. Clear Air Turbulence

Area Covered	800x800nm (1500x1500km)	Global	
Horizontal Resolution	5 nm (10km)	25nm (45km)	
Vertical Resolution	1000 ft (300m)	below 10,000 ft 3000m)	
	2000 ft (600m)	above 10,000 ft 3000m)	
Frequency	Available on call	hourly	
Location Accuracy	1 nm (2km)	5 nm (10km)	
Absolute Accuracy	Vertical gust speed to within ± 3 knots (1.5m/s)		
Timeliness	15 min	15 min	

14. Neutral Density

Area Covered	N/A	Global	
Frequency	N/A	1 hour	
Timeliness	N/A	10 minutes	
Vertical Coverage	N/A	1500 meter intervals 0-60km 3000m intervals from 60-400km	
Horizontal Resolution	N/A	25 km	
Location Accuracy	N/A	5 km	
Absolute Accuracy	N/A	± 5%	

ENCLOSURE B

RATIONALE

1. General

a. Environmental data available from satellites are used in decisionmaking processes. Information derived from processed satellite data is important as an input for targeting tactical and strategic weapon systems. These data are also used for intelligence application as well as for daily synoptic weather analyses, and ionospheric and magnetospheric analyses at weather centrals.

b. For those meteorological parameters on which data are directly available from satellites, the delay caused by central data retrieval and redistribution through various communications links precludes, in some cases, real time support for tactical applications. However, DOD provides a growing amount of its support directly from centralized production systems and, as a result, the weather centrals may often require data in as fine a resolution as do the tactical stations. In view of the differences in some operational requirements of tactical (regional) as opposed to weather central (global) locations, separate requirements are stated for all parameters. In general, to be of direct tactical application, determination of environmental parameters must approach the same scale as the operation which is supported and be available when required without reference to a frequency interval.

c. The rationale for each parameter listed in Enclosure A is presented in the following paragraphs.

2. Cloud Cover

a. Resolution

(1) General. Sufficient resolution is required to define

cloud type accurately, including stage of development, cloud size, and cloud distribution for use in determining and forecasting global synoptic conditions and mesoscale conditions over specific operational areas. Mesoscale meteorology is concerned with the detection and analysis of the state of the atmosphere as it exists between meteorological observing stations or at least well beyond the range of normal observations from a single point: weather phenomena occurring in time within 1 to 100 minutes and over a ground area of from 1 to 100 square kilometers (km). In addition, high resolution is required for terrain and landmark identification which will provide accurate locations of cloud features in relationship to points and areas of interest.

(2) Cloud characteristics. Cloud elements vary in size from several hundred feet to many miles. For example, small cumulus have horizontal dimensions on the order of 300 feet (100 meters), and developing cumulonimbus on the order of 1 nautical mile (nm) (2km), whereas thunderstorms with well-developed anvil tops may cover tens of miles (km). Bands of stratocumulus are typically on the order of 0.5 nm (1 km) wide and extend for many miles (km). Clouds associated with standing waves, cap clouds, and cirrus streamers associated with clear air turbulence have typical dimensions of 0.5 nm (1 km) in width to several miles (km) in length. Studies of cloud element size distribution show that about 20 percent of stratocumulus clouds have widths less than 0.2 nm (0.4 km) and nearly 80 percent are less than 0.5 nm (1 km). For cumulus clouds, these studies show that about 40 percent are smaller than 0.2 nm (0.4 km) in width and more than 85

percent are smaller than 0.5 nm (1 km) wide. Limited studies of spacing between cloud elements show that under some conditions 30 percent of the clouds are spaced less than 1 nm (2 km) apart, with less than 15 percent being 0.5 nm (1 km) apart. Fogs can often be identified by the way they fill small, natural geographic basins or river valleys when high-resolution data are available.

(3) Synoptic applications. The above considerations of cloud characteristics, combined with experience gained in the application of satellite data, indicate that for global synoptic analysis and forecasting needs, a horizontal resolution of 0.25 nm (0.5 km) is required, daytime and night, for identifying and locating cloud features. In addition to identifying all major storms and frontal systems, such resolution is most effective in determining the orientation of major cloud bands in providing an indication of cloud types and portraying cloud fields.

(4) Tactical Applications. As a result of experience gained in applying satellite data to tactical operations, users have stated a requirement for 0.25 nm (0.5 km) resolution over the entire tactical area. This resolution is required to provide definitive data on cloud types and distribution necessary for computing cloud free line of sight and clear line of sight (CLOS) probabilities so essential for employment of precision guided munitions, to improve the assessment of the meteorological situation affecting existing or potential tactical operational areas, and to increase location accuracies by enabling more detailed terrain recognition

(if picture includes land areas) to be made. This resolution will greatly enhance the quantitative determination of the amount of cloud cover over a target or other operational areas. Airmobile and certain airborne and amphibious operations, for example, utilize very small landing area drop zones and beaches. Clouds which prevent visual identification of these areas, and routes thereto, affect the mission.

b. Area Covered

(1) Synoptic coverage must be on a global basis to satisfy overall military requirements for meteorological support. Naval operations, for example, may occur in any area of the world that would require control of the seas. Antarctic resupply and oceanographic operations require coverage over the Antarctic region. Arctic exploration and oceanographic operations (to include some submarine operations) require that observations be taken of the Arctic regions.

(2) For tactical stations, the areas of interest (including the surrounding areas from which weather conditions may move into operational areas) may range from a few square miles (km) involving a local battle area to more than a million square miles (km) where air and/or surface activities range over an entire theater of operations. The stated 2,000 x 4,000 nm (3,500 x 7,500 km) requirement will enable support to tactical operations over an extended area (mesoscale to macroscale).

(3) Shipboard and expeditionary forces readout should be available 2,000 miles (3,500 km) from satellite subpoint to allow task force commanders to observe clouds over targets at extreme operating ranges.

c. Frequency

(1) At weather centrals, the requirement is to have cloud observations at least every 3 hours and for severe weather metwatch at least every 30 minutes. At tactical stations, the requirement is to have cloud observations available on call.

(2) A study of the frequency of category changes in cloud cover (clear, scattered, broken, and overcast) based upon hourly observations at selected stations shows that satellite observations every 2 hours would observe about three-fourths of the hourly changes as they occur and would miss one-fourth. Observations every 3 hours would show about 65 percent of the changes. About 42 percent of the changes would be noted if observations are taken every 6 hours.

(3) The observational frequency required is dependent on a number of variables, such as weather situation, local conditions affecting changes in cloud cover, the type of information to be derived, and the use to be made of this information. In the tropics, storms move with a typical velocity of around 15 knots. In mid-latitudes, frontal zones and storm systems may move with a velocity as high as 50 knots. A storm may change speed and direction or become stationary. The lifetime of a typical mid-latitude squall line is about 4 hours. Thunderstorm development within that squall line may be determined as much as 3 hours prior to the onset of severe weather. On the other hand, thunderstorms may develop and dissipate in the course of 1 or 2 hours.

(4) Synoptic applications. An objective quantitative answer to the question of satellite observational

frequency is extremely difficult. Observations by the geostationary operational environmental satellite indicate that significant synoptic changes take place in time intervals of less than 30 minutes. This means that data required for severe weather metwatch is needed within that time period. Extra-tropical cyclones have been observed to change dramatically in intensity and speed in less than 3 hours. In the tropics, significant changes in atmospheric processes can occur in less than 3 hours. Hurricanes/typhoons have been observed to develop rapidly from tropical depressions in 3 hours or less.

(5) Tactical applications. The operational commander should have real time cloud cover information available oncall for making decisions. Weather centrals supporting tactical operations require a frequency once every 3 hours to track rapidly moving storms and frontal systems and to monitor the development of severe weather that could affect military operations.

d. Location accuracy. Location accuracies must be compatible with resolution requirements.

e. Vertical Resolution

(1) The most stringent requirements for cloud cover vertical resolution are for an interval of 100 feet (30 meters) below elevations of 10,000 feet (3,000 meters) aboveground level (AGL), and 1,000 feet (300 meters) above 10,000 feet (3,000 meters) AGL.

(2) Information of the above nature is required in support of tactical operations. Such requirements are also applicable to flight approaches during inclement weather, low-level reconnaissance operations, search

and rescue operations, and refueling area operations.

(3) Determination of cloud base and top heights is essential for analysis of cloud types, changes in vertical development, correlation with vertical temperature profile, and for indications of conditions favoring precipitation and in-flight icing in clouds.

(4) Based on a standard atmosphere, these requirements translate into temperature accuracy requirements of $\pm 0.3^{\circ}K$ below 10,000 feet (3,000 meters) AGL and $\pm 3^{\circ}K$ above 10,000 feet (3,000 meters) AGL.

f. Liquid (or solid water) content. Used in initializing moisture fields for moist primitive equation models.

3. Vertical moisture profile. Water vapor analysis on a synoptic scale is needed for analysis and forecasting of weather systems, associated fronts, and air mass weather. This parameter furnishes an index of moisture available for adiabatic energy processes such as conversion to visible moisture in the form of clouds, precipitation, or fog. Vertical resolution is required to permit strata analysis in conjunction with forecasting moisture and vertical extent of clouds. These data are required for detecting and forecasting vertical gradients of refractive indices affecting a variety of systems including communications, missiles, surveillance radar, electro-optical weapon systems, and tactical support missions. The ability to forecast accurately conventional parameters such as fog, cloud, haze, and precipitation is also strongly dependent upon water vapor data. The frequency and timeliness of this information should be comparable to rawinsonde data. The accuracy required is $\pm$ 1 percent of the absolute value; the three-dimensional resolution should permit analysis of water vapor with a 50 nm (100 km) grid in 100-foot (30 meters)

increments from the surface to 10,000 feet (3,000 meters) AGL and 1,000-foot (300 meter) increments from 10,000 feet (3,000 meters) to the stratopause.

4. Vertical temperature profile. Since horizontal and vertical temperature gradients are directly related to weather and its changes, temperature data are a fundamental requirement. In areas where terrestrial observations are scarce or absent, satellite temperature observations are needed for analysis and forecasting of clouds, fog, precipitation, winds, visibility, turbulence, and other weather elements. This information is required to determine heights of cloud tops, vertical gradients of refractive index, CLOS, and heights of various pressure surfaces. This last item is a key input into numerical analysis and prognosis programs on which meteorological forecasts are based. Frequency, timeliness, and accuracy of temperature data should be at least comparable with present requirements for rawinsonde observations. The horizontal resolution should be about 50 nm (100 km) with 100-foot (30 meter) vertical increments from the surface to 10,000-feet (3,000 meters), 1,000-foot (300 meter) increments from 10,000-feet (3,000 meters) to 30,000-feet (9,000 meters); and 2,000-foot (600 meter) increments from 30,000-feet (10 km) to 200,000-feet (60 km).

5. Albedo. Variations in time and space of the heat budget of the earth and its atmosphere, as represented by albedo observations, are required to establish large-scale trends or changes which cannot be foreseen by observations within the earth's atmospheric envelope. The albedo can also be applied to cloud analyses and calculation of inherent contrast between target and background for electro-optical weapon systems. Albedo measurements are required from the visible through

near infrared wavelengths. Small-scale albedo data are required with a 25 x 25 nm (45 x 45 km) resolution.

6. Visibility

a. General. The employment of precision guided munitions in a tactical scenario requires target acquisition using a variety of electro-optical devices. The guided munitions require that the apparent contrast seen by the television (TV) sensor exceed a threshold value for successful lock-on to the target. The parameter used in operational decision-making is the seeability which is an expression of the distance at which the target/background contrast exceeds the required threshold. This parameter is related directly to the aerosol content along a slant path between the target and sensor. The aerosol extinction profile can be inferred from the visibility profile. This information can be combined with data on background reflectance to estimate the ratio of sky radiance to ground reflected radiance. These, in turn, can be used to estimate the transmission of target/background contrast from the target to the sensor.

b. Requirements. Visibilities are required with 5 nm (10 km) horizontal resolution to support tactical operations. Visibility estimates are required at 500-foot (150 meter) intervals in the vertical to adequately define the slant-path seeability. The wavelength interval 0.4-0.7 μm coincides approximately with that of most TV target acquisition devices. Requirements for absolute accuracy, timeliness, location accuracy, and frequency are consistent with the time and space scale of tactical decisionmaking.

7. Precipitation. Measurement of this parameter is required for the analysis of synoptic-scale weather features, such as

fronts and tropical storms, and for evidence of isolated or scattered showers or thunder storm activity. Precipitation discrimination is needed to define intensity to the nearest 0.1 inch (0.3 milimeter) per hour. Observations must be sufficiently frequent to track storm movement and development. Data provided must permit assessing the effect of precipitation on air and surface operations. On the ground, this information is required to forecast soil trafficability, river stages, and flooding. Effects on communications, air operations, and reconnaissance systems, weapons delivery, field engineering activities, and surveillance systems are determined by the intensity and extent of the precipitation. Space mission recovery areas are often selected on the basis of precipitation forecasts. The horizontal resolution requirement is based on the size of a precipitation area associated with a small-to-moderately sized rain shower. Precipitation, presently observed visually or by radar and an input to almost all surface analyses, is also used extensively in making forecasts and prognoses. Global coverage would provide precipitation information in the areas where there are no other observations available, thereby greatly enhancing the accuracy and extent of the analyses.

8. Winds

a. Accurate surface (over ocean areas) and upper level wind data are required to support all aspects of military operations, such as assessing radioactive fallout conditions, movement of weather systems, and predicting winds for weapons delivery and tactical operations.

b. At weather centrals, wind observations are needed in sufficient spatial density to define low level and layered wind fields, to derive sea state and areas of convergence and divergence, and to establish criteria for integrated wind fields for tropical storm development and steering forecasts. Frequency of observation is based on synoptically significant short-term variability of wind.

Surface Temperature

a. A 5 nm (10 km) horizontal resolution is required for surface temperature analyses. Surface temperature is derivable from infrared or microwave data.

b. Surface temperature must be observed in order to analyze effects at the interface between the earth and its atmosphere. Radiative, convective, and advective activity is of great importance in establishing the temperature structure of the lower atmosphere, and depends on processes which can be quantitatively determined by observations of surface temperatures. Surface temperature information is needed for support of rescue operations (aircraft/spacecraft), polar activities, land/sea assault operations, and soil trafficability, river stage, and flood forecasts. It is also required for contigencies involving the dispersion of chemical and nuclear agents.

c. The Fleet Numerical Weather Central (FNWC) currently analyzes sea-surface temperature over the oceans of the Northern Hemisphere, using limited observations. This analysis is an input to a number of meteorological and oceanographic prognosis programs. Worldwide availability of sea-surface temperature would greatly improve the analysis, provide Southern Hemisphere coverage, and improve the dependent prognoses. Sea-surface temperature is significant in the forecast of severe weather over ocean areas and is used in the assessment of oceanographic effects on antisubmarine activities.

d. The Air Force Global Weather Central currently produces an automated 3-hourly cloud analysis for the Northern Hemisphere and 6-hourly cloud analysis for the Southern Hemisphere. These analyses require accurate surface temperatures for cloud-no cloud decisions.

10. Snow and Landlocked Ice Cover. These parameters are required for support of high latitude and mountain operations. Forecasts of soil trafficability, river stage, flood, air rescue conditions, and other phenomena are dependent on this information. Snow and ice cover data are used to determine types of equipment required for certain operations. These requirements can be partially satisfied by information derivable from cloud cover sensors, except when the ground is obscured by clouds. The high-resolution data will be used to locate snow lines in mountainous areas. These data are also used in the automated three dimensional cloud analyses for making the cloud-no cloud decision. Availability of measurements of snow and ice thickness would greatly enhance estimates of flooding due to snow/ice melt and localized damming.

11. Sea ice cover. The knowledge of the degree and extent of sea ice coverage is essential to the planning and execution of polar operations. Availability of high-resolution ice cover data would greatly enhance the ice observation and forecast program of the Naval Weather Service. Elimination of many ice reconnaissance flights might result. Resolution of 15 meters would allow detection of icebergs in addition to providing accurate boundaries of sea and other information required for polar operations.

12. Sea state. Wave and swell significant heights for the Northern Hemisphere are currently analyzed twice per day and forecast at FNWC, Monterey. Analysis is done by

computation from the observed wind field. Direct measurement of wave height and direction would greatly increase the accuracy of the analysis and improve the accuracy of the dependent prognoses. These parameters are extremely important in planning and conducting all types of naval and amphibious landing operations.

13. Soil moisture. This parameter is essential for determination of the capability of the soil to support land traffic, to position heavy weapon systems, and to determine river stage and potential flooding for field engineering purposes. A resolution of 25 nm (45 km) for synoptic purposes and 1 nm (2 km) for tactical purposes is considered adequate for the above uses, and the required accuracy is within 10 percent (in terms of saturation).

14. Clear air turbulence (CAT). CAT, at all levels, is a significant operational parameter required by tactical commanders and also by meteorologists for observation and forecast purposes. Satellite observations appear to be an efficient means of detecting and locating CAT, providing suitable sensors are developed. CAT observation and forecasts will permit avoidance of areas where CAT would present hazards to air operations such as airdrops, airlift, air-to-ground weapons delivery, and transport of shock-sensitive cargo.

15. Neutral density. Density measurements in the 0-to-200,000-feet (0-to-60,000 meters) altitude range are required for high-precision targeting of artillery and ballistic missiles. Frequent real time density measurements are needed in order to improve the prediction of density. Density measurements in the 60-400 kilometer interval are required for prediction of satellite ephemeris. Command and control of lower orbiting satellites must be responsive to anticipated changes in density. Space track facilities also need proper ephemeris to manage acquisition and tracing operations.

APPENDIX D

DEPARTMENT OF THE INTERIOR

SATELLITE REMOTE-SENSING DATA APPLICATIONS

AND SYSTEM REQUIREMENTS

Department of the Interior Satellite Remote Sensing Data Applications and System Requirements

I. Introduction

The Department of the Interior (DOI), through its various bureaus and offices, has direct administrative responsibilities for more than 500 million acres, or roughly 40 percent, of the total land and continental shelf areas of the United States. In addition, the Department has mapping and resource appraisal responsibilities for the entire country, as well as responsibilities in the Trust Territories of the United States, in Antarctica, and for conducting studies in other countries in cooperation with foreign governments. The vastness of the territories involved in the inventory, monitoring, mapping, and management activities of the Department of the Interior requires efficient and effective means for acquiring many different types of information. Satellite remotely sensed data represent one such source of information that have been applied and will continue to be applied with increasing frequency in many different applications by DOI bureaus and offices.

The objective of this document is to identify satellite remote sensing system and data characteristics needed to meet the research and applications requirements of the Department of the Interior. The information requirements of the countless existing and potential Departmental uses and applications of satellite remotely sensed data provide the basis for defining those system and data requirements. This document presents and discusses representative examples of such existing and potential satellite data uses and applications under categories of major Departmental responsibilities and functions. The objectives and information requirements of these applications are briefly described and consequent satellite system and data requirements are identified on corresponding matrix charts.

II. Geologic Investigations

It is the responsibility of the U.S. Geological Survey to collect and disseminate basic geologic information, access the Nation's energy and mineral resources, determine regional geologic frameworks and define their formative processes, evaluate geologic hazards, and conduct fundamental geologic research to address current and future national needs. Other DOI bureaus and offices, such as the Bureau of Land Management, Bureau of Mines, Minerals Management Service, Bureau of Reclamation, and the Office of Surface Mining also conduct geological investigations in support of their administrative responsibilities. The principal role of satellite remotely sensed data in these investigations is as a source of geologic information from which meaningful geologic interpretations can be made. Satellite data offer the unique advantage of providing continuous information, over large areas, relating to the composition, form, distribution, and structural relationships of geologic materials exposed on the Earth's surface. Such information can be used not only to map and characterize surface geologic materials and relationships but also to extrapolate to the subsurface to interpret and predict important relationships present beneath the Earth's surface. While most DOI requirements for geologic information are domestic in nature, certain responsibilities require access to geologic information from foreign countries, the principal source for which may be satellite data.

Regional/General Geologic Mapping. The objectives of geologic mapping are to provide basic lithologic and structual information which describe the geologic settings and relationships of specified areas and which can be used in such varied endeavars as interpreting regional tectonic frameworks, evaluating energy and mineral resource potentials, land use planning, etc. Specific information requirements which can be addressed with satellite remote sensing include landform identification, definition of drainage pattern and density, orientation of stratigraphic beds, lineament identification, and rock type determination.

Detailed Structural Delineations. Investigations such as mine stability studies, dam site evaluations, detailed studies of complex tectonic regimes, and fluid migration studies often require more detailed determination of the occurrence and orientation of faults and fractures than is typically provided by routine geologic mapping. Determination of such information requires identification of subtle landform boundaries, surface material boundaries, variations in relief, and drainage patterns. Satellite data have potential application in identifying these subtle variations.

Determination of Rock Composition. Knowledge of the detailed mineralogic composition of surface rock and soil materials is important in many geologic investigations such as facies mapping for sedimentary basin analysis and evaluation of hydrocarbon potential, alteration mapping for mineral and energy appraisal, and many other investigations where detailed lithologic determinations are important. Compositional information can be derived from physical rock properties expressed as textural variations on remotely sensed image data, however the greatest promise for determining unique compositional properties from satellite remotely sensed data lies in the potential of future systems for detailed measurement of spectral responses which are uniquely related to the mineralogic composition of the source.

Geologic Hazard/Thermal Monitoring. Earthquakes and volcanic erruptions are natural events that constitute two common and potentially devastating geologic hazards. Predicting the occurrence of these events is a high priority goal that can be facilitated with satellite remotely sensed data by mapping locations of potentially active faults and monitoring movement along those faults, and by monitoring thermal activity associated with active or potentially active volcanos. Thermal monitoring by satellite systems also has potential application in geothermal exploration and resource evaluation.

Geobotanical Studies. A major percentage of the Earth's land surface is covered by vegetation, thus preventing direct observation of rock and soil materials. Geobotanical remote sensing studies attempt to characterize and utilize variations in vegetation type, density, distribution, and vigor to determine rock type and distribution parameters and to identify structural features. Spectral information provided from future space systems may detect plant stress conditions induced by man-made pollutants or by anomalous concentrations of minerals associated with ore deposits or hydrocarbon occurrences.

III. Hydrologic Investigations

The responsibilities of Department of the Interior in hydrologic investigations include the determination of water occurrence, extent, quantity, quality, and use. The scope of these responsibilities includes inventory, monitoring, evaluation, development, management, problem solving, and prediction. Conventional, ground-based procedures are in operational use by the Bureaus to carry out most of these hydrologic activities. Remotely sensed data are presently used mainly as a secondary source of information because of the high costs of data acquisition and anlaysis, the need for frequent repetitive coverage for most objectives, the limited hydrologic information in the data for any single objective, and uncertainty as to the accuracy of information obtained from the data. Yet, the potential for beneficial application of remotely sensed data in hydrologic investigations is high. A number of trends suggest an increasing hydrologic application need for remotely sensed data. These trends include the increasing frequency, area, and severity of water problems, a need for more hydrologic information, acquired more frequently, a need to better characterize drainage basins and aquifers, and a need to obtain more accurate results by hydrologic modeling. Improved system parameters and improved data availability will result in wider use of satellite remotely sensed data for hydrologic applications.

Monitor Mountain Snowpack. Most streamflow and nearly all aquifer recharge in the western states comes from melting of the mountain snowpack, thus important predictions of water availability require reliable information on snowpack conditions. The objectives of snowpack mapping are detection of snowlines and landmarks, measurement of areas of thick and thin snow, and the determination of some relative differences in density and liquid water content of snow. Frequent cloud cover in mountainous regions is a constraint on the use of remote sensing to obtain this information. Thermal infrared images, which can be obtained day or night, and radar images, which can be obtained regardless of cloud cover, are very desirable for an operational program of snowpack mapping.

Monitor Lakes and Ponds. Most surface water is stored in large lakes and reservoirs. However, small lakes and farm ponds store significant amounts of water, provide an important part of the water used in rural areas, and represent an unknown quantity in water budgets. Existing records show that hundreds to thousands of farm ponds have been constructed in most counties, but neither these ponds nor small natural lakes have ever been adequately inventoried. There are two purposes for this application: an inventory of small lakes and farm ponds, and the monitoring of the area of these water bodies as an indication of drought conditions and for water budget purposes. Surface area of lakes and ponds can be used to calculate volume of water in storage.

Measure Irrigated Acerage. Irrigation constitutes about 70 percent of total water use in the western states and up to 90 percent of total water consumption by evapotranspiration. Detailed farm inventories of water diversion and pumpage are available in a few areas, but irrigation water use is estimated from partial inventories in most areas. Estimates by different agencies commonly have considerable variation from area to area and from time to time. More accurate calculations of water use can be made from the measurement and monitoring of irrigated lands. This object requires a separation of irrigated crops from dryland crops and natural vegetation. The area of irrigation can then be used to calculate water use. Cloud cover is a constraint on an operational program, and it is important that some images are obtained regardless of cloud cover.

Monitor Water Turbidity. Water turbidity is generally related to the level of eutrophication in lakes and reservoirs and to the sediment content of water. Turbidity patterns also show many water current and water circulation patterns. Detailed monitoring of these water characteristics requires a sampling approach: the chances are small of a single image showing any selected condition or event, but the chances of showing a range of condition or events by a long sequence of images is excellent.

Interpret Shallow Aquifers. Shallow aquifers store more fresh water than all lakes and reservoirs, and aquifers supply most of the water for all uses. Consequently, information about aquifer characteristics and discharge potential is important to many evaluation, development, and management activities. Remotely sensed data show only the land surface, and the information on the occurrence and salinity of ground water must be obtained by interpretation. These interpretations are based on topography, landforms, drainage patterns, and vegetation types and patterns. Significant improvements in the accuracy of these applications require stero coverage.

IV. Cartographic Mapping

The National Mapping Division (NMD) of the U.S. Geological Survey has the mandated responsibility for base map production of the land areas of the United States. Other agencies, including the Bureau of Reclamation, the Bureau of Land Management, and the Bureau of Indian Affairs carry out mapping activities, such as the production of thematic maps designed to support their specific management needs. Satellite remotely sensed data, when geometrically fitted to control data, provide an image map to which thematic information can be fitted. Furthermore, the remotely sensed spectral data can be classified to provide a foundation for the thematic mapping process and creation of derived products. The derived products include the image map itself merged with selected thematic overlays, terrain data created through stereo models from image data, and thematic base categories, such as forest, waterbodies, and urban for inventory and update. The periodic coverage of satellite data is particularly important for updating thematic base categories and identifying areas that require base map revision. These products are useful both within the United States and in developing countries which may not have advanced mapping programs.

Image maps. Image maps provide a synthesis of spectral data with selected thematic overlays which can be effectively used for interpretation. Image maps can be used as base maps for tasks including land use/land cover mapping, general geological and soils mapping, and corridor placement, as well as for tasks appropriate to the original thematic overlays. Important considerations for image maps are dates of coverage, spectral bands appropriate to anticipated interpretation needs, and sensor resolution and geometric accuracy appropriate to map scale.

Terrain models. Production of accurate topographic products is presently a resource intensive task. Many regions of the world have not yet been mapped in detail. Satellite imagery, acquired in stereo, could serve as a basis for mapping these regions. Satellite platforms could also serve as an efficient source of digital terrain data for many kinds of geographical analysis. Sensor and sensor platform considerations specific to topographic mapping are sensor resolution and geometric accuracy appropriate to the map scale, stereo coverage, and accurate satellite attitude data.

Thematic Base Cartegory Inventory and Update. The periodic coverage of multispectral sensors from a satellite platform provide an excellent means for the inventory and update of thematic base categories. The compilation of inventory data for use in base mapping is often not readily available at the national level. By taking advantage of the synoptic coverage of satellite data, broad themes can be readily mapped. Examples include the waterbody category, the forest category,the wetlands category, and the urban category. Satellite data can be used to detect areas of change related to the categories that require base map updating.

V. Land Management Activities

The Bureau of Land Management and the National Park Service are specifically charged with the land management responsibilities of the Department of the Interior. Other DOI bureaus and offices are responsible for the collection of data that are used by other governmental agencies in the land management process. Administration of Federal lands requires an intimate knowledge of what is currently on the land and periodic updates of that knowledge in order to make proper decisions about management of these lands. Federal lands are affected by man's use as well as by catastrophic events, each of which require specific information to assess their effects on the land and its cover. In addition, multiple use demands made on these lands make decisions even more complex. The vast areal extent, diversity of terrain and cover, variety and timeliness of information needs, requirements for repetitive coverage, and restricted manpower and budget all point to the important role remote sensing can and does play in DOI land management activities.

Vegetative land cover mapping represents one of the major operational uses of satellite data, particularly in Alaska. Monitoring of land cover change, especially due to man's activities, is useful in following the conversion of naturally vegetated lands to other uses and the change in natural cover due to management or catastrophic events. With improvements in spatial and radiometric resolution, reliability of coverage, and analysis capabilities, additional uses of remotely sensed data will benefit the mission of DOI.

Rangeland. Much of the DOI land in the western United States is managed as rangeland. Short term and long term effects of use must be assessed and management decisions made regarding continuation or change of current use. Status of vegetation condition, both during the growing season and change with years of management is essential to maintaining or improving the land cover. Satellite remote sensing provides a means of monitoring vegetation condition over the large area of Federal lands and in the repetitive timeframe required. Current investigations are designed to determine the reliability of biomass estimations under a variety of climatic and geographic conditions and relate these measurements to short-and long-term trends in the vegetation.

Land Cover Change Detection. Change detection, such as conversion of agricultural land to urban use, is necessary for updating of maps and statistical data produced by DOI agencies. Mining activities, natural disasters, and degradation of natural land cover represent additional change events which impact management decisions. Since satellite remote sensing can systematically acquire data over all areas of concern, it provides a mechanism for search and location of land cover change. Previously acquired data provides a basis for comparison with current and future acquisitions.

Stress Detection. Management of natural resources requires monitoring of the resource for conditions which affect the ability of the resource to maintain itself. Drought, disease, and insects impose stress conditions on the resource which, if not considered in management decisions, will have adverse effects on the resource. Stress detection requires an examination of the physiological state of the vegetation, which relates directly to the reflectance responses measured by satellite sensors. Frequent coverage during the growing season also is necessary to detect events, such as insect infestations, which can be of short duration and intense in effect.

Agricultural Crop Classification. Knowledge concerning the specific crops grown provides a refined level of data which impacts such things as water use calculations, potential effects of natural disasters, and development of statistics for irrigation project planning. Site-specific coverage requirements can be met through the general coverage acquired routinely. Multitemporal coverage over a growing season optimizes the efficiency of classification.

Geographic Information Systems. The ability to integrate various data sources into the decision-making process enhances the execution of responsibilities of all DOI agencies. Remote sensing provides the spectral information from which relevent vegetation information can be interpreted. The digital geometric registration of remotely sensed data provides for a convenient and efficient incorporation of the data into a geographic information system. Data requirements can be tailored to the immediate task.

VI. Wildlife Management and Inventory

Interior responsibilities for wildlife management and inventory occur at several levels. For example, the U.S. Fish and Wildlife Service conducts numerous programs involving the management of wildlife, habitat management, and the regulation of activities affecting wildlife. Land management agencies within the Interior such as the Bureau of Land Management and the National Park Service are mandated to consider fish and wildlife as resources to be taken into account when management decisions are made. Several other agencies, such as the Geological Survey, Bureau of Reclamation, and Office of Surface Mining, while not directly involved in wildlife management, are required by their charters to collect data which is essential to the management and preservation of our nation's wildlife resources.

In many cases, satellite remote sensing is used to collect at least some of the information required by these agencies in their wildlife-related activities, and possible future improvements in data quality, timeliness, and availability will render remotely sensed data even more valuable. Only rarely is remote sensing capable of providing data that is technically impossible to collect by ground-based techniques. However, it often makes possible data collection that would not be economically feasible by other means. The vastness of the area of interest, inaccessibility or remoteness, and the ephemeral nature of the data, which requires frequent updating and remeasurement, are data acquisition problems that can be solved by satellite remote sensing.

Vegetation Mapping (Habitat Inventory). Wildlife management is dependent on a knowledge of the amount and distribution of habitat available for wildlife. This usually requires a knowledge of the amount, kind, condition, and location of land cover, as land cover provides food and protection for wildlife and may affect habitats elsewhere, for example, in preventing erosional effects on downstream fisheries. Satellite remote sensing provides an opportunity for collecting the large quantities of data needed due to the broad aerial extent of many habitats of interest.

Vegetation Change Monitoring (Habitat Analysis and Monitoring). Although a one-time inventory of habitat may provide sufficient data for certain management activities, usually a continuing periodic monitoring program is necessary to permit detection and documentation of changes in habitat, either as a result of external forces or as a result of management practices. Satellite remote sensing may permit relatively inexpensive timely collection of the data required.

Wetlands Inventory and Evaluation. Numerous species are dependent on wetlands for survival, but these unique habitat environments are of particular interest due to their importance to migratory waterfowl, and the fact that modern agricultural practices are resulting in a drastic decrease in wetlands. Furthermore, the condition of wetlands, and hence their suitability as waterfowl habitat, varies greatly from year to year due to weather conditions. This ephemeral chacteristic makes frequent monitoring of wetland extent and condition highly desirable.

Wildlife Tracking. Although satellite remote sensing does not lend itself to detection of wildlife per se, satellite-based telemetry systems have proven to be very useful in collecting data from radio devices attached to wildlife, thus providing information on movement and location. These data, when combined with habitat information, can yield valuable information on habitat preference, mobililty, habits, etc.

VII. Environmental Monitoring

The bureaus and offices of DOI have certain environmental monitoring responsibilities that must be carried out in conjunction with their overall administrative and management responsibilities. Development of mineral resources, domestic and industrial uses of water resources, multiple uses of forest and wilderness areas, and other development activities have an environmental impact that must be considered.

Satellite remotely sensed data can be used to detect and monitor site specific conditions which are potentially detrimental to the environment as well as the regional effects of environmental pollutants, such as acid rain. In addition, satellite remotely sensed data can be used to monitor environmental recovery, such as strip mine reclamation.

Detecting Thermal Pollution. The most common method of disposal of liquid industrial waste is discharge into rivers and lakes. If not properly cooled, the waste often will be warmer than the receiving water body, resulting in thermal pollution which may be detrimental to aquatic plants and animals. Satellite thermal infrared sensing can detect and monitor sources of thermal pollution.

Detecting and Monitoring Oil Pollution. More intense development of the oil resources of coastal waters and remote land areas has increased the potential for accidental oil pollution. Early detection of oil spills from pipeline leakage or on water and monitoring the movement of oil spills on water can significantly reduce the damage to the environment. Repetitive coverage by satellite remote sensors can facilitate the early detection and monitoring of oil spills.

Monitoring Surface Mine Reclamation. Reclamation of surface mines is a mandated activity to prevent pollution of surface water and to return the land to its former use by burying the mine spoils, reshaping the terrain, replacing the top soil, and revegetating the surface. An indicator of successful reclamation is the condition of the replaced vegetation. Satellite remotely sensed data can be effectively used to monitor the reclamation process.

Monitoring Affects of Acid Rain. The use of fossil fuels and other industrial processes has resulted in the pollution of the atmosphere with acidic chemical compounds. The acidic compounds are returned to the surface by rainfall which comes in contact with vegetation and eventually enters the lakes and streams. An early indicator of acid rain pollution is the stress or death of forest vegetation. Satellite remotely sensed data can be used to monitor the condition of forest in areas susceptible to acid rain pollution.

DEPARTMENT OF THE INTERIOR SATELLITE REMOTE SENSING DATA REQUIREMENTS

ACTIVITY: Environmental Monitoring

Application	Spectral Characteristics			Spatial Resolution (EIFOV)		Minimum Area of Unit Coverage	Geographic Coverage	Acquisition Frequency	Data Format Requirements	Data Delivery Time	Stereo Priority	Other Parameters of Importance	Comments
	Wavelength (in micrometers)	Band-Width	Sensitivity	Minimum	Optimum								
Surface Mine Reclamation	.48 .56 .66 .95 1.60 10.4–12.5	.05 .05 .05 .05 .05 0.5	<1% <1% <1% <1% 1% .2°K (NEΔT) at 300°K	30 m	10 m	40x40km	U.S. and possessions	14 days	film	30 days	high		
Monitoring Affects of Acid Rain	.48 .56 .66 .74 .78 1.65 2.0–2.4 (3-4 bands)	.05 .05 .05 .01 0.4 0.2 .02	<1% <1% <1% <1% 1% 2%	30 m	10 m	60x60km	global	14 day	digital and film	30 days	low		
Detecting Thermal Pollutants	3-5 8.0–14.0 (3 bands)	0.5	.2°K (NEΔT) at 300°K	30 m	10 m	40x40km	U.S. and possessions	1 day	digital and film	15 days	low		measurements should be made both during day and night
Detecting and Monitoring Oil Pollution	.35 .45 11.0	.05 .05 0.5	<1% <1% .2°K (NEΔT) at 300°K	30 m	10 m	40x40km	global	daily to hourly	film	low			

DEPARTMENT OF THE INTERIOR SATELLITE REMOTE SENSING DATA REQUIREMENTS

ACTIVITY: Geologic Investigations

Application	Spectral Characteristics: Wavelength (in micrometers)	Band-Width	Sensitivity	Spatial Resolution (EIFOV): Minimum	Desired	Minimum Area of Unit Coverage	Geographic Coverage	Acquisition Frequency	Data Format Requirements	Data Delivery Time	Stereo Priority	Other Parameters of Importance	Comments
Regional/ General Geologic Mapping	0.4-1.0 (~10 bands) 1.0-2.0 (2-3 bands) 2.0-2.4 (~4 bands) 8-14 (~3 bands) Microwave	.05 .05 .05 0.5	<1% 1% 2% .3°K (NEΔT) at 300°K 5 dB SNR in image	50 m 50 m 50 m 80 m 50 m	20-30 m 20-30 m 20-30 m 30 m 20-30 m	100x100km	global	3-4/year depending on seasonal effects; less for radar	digital and film	2 weeks	high	Spaceborne gravity and magnetic data. Also have major application in global crustal and mantle studies.	radar should be variable frequency; multiple polarization and incidence
Detailed Structural Delineations	.45 .55 1.0 1.5 3 cm	.05 .05 .05 .05	<1% <1% <1% <1% 5 dB SNR in image	20 m	5-10 m	20x20km	primarily U.S. and possessions	3-4/year because of variable illumination; less for radar	digital and film	2 weeks	high		radar should be multiple polarization and incidence
Determination of Rock Composition	0.4-2.4 (as many as 100 or more bands) 8-14 (6-8 bands)	.02 0.5	<1%-2% 0.2°K (NEΔT) at 300°K	30 m	10-20 m	60x60km	global	1/year or less (summer)	digital and film	2 weeks	moderate-low		
Geologic Hazard/ Thermal Monitoring	.45 .55 1.0 1.5 3-5 8-14 (3 bands)	.05 0.5	1% 0.2°K (NEΔT) at 300°K	50 m 80 m	30 m 20-30 m	60x60km	global	1/year or less weekly to hourly	digital and film digital	2 weeks daily to hourly	high high	Non-imaging telemetry ranging system to detect motion along faults. Gravity data.	Thermal IR data should be collected during both day and night
Geobotanical Studies	0.4-2.4 (10-12 bands)	.01 or .05 (depending on band)	<1%-2%	30 m	10-20 m	60x60km	global	6-12/year	digital film	2 weeks	moderate		

DEPARTMENT OF THE INTERIOR SATELLITE REMOTE SENSING DATA REQUIREMENTS — ACTIVITY: Hydrologic Investigations

Application	Spectral Characteristics: Wavelength (in micrometers)	Band-Width	Sensitivity	Spatial Resolution (EIFOV): Minimum	Desired	Minimum Area of Unit Coverage	Geographic Coverage	Acquisition Frequency	Data Format Requirements	Data Delivery Time	Stereo Priority	Other Parameters of Importance	Comments
Monitor Mountain Snowpack	.65 .95 11 3 cm	.1 .3 0.5	<1% <1% 0.2°K (NEΔT) at 300°K 5 dB SNR in image	500 m 500 m 500 m 100 m	30 m 30 m 30 m 30 m	185x185km	western 18 states	weekly	digital and film	3 days	medium		operational satellite necessary
Monitor Lakes and Ponds	.75 .95 3 cm	.1 .3	<1% <1% 5 dB SNR in image	30 m 30 m 20 m	10 m 10 m 10 m	100x100km	U.S. and possessions	weekly to monthly	digital	3 days to 3 weeks	low		
Measure Irrigated Acreage	.65 .95 11 3 cm	.1 .3 0.5	<1% <1% 0.2°K (NEΔT) at 300°K 5 dB SNR in image	80 m 80 m 80 m 50 m	30 m 30 m 30 m 20 m	185x185km	western 18 states	weekly to biweekly	digital and film	1 week	low		operational satellite necessary
Monitor Water Turbidity	.45 .55 .65 .75 11	.1 .1 .1 .1 0.5	<1% <1% <1% <1% 0.2°K (NEΔT) at 300°K	100 m 100 m 100 m 100 m 100 m	10 m 10 m 10 m 10 m 30 m	185x185km	U.S. and possessions	weekly	digital	2 weeks	low		operational satellite necessary
Interpret Shallow Aquifers	.55 .65 .75 .95	.1 .1 .1 .1	<1% <1% <1% <1%	100 m 100 m 100 m 100 m	20 m 20 m 20 m 20 m	185x185km	U.S. and possessions	monthly	film	N/A	high	thermal IR and radar useful	

DEPARTMENT OF THE INTERIOR SATELLITE REMOTE SENSING DATA REQUIREMENTS

ACTIVITY: Wildlife Management and Inventory

Application	Spectral Characteristics: Wavelength (in micrometers)	Spectral Characteristics: Band-Width	Spectral Characteristics: Sensitivity	Spatial Resolution (EIFOV): Minimum	Spatial Resolution (EIFOV): Optimum	Minimum Area of Unit Coverage	Geographic Coverage	Acquisition Frequency	Data Format Requirements	Data Delivery Time	Stereo Priority	Other Parameters of Importance	Comments
Vegetation Mapping (Habitat Inventory)	.56 .66 .83 1.65	.05 .05 0.1 0.2	<1%	80 m	20 m	180x180km	North American and U.S. possessions	5 years	digital and film	3 months	low		
Vegetation Change Monitoring (Habitat Analysis and Monitoring)	.56 .66 .83 1.65	.05 .05 0.1 0.2	<1%	80 m*	20 m	100x100km	North America and U.S. possessions, regional	annual; occasionally monthly	digital and film	30 days	low		data delivery time is critical
Wetlands Inventory	.56 .66 .83 1.65	.05 .05 0.1 0.2	<1%	40 m	10 m	50x50km	North America and U.S. possessions, regional	15-30 days	digital and film	10 days	low		data delivery time is critical
Wildlife Tracking	N/A	—	—	100 m (positional)	10 m (positional)	N/A	North American and U.S. possessions, regional	daily	digital	7 days	low		non-imaging, using telemetry technology

*500-1000 m resolution is suitable for many large area mapping/monitoring/change detection applications.

DEPARTMENT OF THE INTERIOR SATELLITE REMOTE SENSING DATA REQUIREMENTS

ACTIVITY: Land Management

Application	Spectral Characteristics: Wavelength (in micrometers)	Band-Width	Sensitivity	Spatial Resolution (EIFOV): Minimum	Desired	Minimum Area of Unit Coverage	Geographic Coverage	Acquisition Frequency	Data Format Requirements	Data Delivery Time	Stereo Priority	Other Parameters of Importance	Comments
Rangeland Monitoring	.49 .56 .66 .92 1.65 2.20	.05 .05 .05 .02 .02 .02	<1% <1% <1% <1% 1% 2%	80 m*	15 m	60x60km	U.S. and possessions	7-10 days	digital and film	24 hours	low		data delivery time is essential for near real time management
Land cover Change Detection	.49 .56 .66 .92 1.65 2.20	.05 .05 .05 .02 .02 .02	<1% <1% <1% <1% 1% 2%	80 m*	20 m	60x60km	U.S. and possessions	7-10 days except for catasrophic events	digital and film	7-10 days (24 hour, see comments)	low		natural catastrophic monitoring would require as rapid as possible turnaround
Stress Detection	.66 .74 .78 1.15 1.65 2.20 11.5	.05 .01 0.4 0.3 0.2 0.2 0.5	<1% <1% <1% <1% <1% 1% 2% 0.2°K (NEΔT) at 300°K	30 m	10 m	60x60km	U.S. and possessions	3-5 days	digital and film	24 hours	low		stress detection requires sensor capabilities which currently are not present on operational systems
Agricultural Crop Classification	.49 .56 .66 .92 1.65 2.20	.05 .05 .05 .02 .02 .02	<1% <1% <1% <1% 1% 2%	30 m	10 m	60x60 km	U.S. and possessions	7-10 days	digital and film	7-10 days	low		multitemporal coverage within growing season important
Geographic Information Systems	.49 .56 .66 .92 1.65 2.20 11.5	.05 .05 .05 .05 0.2 0.2 0.5	<1% <1% <1% <1% <1% 1% 2% 0.2°K (NEΔT) at 300°K	80 m*	10 m	60x60 km	U.S. and possessions	7-10 days	digital and film	7-10 days	low		data requirements will vary depending on the task to be accomplished

***500-1000 m resolution is suitable for many large area mapping/monitoring/change detection applications.**

DEPARTMENT OF THE INTERIOR SATELLITE REMOTE SENSING DATA REQUIREMENTS

ACTIVITY: Cartographic Mapping

Application	Spectral Characteristics			Spatial Resolution (EIFOV)		Minimum Area of Unit Coverage	Geographic Coverage	Acquisition Frequency	Data Format Requirements	Data Delivery Time	Stereo Priority	Other Parameters of Importance	Comments
	Wavelength (in micrometers)	Band-Width	Sensitivity	Minimum	Desired								
Image Mapping 1:100,000 to 1:250,000	.4-1.0 (4 bands) 1.0-2.0 (2 bands) 2.0-2.4 (4 bands) 8-14 (3 bands)	.05 .05 .05 .05	<1%	80 m	20 m	185x185km	global	5 years (more frequent in areas of high change)	digital	30 days	low	precise attitude, position, and time or ground control	plannometric band selection and date of acquisition must serve general audience. Meets NMAS in horizontal dimension
Topographic Mapping 1:100,000	.6	.1	<1%	15 m	5 m	50x50km	global	1 time	digital and film	30 days	high	precise attitude, position, and time or ground control	contour meeting NMAS in vertical dimension is limiting factor
Forest and Cartography Update and Inventory	.45 .55 .65 .9 1.5	.05	<1%	80 m	30 m	185x185km	primarily U.S. and possessions	1/year	digital and film	30 days	low		
Water Category Update and Inventory	.45 .55 .65 .75	.05	<1%	30 m	10 m	185x185km	primarily U.S. and possessions	1/year	digital and film	30 days	low		
Urban Category Update and Inventory	.45 .55 1.0	.05	<1%	30 m	10 m	185x185km	primarily U.S. and possessions	1/year	digital and film	30 days	low		

APPENDIX E

GLOSSARY OF ACRONYMS

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GLOSSARY OF ACRONYMS

AFGWC	-	Air Force Global Weather Central
AHOS	-	Automatic Hydrologic Observing System
AID	-	Agency for International Development
AISC	-	Assessment and Information Services Center
AMSU	-	Advanced Microwave Sounding Unit
APT	-	Automatic Picture Transmission
ASDAR	-	Aircraft to Satellite Data Relay System
AVHRR	-	Advanced Very High Resolution Radiometer
BLM	-	Bureau of Land Management
BOR	-	Bureau of Reclamation
CE	-	Corps of Engineers (U.S. Army)
CG	-	Coast Guard (U.S.)
CRREL	-	Cold Regions Research and Engineering Laboratory
DCP	-	Data Collection Platform
DCS	-	Data Collection System
DOD	-	Department of Defense
DOI	-	Department of Interior
DOT	-	Department of Transportation
DMSP	-	Defense Meteorological Satellite Program
DSB	-	Direct Sounder Broadcasts
EOS	-	Earth Observing System
ENSO	-	El Niño/Southern Oscillation
ERS-1	-	ESA Remote-Sensing Satellite
ESA	-	European Space Agency

FAA	-	Federal Aviation Administration
FAST	-	Flood Analysis Simulation Technology
FEMA	-	Federal Emergency Management Agency
FNOC	-	Fleet Numerical Oceanography Center
GEOSAT	-	Geodetic Satellite (U.S. Navy)
GIS	-	Geographic Information Systems
GMS	-	Geostationary Satellites (Japanese)
GOES	-	Geostationary Operational Environmental Satellite
HRPT	-	High Resolution Picture Transmission
ICAO	-	International Civil Aviation Organization
Landsat	-	Land Satellite
LEAP	-	Landsat Emergency Access and Products
Meteosat	-	Meteorological Satellite (European)
MSS	-	Multi-Spectral Scanner
NASA	-	National Aeronautics and Space Administration
NESDIS	-	National Environmental Satellite, Data, and Information Service
NOAA	-	National Oceanic and Atmospheric Administration
NOS	-	National Ocean Service
N-ROSS	-	Navy Remote Ocean Sensing System
NWS	-	National Weather Service
OFDA	-	Office of Foreign Disaster Assistance
POES	-	Polar-orbiting Operational Environmental Satellite
RAWS	-	Remote Automated Weather Stations
SARSAT	-	Search and Rescue Satellite-Aided Tracking
SESC	-	Space Environment Services Center

SPARRSO	-	Space Research and Remote Sensing Organization (Bangladesh)
SPOT	-	System Probatoire d'Observation de la Terre (France)
TIROS	-	Television and Infrared Observation Satellite
TM	-	Thematic Mapper
TOVS	-	TIROS Operational Vertical Sounder
USDA	-	U.S. Department of Agriculture
USGS	-	U.S. Geological Survey
WRD	-	Water Resources Division